Resilient Food Systems for a Changing World:

Proceedings of the

5th World Congress of Conservation Agriculture

INCORPORATING

3rd Farming Systems Design Conference

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Resilient Food Systems for a Changing World*:*

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5th World Congress on Conservation Agriculture

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25 – 29th September 2011, Brisbane, Australia

Co-location of the 5th World Congress on Conservation Agriculture (WCCA) and the 3rd Farming Systems Design (FSD) Conference, with substantial input from Landcare, provides a great opportunity to explore the application of conservation agriculture practices and principles in a broad systems context.

Our common objective is the design of more productive, economic, and sustainable farming systems to meet the challenges of expanding population, global change, and environmental degradation.

5th World Congress on Conservation Agriculture

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3rd Farming Systems Design Conference

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Conservation Agriculture: have the good years become the bad years?

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Introduction

Have the good years become the bad years? Have recent high rainfall years impacted on practice change and conservation agriculture? Have the practices put in place as a response to bad (low rainfall, low profit) years led to good years (high rainfall high profit) turning bad (high rainfall low profit)? An average season is an interesting concept for an Australian farmer. What exactly is an average season? The years where an average amount of rainfall falls at predictable nicely spaced intervals accompanied by average temperatures that are warm when they are meant to be warm and cool when they are meant to be cool and not an average of Saharan and Antarctic conditions are few indeed. The perception of agriculture in Australia is that we deal more often with extremes, the dry years are very dry and the wet years are very wet. Because of this variability the profitability of agricultural enterprises that rely on natural weather cycles tends also to be variable. Years where virtually the entire costs of purchasing a farm can be met do sometimes occur, however just as likely are the disastrous years in which several seasons of profit can be lost. The development of conservation agriculture has in lot of respects been driven by the desire to eliminate these disaster years which in the past were more often than not associated with drought.

Dry years were the bad years. Low rainfall would often result in complete crop failures and no income whatsoever. It was really no surprise then that practices that could lead to more water being available to crops in those same low rainfall years were pretty quickly adopted. Llewellyn and D'Emdens (2008) survey into adoption of no-till in Australia found that adoption levels are plateauing around 90% in many regions. Given that in the early 90's the adoption of no-till was around 10% this is a remarkable rate of increase. Looking over the fence from your dying or dead crop onto one which is still alive can be strong motivator driving practice change. Farmers tend to remember bad crop experiences more than good ones and a practice change which results in a good or better crop experience in the same environmental conditions in which a bad crop experience has previously occurred is certain to be adopted. The adoption of no-till in combination with controlled traffic has been results driven. So the question now becomes what are the new bad experiences that farmers are seeing that could drive the next round of practice change?

The new bad years

For bad years we need to look no further than last year (2010). This was yet another year of extremes for the NW of NSW and Southern Queensland cropping areas. Constant rainfall events right through the growing season which up until harvest time – on any assessment of the old paradigm – would have been regarded as a good year. From Dubbo north, crops of wheat, barley and chickpeas were all growing magnificently. What was also occurring though was a frantic effort to keep disease under control and in many cases that effort was to no avail. In Chickpeas and Durum Wheat especially but also in Wheat, Barley and Canola, battles were fought and lost against Aschochyta Blight, Botrytis Mould, Fusarium Head Blight, and Net Blotch to name a few. These battles were expensive. On many farms hundreds of dollars were spent a hectare to try and protect crops which ultimately failed and went unharvested. Even before the disaster brought by rain at harvest time, what should have been a good year had turned into a very very bad year. How have farmers reacted to this bad cropping experience? In many cases stubble is being seen as the obvious culprit and an easy target to do something about. The mantra of "retain stubble at all costs" driven by bad experiences in dry years is being replaced in some circumstances by an attitude that "perhaps stubble has to be more strategically managed" driven by bad experiences in wet years (more than just 2010). This attitude is driving practice change such as wide spread chaining (use of a diamond configuration prickle chain harrow), burning of stubble and some return to aggressive cultivation.

On farm response options

Is conservation agriculture dead then? Of course not. The fundamental driver behind no-till and controlled traffic, being extra plant available water, is still the critical factor for successful cropping in Australia. The reason that I believe that we all need to look carefully and learn from some of the experiences from last year is that the management practices that are being used to cope with the consequences of wet years are fundamentally at odds with what drove practice change to alleviate the effects of the dry years. We need to find ways to keep the good years good or risk the possibility of the dry years becoming bad again. There is also a lot of decision making done in the absence of good robust data on the economic effects on farming systems of various practices. There is not much more than gut feel available to assess the impact that one prickle chain operation performed within a controlled traffic setup will have on the stored moisture for the following crop. The same can be said for how much effect that operation will actually have on reducing the stubble born disease load for the next crop which is one of the main reasons why the practice is becoming fairly wide spread.

On my farm in 2010, I spent an average of $60/Ha in fungicides on my durum wheat (including application costs). Despite this we still suffered downgrading due to fungal staining and the presence of Fusarium Head Blight. The combination of control costs and loss from downgrading was anywhere from $200 - $300/Ha depending on yield. A bad experience! My reaction to that bad experience is to look very suspiciously at the level of inoculum carrying over in stubble and what management practices I have available to ameliorate that risk. A prickle chain operation will incorporate stubble and I have access to a machine that I can use that will fit into my controlled traffic operation. The best information that I can find on the impact on soil moisture levels of that operation and the subsequent impact on the next crop yield to aid my decision making is that controlled traffic with zero till can have a 183kg/ha yield advantage over controlled traffic with a stubble mulching operation (Tullberg et al. 2001). If I look at that in terms of $/ha potentially lost on $220/ton wheat it works out at $40/ha reduction due to lost soil moisture. Compared to the $60 fungicide costs, let alone the loss from downgrading, a cultivation to reduce risk from carry over inoculum looks attractive. I am not suggesting for a minute that the above example is an infallible example of why Stubble incorporation should become standard practice again. There are many untested assumptions in the suggested course of action

and the extrapolation of the tillage research to our farm and figures is hardly robust. What I do want to demonstrate though is the thought process behind a significant practice change.

Some of our paddocks that were cultivated this year had not been cultivated for the last ten years. I would consider myself a committed no-till farmer. I cannot afford to have experience like last year however and so a focus on disease inoculum in stubble is forefront for me at the moment. I have many options available such as crop choice, burning, cultivation (light or heavy) or doing nothing and relying on in crop control. Out of all of these the most logistically appealing and (from limited information) economically attractive is a light cultivation, so out come the prickle chains. The frustrating aspect of this decision is the limited amount of hard information to base it on. All of the management options above have loads of information available for assessing economic impact of the particular practice in isolation. The assessment of the impact within the context of a farming system with a four or five year cropping rotation is somewhat more limited. Assessing a practice change response to the bad experience of dry years is about as black and white as you will ever get in agriculture. No-till and controlled traffic are indisputably the practices that are needed. Assessing a practice change response to bad experiences caused by wet years is much more of a challenge.

Crop sequencing to alleviate disease effects of long term no-till is an area that I believe still needs a lot of work. Soil- or crown-borne pathogens and their persistence under various crop rotations has had a reasonable amount of attention. Persistence of inoculum within stubble and the effects of crop rotations on breakdown however is less well understood, or at least less well able to be put in the context of an economic choice. For example the choice of a sorghum or sunflower crop following wheat may be easy enough to work out economically, however the effect that that crop will have on the likelihood of inoculum being carried over into the following wheat crop (in an economic sense) would not be immediately obvious to a grower. The above example is at least comparing only one variable (different crops) however another common conundrum is the choice of sorghum or cotton following wheat. The negative aspect of the soil water loss from the required pupae busting (tillage) operation is well understood, however as a counter to this the argument that stubble borne diseases are also being controlled at the same time is often used. While this may well be the case the economic impact of the reduction in inoculum versus the economic impact of the loss of soil moisture is only gut feel.

Does one cultivation, a conventional farmer make? There are plenty of long term no-till farmers who now have a prickle chain as part of their equipment line up but still consider themselves to be no-till. There are many and varied reasons why prickle chaining has become so popular. Apart from the stubble incorporation aspect already talked about prickle chains give another non chemical control option for difficult to kill weeds. A less appreciated aspect of prickle chaining is reduced machinery maintenance costs through reducing the roughness of no-till country. Farmers who chain their country talk about how easy it is to sow into nice level stubble incorporated ground. We have all had nightmarish planting experiences in no-till ground. Prickle chaining can vastly reduce that experience so once again we have the removal of bad experiences driving practice change. The term "Strategic Tillage" is one which is being heard more and more. I'm not altogether sure what it means! Generally it is used in the context of tillage that is performed within a system that apart from that one operation would otherwise be no-till. It is generally performed reluctantly or at least with the knowledge that there is a negative side to the practice. Again however the lack of knowledge around exactly when and how that "strategic tillage" should take place is evident. Straight after harvest or immediately before sowing? Hot or cold? Shallow or deep? Should it be a fertiliser incorporating operation? It is happening and I believe will continue to happen. We should be understanding more about its applicability.

Conclusion

The final option I talked about was continuing on a strict no-till path with the knowledge that there will be greater in crop control costs for disease. In Llewellyn and D'Emdens no-till survey 68% of Northern NSW growers believed that no-till will lead to more crop disease. Assuming that disease resistant crops will at best maintain yields this implies that yield increase will require a greater cost of disease control. Even die hard no-till farmers will reach a point where the cost of control of disease caused by stubble retention in no-till will be greater than the benefit of the extra retained moisture. I believe that more research is required to understand how that tipping point can be managed and what the best management practice is, once the tipping point is reached.

Conservation Agriculture, particularly no-till and controlled traffic has had a remarkable uptake because it works in most years. Further research and understanding is needed however to ensure that the response to the years that it doesn't work is appropriate and sustainable in the longer term.

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Sense and nonsense in conservation agriculture: principles, pragmatism and productivity in Australian mixed farming systems

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Introduction

Australian farmers, like many worldwide, have seen sense in the principles of conservation agriculture (CA) and adoption levels in recent industry-wide surveys are high (GRDC 2010, Llewellyn et al. 2011). Diverse rotations supporting reduced (or no-) till systems and the maintenance of surface cover make sense in extensive dryland cropping systems on erosion-prone, structurally-unstable soils, where input and labour efficiency is paramount to maintain profits in export-focussed, unsubsidized commodity markets. Indeed reduced fuel and labour costs, soil conservation and moisture retention are the most commonly stated reasons for adoption of no-till and CA principles by farmers in Australia (Llewellyn et al. 2011, Thomas et al. 2007). Recent advances in controlled traffic (CT) and precision agriculture (PA) technologies are providing further scope for improvement (Robertson et al. 2011, Rainbow and Derpsch 2011).

While principles can be broadly applicable, adaptation and application of principles within specific farming systems is inevitably pragmatic due to the diverse biophysical and socio-economic factors encountered. Inevitable challenges emerge as new farming systems evolve and in many CA systems, these have been surmountable with adaptive on-farm research (Thomas et al. 2007; Bollinger et al. 2006). But this has not been the case in some systems, such as small-holder systems in Africa, where the relevance of some CA principles have been questioned (Giller et al. 2009). There is also ample evidence of pragmatism underlying the adoption of CA in Australia, as most no-till adopters continue some cultivation (~30% cropped area), intensive cereal systems dominate and significant regional differences persist (Llewellyn et al. 2011). Mixed crop-livestock farming systems in southern Australia present inherent challenges for "ideal" CA principles as they are now commonly promoted - zero till, permanent residue cover, diverse rotations and animal exclusion from cropped land. Do the principles make sense, or is the high degree of flexibility in the approach to CA principles as practised in southern Australian mixed farming systems warranted?

Increased yield has not been the main driver for CA adoption in Australia. Synergistic interactions of CA and other technologies have certainly increased yield, but the yield responses to specific components (e.g. less soil disturbance in no-till systems) where evident, appear modest (Kirkegaard 1995, Thomas 2007). Recent evidence also question the potential for C-sequestration (Chan et al, 2011), reductions in greenhouse gas emissions (Maraseni and Cockfield, 2011) and increased energy efficiency (Moreno et al. 2011) often assumed for no-till systems. Understanding and addressing these surprising contradictions and apparent "nonsense" will be paramount if CA principles are to underpin efforts to maintain productivity and address global food security.

We consider the adaption of CA principles in southern Australian mixed farming systems, the reasons for pragmatic adoption of CA principles in the context of system efficiency and profitability and business risk and some of the future innovations that may influence the further evolution of CA systems in southern Australia and elsewhere.

Diversity and evolution of southern mixed farming system – a brief background

Kirkegaard et al. (2011) reviewed the factors influencing the diversity and evolution of southern mixed farming systems. Until the 1980's ley farming systems of wheat and barley rotated with annual legume-based pastures produced mostly wool from self-replacing merino flocks. Since then, the diversity of grain and livestock enterprises has expanded to include dual-purpose flocks, prime lamb and beef production, livestock trading and agistment as well as a range of pulse and oilseed crops and conserved forage. Since 1990, as grain profitability increased relative to wool, the number of farms has fallen (~1% pa), farm size has increased (2.1% pa), and crop area per farm has increased (3.6% pa) generally at the expense of pasture area. Adoption of CA principles has been an integral part of the technology and innovation behind the impressive gains in total factor productivity (i.e. output per unit input) achieved by the Australian broad-acre agriculture sector (2% pa), though concerns over the recent slowdown are acknowledged (Hughes et al. 2011). Aspects of labour and input efficiency, economies of scale and timeliness of CA systems have suited large intensively-cropped farms, as do emerging innovations in CT and PA systems (Robertson et al. 2011). Trends toward more intensive cropping may have weakened recently due to the prolonged millennium drought, herbicide resistant weeds, higher crop input costs and higher livestock prices. Despite the intensification of cropping, medium-term farm business profits vary less with the proportion of cropping than with management skill of individual farmers (Kirkegaard et al. 2011). Most farming regions include some farms that specialise in cropping and those that produce livestock exclusively, but most broad-acre farms in southern Australia retain some mix of crops and livestock with flexibility to alter or diversify the enterprise mix. In view of the relatively high adoption rates of CA principles, we consider some of the contemporary issues influencing the further evolution of CA principles within this mixed farming system context.

Crop and pasture sequences

Australian mixed farming systems tend not to follow set rotations, but rather phased sequences of crops and pastures of various lengths and crop mix according to biophysical and economic signals. Two existing features of the system are worthy of discussion with respect to CA principles – integration of livestock, and intensive cereal systems.

Are livestock compatible with a CA future? Integrating livestock with cropping presents challenges for "ideal" CA systems involving no-till, CT systems where the perceived structural damage caused by livestock and removal of crop residues are of concern. Surprisingly little objective data exist to determine the legitimacy of these concerns, though a recent review (Bell et al. 2011) and recent (unpublished) data suggest little significant impact to following crops from the shallow surface compaction caused by livestock. More risk is associated with the loss of surface cover from overgrazing of pastures and crop residues (Hunt et al. 2011) which is avoidable using rotational grazing, confinement lots and groundcover thresholds (Lilley and Moore 2009). Inevitably pasture phases are lost with more intensive cropping, yet in mixed farming systems pastures represent the most effective way to build soil organic matter (Chan et al. 2011), improve soil structure, fix legume nitrogen, control weeds, reduce business risk and income volatility. The decision to irreversibly cease livestock operations (i.e.

removal of troughs and fences) often owes more to personal preference or changed labour circumstances than to biophysical necessity. Segregating operations onto different land classes rather than integrating crop and livestock operations across all land areas is an intermediate option adopted in some cases. The different optimum paddock sizes required for crop and livestock operations are making it difficult to capture the synergies between the systems, although new technologies such as moveable electric fences or in future, "virtual" fencing allow tactical use of livestock for periodic grazing of crops or stubbles in enterprises where animals are traded. The recent expansion and innovative adoption of dual-purpose crops on mixed farms in southern Australia represents a blurring of the definitions of crop and pasture and is problematic for the segregation approach. Cereal and canola crops sown early can be grazed in winter with no impact on grain yield providing valuable feed during the winter "feed-gap" and providing a spell for winter pastures (Kirkegaard et al. 2009). Grazing of winter crops has allowed mixed farmers to simultaneously increase both crop and livestock production from the farm through provision of winter (forage) and summer (stubble) grazing and additional grain production. By better using the feed-base across mixed farms, these systems are significantly increasing the overall efficiency of input use and are highly flexible, profitable and assist in the management of risk. Paddock selection and careful livestock management can reduce the potential impacts of occasional crop grazing on soil structure within a sequence of crops and pasture (Hunt et al. 2011, Bell et al. 2011). Overall, well managed pasture phases and good livestock management within mixed crop-livestock systems can arguably provide the same if not greater benefits as those sought from CA principles within continuously cropping systems, and should be considered compatible with them.

Continuous cropping and intensive cereals. Despite the diversity of pulse and oilseed crops available in Australia, and their demonstrated benefits to cereal crops in the rotation (Kirkegaard et al. 2008), cropping systems are dominated by intensive cereal production (60 - 84%). Cereals are attractive due to the ease of management and marketing, and lower risk due to reduced up-front costs and more reliable performance in difficult seasons with as much as 50% of wheat crops sown after wheat in southern Australia during the recent millennium drought. Break crops such as canola and lupins can be highly profitable, especially when whole-of-sequence impacts are included, yet their inclusion in the sequence at levels lower than would seem optimal belies these benefits (Robertson et al. 2010). In addition to their economic and other advantages in recent drought years, intensive cereal systems have been supported by improvements in varietal disease resistance, seed and foliar fungicides, precision inter-row sowing systems and better residue management as well as DNA soil testing to monitor the build-up of root diseases. The control of grass weeds including herbicide resistant weeds remains one of the major reasons for the inclusion of broadleaf break crops (or pasture) in the crop sequence. New herbicide modes of action are set to provide more opportunity to extend cereal rotations under no-till conditions. Apart from their profitability, intensive cereal systems provide the added benefit of increased soil cover from residue (compared to broad leaf crops) for erosion control and water conservation, soil C inputs and/or livestock grazing in poor seasons and drier areas. Current economics appear to favour the tactical use of oilseed and legume break-crops in intensive cereal systems when required to manage intractable weed and disease issues, restore soil N levels and/or to capture market opportunities for higher oilseed or pulse prices, rather than their inclusion in fixed rotations. Currently, it seems that sequences of cereals make sense in Australian CA systems, with break-crops and pastures used strategically rather than in fixed rotations.

The new PA and CT systems now emerging may facilitate novel options to more readily manage mixtures of crops in the same year as intercrops or relay crops to capture the rotational or synergistic benefits that can arise from such diversity. The logistical difficulties previously associated with these options are more manageable with new PA technologies and a range of new herbicide resistant crop types. Such approaches may provide new ways to capture the benefits of break crops across a wider area of the farm in all years if significant benefits can be demonstrated.

Strategic tillage – evolution or devolution of CA principles?

Few farmers (< 5%) currently practice multiple cultivations in Australia (GRDC 2010). Most retain a flexible approach to tillage performing some soil disturbance on 30% of cropped area, using narrow points for soil disturbance at sowing rather than discs (88%) (Llewellyn et al. 2011) but the appropriate level of soil disturbance in CA systems is contentious. Those promoting the "ideal" of no soil disturbance and full residue retention using disc seeders, (as widely practiced in South America), predict irreparable damage to soil from occasional tillage (Grandy et al. 2006), although the evidence for this has been disputed (Baan et al. 2009; Wortmann et al. 2010). Advances in machinery design, herbicide chemistry and PA technologies are certainly providing success for these approaches in some circumstances (Rainbow and Derpsh 2011), and clearly any unnecessary soil disturbance can cost time, energy, soil water and can stimulate some weeds. The factors that lead farmers to retain flexibility in their approach to soil disturbance in Australia are shared by other countries, but what is the case for pursuing the no disturbance "ideal" and what risks are involved in retaining the current flexible approach to tillage currently practiced by Australian farmers?

Weed management
Australian cropping systems have developed widespread resistance to most herbicide groups including glyphosate in economically important weeds such as annual ryegrass (*Lolium rigidum*). Integrated weed management principles include the use of strategic tillage as an option to manage herbicide resistant weeds, especially under continuous cropping (Preston 2010). The need for some soil disturbance and soil "throw" for efficacy of soil-applied pre-emergent herbicides underpins a preference for narrow points and press-wheel systems compared with disc systems although success will be dependent on soil-type, weed species and the specific herbicide involved. The emergence of problem weeds of the summer fallow within continuous, no-till cropping systems, either not controlled by glyphosate (e.g. fleabane (*Conyza bonariensis*)), and/or resistant to glyphosate (e.g. windmill grass (*Chloris truncata*)) is of concern especially where few other economic or adequate chemical control options exist. In the summer chemical fallow of no-till, no-livestock systems, there is no competition, and few alternative non-chemical control options, though a "double-knock" using a sequence of two different knock-down herbicides is often effective. Diversity in approach is the key to managing weeds, and where pastures, soil disturbance, and regular break crops have been removed from the system, vigilance and novel approaches to manage weed seed banks are vital. Sound agronomy, competitive crops, green/brown manures, herbicide rotation, and weed seed harvesting and destruction are options but may prove insufficient in some cases. It makes little sense to forsake the considerable overall benefits of CA and risk herbicide resistance by avoiding strategic tillage where it is safe and applicable.

Tillage for incorporation of slowly mobile elements
The need for lime incorporation on acid soils is a problem shared by Brazil and southern Australia. Amelioration without soil disturbance is facilitated on some Brazilian soils by high rainfall, permeable soils and high residue loads (Bollinger et al. 2006) but the same is not true for Australian systems characterised by low rainfall (400 – 600 mm in the grain belt), low annual residue input, and the predominance of soils with unstable physical structure and poor profile hydrology. Amelioration by surface applied lime can take 2-4 years longer in no-till than disturbed systems (Conyers et al. 2003) and acidification of the sub-surface remains a serious threat in some areas (Paul et al. 2003).

In Australia, lime is often incorporated during planned tillage at the end of the pasture phase, prior to responsive canola crops that offset the cost, so there is no additional tillage. The adequate incorporation of lime to depth underpins the productivity of subsequent crops and successful establishment of pastures, and more expensive deep incorporation strategies are warranted on deep acidic sandy soils. The associated problem of nutrient stratification in undisturbed no-till systems, whereby immobile nutrients (especially P) are concentrated in surface mulch layers and may be unavailable, poorly accessed and inefficiently used by plants during extremes of temperature or dry periods can be a problem under Australian conditions (Paul et al. 2003). This also has implications for C-sequestration, which is discussed in a later section.

New technologies which allow deeper and more rapid penetration of surface applied lime or nutrients to depth may be required in systems without significant soil disturbance to reduce acidification of subsoils. Precision placement of nutrients to depth for more efficient use, including new fluid and slow-release formulations is possible in PA systems to counter the effects of surface accumulation of nutrients. But until these new technologies become practical, the productivity of mixed farming systems on acid soils will require regular and effective incorporation of lime.

Soil structure and water infiltration
The structural degradation caused by excessive long-term cultivation is not disputed, but strategic and targeted tillage can improve water infiltration under specific circumstances (Hatfield et al. 2001). Strategic tillage in mixed farming systems is often timed to assist in lime incorporation, reduce shallow compaction by livestock, encourage mineralisation and commence a pre-crop fallow period subsequently maintained with herbicides Under these circumstances, surface roughness and pasture residues minimise the potential impacts of disturbance on water infiltration. Renovation may also be used to generate some surface roughness to reduce erosion when cover is low after long periods of drought. Though some argue that even occasional tillage may do irreparable damage to soil structure (eg. Grandy et al. 2006), the evidence for this under Australian systems is scant. Long-term experiments comparing no-till systems with single annual pre-seeding tine cultivation on red loam soils in southern Australia shows no evidence of a decline in crop production after 20+ years of continuous cropping (Watt et al. 2006). Limited soil disturbance using narrow tine and press-wheel seeding systems combined with infrequent strategic cultivation during phase changes in crop-pasture systems appear to pose little threat to long-term sustainability. On structurally unstable soils, the maintenance of adequate surface cover will be paramount to avoid surface sealing and this should be a priority in any tillage (or grazing) operation (Hunt et al. 2011).

Disease and inhibitory organisms
Though many structural and biological properties of soil improve under no-till systems, undisturbed soils can also favour root diseases such as *Rhizoctonia solani*, nematodes as well as inhibitory organisms such as *Pseudomonas* bacteria (Watt et al. 2006). The build-up of inhibitory *Pseudomonas* on the slow-growing root tips of wheat in no-till soils has been linked to the slow early growth and reduced yield of wheat at some sites in southern Australia and *Rhizoctonia* remains a significant problem for no-till cropping on light-textured sandy soils. Soil disturbance using deep narrow tines below the seed, while maintaining inter-row surface structure remains an effective control measure for these organisms as do other approaches to increase the rate of early root growth, such as earlier sowing and the use of vigorous varieties (Watt et al. 2006). New fungicides may also provide further control options for *Rhizoctonia*. Interestingly the maintenance of long-term, intensive no-till cropping can generate disease suppression on some soils whereby the pathogen though present, does not cause crop disease due to the build-up of suppressive organisms. In Australian cropping systems, the flexible rotations between crop and pasture, and the need for periodic break crops for weed control make control through this form of long-term disease suppression difficult.

Multiple benefits from strategic tillage
An interesting, if somewhat extreme example of strategic tillage in Australian broad-acre systems is the one-off use (once every 10 years) of a mouldboard plough on acid, water-repellent sands in Western Australia where long-term, no-till farming had generated a problem with herbicide-resistant ryegrass. Inversion tillage, timed when the soil was moist and erosion risk low, simultaneously buried the herbicide resistant ryegrass seed, incorporated lime to depth and ameliorated water-repellent surface soils and provided significant on-going yield and economic benefits to the system (Preston 2010).

Summary
Strict adherence to "ideal" zero-till may prevent the full benefits of CA systems being realised where one or more of the issues above are operating and have no immediate solution. If the risks of permanent damage are low, and the economics favourable, then pragmatism and good sense would support strategic tillage. Interestingly, rather than avoiding soil disturbance, occasional strategic disturbance may be necessary for crops to capture the promoted soil benefits which build, but may not be expressed in undisturbed soil due to one or more underlying constraints (Watt et al. 2006). The biological constraints associated with slow wheat root growth in undisturbed soils in southern NSW (Watt et al. 2006) are one example where research has revealed plausible biological mechanisms, but further study is needed to support the case for strategic tillage in other systems.

Stubble retention – the more the better, or critical thresholds?

The current average wheat yield in Australia is around 2.2 t/ha generating around 3 t/ha of residue (harvest index of 0.4), but this may vary from < 1 to >8 t/ha of residue (for 6 t/ha grain yield). Farmers have shown sense with respect to crop residue retention in Australian farming systems. High adoption levels in northern, western and lower rainfall southern cropping zones reflect the high risks of water and wind erosion, the importance of water conservation for crop production and lower residue loads that suit the passage of most machinery (GRDC 2010). On mixed farms, crop residues are invariably retained throughout most of the fire-prone summer (cannot be burnt by law) but are often grazed after harvest to capitalise on spilt grain and the feed quality of new straw. To maintain cover and avoid erosion, ~2 t/ha of residue is recommended which represents most of the residue available from average crops. It is generally the heavy cereal residues in wetter areas and seasons where residue reduction through late autumn burning, partial removal or incorporation persists (Scott et al. 2010), although windrow burning for the destruction of herbicide-resistant weed seeds has been a common practice in no-till systems in Western Australia. Advances in post-harvest stubble management, new seeding technologies, and inter-row sowing (Rainbow and Derpsh 2011) continue to reduce the need for residue reduction, though circumstances inevitably arise (eg. the 2010/11 wet summer in much of southern Australia), where pragmatic decisions to reduce heavy, weed-infested stubble loads prior to subsequent crops made sense.

In continuously cropped, no-till, CT farming systems (no livestock) the imperative to retain crop residue is high and many adjustments to the system, from cutting height and straw spreaders at harvest, wider row spacing, disc openers and herbicide choices, and even crop sequence can be adjusted to fulfil the goal of full residue retention with success. In mixed farming systems, grazing can flatten stubbles

and make passage of tined seeding equipment difficult. In higher rainfall or irrigated cropping systems, where large amounts of residue remain, efforts to preserve residue through wider row spacing may limit yield potential, and partial stubble removal can provide a feasible compromise (Govaerts et al. 2005). In mixed farming systems in higher rainfall areas, where the pasture phase builds organic matter and most other benefits of residue retention can be realised by maintaining threshold levels adequate for soil protection and moisture conservation over summer, there is good sense in a more pragmatic approach to residue management. This may include partial removal where there is a market, heavy grazing and/or late burning.

The carbon conundrum for CA systems?

Maintenance or improvement of soil organic carbon (SOC) is a widely promoted benefit of CA systems and since 75% of all Australian agricultural soils are below 2% SOC, significant potential for C sequestration has been proposed. Notwithstanding the demonstrated recovery of SOC at badly degraded sites, the build-up of SOC under CA cropping systems in Australia is generally non-existent or frustratingly slow, but not always due to inadequate residue inputs (Chan et al. 2011). Several studies now question claims of SOC increases under CA systems. Franzluebbers (2005) suggested no-tillage increased soil C sequestration rates by 0.42 ($\pm$0.46) t ha^{-1} y^{-1} compared to conventional tillage, while a review by Baker et al. (2007) and meta-analysis by Luo et al. (2010) found greater accumulation of SOC at the surface (<30 cm) but no significant difference in total SOC stocks under no-till in experiments where soil was sampled below 30-40 cm. Rumpel (2008) compared burning and incorporation of wheat residues over 31 years in France and even with such an obvious difference in residue returned to the soil (mean of 0.8 t/ha compared to 3.2 t/ha per year), there was no difference in SOC levels. What is limiting C build-up in these circumstances?

Recently the importance of the inorganic nutrients N, P and S in stabilising SOC has been rediscovered and may provide clues to the slow build-up of stable SOC in no-till systems. Kirkby et al. (2011 and this conference), have demonstrated relatively constant ratios of C:N:P:S in the stable SOM, a consequence of its largely microbial origin. In modern no-till systems, nutrients can become stratified on the soil surface where they are less available to soil organisms, and efforts to achieve efficient fertiliser inputs for crop production may limit those available for C stabilisation. Crop residues low in inorganic nutrients and concentrated at the surface limit the stabilisation of C and may accumulate as a labile "light-fraction". Surface retained residues and light fraction play important roles in soil protection and tilth, but they are unstable and not part of the permanent humus pool from which fertility is derived and C-sequestration evaluated. Numerous studies have found that incorporating crop residues accompanied by adequate inorganic fertiliser addition can lead to consistently increased SOC levels (Moran et al. 2005, CSIRO 2010). In Australian farming systems, it may often be P and S rather than N that limits the stabilisation of C and as with the problem of lime incorporation, some soil disturbance may be necessary to assist these processes.

In view of the demonstrated value of pasture for C-sequestration in Australian mixed farming, the slow but ongoing decline in SOC stocks under continuous cropping, and the relatively small or non-existent differences in total SOC between CA and conventional systems growers should be cautious in assessing the C-sequestration potential of their CA systems (Chan et al. 2011, CSIRO 2010).

Energy efficiency of CA systems

The gains in on-farm efficiencies in time, labour, and fuel are undisputed benefits of the adoption of CA principles, and the further integration of CT and PA technology will add further gains. Though profit and not energy efficiency drive management decisions, CA aims to balance environmental and energetic effects with production. Irrespective of the small changes in soil C discussed above, CA systems are generally considered to reduce on-farm greenhouse gas (GHG) emissions through reduced fuel use and efficient use of inputs. However, a recent analysis of on-farm and off-farm GHG emissions for grain cropping systems in Queensland suggests that the impacts of switching to zero-tillage are relatively small (Maraseni and Cockfield 2011). In essence, for wheat production, the reduced GHG emissions associated with reduced cultivation in zero-till systems (97 kg CO_2e/ha) were largely substituted for increased emissions associated with agrochemical use (80 kg CO_2e/ha). So what is the overall energy efficiency of systems where tillage has been replaced with manufactured herbicides, and continuous cropping is supported by various inputs to replace legume pasture phases and break crops?

No equivalent comparative study for southern Australian mixed farming systems could be found, though a recent example from a long-term (15 yr) system experiment in a semi-arid cropping zone in Spain (Moreno et al. 2011) is relevant. The study found no difference in the energy efficiency (yield per unit of energy input) between conventional (173 kg GJ^{-1}) and conservation tillage systems (177 kg GJ^{-1}), and higher efficiency in cereal-legume rotations (360 kg GJ^{-1}) than cereal monoculture (137 kg GJ^{-1}). Organic systems using tillage but no chemical inputs had highest efficiency (400 kg GJ^{-1}) but lower crop yields (energy output) compared to the other systems (17.9 compared with 24 GJ ha^{-1}). The study did not account for changes in soil nutrient status and considered only those inputs under the control of farmers. However the study reveals the high embodied energy cost of fertilisers and agro-chemicals which are often used with low efficiency in semi-arid areas where yields vary due to unpredictable seasonal conditions. A definitive assessment of the energy efficiency of Australian mixed farming systems is difficult due to their diversity and flexibility but two conclusions can be drawn. Firstly, the current drive for improved nutrient and input-use efficiency within modern CA systems incorporating CT and PA systems in the cropping phase is likely to contribute to ongoing improvements in energy efficiency. Secondly, however, it seems unlikely that pragmatic approaches of tactical phases of legume-based pastures and break crops, strategic tillage and managed residue thresholds as currently practiced in southern Australia will significantly diminish the energy efficiency of the overall system. Further studies are warranted to investigate this issue.

Capturing system synergies and the productivity imperative

Though discussions of component technologies are necessary for mechanistic understanding, most recognise the synergies at the whole system level as the hallmark of CA systems. Kirkegaard and Hunt (2010) investigated the nature of these synergies during the evolution of CA systems in southern Australia during the last 30 years with a specific focus on yield and water-use efficiency. The case study farm and related simulation demonstrated how the deployment of CA components combined to generate yield (from 1.67 t/ha to 4.54 t/ha) and WUE improvements (6.0 to 15.2 kg/ha/mm) which could not be achieved when individual components were adopted singularly (Table 1). Interestingly fallow weed control and early sowing, rather than stubble retention and reduced tillage *per se* underpinned the largest increases in yield and WUE, though each component operationally enabled adoption of the others. In the study, significant potential for further improvement involved the use of a novel wheat genotype with long coleoptiles to enable deeper sowing into stored water with planned early sowing (Table 1). Such varieties are now in development and exemplify the potential to consider opportunities for Genotype x Environment x Management interactions (GxExM) that may benefit future CA farming systems. The new CT and PA seeding systems offer unprecedented opportunities to place both chemical inputs and seed (and thus the root system) more precisely, to manage the

developing crop canopy and the weeds within it in timely ways attuned to seasonal conditions, and to manage crop residues for successful establishment of the following crop. Disease resistant, herbicide tolerant and hybrid crop varieties already have advantages for emerging CA systems but some of the targets of current breeding in wheat production systems may provide opportunities for further synergies - phenological development, increased early vigour, tillering ability, canopy architecture, storage of stem carbohydrates, root depth and architecture and nutrient-use efficiency. The germplasm is already available and genetics well-understood for many of the traits (Rebetzke et al. 2008). The key will be to identify and assess those large numbers of advanced breeding lines for synergies under emerging CA systems independent of the routine large-scale testing in the current systems.

Table 1. Management scenarios depicting the baseline scenario and the sequential adoption of new agronomic innovations in the Victorian Mallee region of southern Australia. The Table shows the simulated wheat yield (t/ha) and water-use efficiency (kg/ha.mm ET) for the baseline and those for innovations adopted sequentially (2-6, additive), or singularly for the years 1962 to 2009 (from Kirkegaard and Hunt 2010).

Scenario	Mean grain yield (t/ha)		Mean WUE (kg/ha.mm)	
	Additive	Singular	Additive	Singular
1.Baseline management (1980s)*	1.57	1.57	6.0	6.0
2. Min-till (replace burn, cultivate)	1.81	1.81	6.8	6.8
3. Fallow weed control (replace graze)	2.77	2.34	9.6	8.0
4. Crop sequence (forage pea in sequence)	3.41	1.73	11.1	6.3
5. Early sow (from 25 April)	3.98	2.04	12.9	7.1
6. New variety**(long-coleoptile)	4.54	1.42	15.2	5.1

* Graze stubble (no weed control), burn residue, cultivate, continuous wheat, sow after mid-May
** Allows earlier sowing into stored water on 25 April

Summary

Australian farmers have adopted and adapted the principles of CA in a diversity of ways to develop practices that suit not only their soils and environment, but their enterprise mix and financial and family circumstances. Current CA adoption levels suggest they have seen sense in these principles and the adoption rates of the more recent CT and PA technologies appear to be following a similar pattern of cautious and pragmatic step-wise integration (Robertson et al. 2011). In most areas, some large farms with extensive cropped areas and no livestock have adopted zero-till, stubble-retained systems with GPS guided precision seeding, spraying and harvesting. They are experimenting with wider rows, inter-row or on-row seeding, shielded sprayers and the Weed Seeker technology for spot spraying of weeds as well as yield and soil mapping to assist in variable rate application of inputs. Capital costs and depreciation of equipment, exposure to risky grain commodity prices and prolonged drought, and vigilance regarding the development of herbicide resistant weeds remain challenges to these systems. Further innovation to improve productivity and efficiency within these systems will no doubt emerge at this meeting.

In this paper we have discussed the underlying reasons for the more flexible and pragmatic approach to aspects of CA systems as currently practiced on most southern Australian mixed farms. We have provided evidence to demonstrate that mixed farming system based on phases of legume-based pastures, intensive cereals with tactical break crops, strategic soil disturbance and managed cover thresholds with careful livestock management make sense for many farm enterprises and are compatible with the principles of CA. In addition to individual on-farm concerns of productivity, profitability and business risk, it appears that such practices are more favourable in terms of wider overall carbon and energy balance than previously thought. Further innovations in mixed farming systems will also inevitably emerge to minimise any on-going trade-offs inherent in integrating livestock and cropping on mixed farms. Our Australian experience suggests that we should continue to apply good science to sift the sense and nonsense in the evolution and adaptation of CA worldwide, and be pragmatic rather than prescriptive in how the principles are applied. The global food productivity imperative demands this of agricultural scientists.

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Production systems for the future: balancing trade-offs between food production, efficiency, livelihoods and the environment

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Introduction

The world is under significant pressure. Human population is projected to increase by 30% over the next quarter of a century to reach 8.3 billion by 2030 (UNPP, 2008). During this period, in developing countries there is likely to be a rapid increase in demand for livestock products, driven by increasing urbanisation and rising incomes (Delgado et al., 1999). At the same time, the impacts of a range of driving forces such as water availability, climate change, and technological innovations on smallholder crop and livestock production may be substantial. The result of these drivers is that the farming systems responsible for global food security will inevitably change. The challenge is to ensure that the resource-poor, mixed crop-livestock, smallholder sector, which currently provides the majority of grains, milk and meat in the tropics, is able to evolve to feed the increasing human population. To do so, agricultural systems will need to intensify, but it is vital that this does not compromise natural resources and rural livelihoods.

Integrated assessment of food security and the environment

A range of integrated assessments have studied the state and future of global ecosystems and their capacity to provide key services for humans (food, fibre, energy and others) while maintaining ecosystems functions (MA, 2005; CA, 2007; GEO4, 2007, Foresight 2011). The IAASTD (2009) recently highlighted the future pressures on global food production and the need for additional investments in science and technology as a prerequisite to meet increasing human demands in a sustainable way. The CGIAR invested in an integrated assessment based on the main findings of the IAASTD study, to identify the impacts of key drivers of change on diverse production systems in the developing world. The main objective was to identify differentiated policies for the sustainable intensification of food production and maintenance of ecosystems services for the developing world (Herrero et al., 2009). A summary of the main findings is presented in Table 1 and elaborated in the paper.

Table 1 – Balancing food production, maintenance of ecosystems service and poverty reduction in the developing world through policy, investment and technology (Herrero et al 2009)

	What the future may hold	Policy needs	Investment needs	Technology needs
Agro-pastoral systems	Significant rural – urban migrations, more conflicts, higher numbers of vulnerable people, increases in livestock numbers in some places, significant impacts of climate change in places, resource degradation	Frameworks for diversifying income sources including payments for environmental services and others, insurance-based schemes	Roads, livestock markets, health and education establishments, development of water sources, food storage systems, telecommunications	Matching livestock breeds to the environments, livestock species changes in some places, suitable crops if required, early warning systems, mobile phone based telecommunication products: prices information and others
Extensive crop-livestock and cropping systems	Manageable increases in population density but significant rural-urban migrations, potential for increased crop and livestock production through intensification, though large impacts of climate change in some places	Policies to create incentives and an enabling environment to produce food in these regions, appropriate credit, land tenure rights, incentives for public-private partnerships, service and support institutions	Infrastructure: roads, post harvest storage systems, water sources and storage, health and education establishments, markets, development of value chains, involvement of the private sector, product processing plants, telecommunications	Crop varieties suitable for the environment, fertilisers and agricultural inputs, livestock feeds, breeding systems, livestock vaccines and health management
Intensive crop-livestock and cropping systems	Large increased population densities, reductions in primary productivity of crops in places, water scarcity or soil fertility constraints, large increases in livestock numbers, increases in food prices, potential food insecurity, environmental degradation, increases in zoonotic and emerging diseases	Regulations for intensification / de-intensification, monitoring and evaluation frameworks for assessing environmental impacts. Appropriate regulatory frameworks for global food trade	Infrastructure to support value chains: ports, railways, cold chains, processing plants, supermarkets and storage facilities. Human capacity development to improve management skills	Options with high efficiency gains: more crop per drop, more crop per unit of fertiliser, species or animals with improved conversion efficiencies of feed into milk and meat

Industrial livestock systems	Most growth in monogastric production will occur in these systems, heavy dependence on grains as feed, expansion into areas further away from centres of demand as transport efficiency develops	Regulations for intensification / de-intensification, monitoring and evaluation frameworks for assessing environmental impacts. Appropriate regulatory frameworks for global food trade	Infrastructure to support value chains: ports, railways, cold chains, processing plants, supermarkets and storage facilities	Animals with improved conversion efficiencies of feed into milk and meat, more efficient diet formulation, technologies for waste disposal

There is a significant need for further differentiation of data from global assessments to be able to design technology, policy and investment options with more focus, that are of greater relevance to the social groups in question (Herrero et al. 2009, 2010).Agricultural systems in the tropics are multifunctional and very heterogeneous. It is necessary to understand their basic differences in structure and function in order to design improved and more sustainable options (Giller et al 2011). On the other hand location, demographics, markets and agricultural potential play a significant role in how these systems might evolve and what is feasible to implement locally (Byerlee et al., 1982; Pender et al., 2004). In its most simple form, at least 4 systems, with many configurations, depending on location can be found. For example, agro-pastoral systems with low population densities, low agricultural potential and poor market access. These areas are characterised by livelihood systems depending mostly on ruminant livestock. Extensive crop-livestock systems with medium population densities, where there is crop cultivation but low yields, extensive livestock production mainly for meat production, low input use, and poor connectedness to markets; intensive crop-livestock systems with high population densities, high agricultural potential including the use of irrigation sometimes, high input use, intensive livestock rearing predominantly for dairying, and good market access; and industrial systems: as developing countries industrialise, large-scale monogastric production systems spring-up and tend to be located close to urban centres to minimise the problems associated with product conservation and transportation (Steinfeld et al., 2006). These are essentially landless systems.

Mixed crop-livestock systems: the backbone of food security

Mixed crop-livestock systems, where interactions between crops and livestock activities are significant (Figure 1), are and will continue to be the backbone of sustainable pro-poor agricultural growth in the developing World to 2030 (Herrero et al 2009, 2010). Their significance cannot be ignored in the global development agenda. Two thirds of the global rural population live in these systems and in many places they have low opportunity costs of labour, hence maintaining a large smallholder sector (Wright et al 2011). They produce 50% of the world's cereals and more importantly, produce most of the staples consumed by poor people: 41% of maize, 86% of rice, 66% of sorghum and 74% of millet production (Figure 2, Herrero et al 2009). They also produce the bulk of livestock products in the developing world - 75% of the milk and 60% of the meat - and employ many millions of people in long value chains. Rates of growth in production and consumption of agricultural products are significantly higher in these systems than in others, with livestock production and consumption rates doubling those of crops (Delgado et al., 1999; Herrero et al., 2009, 2010).
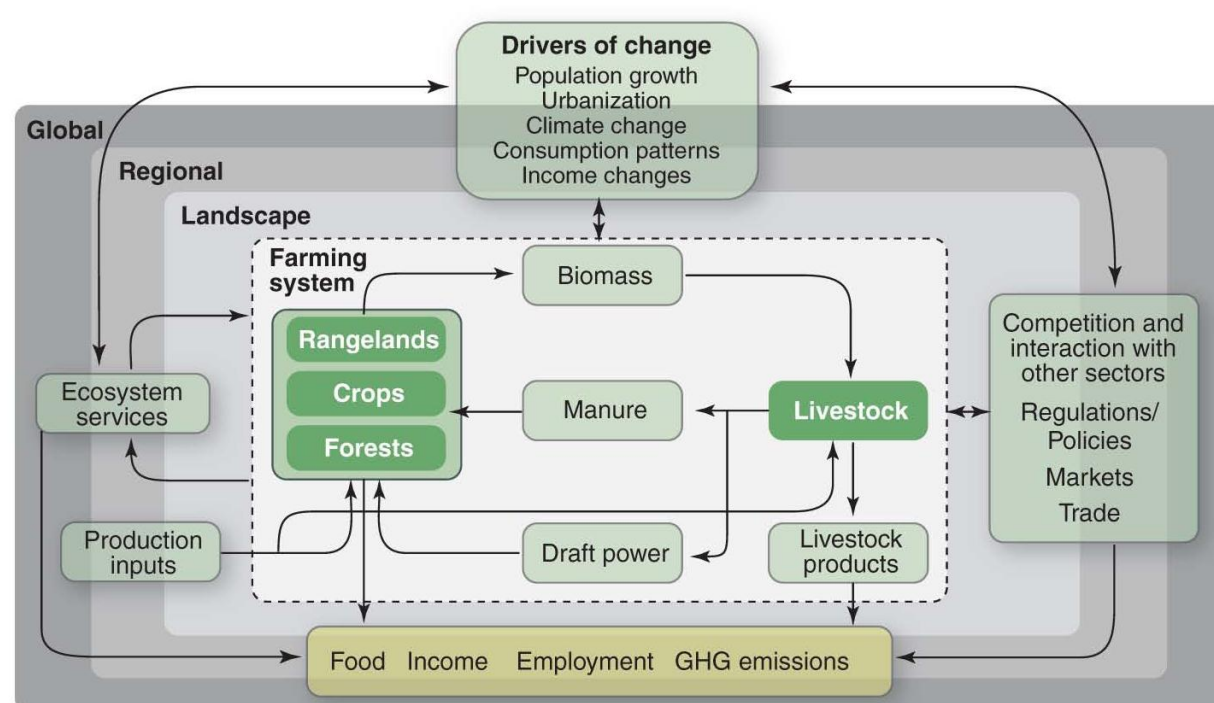
Figure 1. Main interactions in crop-livestock systems in the developing world (Herrero et al. 2010)

Traditionally, governments in developing countries have often targeted public investments to the mixed intensive systems as they have been seen as the engines of agricultural growth in these regions (Fan and Hazell, 1999), typified by the green revolution in South Asia in the 1970s. At the same time, public investment has historically been significantly higher in crops than in the livestock sector, often by a factor of ten or more (IEG 2004).
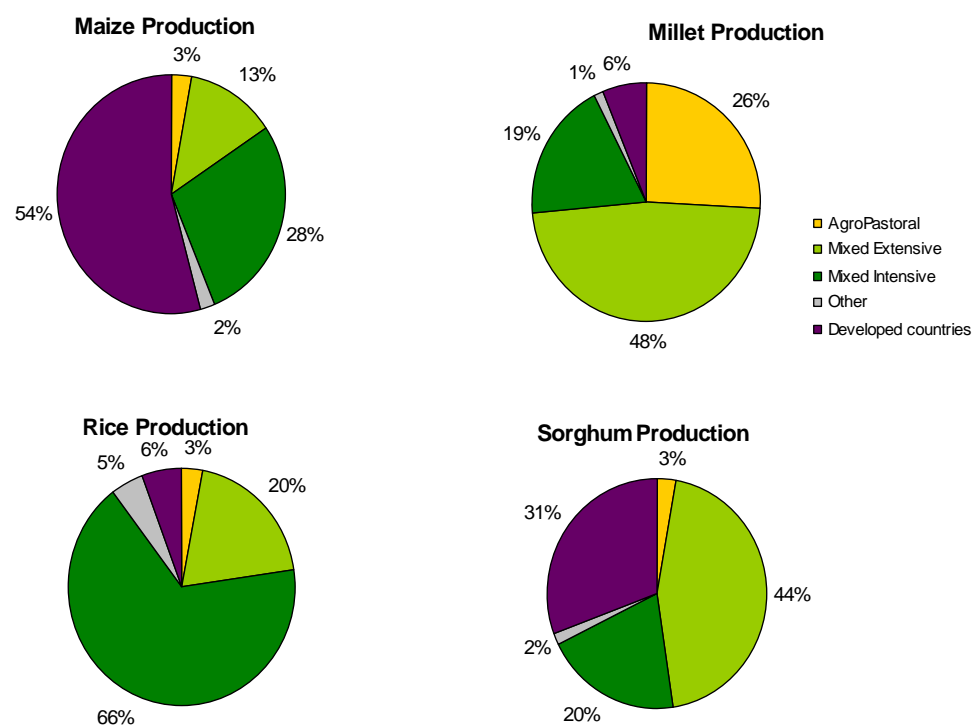
Figure 2. Global share of production of maize, millet, rice and sorghum in mixed intensive, extensive and agropastoral systems in the developing world relative to production in the developed world – 2000 (Herrero et al 2009).

The future of high potential areas in the developing world

In some parts of the developing world, high potential crop-livestock systems are under significant pressures, and the substantial growth rates in productivity observed in the past may be attainable no longer. These pressures are larger in some systems than in others but are all caused by the rising demands of the human population, income shifts, and high rates of urbanisation. Globally, population in these systems will increase from 2.5 billion people to 3.4 billion by 2030, predominantly in Asia. Intensive crop-livestock systems in South Asia are reaching a point where production factors are seriously limiting production as land per capita decreases. Rice and wheat production in the future may not grow fast enough to meet human demands due to water constraints (IAASTD, 2009). At the same time, livestock numbers will increase significantly: cattle and buffalo will increase from 150 to 200 million animals to 2030 while pigs and poultry will increase by up to 40% over the same period. The pressures on biomass to feed these animals are already high and significant trade-offs in the use of resources (land, water, nutrients) exist in these systems, especially as the demands for biomass for food, feed and energy increase (Dixon et al., 2009). In the high-potential areas of Africa, such as the East African highlands, these phenomena can also be observed. They are manifested in significant reductions in soil fertility, loss of carbon, environmental degradation, reduced production and shrinking farm sizes (Waithaka et al., 2006, Tittonell et al 2009).

Systems with high degrees of intensification, like in parts of the Indo-gangetic plains and some parts of South-East Asia, will require options with high efficiency gains without using any more land and water. While crop production is reaching its yield increase limits in some of these systems, there is considerable scope for increasing resource use efficiency in both crops and livestock (Herrero et al 2010, Giller et al 2011). Monogastrics such as chickens and pigs have doubled the efficiency of conversion of grain into meat in the last 30 years (Steinfeld et al., 2006). This has led to increased use of grains to feed livestock, at the same time producing more meat per unit of grain fed. Growth in this sector has reduced global poultry prices significantly at the expense of increased cereal demands that not only compete with food for humans but may fuel deforestation (Steinfeld et al., 2006). In some regions, livestock species shifts will be required to use resources more efficiently and policies to promote specialisation of production will need to be implemented. Specialisation and intensive industrial livestock production will also require environmental and trade regulations, as they may lead to concentration of animals and potential environmental problems such as large nutrient loadings in peri-urban areas (Steinfeld et al., 2006). This may affect water quality for human populations and increase the risk of epidemics of emerging diseases that could affect both livestock and humans (Perry and Sones, 2007). Evidence from South Asia suggests that species shifts are already occurring in intensive crop-livestock systems, and these will continue. For example, rates of growth in poultry production to 2030 are projected to be higher than 7% per year, two to three times higher than rates of growth in ruminant or crop production (Herrero et al., 2009).

Not putting our money where our mouth is: a necessary paradigm for sustainable global food production, ecosystems maintenance and poverty reduction?

Resource constraints in some land-based mixed intensive systems are reaching are a point where crop and livestock production could decrease and where environmental degradation may have deleterious impacts on humans. In more extensive systems, with less pressure on the land, the yield gap for crops and livestock is still large. For example, yields of dryland crops such as sorghum, millet and cowpea could be increased by a factor of three with appropriate use of inputs (Cooper et al. 2008). Important productivity gains could be made in these more extensive mixed rainfed areas with risk reduction technologies for reducing the impacts of climate variability. Pro-poor policies and public investments in infrastructure will be essential to create systems of incentives, reduce transaction costs, and improve risk management in these systems. Integration of production in these systems to supply agro-ecosystems services (feeds, food, etc.) to the more intensive systems will also be needed to ensure the viability of the more intensive systems in the future.

Considerable changes in public and bilateral resource allocation may thus be required. Governments and donors will need to prioritise investments in a non-traditional way. Instead of allocating most resources to areas that are highly populated or that have high agricultural potential but unviable farm sizes, investing in infrastructure and services in slightly more extensive areas may be the key for the food security of the future. Early actions in this area are essential to combat increasing risks of food insecurity, especially considering the likely impacts of climate change in some regions (IPCC, 2007).

Rural-to-urban migration rates in extensive crop-livestock systems are high (World Bank, 2008) but with the right sets of incentives, such as roads and market creation, infrastructure, health facilities and other services, these could decrease. Nurturing the next generation of food producers in the developing world is of key importance for the food security and poverty reduction of large areas of the globe. At the same time, with these incentives, some pastoralists will grow marginal crops, changing their systems from pastoral to crop-livestock systems. This additional food production, although small, is crucial to the livelihoods of poor people who are largely dependent on livestock (Nkedianye et al., 2009).

Intensification and resource use efficiency: how far can we go?

Sustainable agricultural intensification has received significant attention as a mechanism for increasing food production for feeding 9 billion people (Foresight 2011). Some of the benefits mentioned include higher resource use efficiency (water, nutrients, land), less greenhouse gas emissions per unit of product, land sparing impacts and reductions in deforestation, and others (Royal Society 2009). Defining the limits to agricultural intensification is crucial for developing regulatory frameworks for sustainable food production and for maintaining ecosystems functions. When does sustainable become unsustainable, when do useful nutrients become pollution? These kinds of questions are essential for a resource-constrained world and more relevant in some places than others. Intensification of production through science and technology investments (increased input use, changes in crop varieties or animal breeds, higher resource use efficiency, etc.) has been enormously successful in increasing global food production over the last 200 years. With this has come increased understanding that there can be serious consequences for the environment associated with intensifying systems without limits (i.e. parts of China and India). Particularly in the developing world, there is a need for understanding and developing a set of criteria to define the thresholds of intensification, more for livestock systems than for crops, before irreversible environmental degradation occurs (i.e. nutrient overloads due to large animal concentrations). The limits and criteria will differ depending on location and production system but they should lead to a regulatory framework for systems' intensification that can be applied at the local level. Within this framework, it may well be that some systems will need to de-intensify or stop growing to ensure the sustainability of agro-ecosystems or to protect key resources (i.e. water) for the future of specific regions. This will need to be accompanied by the development of options for diversification of income sources for users of key resources through smart schemes for payments for ecosystems services in these regions. Successful examples are starting to appear in the literature (FAO, 2007).

On the other hand, in parts like most of sub-Saharan Africa, the efforts to increase resource use efficiency need not to be confounded with the massive need for increased input availability and use (i.e. more fertilisers). They need to be pursued in parallel.

Additionally, new paradigms for agricultural development will play a key role in determining how well smallholders will fare, and how agricultural investments are made in the future. For example the ongoing debate on the increased efficiency of large, consolidated farms vs a fragmented smallholder sector could have a big role in shaping the RandD agenda in the coming years. However, serious studies covering multiple dimensions (from the social to the economic and ecological) and not based solely on efficiency criteria will be required to elucidate the impacts of these kinds of changes on global food systems. At the same time, technological changes of unprecedented magnitude as a result of technological breakthroughs could yield solutions that could reduce significantly the pressures on agro-ecological systems. Additionally, it is still unknown if some of these solutions, and other adaptation practices, will be able to mitigate the impacts of climate change on crop and livestock production. How to balance the objectives of increased productivity and higher resource use efficiency under climate change is still a subject that requires more research and solutions, especially for smallholders.

Conclusions

The viability of global food production, the maintenance of ecosystems services, and the reduction of poverty, involve an increasingly complex and subtle balancing act of promoting well-regulated, differential growth in crop and livestock production, and in investing in food producing systems, including those that traditionally have not received as much attention in the past. These strategies can only be implemented with new, more dynamic policies that weight carefully the trade-offs between agro-ecosystems services and human well-being. The rules of the game have changed, as protecting global goods becomes an integral part of how we feed the world in the future.

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Making Conservation Agriculture ever green

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After decades of research, and the sustained efforts of pioneering farmers, the practice of conservation agriculture (CA) has been steadily increasing globally. Currently, about 117 million hectares of land are now managed under minimum or zero-tillage conservation farming practices. However, the uptake of CA in Africa, and in the rainfed upland areas of Asia, has been modest so far. Why is that?

This paper reviews the key constraints limiting the practice of CA in tropical rainfed agroecologies. It examines evidence from research, and from widespread indigenous practice, that indicates that successful CA systems for tropical smallholders would benefit substantially from the integration of trees. It argues that Conservation Agriculture with Trees (CAWT) addresses a number of the critical constraints to sustained smallholder CA uptake, and notes that there is now clear evidence of its success at scale in several countries in Africa.

There are three long-established principles in conservation farming: Minimum soil disturbance, crop residue retention, and crop rotation. The short-term advantages observed where CA is currently practiced are earlier planting to enable better use of seasonal rainfall, and increased rainwater conservation in the soil to better tide crops over during drought periods (Rockstrom et al 2009). But there are a number of unique constraints to smallholder adoption of CA that are retarding its more rapid uptake. Most important among these are: Competing uses for crop residues where livestock production is common, inadequate biomass accumulation of cover crops in the off-season, increased labor demands for weeding when herbicides are not used, variable yield results across soil types, and the need for greater application of organic and inorganic nutrients.

Giller et al (2009) discussed these constraints. They pointed out that most African smallholders are engaged in both crop and livestock production, and that their available fodder resources are usually very inadequate. Thus, farmers must typically use all of their available crop residues for animal fodder or fuel, and cannot afford to retain these valuable materials as a soil cover. This highlights the imperative to find other ways to increase plant biomass. In addition, more than 75% of African smallholders are not applying any inorganic fertilizers, often because of cash constraints and high climatic risk. Thus, low yields and soil fertility decline in CA are inevitable if greater use of biological nitrogen fixation and more efficient nutrient cycling are not practiced.

How can biomass production be increased to enhance surface cover and to generate greater quantities of organic nutrients to complement whatever amounts of inorganic fertilizers a smallholder farmer can afford to apply? Recently, the CA and agroforestry research and development communities have mutually recognized the value of integrating fertilizer trees and shrubs into CAWT systems (illustrated in Figure 1 and 2) to dramatically enhance both fodder production and soil fertility (eg FAO 2010; FAO 2011). Practical systems for intercropping fertilizer trees in maize farming have been developed and are being extended to hundreds of thousands of farmers in Malawi and Zambia (Ajayi et al 2011). The portfolio of options includes intercropping maize with *Gliricidia sepium*, *Tephrosia candida* or pigeon peas, or using trees such as *Sesbania sesban* as an improved fallow.

One particularly promising system is the integration of the *Faidherbia albida* into crop fields at a 10 m by 10 m spacing. *Faidherbia* is an indigenous African acacia that is widespread on millions of farmer's fields throughout the eastern, western, and southern regions of the continent. It is highly compatible with food crops because it is dormant during the rainy season. It exhibits minimal competition, while enhancing yields and soil health (Barnes and Fagg 2003). Several tons of additional biomass can be generated annually per hectare to accelerate soil fertility replenishment, provide additional livestock fodder. Numerous publications have recorded increases in maize grain yield when it grown in association with *Faidherbia,* ranging from 6% to more than 200% (Barnes and Fagg 2003), depending on the age and density of trees, agronomic practices used, and the weather conditions.

Faidherbia's effects tend to be most remarkable in conditions of low soil fertility. In semi-arid cropping systems based on millet and sorghum, double-story production systems with medium-to-high densities of fertilizer trees are now observed across more than five million of hectares in the Sahelian countries (Garrity et al 2010). Depending upon which woody species are used, and how they are managed, their incorporation into CA helps to maintain vegetative soil cover, increase nutrient supply through nitrogen fixation and nutrient cycling, suppress insect pests and weeds, enhance soil structure and water infiltration, increase carbon storage and soil organic matter, and conserve above- and below-ground biodiversity.

Evergreen Agriculture is defined as the incorporation of trees into crop production systems, either in the presence or absence of CA (Garrity et al 2010). Thus, CAWT systems are a type of Evergreen Agriculture. CAWT retains an emphasis on reduced tillage, but it expands on the principle of residue retention to include the integration of trees and shrubs throughout the crop fields to supply increased high-quality residues from tree biomass and other organic sources of nutrients. This broadens the concept of crop rotations to incorporate the role of fertilizer/fodder trees to more effectively enhance soil fertility and provide needed biological and income diversity in the system.

In Niger, millet production in combination with *Faidherbia* is accompanied by non-inversion tillage methods. The majority of Nigerian farmers do not use the plow or the hoe for land preparation on their typically sandy soils. Rather, they use a hand-drawn form of shallow-sweeping implement that is passed just underneath the soil surface, loosening the soil and undercutting the weeds. Thus, agriculture in Niger is now essentially a CAWT system. In Burkina Faso, *zai* cultivation in planting pits is a variation of CAWT. Its practice has been steadily expanding for decades. The pits intensify cereal and tree production in combination. Biomass production in these systems is dramatically increased, for both soil amelioration as well as livestock fodder.

Incorporating trees into crop farming may confer sustainability benefits through ecological intensification. They may increase the resilience of the farm enterprise to climate change through greater drought resilience, and they sequester more carbon. Conventional CA systems tend to sequester a maximum of 0.2−0.4 t C ha−1yr−1. CAWT systems accumulate carbon both above and below-ground in the range of 2−4 t C ha−1yr−1, roughly an order of magnitude higher than with CA alone. This is particularly true for systems incorporating fertilizer trees such as *Faidherbia* or *Gliricidia* (Makumba et al. 2007). Consequently, there is considerable interest in the development of reward systems to channel carbon offset payments from developed countries to stimulate more carbon sequestration in African food crop systems while

simultaneously enhancing the livelihoods of smallholders and the environment. These investments will encourage development pathways resulting in higher carbon stocks at a whole landscape scale.

CAWT systems should attract much more research and extension attention than has been the case so far. Their success will depend on the use of a wider range of tree species for varied agroecologies, higher quality tree germplasm, better tree seed dissemination systems, and further improvements in tree propagation and establishment methods. The optimum tree densities for different CAWT systems have yet to be fully understood, and the best practices in exploiting the soil fertility synergies between organic and inorganic nutrient sources need to be elucidated. Targeting and scaling-up methodologies deserve particular attention. These need to be supported by work to reverse deleterious policy frameworks in some countries that may discourage farmers from cultivating trees. Also, active farmer organizations have always been instrumental in the development and spread of CA. Thus, the growing interest in Landcare for grassroots mobilization in Africa and Asia can provide a particularly suitable approach for the engagement of farming communities in the refinement and spread of CAWT.

Figure 1. National recommendations for maize conservation farming in Malawi and Zambia include cultivation of 100 *Faidherbia albida* trees/ha at 10 m x 10m spacing.

Figure 2. Smallholder conservation farming in Zambia features the intercropping of *Faidherbia albida* trees to provide additional biomass and enhance soil fertility.

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THEME 1: MoreEfficient Management Practice for CA

Spatial variation of soil constraints and its implications for site-specific soil and nutrient management in Conservation Agriculture

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Introduction

Soil constraints such as salinity, sodicity, acidity and phytotoxic concentrations of chloride (Cl⁻) in soil are major constraints to crop production in many soils of north-eastern Australia. Many of these constraints occur simultaneously both in top soil and subsoil layers. The soil constraints vary both spatially across the landscape and within soil profiles (Dang et al. 2010) and the complex interactions that exist between the constraints necessitate site-specific management (SSM; also called precision agriculture). Identifying the spatial variability of these constraints and appropriate management options offers challenges and opportunities to manage this variation for profitable outcomes. The concept of site-specific management is neither new nor complicated; it has been practiced in ancient times with farmers managing smaller fields than exist today differently through conscious and unconscious actions (Plant 2001). However, modern large fields resulted in saving of labour but also led to application of inputs at uniform rates, resulting in reduced nutrient use efficiency as inputs were applied at an inappropriate rate in some parts of the field, especially in areas with soil constraints. These uniform applications of fertilizer nutrients to the constrained parts of a field not only result in economic losses, but also present greater risk of nutrient losses in leaching and runoff (Wong et al. 2006). Site-specific nutrient application as a means to improve economic and ecological outcomes has become an attractive and intuitive approach because of increasing fertilizer nutrient input costs and environmental concerns arising from their use. In this study we attempt to quantify the potential economic benefits of site-specific soil and nutrient management on a case study farm located in the north-eastern Australia.

Materials and Methods

A 74-ha field with known significant spatial variability in grain yield was selected near the town of Biloela (Lat. 24º33' S, Long. 150º54' E). We delineated three potential management classes (PMC) using k-means classification of the interpolated data of apparent electrical conductivity (EC_a) and the available years of grain yield maps. A minimum of four locations were selected within each PMC for soil sampling in 0-0.10 m followed by 0.20 m depth intervals down to 1.5 m. Samples were analysed for physico-chemical properties. Soil in each PMC was characterised for bulk density, drained upper limit, crop lower limit and plant available water capacity (PAWC). In 2009, replicated strips were established in each PMC and 0 and 23 kg N/ha was applied across the field aligned in the direction of management operations while the rest of the field received 46 kg N/ha. Wheat was sown and at crop maturity, plant samples were taken from quadrats within each N rate strip in each PMC. Nitrogen requirement for each PMC was calculated using average yield in each class, protein goal (12%) and NO_3-N present in soil (Cox and Strong 2009):

N requirement (kg/ha) = (grain yield x protein goal x 1.75 x 2) - NO_3-N to 0.9 m.

Partial gross margins were calculated for uniform and variable N rate using wheat grain prices of $0.20/kg, and $1/kg for N fertilizer and measured grain yields for each PMC.

The APSIM modelling framework (Keating et al. 2003) of crop growth, water and N dynamics was calibrated for the 3 PMCs and historical meteorological data used for the site to estimate wheat yield and potential environmental consequences in response to applied N.

Results and Discussion

The PMC identified by our analysis (Figure 1a) were: (i) a low-yielding class (mean yield=1.27 t/ha; mean EC_a=122 mS/m; PAWC=78 mm); (ii) a medium-yielding class (mean yield=1.99 t/ha; mean EC_a=89 mS/m; mean PAWC=112 mm); and, (iii) a high-yielding class (mean yield=3.36 t/ha; mean EC_a=56 mS/m; PAWC=192 mm). Soil bulk density at each depth was significantly higher in the low-yielding class compared with medium- and high-yielding classes; however, differences in medium- and high-yielding classes were not significant. High bulk density reduces porosity and makes it harder for roots to extract moisture. Soil Cl⁻ was significantly higher (>800 mg/kg) below 0.8 m depth in low- and medium-yielding classes compared with high-yielding class. High Cl⁻ in subsoil has been shown to restrict the ability of wheat roots to extract soil water and thus results in reduced yields (Dang et al. 2010). Exchangeable Mg percentage (EMgP) was significantly higher (>25%) in the low-yielding class compared with medium- and high-yielding classes at all soil depths; however, differences between the medium- and high-yielding classes were significant only at 0.4 and 0.8 m soil depths. Presence of an excessive EMgP can result in soil dispersion. Soil moisture at the lower limit was significantly higher in low- and medium-yielding classes than the high-yielding class at 0.6 m soil depth; however, differences between low- and medium-yielding classes were not significant. Presence of soil constraints in low yielding areas, resulting in higher lower limit of soil moisture reduces PAWC, and poses a high risk of deep drainage (Dang et al. 2010). The NO_3-N below 0.6 m depth was significantly higher in low-and medium-yielding classes compared with the high-yielding class (Figures not shown). APSIM modelling indicates an increased risk of N-leaching and denitrification losses with increasing rates of applied N. These losses were highest in low-yielding class and lowest in high-yielding class (Figure 2a, 2b). Nitrogen use efficiency was substantially higher in high-yielding class as compared to medium-, and low-yielding class. The differences between medium- and low- yielding classes were minor (Figure 2c). Wong et al. (2006) showed that presence of unutilized N in poorest performing parts of the field poses the greatest risk of N leaching, thus creating the greatest financial and environmental risk.

No significant response to applied N was obtained in the low yielding area; however, significant increases in wheat grain yield were obtained with increasing rates of N application in both medium- and high-yielding zones (Figure 1b). Nitrogen requirement calculated using average wheat yield in different PMC, underlying soil NO_3-N and protein goal (11.5%), showed that low-yielding area of the field

(29 ha) had substantial un-utilized NO_3-N in soil profile from previous uniform N applications. Application of an additional 46 kg N/ha results in net wastage of 2.9 t urea as per farmer's uniform N management practice. With the standard price of N, this is worth $46/ha/annum, with potential environmental pollution due to NO_3-N leaching into ground water. On the other hand, high yielding areas of field (16 ha) were under-fertilized.
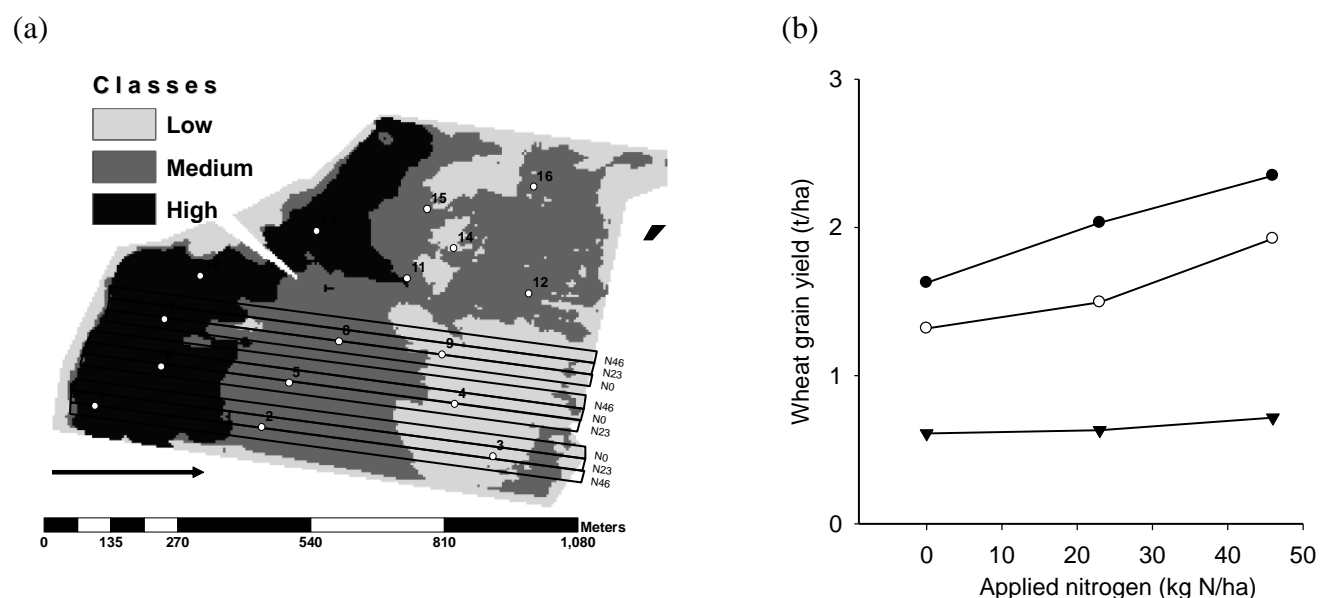
Figure 1. (a) Potential management classes based on grain yield and EC_a. Horizontal arrow indicates directions of field operations; (b) wheat yield response to applied N in low- (▼), medium- (○), and high-yielding (●) classes.
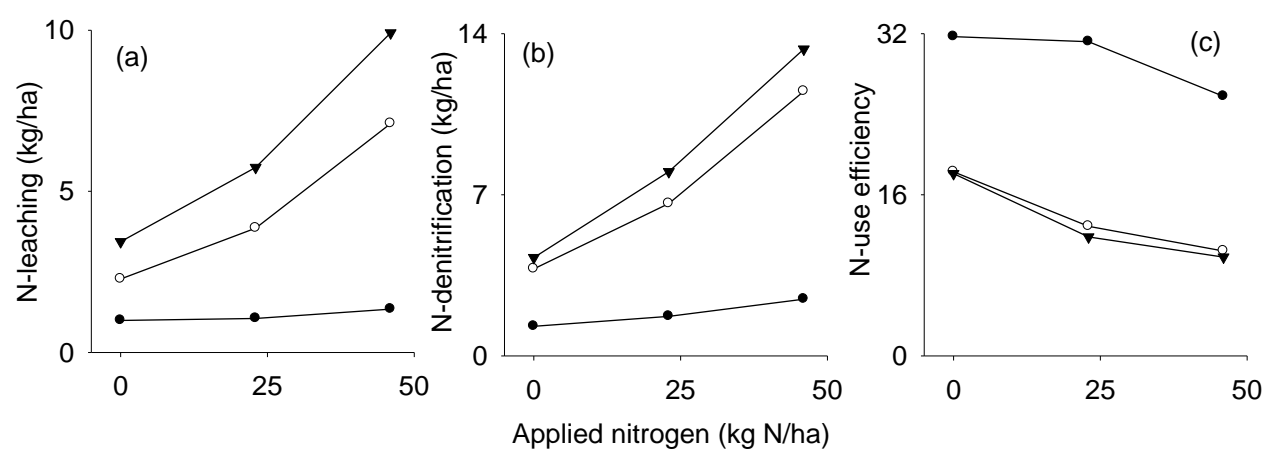
Figure 2. APSIM estimated annual average (a) N-leaching, (b) N-denitrification, and (c) N-use efficiency (kg grain/kg crop N use) in response to applied N in low- (▼), medium- (○), and high-yielding (●) classes.

Table 1. Gross margin analysis for comparisons between field uniform application of nitrogen and that possible under optimal rate management

	Low yielding class (29 ha)	Medium yielding class (19 ha)	High yielding class (16 ha)	Field average (74 ha)
Average wheat yield (t/ha)	1.3	2.2	3.3	1.8
Nitrogen requirement (kg/ha)	59	100	150	82
Available NO_3-N in 0-0.90 m soil (kg/ha)	119	55	36	70
Uniform N (kg/ha) Actual N required (kg/ha)	46	46	46	46
Consequence of uniform N application	0	45	114	12
	2.9 t urea waste	0.04 t urea required	2.3 t urea required	5.5 t urea waste

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Disc seeders in conservation agriculture: An Australian survey

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Introduction

No-tillage (no-till) farming is being widely adopted across Australia by farmers in search of more robust cropping systems with improved water use efficiencies, in an increasingly moisture stressed environment. Recent data by Llewellyn and D'Emden (2009) highlighted a rapid adoption rate in previously lagging regions over the last 5-10 years, and no-till adoption levels are now stabilising near 90 % in many districts. One recognised 'pillar' of Australian no-till farming is the "narrow opener, press-wheel system" - or tyne seeding technology - used to loosen deep and narrow furrows, often incorporate and concentrate soil applied herbicides onto the inter-row zone, and shape water-harvesting furrows using press-wheels.

In contrast, the consideration of disc seeders – enabling direct seeding operations with potentially very low soil and residue disturbance - is recently gaining ground in Australia, particularly among the long term no-till farmers, who are seeking to fine-tune the performance of their conservation farming systems under a 'zero-tillage' (zero-till) approach, a nuanced no-till terminology in Australia associated with the use of disc – rather than tine - seeders.

A nation-wide survey of 200 disc seeder users was conducted in 2007 to identify the main incentives behind the adoption of disc seeders, as well as the limitations encountered on-farm. This paper highlights the main findings of the survey results and illustrates example farmer practices dealing with some of the challenges encountered.

Survey Results and Discussion

Survey respondents
96% of respondents were farmers, managing cropping areas ranging from 100 ha to 18,000 ha, with an average 90 % of area cropped under a zero-tillage system. 29 % of respondents had practised no-till for more than 12 years while 10 % were recent adopters (1-3 years prior). 39 % of responses originated from combined winter/summer cropping regions while, in the winter only cropping regions, 26 % of responses originated from low rainfall (< 250 mm growing season) and 22 % from high rainfall (> 350 mm growing season) areas.

Cited incentives to adopt disc seeding:
Respondents cited the ability to retain heavy crop residue (53 % of responses) as a major strategic reason for acquiring a disc seeder. The reported benefits of being able to retain heavy (full) stubble loads included no soil degradation (effective soil erosion control), enhanced water harvesting (via superior rainfall infiltration and soil moisture preservation, leading to improved water use efficiency and grain yield potential), improved soil health and biological activity, easier harvesting and seeding operations, enhanced cropping system flexibility (e.g. opportunistic crop rotations, simplified stubble management and pasture establishment).

Other reasons for adopting disc seeders included: i) minimised soil disturbance, ii) high speed capability with associated efficiencies and cost-savings per ha, iii) ability to handle stones and create minimal field roughness at sowing - with no further management of stony areas - and to establish better crops in these traditionally low output areas of the farm, iv) ability to cut and plant unhindered through viny weed environments and, v) narrow seed row spacing capability while direct seeding into residue (especially for pasture establishment and/or for increased crop competition). The high work rates of disc seeders were particularly relevant to the larger farms where timeliness of crop sowing is significantly improved over the whole cropping programme, and reduced labour cost and fuel use can amount to significant savings.

Other reported incentives to disc seeder adoption could be classified as 'technology-specific' as not applying across all disc seeder designs, and included: vi) seeding depth uniformity and accuracy and, vii) low draught requirement. Research experience to date (e.g. Ashworth et al., 2010) shows that the superior seeding accuracy and uniformity anticipated with disc seeders is not always guaranteed, and can be undermined with specific configurations of the seed banding unit or when operating in challenging conditions (e.g. sticky soils). Tractor power data compiled from the responses illustrated a wide range of engine power requirements per seeder row (e.g. median values ranging from 2.7 to 5.8 kW across 12 disc seeder models), often correlating with the weight of the zero-till seeder and the ability to transfer that weight onto each row unit for effective penetration into hard soils (e.g. heavy duty disc seeders often used much greater power). High power requirements are also linked to the greater operating speeds used (e.g. median operating speed was 11 km/h with upper quartile at 12.5 km/h).

The combined benefits of low soil disturbance - minimising seedbed moisture loss at seeding - and seed placement accuracy were associated with more even crop establishment in marginal moisture conditions, lower weed seed germination, reduced seed inputs, smoother fields after planting, and a better capacity to establish or regenerate pastures.

Limitations experienced with disc seeders:
Conversely, important limitations were reported, some of which are known to create significant barriers to a more rapid and widespread adoption of disc seeders in Australia. These included: poor handling of sticky soils (68 % of respondents), inadequate incorporation of soil applied herbicides with specific disc seeder types (38 %), poor penetration capacity (35 %), high maintenance cost – especially related to early bearing failures (34 %) and residue pinning limitations (34 %). The latter problem occurs when crop residue is forced into the furrow by the disc blade, rather than being effectively cut. This results in poor soil to seed contact, erratic furrow closure and leads to reduced and patchy crop establishment. The limitations of poor herbicide incorporation, high wear and maintenance costs were often balanced against the superior seeding quality and cropping outcomes achieved in challenging conditions (eg. high residue environment, stony areas), with many disc owners ready to accept shortcomings for long term gain.

Other reported limitations were linked to specific soil conditions, and included damage and high wear in stony soils, poor closure of seed furrows in wet compact clays (leading to patchy crop establishment), poor disc drive in soft soils (leading to increased furrow disturbance and residue pinning risks), furrow smearing and compaction in wet clay conditions and high draft in compacted soils. Irregular seed placement with particular technologies and crop damage from pre-emergence herbicides were also cited in some cases.

Example management approaches to key limitations

While the severity of the issues below was reported to decrease over time in line with soil structure and biological health improvement, management approaches are available to improve disc seeder performance in the field:

Sticky soil handling: the issues interfering with the seeding functions including seed boot blockage, excessive soil build-up onto rotating components and slowing down or stalling of the disc blade rotation, can often be managed by delaying seeding by up to 1-3 days until a dry surface crust is observed. Additional strategies included reducing operating depth, minimising down force on gauge wheels, increasing operating speed, never stopping the seeder in the ground or making tight turns. Field experience also highlighted the need to maximise disc driving forces by controlling all drag forces, including those from closely set gauge wheels and mud scrapers.

Penetration capacity: In practice, the disc blade requires significant weight to achieve penetration and the draught force is a proportion of the down-force applied (Tola and Desbiolles, 2009). Data also show the vertical force reaction at a given operating depth significantly reduces with smaller disc diameter, thinner disc blade, smaller wedge angle, notched blade periphery and large tilt angle. While the timing of operation in hard-setting soils has a significant bearing on soil/blade forces, a compaction management strategy such as controlled traffic was cited as longer term best practice most suitable with the use of zero-till disc seeders.

Residue pinning: Successfully managing residue pinning revolves upon two principles, namely i) maximising residue cutting capacity and ii) using residue avoidance techniques. Literature shows (e.g. Ashworth et al., 2010) crop residue cutting is improved by optimising both disc and stubble parameters, and includes considerations of cutting edge sharpness, timing of operation targeting dry stubble and sufficient soil strength for appropriate soil backing reaction during the cutting process, maximising the disc speed ratio (i.e. ratio of disc peripheral speed to travel speed) with more effective disc drive, and down force availability sufficient to deliver the required cutting force.

Residue avoidance techniques include the use of row-cleaning residue managers and inter-row sowing into standing stubble using precision guidance technologies. The 2007 survey highlighted 95 % of respondents operated their disc seeders in standing stubble and 88 % used a straw spreader/slasher on their harvester, 44 % practised inter-row sowing and 30 % using RTK auto-steer technology. Precision guidance at seeding is increasingly becoming a mainstream practice underpinning the on-going development of Australian conservation farming techniques.

Conclusion

The zero-till farmer survey emphasized many short-term and long-term benefits offered by disc seeders over the common no-till tine seeders used in Australia. The survey also highlighted significant challenges often faced in difficult soil situations, which reveals an adoption process requiring strong commitment to success and a readiness to follow a steep learning curve. The severity of poor penetration, residue pinning and high draft limitations was reported to significantly decline over time under a best practice zero-tillage and controlled traffic management. The majority of the disc seeder users surveyed were motivated by the long term agronomic, environmental and economic benefits to their cropping system.

Over the 3 years since the survey was conducted, disc seeder suppliers in Australia have been reporting a continuing and rapid rise in disc seeder interest from no-till farmers, and the industry is witnessing an increase in the number of commercial brands (currently in excess of fifty) represented in Australia. This interest is matched by an increased field research focus among farming system groups aiming to evaluate and demonstrate the relative performance of zero-tillage systems. New pre-emergence herbicide chemistries such as pyroxasulfone (*Sakura*[®]) are also becoming available, which are expected to better suit low soil disturbance disc seeders in Australian cropping systems. It is anticipated that disc seeders will gradually come to play a leading role in the highly mechanised, large scale Australian conservation agriculture context.

Acknowledgements

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Soil and yield improvements from Controlled Traffic Farming CTF on a Red Chromosol were similar to CTF on a swelling Black Vertosol

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Keywords: soil compaction, root growth, soil structure, biological tillage, wheel traffic

Introduction

There is a significant body of knowledge on the detrimental effects of soil compaction in agriculture, the benefits of Controlled Traffic Farming CTF (Hamza and Anderson, 2005) and its synergy with no-till (direct drilling) practices (Tullberg, 2010). Greater adoption of CTF could be one obvious step towards feeding a growing world population, using less energy and a decreasing soil resource (Cribb, 2010). The benefits of CTF on swelling Black Vertosols in northern New South Wales and Queensland, Australia have been reported consistently for two decades e.g. (Tullberg et al., 2007). These include higher yields, less runoff, less erosion, better direct drilling and more energy efficient field operations. On the sandy soils of Western Australia, deep tillage and subsequent exclusion of traffic has had similar results. The effects of CTF on Vertosols have sometimes been attributed to the natural swelling and cracking characteristics; on the sandy soils, the disruption by deep ripping (deep tilling) of indurated layers has improved root and crop growth e.g. (Hall et al., 2010). Without the swelling characteristics of the Vertosols, nor the indurated layer of the sands, Red Chromosols and other soils in south eastern Australia have been thought unlikely to benefit from CTF (unpublished opinions). Here we revisit a large CTF experiment conducted on a Red Chromosol in South Australia (SA) from 1989 to 1994, which compared the effects of wheel traffic, deep ripping and their interactions (Sedeghatpour et al., 1995). These effects showed remarkable similarity to those on the swelling Black Vertosol i.e. (1) decreased bulk density and penetration resistance, increased aggregate stability, visible porosity, infiltration, worm population, root growth and crop yield; and (2) increased load-bearing capacity of the permanent tracks. (1) was also manifested as better soil friability giving improved tillage and direct drilling efficacy. Most notable on both the Black Vertosol and the Red Chromosol was that greatest improvements occurred when wheel traffic was excluded, without deep ripping. More friable soil, combined with greater trafficability, can also lead to systemic improvements from CTF – some are often not obvious *a priori* e.g. fewer machine hours needed, requiring less powerful tractors; more timely chemical application etc. We suggest greater attention should be paid to the possibility of wider adoption of CTF in SA and south eastern Australia to raise yields, improve soils and lower inputs.

Materials and Methods

Details of the experiment are presented in Ellis (1990) and Sedeghatpour et al. (1995). Field trials were established at the (then) Roseworthy College (28°30'S, 115°7'E; elev. 68 m), now a campus of the University of Adelaide, about 40km NNE of Adelaide, SA. The climate is Mediterranean-like with winter dominated annual average rainfall and potential evaporation of 440 mm and 1750 mm, respectively. The soil was a Red Chromosol (Isbell, 1996). A compact layer (~100 mm thick) existed below the tilled depth (~75 mm), which tended to contort and deflect roots, although not dramatically. The majority of root branching, with thickened and flattened root tips, occurred in horizontal fissures. Deeper seminal and tap roots existed mainly in old root channels and other biopores. Deep tillage (main treatments) and wheel traffic (sub treatments) were arranged in a randomised split-plot design. This produced four replicates of the four treatments: conventional wheel traffic (C); no wheel traffic (CT); conventional wheel traffic, deep ripped (CR) and no wheel traffic, deep ripped (CTR). Deep ripping to 300 mm depth was done once, at trial establishment, using a chisel plough fitted with narrow points. Tillage, seeding and spraying of CT and CTR was undertaken using a self-propelled gantry, which spanned 4 m wide beds and used 400 mm wide tyres; a harvester was modified to match the wheel tracks so that CT and CTR experienced no traffic at all. Conventional tractors and trailed implements were used for all operations on C and CR with wheel tracks covering 40-60% of the area each year. Where possible, in C and CR, tractor-implement combinations were alternated to distribute the traffic as evenly as possible. All four treatments received identical field operations within a 24 hour period. Sheep were grazed on all treatments over the dry summer months. Crops grown from 1989 to 1994 were: barley (*Hordeum vulgare*), bean (*Vicia faba*), wheat (*Triticum aestivum*), bean (*Vicia faba*), wheat (*Triticum aestivum*) and medic pasture (*Medicago trunculata*). Observations included: soil strength (by penetrometer), bulk density (of core samples), visible porosity (resin impregnation), aggregate stability (wet sieving) and surface hydrology (laboratory rainfall simulation), root morphology (whole, washed samples and profile pin boards), root density (washed and scanned core samples), earthworm population ($1m^2$ x 0.1m pits), grain and biomass yields (harvester and quadrats).

Results and Discussion

The previously compacted soil ameliorated under CT i.e. exclusion of wheel traffic without deep ripping (Figure 1). Earthworm densities in C and CT in August 1993 wheat were 12 and 23 worms m^{-2}, respectively ($p<0.03$). Root abundance on inspection was consistently greater in CT compared to C (Figure 1). This "biological tillage" is thought to have helped disrupt the compact layer and form smaller, blocky aggregates (Figure 1). Root straightness and abundance followed the order: C<CT<CR<CTR. Root length density of wheat in 1991 at 300 mm depth was 16 (Sdev 3) and 31 (Sdev 3) mm cm^{-3} in C and CT, respectively. In 1994, medic cumulative root length from 0 to 750 mm deep was 912 (Sdev 61) and 1251 (Sdev 220) mm cm^{-2} in C and CT, respectively. Bulk density (Figure 2) and penetration resistance consistently decreased during the trial and wet aggregate stability (Figure 2), visible porosity (Figure 3) and water infiltration increased (Figure 3) in CT. Deep tillage reduced penetration resistance to 300 mm deep but also reduced wet aggregate stability of surface soil. In five of the six years, CT significantly improved grain yields (by 12 to 17%) of barley, wheat, bean and pasture biomass (22%). This more than compensated for the land area lost to permanent, bare wheel tracks (10%). The exact reasons for yield increases are unknown but the biological tillage effects deserve greater attention to elucidate these, which could include: greater access to soil water, reduced root disease or less gaseous loss of nitrogen. It appears that the amelioration of soil structure once wheel traffic is excluded is not peculiar to swelling clays. In addition, as with the Black Vertosol, biological tillage appears to be more favourable (and less costly) than deep ripping, which did not significantly increase yields. Soil structural changes resulted in: 1) more friable and better-drained topsoil, which produced better tilth and better soil-seed contact and seed coverage in direct drilling; and 2) harder wheel tracks in CT and CTR, which were more trafficable than the cropped zones in C and CR. These soil conditions often produce other opportunities (e.g. fewer rain delays to operations; greater timeliness of tillage, seeding and spraying). These effects are commonly reported by CTF farmers but were not exploited in these trials. It is likely that they would result in even higher yields from CTF and need to be quantified. In the face of a possible coming world famine (Cribb, 2010), there is ample and longstanding evidence that CTF can improve yields (possibly ~20%) and

protect and improve the structure of swelling and non-swelling soils in southern Australia. Future research should also explore other, systemic advantages (e.g. timeliness; earlier seeding etc.), which are mostly unmeasured or unreported.
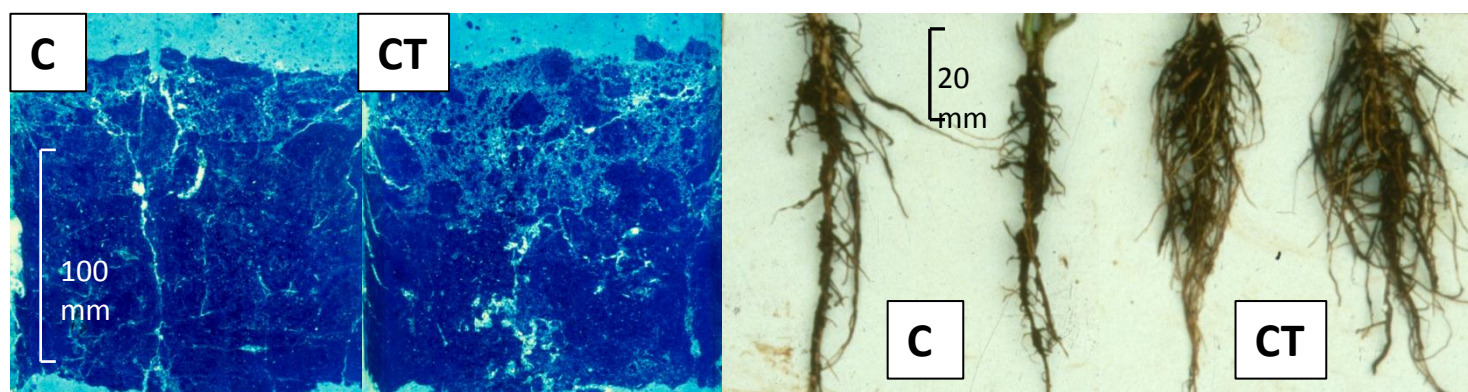
Figure 1 Resin impregnated soil profiles (left) and bean (*Vicia faba*) seedling roots (right)
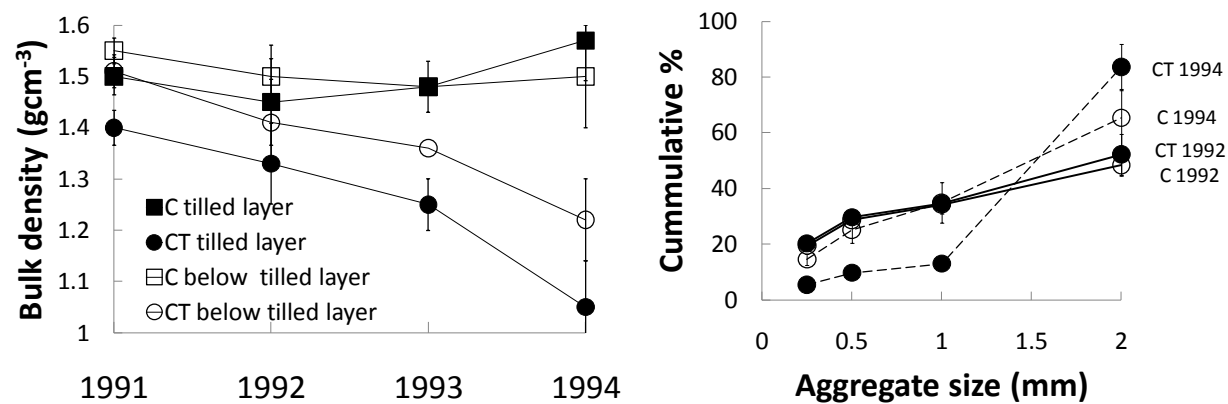
Figure 2: Evolution of soil bulk density with time (left) and evolution of wet aggregate stability (right). Error bars represent one standard deviation.
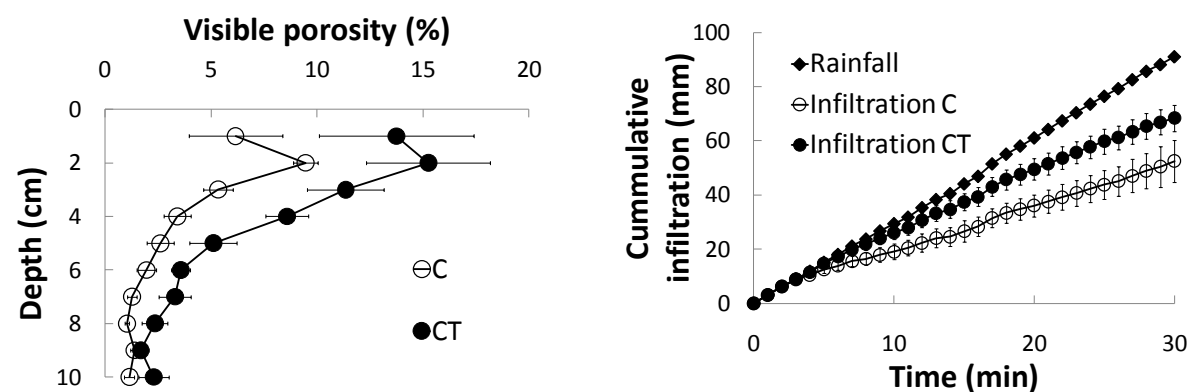
Figure 3: Soil visible porosity after 6 years (left) and surface water infiltration after 6 years (right). Error bars represent one standard deviation.

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Crop roots and crop residues management: impacts on soil structure under zero tillage

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Keywords: conservation agriculture, porosity, roots-soil interplay, thin sections

Introduction

The soil physical condition plays a key role in processes such as aeration, water infiltration, water capillary movement, accessibility of soil solution to particle surfaces for chemical exchange, sorption reactions and biological activity. Root-soil interplay and crop residues management influence soil aggregation and increased soil pore complexity (Gregory et al. 2006). Total soil porosity and pore sizes are important parameters to assess soil structure. However the pore type identification provides more information regarding the movement of water and air in the soil, than the pore sizes. In a long-term experiment in the International Centre for Maize and Wheat Improvement (CIMMYT) in the central highlands of Mexico we investigated the effect of different management practices, i.e. zero tillage (ZT), conventional tillage (CT) with (+r) or without (-r) residues retention and maize-wheat rotation (R) or monoculture (M), on physical and chemical soil quality. After 15 years of continuous practice, ZTM+r and ZTR+r resulted in increased soil physical quality compared to the other practices (Govaerts et al. 2006; Fuentes et al., 2009), while removal of crop residue resulted in reduced soil quality, except for ZTM-r with wheat that showed intermediate soil physical quality (especially aggregation). It seemed that the continuous cultivation of wheat could compensate somehow for the removal of the residue as this treatment did not show the same degree of degradation as the other ZT plots with residue removal. We hypothesized that the interplay between soil-roots under wheat leads to a more conducive-pore soil system compared to maize systems. The current research evaluated the influence of two root systems (maize and wheat) and crop residues management on the soil pore system.

Materials and Methods

The study was conducted at El Batán (Experimental Station of CIMMYT), situated in the semi-arid, subtropical highlands of Central Mexico, in a Haplic Phaeozem having 250, 370 and 380g 1000 g^{-1} of sand, silt and clay content, respectively. The experiment was set up in 1991 and consisted of thirty-two treatments of which the current research only considered six treatments: ZTM-r, ZTM+r and ZTR+r under maize or wheat. The total porosity, compound packing voids, channels or bio-pores and fissures were quantified on thin sections which were obtained from root-centered positions at four soil depths (0–5, 5-10, 10-15 and 15-20 cm) of undisturbed soil samples. Complete or selected areas of thin sections were photographed and the images processed with the program Image-Pro®; statistical analysis consisted of a linear model and an analysis of variance were done in order to test the experimental factor effects on the studied variables with SAS® software.

Results and Discussion

Treatments affected total porosity in the 0-5 cm (P<0.01) and in the soil layers of 5-10, 10-15 and 15-20 cm (P<0.05). In the 0-15 cm layer the greatest total soil porosity was found in the soil under conservation agriculture (CA or ZTR+r) cultivated with maize (Figures 1 and 2). CA cultivated with wheat showed a lower total porosity than CA cultivated with maize. We assume that the wheat roots-soil relationship created better soil conditions for the development of maize roots, while the interplay maize roots-soil reduced soil porosity and soil physical quality for wheat growth. Gregory et al. (2006) showed that wheat roots promoted aggregate formation to a larger extent than maize roots. In the 0-10 cm soil layer, the soil under ZTM+r (wheat) exhibited high porosity (second place of all treatments), confirming the hypothesis that the wheat root system improves the soil physical condition (Figure 1). The soil with rotation showed a lower proportion of fissures than soil with monoculture (wheat and maize) (Table 1 and Figure 2). This parameter is an indicator of soil degradation and the rotation practice wheat-maize improves the soil physical quality compared to monoculture practice.

The soil under ZTM+r (wheat) had more bio-pores (formed mainly by roots) than ZTM+r (maize), the same pattern was observed when ZTM-r (wheat) was compared to ZTM-r (maize) (Table 1). The samples from ZTM+r showed more pores in the 0-5 cm layer than the samples from ZTM-r. The crop residues are involved in the formation of soil aggregates, which in turn is associated with pore formation. In the ZT treatment the crop residues are accumulated in the 0-10 cm soil layer (Fuentes et al, 2009), thus the differences in porosity between soils with and without residues were more evident in the first centimeters of the soil profile. The greatest proportion of compound packing pores in 0-20 cm was found in soils under CA cultivated with wheat or maize compared to the other treatments (Table 1). This type of pores favors water movement in the soil, because they are interconnected and they are located between soil aggregates (Fox et al., 2004). In the 0-10 cm layer the proportion of compound packing pores was greater in soils under ZTM-r (wheat) than in soils under maize. We conclude that the root wheat-soil relation favors the formation of pores, especially bio-pores and composite packaging pores. These kinds of pores contribute to the soil physical quality, however research must take into account that roots *per se* do not generate a fully satisfactory soil structure; it is necessary to keep crop residues at the soil surface. Conservation agriculture improves soil porosity (see Figure 2), though it is necessary to use adequate crop rotations in order to promote effective root-soil relations.
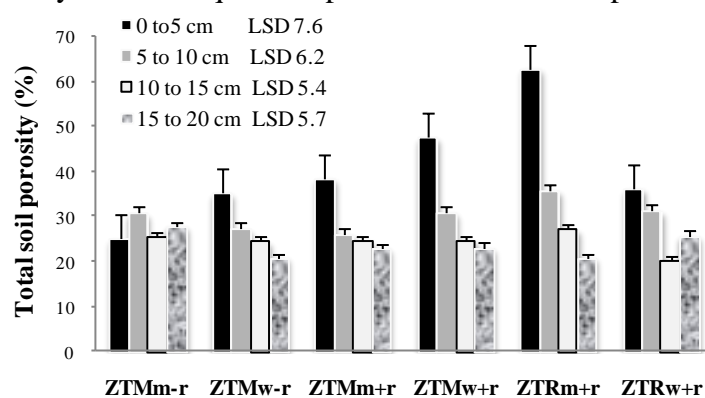
Figure 1 Total soil porosity maize (m) and/or wheat (w), zero tillage (ZT), rotation (R) and monoculture (M), with residues (+r) or without residues (-r) treatments at CIMMYT's long-term tillage sustainability trial El Batán (México). Data from thin sections image analysis.
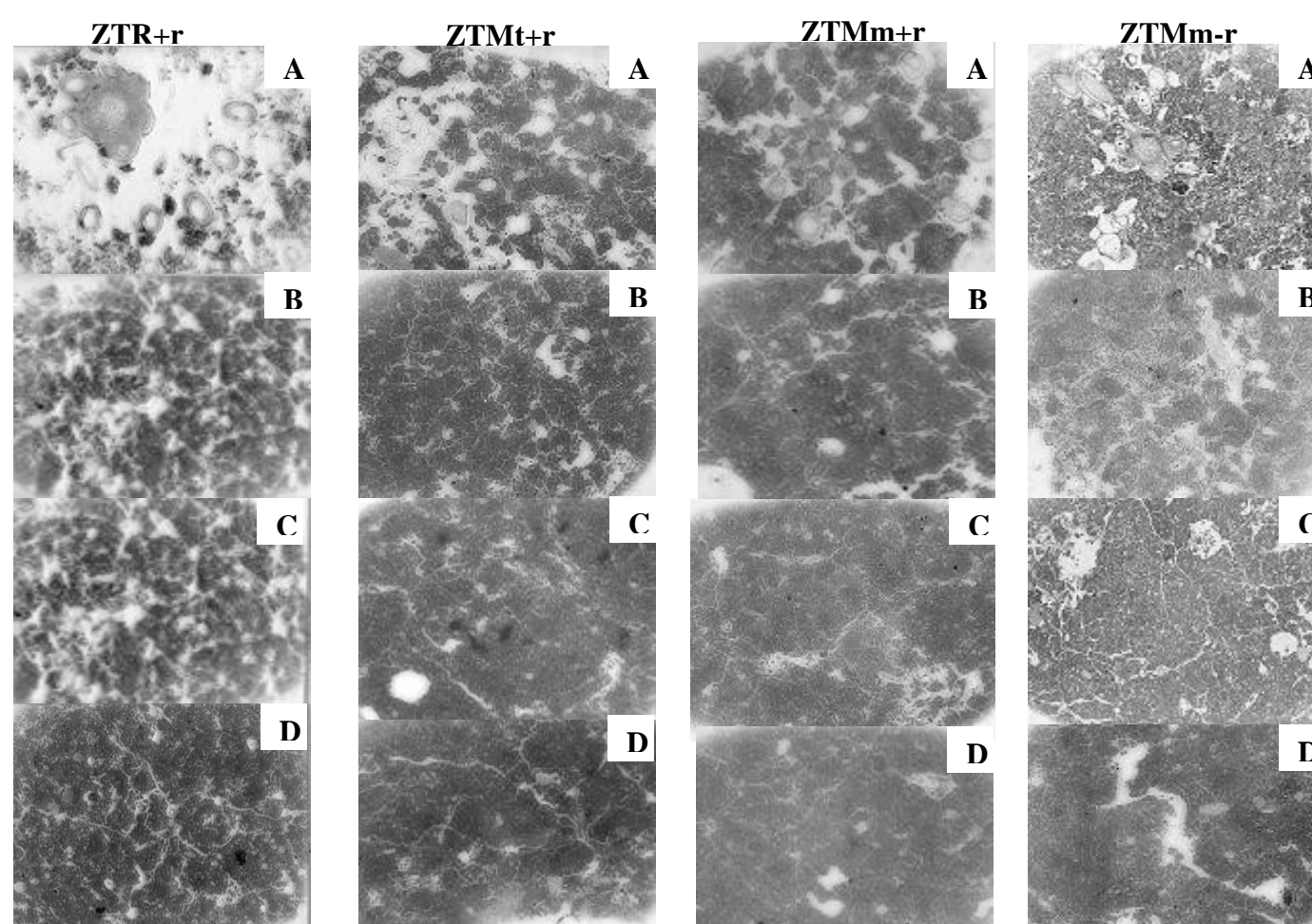
Figure 2 Thin sections (original size 5 by 7 cm) image, different soil profile A: 0-5cm, B: 5-10 cm, C: 10-15 cm and D: 15-20 cm under maize (m) and/or wheat (w), zero tillage (ZT), rotation (R) and monoculture (M), with residues (+r) or without residues (-r) treatments at CIMMYT's long-term tillage sustainability trial El Batán (México).

Table 1. Compound packing voids and channels maize (m) and/or wheat (w), zero tillage (ZT), rotation (R) and monoculture (M), with residues (+r) or without residues (-r) treatments at CIMMYT's long-term tillage sustainability trial El Batán (México). Data from thin sections image analysis.

Treatments	Channels or Biopores (cm 100 cm^{-2})				Compound packing voids (cm 100 cm^{-2})				Fissures (cm 100 cm^{-2})			
Depth (cm)	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20
ZTMm-r	0.37	2.08	0.83	2.01	3.63	3.54	1.97	0	1.74	1.97	8.8	18.13
ZTMt-r	0.81	2.94	0.95	2.29	29.00	4.10	0	0	3.01	4.64	7.96	6.91
ZTMm+r	0.80	6.18	3.73	1.89	32.63	5.80	3.91	0	2.68	9.76	9.36	6.75
ZTMt+r	2.94	7.35	7.07	6.70	38.86	5.59	2.86	1.83	1.53	6.21	3.4	6.55
ZTRm+r	0	1.55	1.28	2.88	62.81	30.25	16.03	3.62	0	1.19	2.25	2.57
ZTRt+r	0.15	0.62	3.98	3.74	32.20	27.30	2.09	7.25	1.11	0.85	3.47	3.7
LSD	2.1	4.7	3.6	3.8	12.3	7.4	8.2	6.7	1.0	4.9	3.9	4.1

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The effect of tillage practice and residue management on wheat yield and yield stability in two agro-ecological environments in Mexico

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Introduction

Wheat is an important food and income source and demand in the developing world is projected to increase. Meeting this growing demand is challenged by poor productivity growth or stagnation in the green revolution areas of South Asia and low yields for major staples in Africa. Climate change could affect wheat production and further complicate meeting the demand. This paper evaluates different tillage and residue management practices with respect to wheat yield and yield stability in two contrasting production systems and agro-ecological environments in Mexico: a rainfed system in the subtropical, semi-arid highlands (Central Mexico) and a furrow-irrigated system in arid conditions (north-western Mexico). The data for the rainfed system were collected in a long-term trial in the central highlands of Mexico. Rainfed cropping predominates in the area, with rainfall (350–800 mm) for four to six months during summer, followed by dry, frosty winters. The climate is representative of many highland areas in the West Asia and North Africa region, the Southern Cone and Andean Highlands of South America, the central highlands of Ethiopia and the Mediterranean coastal plains of Turkey. On-farm cereal grain yields are low (< 2 t ha^{-1}). Moreover, fields are often weedy and crops are N deficient, soil structure is poor, and sheet and gully erosion are widespread. The data for the irrigated system were collected in a long-term sustainability trial, which is agro-climatically representative of areas where 40% of the wheat is produced in the developing world, such as the Indian and Pakistani Punjab and the Nile Valley in Egypt. Grain yields in the area exceed 6 t ha^{-1} and fertilizer inputs are high.

Materials and Methods

The rainfed experiment was initiated in 1991 in El Batán in the semi-arid, subtropical highlands of Central Mexico. The soil is a Haplic Phaeozem (Clayic) and has good chemical and physical conditions for farming. The major limitations are periodic drought, periodic water excess and wind and water erosion. The experiment has 32 treatments varying in tillage practice, crop rotation and crop residue management. This paper only includes 6 treatments all with a maize-wheat rotation: Conventional tillage with residue incorporation (*CT-Keep*) or removal (*CT-Remove*), zero tillage with residue retention (*ZT-Keep*), removal (*ZT-Remove*), retention of approximately half of the residue (*ZT-Keep1/2*) and retention of all maize residue and 15 cm standing wheat stubble (*ZT-KeepM1/3W*). Details on plot management can be found in Govaerts et al. (2006).

The irrigated experiment was initiated in 1992 near Ciudad Obregón, Sonora, Mexico. The climate is arid and the soil is a Hyposodic Vertisol (Calcaric, Chromic), low in organic matter (<1%) and slightly alkaline (pH 7.7). Wheat and maize are planted on 0.75 m raised beds with irrigation applied in the furrows and managed in an annual rotation: wheat as a winter crop followed by maize as summer crop. The evaluated tillage-straw systems are: (1) *CTB-Keep*: Conventionally tilled raised beds (conventional tillage with beds formed after each crop); wheat and maize residues are incorporated through tillage; (2) *PB-Burn*: Permanent raised beds (PB; zero tillage with continual reuse of existing beds, which are reformed as needed); all residues are burned; (3) *PB-Remove*: PB; loose residues are removed by baling; (4) *PB-Partial*: PB; maize residues are removed by baling and wheat straw is retained on the soil surface; (5) *PB-Keep*: PB; all residues are kept on the soil surface. Details on plot management have been reported in Verhulst et al. (2011).

Wheat yield was determined by combine harvesting the central 1.5 m of each plot and determining grain weight at 12% H$_2$O. Yield stability was assessed by two methods: i) the coefficient of variation (CV) of yields over time was calculated for each plot; and ii) annual treatment mean yields were regressed against annual average yield, thus reflecting the overall growing conditions for each year. Regressing treatment yields on the annual mean yield allows one to evaluate the relative response of the treatments under the range of growing conditions that occurred.

Results and Discussion

In irrigated conditions, the highest average yield was obtained with PB-Keep and the lowest with PB-Burn (Table 1). Farmer practice (CTB-Keep) had significantly lower average yield than conservation agriculture (CA)-based practices where all residue was retained (PB-Keep) or only standing stubble was left in the field (PB-Remove). The CV was the lowest for PB-Keep, but the difference with other treatments was not significant (Table 1). The regression lines of treatment mean vs. annual mean differed among agronomic practices: the hypothesis of coincidence was rejected by the F-test ($p<0.0001$; Figure 1). The regression analysis did not reveal significant differences in stability between treatments: the hypothesis of equality of slopes was not rejected ($p=0.6006$). In these high-input conditions with full irrigation and high N fertilization, the average yield advantage of CA seemed to be more important than a differential yield response to yearly fluctuations.

In rainfed semi-arid conditions, yield differences were larger than in irrigated conditions (Table 1). Average wheat yield was the highest for ZT-Keep and ZT-Keep1/2 and the lowest for ZT-Remove and CT-Remove. The CV was significantly higher for ZT-Remove and ZT-KeepM1/3W than for the other agronomic practices (Table 1). As for irrigated conditions, the regression lines differed among agronomic practices ($p<0.0001$; Figure 1). However, for rainfed conditions, the differences were due to different slopes ($p=0.0101$) as well as different intercepts ($p<0.0001$). When comparing regression lines with the regression line of ZT-Keep (the highest yielding and most stable practice), ZT-Remove and CT-Remove (the lowest yielding practices) showed similar slopes ($p=0.5851$ and $p=0.12$, respectively), and thus stability, but significantly lower intercepts ($p<0.0001$ and $p=0.0033$ respectively; Figure 1). Retaining only part of the residue with zero tillage resulted in steeper slopes, and thus reduced stability, compared to keeping all residue on the soil surface ($p=0.0071$ for ZT-KeepM1/3W and $p=0.0816$ for ZT-Keep1/2). The regression line of CT-Keep was not significantly different from the one of ZT-Keep ($p=0.20$ for hypothesis of coincidence). Summarizing, the CA-based practices were the highest yielding in both environments, but differences in stability were only found in rainfed, more adverse conditions. Removal of part of the residue resulted in a reduction of yield stability in rainfed conditions but not in irrigated conditions. Removal of all residues by baling (ZT-Remove) or burning (PB-Burn) resulted in stable but low yields and is not a sustainable management option.

Table 1. Effect of tillage practice and crop residue management on wheat yields and yield stability analysis in CIMMYT's long-term sustainability trials at Ciudad Obregón and El Batán, Mexico

Management practice	Average yield		Coefficient of variation		Regression of treatment means vs. year means		
	(Mg/ha at 12% H$_2$O)		(%)		Slope	Intercept	R²
Irrigated wheat in arid conditions (1999-2009)							
CTB-Keep	7.01	bc*	10.69	a	1.07	-0.52	0.95
PB-Burn	6.65	c	11.66	a	1.09	-0.98	0.91
PB-Remove	7.24	ab	9.53	a	0.96	0.42	0.96
PB-Partial	6.91	bc	10.28	a	1.00	-0.11	0.93
PB-Keep	7.42	a	8.65	a	0.85	1.44	0.91
Rainfed wheat in semi-arid highlands (1997-2008)							
CT-Keep	5.31	bc	22.3	b	0.82	1.12	0.85
CT-Remove	5.04	c	23.2	b	0.88	0.52	0.86
ZT-Keep	5.96	a	19.0	b	0.82	1.77	0.80
ZT-Remove	3.92	d	35.8	a	1.06	-1.49	0.86
ZT-KeepM1/3W	4.93	c	33.8	a	1.33	-1.90	0.97
ZT-Keep1/2	5.59	ab	24.7	b	1.09	-0.02	0.94

Tillage practice: CTB, conventionally tilled raised beds; PB, permanent raised beds; ZT, zero tillage; CT, conventional tillage; *Residue management:* Burn, straw burned; Remove, all straw removed; Partial, straw partly retained; Keep, all straw retained; KeepM1/3W, keep all maize straw and 15 cm wheat stubble; Keep1/2, keep maize stubble until below ear and 25 cm wheat stubble;
*Management practices with the same letter are not significantly different at the 0.05 probability level
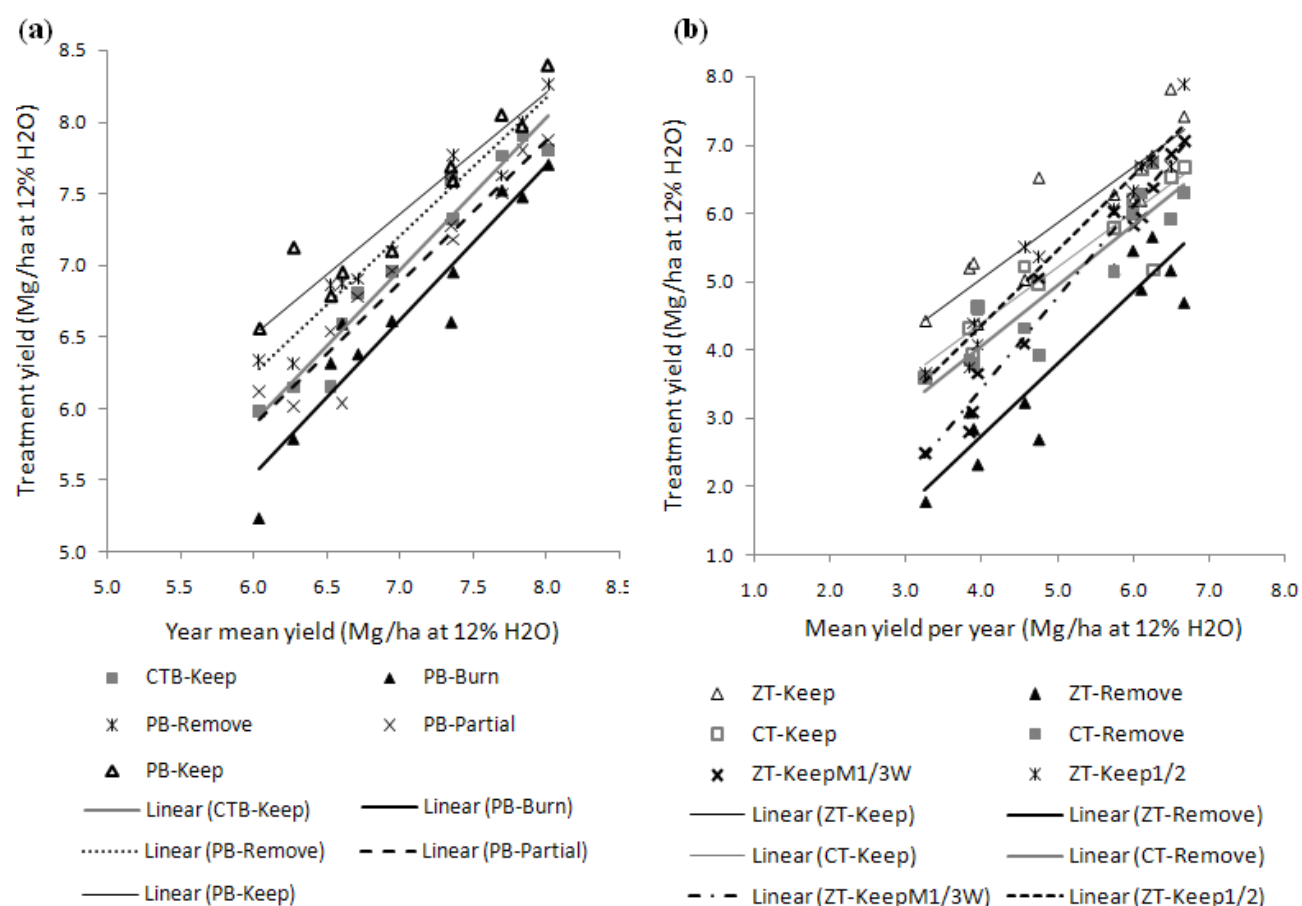
Figure 1. Linear regressions for agronomic treatment wheat grain yield on the annual average wheat grain yield in CIMMYT's long-term sustainability trials at (a) Ciudad Obregón and (b) El Batán, Mexico with treatment abbreviations as for table.

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Conservation Agriculture in cereal systems of South Asia: effect on crop productivity and carbon-based sustainability index

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Key words: conservation agriculture, cereal systems, carbon sustainability index

Introduction

Maize, wheat and rice, the major cereals grown as monoculture or in sequence, contribute the bulk of food and incomes in rural regions of South Asia. The large increases in food production are one of the greatest achievements of the second half of the 20th century, but sustaining these gains is a major challenge. Inappropriate management practices and intensive cropping in the past have led to the twin challenges of resource depletion and decelerating productivity growth of cereal crops. The efficiency and sustainability of a production system depends on system-based management optimization of crop yields, economic benefits, and environmental impacts. The long term sustainability of a cropping system depends on its carbon inputs, outputs and carbon use efficiency which indicate long-term sustainability in terms of yield, environment and ecology. Similarly, efficient utilization of carbon-based resources mitigates the increasing level of CO_2 in the environment. Most of the indices used by researchers in the past to evaluate the sustainability of any cropping systems have been based on economic yield or yield sustainability, without giving due emphasis to environmental issues. In this study, three major cereal systems (rice-wheat, rice-maize and maize-wheat) were evaluated under conservation agriculture practices and compared with conventional tillage in terms of yield, carbon (C) inputs and outputs, and a carbon based sustainability index.

Materials and Methods

Three tillage treatments (no-till on the flat, permanent raised beds, conventional till) and 3 cropping systems (rice-wheat, rice- maize, and maize-wheat) were implemented in large plots (1000 m²) at Rajendra Agricultural University, Samastipur, and also in on-farm (farmer participatory) trials, in Bihar, India. The different crop sequences were initiated in different years - rice-wheat (2007), rice-maize (2008), maize-wheat (2009) – resulting in datasets for 4, 3 and 2 years, to date, respectively. All crops except transplanted rice were planted using a multi-crop, multi-purpose no-till seed-cum-fertilizer planter. The permanent beds were of 67cm width (furrow-to-furrow) with 2 rows of rice or wheat and one row of maize. In the conventional till system, the maize and wheat were planted after 4-dry ploughings, while the rice fields received dry tillage followed by wet tillage (puddling) and transplanting of 23 day old seedlings. The residue management was common irrespective of tillage wherein partial (30-cm anchored) residues of monsoon crops (rice and maize) were recycled and in winter crop (wheat) only 10-cm stubbles were recycled.

Carbon sustainability index (CSI), the ratio of the difference between C output and input to the C input (Lal, 2004), was used for analysis of the sustainability of the cropping systems x tillage treatments. C input was calculated as the sum of the C equivalent of all inputs i.e. tillage operation, fertilizer, seed, pesticide, harvesting, threshing etc. C output was computed as the sum of the C equivalent of grain, straw and root biomass produced by the crop. C equivalent of inputs as well outputs was calculated using published data (Dubey and Lal, 2009).

Results and Discussion

In the rice-wheat cropping system, the average yield of rice was slightly higher under the conventional puddled transplanted system (PTR) than with permanent beds (direct seeding) and no-till direct dry seeding (DSR) (Table 1). However, wheat and total system yields were highest with no-till (NT). In the rice-maize cropping system, rice yield was similar in all planting/tillage systems, but the maize and system yields were highest with permanent beds (PB) followed by NT. In the permanent bed and NT treatments, the improved soil porosity and infiltration rate provides more favourable conditions for the upland crops (Jat et al, 2009). In conventionally tilled systems, particularly puddled rice systems, intensive tillage leads to the development of a compacted layer in the root zone soil, and massive soil structure above this layer, resulting in restricted root penetration of succeeding upland crops, poor aeration and soil nutrient-moisture and crop root interactions, and hence low productivity of upland crops (Jat et al., 2009). In the maize-wheat system, maize, wheat and system productivity was higher in NT than PB and CT, while CT had the lowest system productivity.

Table 1. Productivity and carbon sustainability index of different cropping systems under various tillage/establishment practices

Tillage/ establishment options	Rice-wheat system (Av of 04 yr)			Rice-maize system (Av of 03 yr)			Maize-wheat system (Av of 02 yr)		
	Rice	Wheat	RW system	Rice	Maize	RM System	Maize	Wheat	MW system
Grain yield (t/ha)									
No-till	5.0b	3.9a	9.0a	4.6a	7.1b	11.7b	4.4a	4.4a	8.8a
Permanent Beds	5.2b	3.1b	8.3c	4.7a	7.7a	12.4a	4.2a	3.9b	8.1b
Conventional till	5.8a	2.9b	8.7b	4.7a	5.3c	10.0c	3.7b	3.9b	7.6c
C Sustainability Index (CSI)									
No-till	4.9	8.8	6.8	4.9	27.3	16.1	22.2	10.3	16.2
Permanent Beds	5.5	7.1	6.3	5.2	31.5	18.4	22.2	9.7	16.0
Conventional till	2.7	5.1	3.9	2.5	20.4	11.4	13.4	10.0	11.7

The C sustainability index was lower in rice than wheat and maize (Table 1).The effect of cropping system on the CSI was much greater than the effect of tillage/establishment method, and was highest in rice-maize and least in rice-wheat. The C sustainability of rice systems alternated with upland crops is lower than other system and is also contrary to continuous rice system wherein anaerobic conditions restricts oxidation of C. Within cropping systems, the CSI with conventional tillage was much lower than the other tillage/establishment methods, with only small differences between PB and NT. Dubey and Lal (2009) also reported that conservation tillage improved carbon sustainability index in comparison to conventional planting system in two different types of ecologies and production systems (Ohio, US and Punjab, India). There was a strong relationship between maize grain yield and CSI in both rice-maize (r^2=0.96, $p<0.05$) and maize-wheat (r^2=0.81, $p<0.05$) systems followed by rice (r^2=0.44, $p<0.05$) and wheat (r^2=0.41, $p<0.05$) in the rice-wheat rotation (Figure 1).

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The CA based tillage practices led to highest system yield and C sustainability index irrespective of the cereal based systems. However, the productivity and CSI between cropping systems and within CA based establishment practices Varied remarkably. In rice-wheat and maize-wheat cropping systems, the highest system productivity and CSI occurred with NT, whereas in rice-maize, these parameters were maximum with permanent beds.

a. Rice-wheat cropping system

b. Rice-maize cropping system

c. Maize-wheat cropping system

Figure1. Correlation between grain yield (t/ha, X- axis) and C sustainability index (Y-axis) in (a) rice-wheat, (b) rice-maize and (c) maize-wheat cropping systems

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Short-term effect of no-tillage on profitability, soil fertility and microbiota: a case study in a tropical ecosystem (altitude plains, Lao PDR)

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Keywords: Agri-environmental evaluation, Agricultural practices, DMC systems, Conservation Agriculture, microbiotoa, B-ARISA, Tropical soils, Plain of Jars, Lao PDR.

Introduction

The Plain of Jars is a vast, acid and infertile savannah grassland located in the western part of Xieng Khouang Province, north-eastern Lao PDR. The farming systems in this region are mainly based on lowland rice cultivation and extensive livestock production. With limited opportunities for agricultural expansion in the lowlands, the development of agricultural production in the uplands is a key challenge for the subsistence farmers. Since the last decade, many attempts, all based on soil tillage for land preparation, have been made to develop staple and cash crops production in the uplands. Since 2007, conservation agriculture (CA) systems, largely presented as more sustainable systems than conventional ones (Hobbs et al, 2008), have also been tested. However, there is limited information regarding the profitability of these practises and their environmental footprints in such agroecology. In order to evaluate the short term agri-environmental impact of various land use management, agronomical and economical performances of four different till and no-till systems were monitored during the first years of trials implementation (2007-2010 period). The impact of these practises on top soil (0-10cm) chemical characteristics, aggregate stability and microbial communities' evolution was evaluated in 2009 by comparison with the natural surrounding pastureland (PAS).

Materials and Methods

A 3-years rice / corn / soybean rotation was conducted both under conventional (CV) and direct seeding mulch-based cropping (DMC) systems (compared land use description in Table 1). Yields, production costs and labour required were yearly recorded for each elementary plot. Aboveground biomasses were yearly measured for each plot on 10 squares of 4m2 each. Belowground biomasses were estimated from above ground biomasses using crops indexes. Chemical characteristics were analysed in France at CIRAD's Soil Analysis Laboratory using international standards. Soil aggregate stability was estimated through various aggregate indices based on aggregate size distribution after wet sieving (Yoder method, calculation of the Mean Weight and Mean Geometric Diameter -MWD and MGD- of aggregates) and soil texture (Aggregate Stability Index -AS- developed by Castro Filho and al, 2002). Microbial abundance and diversity was evaluated using molecular tools as described by Ranjard et al (2001): After extraction and purification of soil microbial DNA, bacterial and fungal populations were quantified using quantitative Polymerase Chain Reaction (qPCR 16 and 18S); bacterial communities' diversity was analysed through B-ARISA (bacterial automated ribosomal intergenic spacer analysis) fingerprints analysis.

Table 1. Land use description and number of samples replicates

Land Use	Rep	Description
PAS	16	Savannah grassland dominated by *Themeda triandra* and *Cymbopogon nardus* species
CV	25	Land preparation based on ploughing using discs and burying of crop residues
DMC		No-tillage; direct seeding after mechanical and chemical control of cover crops
DMC 1	25	Year 1: "*fing+pig*", then 3y rotation rice+*sty* / corn+*fing+pig* / soy bean +*oat+buck*
DMC 2	25	Year 1: "*fing+sty*", then 3y rotation rice+*sty* / corn+*sty* / soy bean +*oat +buck*
DMC 3	25	Year 1 "*ruzi+pig*", then 3-year rotation rice+*sty* / corn+*ruzi* / soy bean +*oat +buck*

Fing = finger millet (*Eleusine coracana* Gaern), *pig* = pigeon pea (*cajanus cajan* cv Thai), *sty* = stylo (*stylosanthes guianensis* cv CIAT 184*), oat* = oat (*Avena sativa* L.), *buck* = buckwheat (*Fagopyrum esculentum* Moench), *ruzi* = ruzi grass (*Brachiaria ruziziensis* cv ruzi)

Results and Discussion

No significant differences were observed regarding agricultural systems profitability with equal cumulated production costs, labour and yields for the four first years of implementation (see Table 2). However significant differences were observed regarding total aboveground and belowground biomasses produced and brought back to the soil with higher dry matter restitutions for all three DMC systems compared to CV system (see Table 2). These differences associated with differences in land preparation (no-till vs tillage) might explain the significant differences observed between CV and all three DMC systems regarding soil chemical and physical characteristics evolution. Lower values of pH, organic C, total N and CEC were observed for CV system (see Table 3) as well as a decrease in soil structure stability with lower macro aggregates (0.25–19mm) and lower aggregation indexes values (see Table 4). Regarding indigenous microbiota evolution, slight modifications were observed with the distinction of three indigenous bacterial communities under CV, DMCs and PAS shown by B-ARISA fingerprints analysis (see figure 1). These first observations confirmed the early impact of ploughing on top soil degradation process and the interactions between Soil Organic Matter, soil biota and soil structure as described by Six et al (2002). Macro aggregates disruption, enhanced soil aeration and mixing of residues into the soil induced changes in microbial communities' activity and organic C losses. These results observed after only two years of cultivation also confirmed how fast soil degradation can occur in the tropics.

Table 2. Effect of agricultural practises on soil productivity and profitability

Syst	cum*. prod costs[1] (USD/ha)	cum. labour (md/ha)	cum. grain yields[2] (ton/ha)	cum. aboveground biomass (ton of DM/ha)	cum. roots biomass[3] (ton of DM/ha)	cum. total biomass produced (Ton of DM/ha)
CV	1991 ± 272 [a]	251 ± 30 [b]	7,4 ± 3,0 [a]	12,1 ± 2,8 [a]	1,9 ± 0,3 [a]	14,03 ± 3,2 [a]
DMC 1	2060 ± 308 [a]	231 ± 21 [b]	8,2 ± 2,7 [a]	19,4 ± 3,9 [b]	3,8 ± 0,7 [b]	23,20 ± 4,6 [b]
DMC 2	2122 ± 308 [a]	238 ± 35 [b]	7,8 ± 2,3 [a]	19,2 ± 3,6 [b]	3,8 ± 0,7 [b]	23,00 ± 4,3 [b]
DMC 3	2111 ± 305 [a]	198 ± 28 [a]	6,1 ± 2,8 [a]	22,3 ± 4,2 [b]	6,3 ± 1,3 [c]	28,63 ± 5,4 [c]

* cum. = average cumulated value for all 3 main crops (rice, corn, soybean) and 3 fertilization level
Letters between brackets indicate significant differences according Kruskal-Wallis test (p<0,05), Bonferroni correction
[1] production costs are calculated using average inputs prices of 2007-2010 period. [2] for 2008-2010 period; 2007 cover crops grain production are not included. [3] estimated from aboveground biomass production using coefficients of 0.18, 0.14, 0.10, 0.40, 0.27, 0.10 and 0.07 for rice, corn, soybean, ruzi grass, finger millet, stylo and pigeon pea respectively (adapted from Sà et al, 2001).

Table 3. Effect of land use management on top soil (0-10cm layer) chemical parameters

Syst	pH water	Corg (%)	N tot (‰)	P Olsen (mg/kg)	CEC (me/100g)	TS[1] (%)
PAS	5,29 ± 0,25 [ab]	3,38 ± 0,46 [ab]	2,53 ± 0,37 [b]	3,36 ± 1,01 [a]	2,13 ± 0,81 [a]	35 ± 7 [a]
CV	5,19 ± 0,42 [a]	3,15 ± 0,21 [a]	2,13 ± 0,24 [a]	8,23 ± 2,50 [b]	3,32 ± 0,51 [a]	86 ± 9 [b]
DMC 1	5,54 ± 0,24 [b]	3,36 ± 0,54 [ab]	2,38 ± 0,30 [b]	10,61 ± 3,90 [b]	4,76 ± 1,61 [b]	95 ± 4 [c]
DMC 2	5,44 ± 0,24 [ab]	3,44 ± 0,46 [b]	2,40 ± 0,33 [ab]	10,15 ± 3,44 [b]	4,44 ± 1,35 [b]	98 ± 6 [c]
DMC 3	5,50 ± 0,25 [b]	3,44 ± 0,53 [b]	2,42 ± 0,36 [b]	9,74 ± 2,50 [b]	4,67 ± 1,64 [b]	96 ± 6 [c]

[1] TS = Saturation rate= (Ca+Mg+K+Na)×100 / CEC
Letters between brackets indicate significant differences according Kruskal-Wallis test (p<0,05), Bonferroni correction

Table 4. Effect of land use management on top soil (0-10cm layer) wet aggregate distribution and stability

Syst	Microaggregate (0-0.250 mm) (g. kg-1 soil)	Macroaggregate (0.250-19 mm) (g. kg-1 soil)	MWD (mm)	MGD (mm)	AS (%)
PAS	47 ± 44 [ab]	953 ± 44 [bc]	8,36 ± 0,58 [a]	2,03 ± 0,17 [ab]	91 ± 9 [b]
CV	93 ± 38 [c]	907 ± 38 [a]	6,95 ± 1,24 [a]	1,67 ± 0,22 [a]	81 ± 13 [a]
DMC 1	48 ± 34 [b]	952 ± 34 [b]	9,43 ± 1,16 [b]	2,18 ± 0,28 [bc]	87 ± 13 [b]
DMC 2	45 ± 26 [ab]	955 ± 26 [bc]	9,46 ± 1,33 [b]	2,20 ± 0,28 [bc]	89 ± 14 [b]
DMC 3	33 ± 19 [a]	967 ± 19 [c]	9,70 ± 1,04 [b]	2,27 ± 0,22 [c]	92 ± 7 [b]

MWD = Mean Weight Diameter; MGD = Mean Geometric Diameter; AS = Aggregate Stability Index
Letters between brackets indicate significant differences according Kruskal-Wallis test (p<0,05), Bonferroni correction
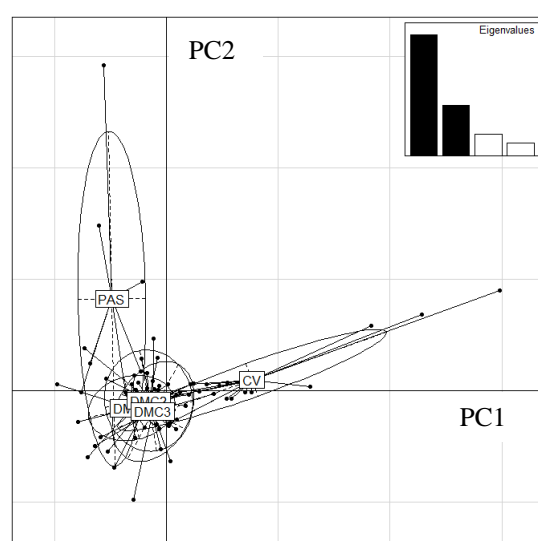
Figure 1. Effect of land use management on top soil (0-10cm layer) bacterial communities diversity (PCA of B-ARISA fingerprints, interclass, between group analysis)

The real adoption of Conservation Agriculture (CA) in the Lake Alaotra area after 10 years of diffusion

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Keywords: CA diffusion assessment method, Madagascar

Introduction

Extension of Conservation Agriculture in Lake Alaotra started in 1998 with two small scale development projects (1998-2001) with very limited success. The large scale development project BV-Lac/AFD, from 2003, has been largely more successful, using a farming system and watershed approach. The best available resources for pinpointing the areas actually cropped under CA are the current development operators' databases from BV-lac. The GSDM, regrouping Research and Development CA operators, compile statistics on CA adoption. These statistics, however, combine different types of activity and systems, which are not all CA activities. We suggest a method to correctly assess cropped areas with CA practices. We will be extremely careful in order to avoid to "mythicize"[1] CA (Penot and Andriatsitohaina, 2010).

Methodology: distinction between CA cropping patterns and other cropping systems

We focus on the identification of what can be considered as a real CA plot. All plots from current project databases which are devoted to pastures, fodder crops, improved fallow, re-forestation, re-greening, preliminary cover-crops (potential CA) and first year (Y0 or CA introductive year with plowing, have been removed. Given the very poor quality data on poor water control rice systems (the 2/3 of rice fields in the lake!), we decided that only 10% of the areas currently monitored by the BV-Lac project were under CA (the real number of farmers and areas under CA is not easy to assess). Figure 1 shows the official figures which include the first year (Y0, considered as the first year of the rotation with tillage. The mere implementation of a new technique by a producer does not transform a farmer immediately into an "adopter", especially in the first two years. The adoption process of CA is slow (between 3 and 6 years) and complex. The first year (Y0), most farmers implement a cover crop after cultivation on soil tillage. CA practices really start in the second year or Y1. However, some systems can be installed directly in direct seeding, without tillage, after a *Cynodon* fallow for instance (Maize or rice). In this case, therefore, farmers start directly in second year (Y1). We considered "adopting farmers" as those with more than one plot in Y1. The method of cohort analysis, developed in 2007 on Vakinankaratra (Narila Andriaradison and Penot, 2007) was adopted in order to have a better assessment of how the CA area was evolving year by year (Table 1). A farmer may have several CA plots of different ages. Therefore, there may be reliable CA areas but not reliable actual numbers of farmers adopting CA. Figure 2 displays the abandonment rate, per year, by age plots. According to the cohort analysis of databases, a recount of real CA has been done. After removing all plots in the first year (Y0) and the non CA plots, the real CA area is assessed at 419 hectares, for the Lake Alaotra project areas (for detailed information see Fabre 2010). The number of adopting farmers is between 600 and 1000. CA systems have evaluated from those introduced in 2003 based on imported biomass with local *Bozaka* to the current systems based on covercrops such as *Dolichos, Styloxanthes, Bracharia, Vicia and crotalaria* mainly associated with Rice, Maize, cowpeas and cassava. System evolution is the topic or another paper presented in this seminar. For the first three years under CA management (Y0 to Y2), abandon rate is between 40 and 60% with a clear decreasing trend over time, confirming that the very early years are the most difficult (Figure 2). Most abandonment occurs after Y0, i.e., a large proportion of farmers are leaving without having experienced CA practices, such farmers are declared "opportunistic". They are very difficult to detect, and effectively undermine the effort of local development projects to widely promote CA adoption. Other sources of abandon after Y1 are: i) land status for 34 % (share cropping or renting), ii) difficulties to master and develop technically the system occurs for only 22 % and iii) lack of cash to invest in the CA system for 15 % (as recorded for the Nordeast zone of the Lake for instance , BRL, 2010).

Table 1:Evolution, according to cohort, of surfaces in DCM in the Lake Alaotra

	03-04	04-05	05-06	06-07	07-08	08-09	09-10	Rate of abandonment according to cohort	Rate of abandonment according to the age of the plot
Year 8							0.2	4%	
Number of abandonment							0.1		
Year 7					0.0	0.3	0.4	13%	35%
Number of abandonment					0.3	0.6	1.5		
Year 6				0.3	0.9	1.9	4.0	13%	74%
Number of abandonment					0.7	-0.6	0.0		
Year 5				1.6	1.3	4.0	10.4	5%	10%
Number of abandonment				2.1	-1.1	6.0	2.1		
Year 4			3.7	0.3	10.0	12.6	32.3	10%	34%
Number of abandonment			1.9	0.9	-5.0	9.3	13.3		
Year 3		5.6	1.2	5.0	21.9	45.5	36.1	14%	26%
Number of abandonment		-1.0	1.6	27.7	1.5	48.9	13.6		
Year 2	4.6	2.8	32.7	23.4	94.4	49.7	81.3	24%	44%
Number of abandonment		0.4	2.8	60.1	-1.4	118.3	55.6		
Year 1	3.2	35.5	83.5	93.0	168.0	136.8	255.0	35%	45%
Number of abandonment		-5.4	110.4	219.8	90.0	195.2	465.0		
Year 0	30.1	193.8	312.8	258.0	332.0	720.0	666.0	100%	58%
Years	03-04*	04-05*	05-06*	06-07	07-08**	08-09	09-10		
ANNUAL TOTAL	38	238	434	381	628	971	1086		

* GSDM data (the databases of the operators could not be obtained for these years)
** GSDM data (the databases of the operators could not be obtained for these years)
-1.1 : Years for which the data are unclear between year n 1 and n-1

Source: Databases of BV-Lac from 2003 to 2006, processed from the database from 2006 to 2010, by Joana Fabre (2010)

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[1] In the sense of: to create a myth of ….
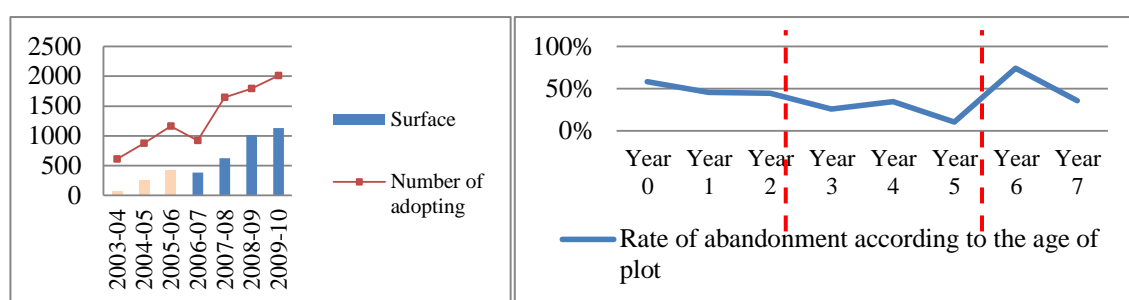
Figure 4 (left): Evolution of surfaces in DCM (in hectare) and numbers of farmers adopting in Lake Alaotra, from 2003 to 2010 (including the first year; Y0)

Source: Database of BV-Lac project from 2006 to 2010, GSDM's data for the years before 2006

Figure 2(right) : Rate of abandonment according to the age of the plot

The first 3 years of CA implementation (learning, transforming, appropriation and then know-how) are key years in adoption and innovation requiring labor, investment, skills and willingness to move, from a paradigm (tillage), to a new method (no tillage coupled with long term vision and strategy). If intensification with mineral fertilizers generally provides an immediate response, this is not the case with CA practices: profits are not always immediately seen or even recorded (Penot et al, 2010). Due to crop rotation, the impact on production stability may only be seen after a minimum of 3 years. Y0 and Y1 can be therefore considered as an "experimental phase of CA", in which most farmers may abandon CA techniques, without having actually implemented them. During the following years Y2, Y3 and Y4 and beyond, abandonment decreased drastically. Farmers that have passed the experimental phase are theoretically sufficiently motivated to go on. Temporary abandons occurred among CA "adopters" that suffered cover crop crash and the loss of mulch. In this case, an "opportunistic" tillage could have been implemented to control weeds or other specific strategies (to benefit from the eventual fertility restoration).

Conclusion

The impact of abandonment rates, between 40 and 60% is considerable due to "opportunistic farmers" who intend to profit from immediate help from projects and will later on abandon after the first year. It is characteristic of farming systems inducing a paradigm change and the price to be paid in the medium term, to have an adoption base wide enough to ensure a sustainable adoption in a medium (10 years) or long term (20 years). The method of Cohort analysis reveals the abandonment extent per year and type and the difficulty of a sustainable adoption at a medium term. Additional surveys from local operators provide information on abandon mechanisms and causes per zone (land status, poor ability or skill to master CA, lack of cash for investment. The difficulty of identifying "opportunistic farmers" withdrawing from the end of the first year is jeopardizing development efforts on CA.

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The synergy of raised beds, controlled traffic, minimum tillage and stubble retention deliver higher water use efficiency in South West Victoria, Australia

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Introduction

About fifteen years ago low wool prices led farmers in this traditional wool growing region to adapt to cropping. Broad acre farmers of South-West Victoria then adopted permanent raised beds (PRBs) to overcome water logging on the heavy, impervious clay soils during the long and cool growing season. The cropping area increased sixfold to 43000 ha from 1994 to 2001 (ABS, 2001). The area under PRBs increased to about 35,000ha in 2003 with an average yield increase of ~20% across sites and seasons (Wightman, unpublished data). Currently about 450,000ha are being cropped with approximately 60,000ha of raised beds (Wightman et.al., 2005). Further expansion of this area has been impacted by a continuing drought in the last 5 years to 2010.The average cereal yield in this 'high rainfall zone' (HRZ) still remains around 2.5 to 3.2 t ha-1 (SFS, 2002; ABS, 2001) with the more entrepreneurial farmers realising yields as high as 8.5 t ha-1 on PRBs in recent times with improved agronomic management.

By their very nature, raised beds encourage the concepts of minimum tillage (MT) and controlled traffic (CT) in broad acre thus minimising the compaction on the majority of the paddock and delivering benefits in soil physical properties (Peries et.al., 2004; Tulberg, 2001; Tulberg et.al., 2001). This can also lead to rapid vegetative growth of crops that often leaves heavy stubble loads on ground in the absence of access to soil water for grain-fill, because of the 'hostile' nature of the subsoil. Recent advances in machinery development are helping farmers in the region to retain the stubble on ground and sow into it, while some are still challenged by the outcomes and are compelled to burn the stubble contrary to the principles of CA. Emerging technology of subsoil manuring is currently investigating opportunities for burying treated stubble and/or other organic amendments within the heavy clay subsoil with minimal soil disturbance, thus creating enhanced porosity in the subsoil (Gill et.al., 2008; Sale et.al., 2011). This paper describes PRB trial results that have helped farmers to achieve incremental yield benefits over time through the continuing and challenging initiatives in the region and advances the hypothesis that the technology currently available in the region is capable of achieving higher WUE from broad acre crops within a CA framework.

Results and Discussion

Field trials conducted between 1998 and 2004 compared systems' performance on bed systems and soils on which the PRB systems were established. Two Vertosols (Isbell, 1996) were compared: one a black friable cracking clay and the other a Grey Vertosol which was sodic at depth. Vertosols represent about 20% of the soils in the region and are known to be more productive due to their greater depth of aggregates (Sarmah et.al., 1996) than the Grey Sodosols which are more widespread in the region. The grey Vertosol used in this study was similar in behaviour to the Grey Sodosol. With CT and MT integral to the PRB system, the Vertosols were able to improve their macro-porosity at depth through their inherent shrink-swell characteristics during the frequent wetting and drying cycles facilitated by improved drainage on raised beds. The improvement in Plant Available Water Capacity (PAWC) was more pronounced at depths below initial tillage (Figure 1), suggesting that the difference in macro-porosity and the accompanying drainage in the absence of further compaction may be encouraging other processes such as extensive root proliferation and biological drilling (Cresswell andKirkegaard 1995) to a degree that was contributing to the enhancement of PAWC and therefore to the WUE of crops grown on raised beds.
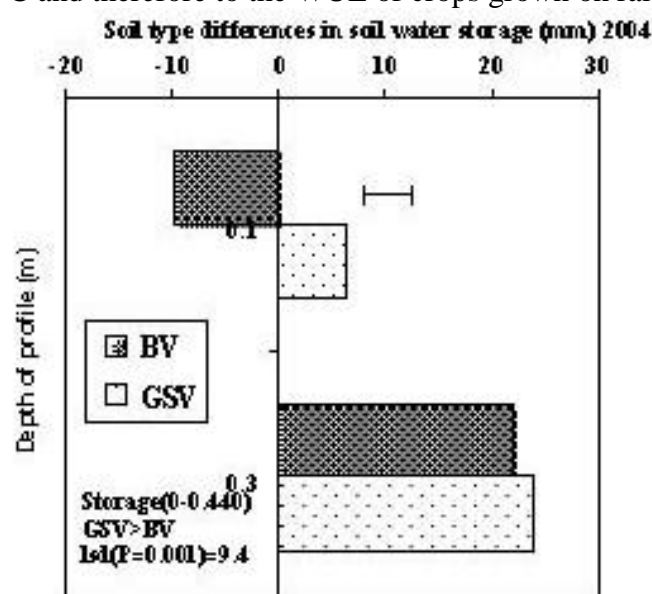
Figure 1. Effect of beds versus flats on soil water storage (at-10kPa) relative to that in perennial pasture on the flat in the profile at depths 0-0.2 and 0.2-0.4 m on 2 soil types in 2004. On the Y axis, the depths of 0–0.2 m and 0.2–0.4 m are denoted by their mid points 0.1 and 0.3 m respectively. The Y axis also denotes the soil water content on the flat perennial pasture and the histograms are measured differences (in millimetres of water/0.2 m soil depth) between raised beds and flat. The horizontal bars are the lsd values for the 0–0.2 m depth. BV =black vertosol; GSV= grey sodic vertosol

A benchmark survey of the raised bed farmers in the region carried out in 2009 (Peries and Gill, 2010) showed that at the lower end of the rainfall, the beds were performing at or above the putative potential WUE (Figure 2). At the higher rainfall end, low infiltration rates in the soil and therefore the lack of adequate PAWC was contributing to run-off resulting in low WUE of crops. In recent and sustained initiatives, amelioration of such soils with large volumes (e.g. 20 t ha-1) of organic amendments has changed the physical properties of those soils at depth, resulting in enhanced macro-porosity (Figure 3) and PAWC and root access to that extra water (Gill et.al., 2008). Cereal crops achieving grain yields of 5t ha-1 and above can potentially leave stubble loads of over 7t ha-1 on ground, which can interfere with subsequent crop establishment. Wet conditions under the stubble also harbour slugs, snails and earwigs that are a serious threat to crop establishment in the high rainfall zone (HRZ), which had led farmers over the years to burn stubble as routine practice until the recent

evolution of appropriate machinery in the region. A further evolving option is the use of 'treated' stubble as an ameliorant (Sale et.al., 2011), when placed in the subsoil, may bring about beneficial changes in soil physical properties similar to those obtained with lucerne pellets or poultry manure (Gill et. al., 2008). Our discussion revolves around the appropriate management package for the HRZ based on long-term research data, farmer experiences including Participatory Action Research (PAR) outcomes and anecdotal experiences in the region, so that farmers are able to make informed decisions within a CA framework.
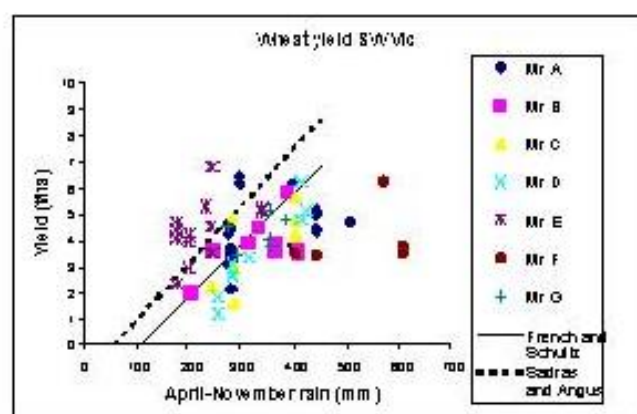
Figure 2. Relationship of grain yiel dto growing season rainfall for wheat during the 2002-2009 period in the HRZ of Southern Victoria. The two separate lines fitted to each graph correspond to WUE values of 20 (French and Schultz, 1984) and 34 kgha-1mm-1 (Sadras and Angus, 2006) respectively
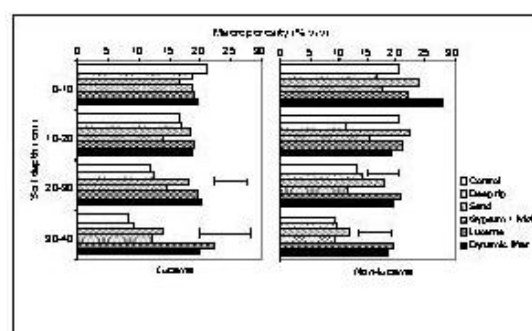
Figure 3. The effect of subsoil manuring using organic amendments on subsoil macroporosity (after Gill etal., 2008)

With the alleviation of water logging through the PRBs, opportunities have evolved for the HRZ farmers to implement practice change that is fundamental to CA. The creation of additional PAWC has also provided crop insurance during below average rainfall years, thus contributing to yield stability in the longer term. This is an aspect that farmers in the HRZ may not have fully appreciated, when they returned to flat, CT cropping during the long drought that preceded the above-average rainfall year of 2010. Several high-performing farmers (8t ha-1+) lost upwards of 40% potential yield (D Langley, pers. comm.) due to water logging and in the process may have also lost the gains made over several years of conservation practice.

'Well-managed' and retained stubble can increase infiltration and improve fallow efficiency particularly through capture of summer rainfall. However, in majority of the hostile subsoils with heavy clay in the HRZ, that extra PAWC needs to be created. The opportunity now exists for farmers to implement subsoil manuring prior to setting up raised beds, which will then be managed with CT and MT without further compaction. Currently manuring may use only poultry, farmyard or green compost, while technology evolves for the use of crop stubbles and/or green manures. Either way, creation of extra PAWC, while resulting in higher WUE, will hopefully also result in higher harvest indices of crops thus resulting in lower stubble loads that are capable of being managed and sown into, through disc seeders that have evolved in recent times. Friable soils with continuously improving drainage on raised beds will favour the build up of soil flora and fauna that will contribute to soil health and further enhance the outcomes from CA practice. This is our hypothesis. Getting the balance right in the gamut of practices available at their disposal is the continuing challenge for the HRZ farmers of Victoria.

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Development of the Conservation Agriculture equipment industry in sub-Saharan Africa

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Introduction

Smallholder farm mechanization in sub-Saharan Africa (SSA) relies heavily on manual labour and the hand hoe is the main implement used for crop production on up to 80% of the arable area. Draught animal power (DAP) represents a major advance in terms of available power and is especially important where human resources are being depleted by age, migration and pandemics. However the use of DAP is restricted by the presence of the tsetse fly and by tick-borne diseases such as east-coast fever. Where DAP is possible it is often used to pull the mouldboard plough, although chisel-tined rippers are increasingly used. Less than 10% of the land area in SSA is cultivated by tractor powered systems, mainly on commercial farms; those systems will therefore not be considered in this paper. Farmers perceive advantages with mechanized tillage operations (e.g.: improved weed control; mobilization of nutrients from the organic matter; preparation of a smooth seed bed; elimination of compacted zones; incorporation of amendments; control of pests and diseases; control of water run-off and accumulation of water). However, the damaging effects of the use of hoes and ploughs soon become apparent. They reduce soil organic matter through oxidation, cause various forms of physical, chemical and biological degradation (especially hard pans, soil crusting and erosion) and produce lower yields, which result in increased poverty and hunger, reduced food security and, eventually, abandonment of degraded farm land.

Conservation agriculture (CA), based on minimum soil disturbance, crop residue retention and rotations has been proposed to reverse this degradation in an effort to move towards sustainable cropping systems; however to date there is little information on the challenges to developing a viable CA machinery sector in SSA. Seed drills and planters developed for tilled soil present difficulties when planting through organic cover (in terms of seed placement and covering whilst penetrating the residues); another challenge is the precise application of herbicides for the control of weeds and management of cover crops.

CA mechanization options for smallholder farmers

Sub-soiling and deep ripping with chisel-point tines have shown significant yield benefits on soils with hardpans. For planting, the mulch can be penetrated or cut with vertical discs or jab planter beaks − or even a pointed stick. Chisel point tines are suitable in low-residue cover situations. The direct planters available incorporate both of these residue management techniques. For weed management all options can be used including shallow scraping, hand pulling, knife rolling, effective utilization of soil cover and cover crops, and the use of herbicides. Chemical weed control has often been an important step towards farmer adoption of CA due to the significant reduction in labour requirement. However, if herbicides are introduced there should be a medium term aim to reduce them to the minimum as soon as the agronomic control measures are showing impact.

Innovations are needed when farmers opt for chemical weed control. The conventional option is the knapsack sprayer, which is notorious for contaminating the operator. Knapsack sprayers can be mounted on a wheeled chassis, fitted with a multi-nozzle boom and hand-pulled so removing the operator from the risk of contamination. Larger capacity boom sprayers are available for animal traction.

Development of the CA machinery manufacturing industry

Brazil has witnessed a revolution in CA equipment development and manufacture in the past 50 years. Pioneer farmers tried new approaches to reduce soil tillage, as they saw that the on-going programmes of physical works for conservation (especially terraces) were not enough to halt erosion. After the initial efforts had been made, research institutes and commercial companies joined the endeavour to investigate cover crops, crop rotations, weed control methods and no-till planters. No-till farmers' associations were formed and consolidated CA adoption. The machinery industry flourished and still produces hundreds of models of planters and sprayers for CA for all sizes of farm and for all soil types. The success of the revolution in Brazil (which has spread to many other countries) can offer important lessons for SSA. There are several examples of fledgling CA equipment manufacturers in SSA, including in eastern Africa (especially Kenya and Tanzania) and southern Africa (including Zimbabwe and Zambia). Some of the relevant characteristics and points of contrast between the Brazilian and SSA situations are:

- *Materials supply*: there may be import duty on steel but not on imported agricultural machinery (e.g. in Kenya). Scrap steel may be appropriate for small-scale blacksmiths, but not larger scale manufacturers.
- *A lack of appreciation of the importance of critical part design and materials considerations*: e.g. jab planter beaks; tine dimensions, attack angles and materials (use of high carbon spring steel or easier to work alternatives such as Bennox steel); vertical loading on discs; seed metering, placement and covering; fertilizer placement, depth control.
- *Creation of demand*: manufacturers are reluctant to produce before receiving firm orders; at the same time farmers complain that the technology is not in the market place. Development projects can create the demand and maintain the interest of manufacturers until effective farmer demand can take over. Other important actions include the creation of dealer networks and their promotional activities through demonstrations and field days. The public sector's role in providing subsidies and credit in the initial stages is also important.
- *Need for training to improve the skills base*: Skills need to be improved at both the user and manufacturer levels in order for equipment to be effectively designed and properly operated and maintained. Important areas are; calibration; field operation; maintenance; business skills (especially for manufacturers and hire service providers).
- *Interactions between stakeholders*. As in the Brazilian case, the different stakeholders in the CA equipment supply chain will include the following groups which should act synergistically with mutually reinforcing policies and actions: Policy makers; RandD institutions (universities, public institutions and private manufacturers); Extension and training services; Finance institutions; Manufacturers, importers and retailers for equipment and spare parts; Machinery hire service providers; Machinery repair services; Farmers.

- *Innovative ideas.* Rather in contrast to Brazil, in SSA the ideas for CA have not emanated from local farmers. CA equipment manufacturers have access to new ideas through the actions of international, donor-funded, programmes and projects. In time local public sector RandD can play a major role in producing locally adapted technologies.
- *Policy environment.* The policy environment which can lead to a well-functioning supply chain should include reduced taxation regimes favouring local manufacture, extending credit and subsidies to farmers for machinery purchase, collaborative research between research institutions, manufacturers, input suppliers and international donors.

Guidelines for success

- The need for manufacturers to carry out market studies. These can be guided by innovation networks which help to overcome the demand vs supply conundrum through promotion of dialogue between manufacturers, researchers, farmers, farmers' groups, farming organizations input and credit suppliers and other stakeholders described above. Study tours for manufacturers can be a source of inspiration for new ideas (e.g. the FAO tour to Brazil in 2008 − ACT website).
- The importance of thorough testing of equipment before commercial batch production. To reduce the possibility of distributing sub-optimal equipment, it is important to subject prototypes to a rigorous testing regime including farmer evaluation in real on-farm conditions. Manufacturers need to be willing and prepared to incorporate user feedback into the next generation design.
- The provision of technical training for operators, dealers and extension staff. Manufacturers and hire service providers will, in addition, often require training and orientation in business skills and business diversification.
- Support for hire service providers. Today there are increasing efforts to support hire services for tractor or animal traction owners. However, often the highest demand is for ploughing and land preparation services. In order for service providers to make their living they may be obliged to offer these traditional services to sustain their business. Hence, the introduction of CA equipment may have to proceed in steps and there will probably be gradual shift as awareness of the CA concept and equipment will develop over time.
- Active promotion of products. Manufacturers need to make their products known amongst the farming community through events such as on-farm demonstrations, field days and participation in agricultural shows. Participation in meetings of functional innovation networks is another excellent vehicle for further promotion and adaptation of equipment.
- The formation of CA practitioners mutual support groups. Would-be CA practitioners derive great help from the support of their peers. CA groups in Brazil and other South American countries continue to support their members and help to solve technical, financial and social problems.

Conclusions

- Generally the CA equipment industry in SSA is in its infancy and needs careful nurturing by many stakeholders for it to achieve the required level of maturity. There is a major opportunity for international donors to support the implementation of the guidelines for success indicated.
- Although it is easier to import, there is a need for local adaptation to materials, conditions, economic circumstances and skills levels.
- National governments aspiring to support the scaling out of CA and the growth of their indigenous manufacturing industries should pay special attention to the creation of an environment in which these goals can be achieved.
- In the long term cheaper equipment tailored to local circumstances will be required. Now is precisely the moment to intervene with appropriate technical support. An example is the recent training and study tour by a group of East African manufacturing technical staff to CA equipment manufacturers in Brazil and Paraguay (Sims, 2010).

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Genetic control of wheat adaptation to Conservation Agriculture

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Keywords: Genotype x tillage interaction, wheat breeding, QTL analysis

Introduction

Conservation agriculture strives for sustainable productivity, quality and economic viability while leaving a minimal foot print on the environment. The preservation of soil and water is at the core of this approach and zero and minimum tillage are techniques used extensively in conservation agriculture. However, most crop breeding programs are conducted on complete tillage regimes thus limiting the identification of crop genotypes responsive to conservation agriculture (Mahmood et al., 2009). Researchers studying genotype x tillage practice interaction (GT) have generally reported a lack of interaction in field crops (Cox, 1991; Ullrich and Muir, 1986; Francis et al., 1984). Thus the probability of finding a significant GT interaction in improved crop germplasm may be limited and the inclusion of greater genetic diversity in applied breeding may be necessary if better adapted cultivars are to be developed. A genetic mapping population based on a parental line identified in an earlier GT study was evaluated in northwestern NSW to identify chromosomal regions linked to superior performance under zero-tillage. The aim was to identify genetic variation that can be used to develop wheat cultivars better adapted to conservation agriculture.

Material and Methods

Based on the performance of the genotype Berkut in earlier genotype x tillage contrast trials a mapping population of 148 doubled haploids from the cross Berkut x Krichauff was developed by Dr Hugh Wallwork from the South Australian Research and Development Institute. The population was genotyped and mapped and the details are described in Genc et al. (2010). Krichauff was chosen for its superior performance in dry environments in southern Australia. The population was sown at the University of Sydney's IA Watson Grains Research Centre near Narrabri in northwestern NSW (29°N, 200 masl) on two soil types with two tillage treatments across two years; 2007 and 2008. The two soil types were a grey vertisol and a red kandosol. The zero-tillage treatment was established in 2005 and the wheat experiments in 2007 and 2008 were sown into standing barley stubble. The 150 entry trial, including both parents, was sown in a unique 2 replicate alpha-lattice design in each tillage treatment on both soil types in both years. Plots area was 12m2 and sown at a density of 100 plants m2. Grain yield, days to heading and plant height were assessed on each plot. In addition NDVI (normalized difference vegetative index) was measured using a spectral radiometer on two dates; at heading and 2 weeks post heading. Trials were protected with fungicide as required and fertilizer managed as per local practice. Analyses of variance were conducted using GENSTAT 11th edition and the adjusted means used to conduct QTL analysis. Quantitative trait loci for yield and NDVI, both prior and post anthesis, were first characterised by interval mapping using Map Manager QTXb20 and confirmed by composite interval mapping using the Windows QTL Cartographer 2.5 application (Wang et al., 2007). A likelihood ratio statistic (LRS) and the amount of the total trait variance that is explained by a QTL is given as a percent.

Results and Discussion

The yield of the Berkut x Krichauff population was significantly higher under zero-till on both soil types (Table 1), largely reflecting the increased water availability associated with conservation agricultural techniques. The extra available water has also contributed to the slightly longer days to flowering in the zero-tillage treatment. The higher yield on the grey vertisol soils compared to the sandier red kandosols reflects differences in clay content and water holding capacity. Nevertheless, the higher NDVI readings on the lighter kandosol soils are at odds with the lower harvested grain yield. It is likely that soil water became limiting during grainfill on these sandier soils and insufficient moisture was therefore available to support the larger biomass. The population showed a differential response to tillage (Figure 1) although the QTL analysis was largely inconclusive as a number of significant QTL identified under drier conditions in 2007 were not found in 2008 (Table 2). Nevertheless, tillage specific regions for yield identified on chromosomes 1B, 1D, 2D and 5B are worthy of closer examination. These chromosomal regions are not associated with known genes that control phenology, plant height or other morphological characters such as coleoptile length or seedling vigour which are likely to influence performance in different tillage regimes. It is likely that the genetic control of adaptation to conservation agriculture and zero-tillage in particular is complex. Therefore the genetic improvement of crops for adaptation to these practices, with the possible exception of the more simply inherited resistance to disease, will be slow.

Table 1. Means of key traits across tillage regimes, years and sites at Narrabri.

Tillage regime	Zero-till	Conventional till	P<
Heading (days)	108.5 a	109.1 b	0.05
NDVI 1	0.5869 a	0.5883 a	ns
NDVI 2	0.4041 a	0.4065 a	ns
Yield (kg/ha)	1702 a	1368 b	0.001
Site/soil type	Grey vertisol	Red kandosol	P<
Heading (days)	109 a	108.6 a	ns
NDVI 1	0.4977 a	0.6775 b	0.001
NDVI 2	0.3855 a	0.425 b	0.001
Yield (kg/ha)	1733.4 a	1337.1 b	0.001
Year	2007	2008	P<
NDVI 1	0.6267 a	0.5485 b	0.001
NDVI 2	0.2318 a	0.5787 b	0.001
Yield	1356 a	1714 b	0.001

The same lower case letters in the same row indicate non-significance at P<0.05
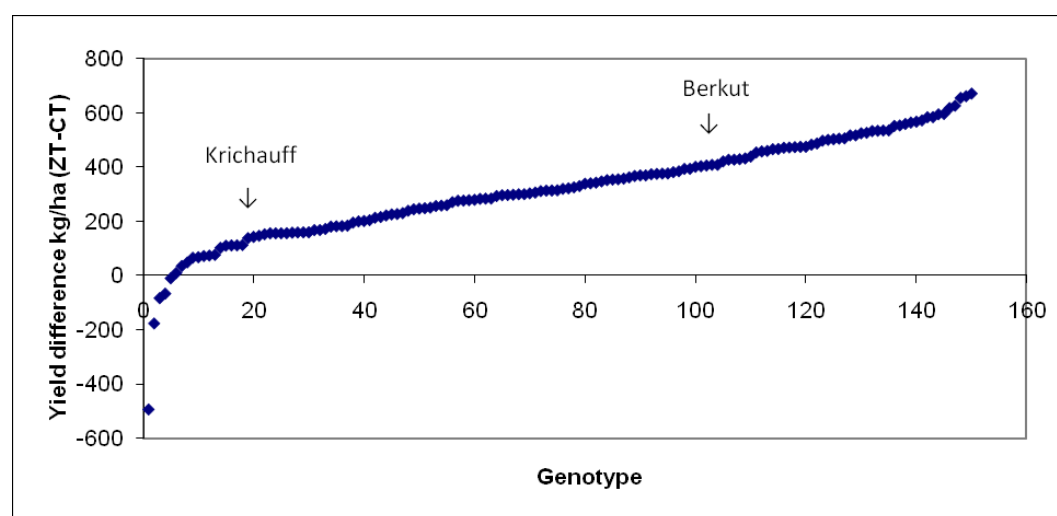
Figure 1. The yield difference between zero-tillage (ZT) and conventional tillage (CT) based on means of 2 sites in 2 years.

Table 2. Significant QTL effects for yield, days to heading, plant height and NDVI under contrasting tillage regimes on two soil types in 2007 and 2008.

Trait	QTL	Chr	Marker	Treatment	LRS (sign >12.9)	Additive effect%	Allele
Yield Qy. 1B1	1B	gwm268/wPt-3475	GV CT	07	13.0	8	K
Qy.1B2	1B	wPt-1313/gmw140	GV	CT 07	14.7	10	K
Qy.1D	1D	cdf19/wmc216	RK	CT 07	15.4	10	K
Qy.2D1	2D	wPt-3728/cfd44	GV	ZT 07	13.6	9	K
Qy.2D2	2D	gmw484/wmc27	RK	ZT 08	14.6	9	B
Qy.5A	5A	cfa2155/wPt1370	GV	ZT 07	41.8	25	B
Qy.5A	5A	cfa2115/wPt1370	GV	CT 07	26.6	14	B
Qy.5A	5A	cfa2115/wPt1370	L2	CT 07	13.9	9	B
Qy.5B	5B	wmc99/wPt2373	GV	ZT07	19.5	12	B
NDVI-1 Qn1.4B	4B	wmc141/wmc617	RK	CT 08	13.7	9	B
Qn1.4B	4B	wmc141/wmc617	GV	ZT 07	13.7	9	B
Qn1.7B	7B	wpt-8282/wPt7318	GV	ZT 08	15.5	10	B
NDVI-2 Qn2.4A	4A	wmc106/wmc491	ZT 07	ZT 07	13.6	9	B

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Trade-offs of crop residue use in smallholder mixed farming systems in Sub-Saharan Africa and South Asia

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Keywords: farming systems, crop-livestock farming, regional scale, farming diversity, system description

Introduction

One of the three pillars of CA is the use of crop residues (CR) for mulching. However, in smallholder farming systems that combine crop production and livestock husbandry (mixed systems), CR are usually an essential source of feed, restricting their availability for mulching. Additionally in these systems, CR fulfil other functions such as providing fuel and additional income through sale. Smallholder production in mixed systems supports the livelihoods of almost two thirds of the global population, especially in Sub-Saharan Africa and South Asia (Herrero et al., 2010). The integration between crops and animals not only enhances agricultural production, but also improves household food intake and income and provides a buffer against climate risks (Thornton, 2010).

The need to cover their own food requirements and household expenses pushes smallholder farmers to favour practices with positive returns in the short term, which may affect the sustainability of the systems in the long term. Farmers' decisions are influenced by biophysical and socio-economic drivers including climate, population dynamics, market access and other institutional mechanisms. The focus of this paper is on the trade-offs of CR use in a range of smallholder mixed systems in Sub-Saharan Africa (SSA) and South Asia (SA). The objective of this paper is threefold: (i) to describe the different CR farmer uses in these mixed systems; (ii) to understand what biophysical and socio-economic drivers explain differences in CR allocation; and (iii) to include these findings in the broader discussion on long term sustainability issues in mixed systems and constraints for CA practices adoption.

Materials and Methods

A total of 96 villages were selected for this study. The selection of the villages, clusters, countries and regions was designed to cover diversity in agro-ecologies, level of agricultural intensification and market accessibility. In the project, 12 clusters in 10 countries in SSA and SA were selected (www.vslp.org), but this preliminary version only includes clusters in Bangladesh (Dinajpur), Ethiopia (K'obo and Nek'emte), India (Karnal and Udaipur), Kenya (Kakamega) and Zimbabwe (Nkayi); the other clusters will be included in the final version. For each cluster, 8 villages were selected based on distance to the market and distance to a main road. In each village, a group interview was conducted, based on a structured questionnaire including general questions about the village: differences between farmers (wealth), current and past crops, CR and livestock management practices, services and market access, and costs and input/output prices. Village questionnaires were answered by a group of 10-25 farmers in each of the selected villages. The composition of the farmer group was as heterogeneous as possible, including farmers of different age, gender and wealth. For each cluster, the data gathered with the village questionnaire were combined (average and standard deviation) at a cluster level to conduct a comparative analysis between clusters. Descriptive analyses were carried out to compare the different clusters in terms of current farming systems, drivers of change and CR management.

Results and Discussion

The comparative analysis shows some similarities in CR management across clusters (Figure 1). Around 20% of CR are left in the soil in Dinajpur, Karnal and Kakamega, while for K'obo, Nek'emte and Nkayi CR are mainly grazed or collected. CR is commonly used as a stall feed in K'obo, Karnal and Udaipur, while almost 30% residues are used as fuel in Dinajpur. These uses depend on the type of crop. For example in Karnal, most of the wheat CR are used for stall feeding, while rice residues are left in the field, burnt or used for stall feeding (Erenstein and Thorpe, n d).
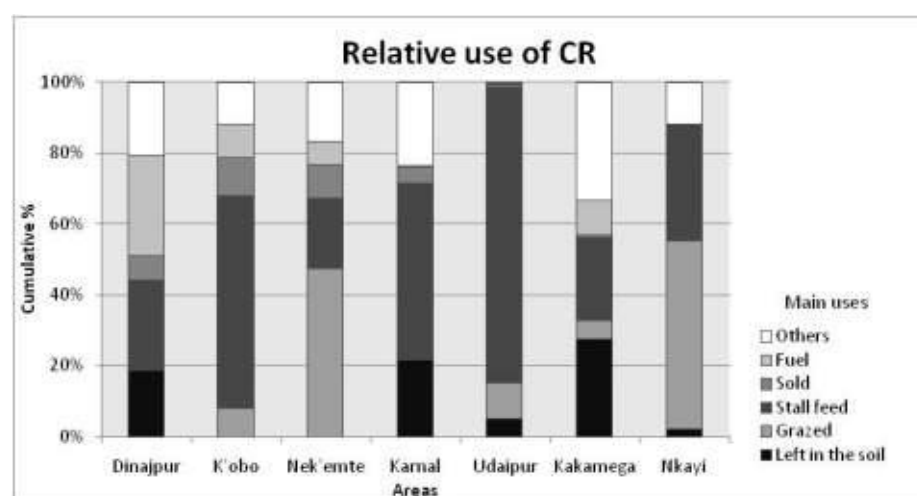
Figure 1. Relative use of CR per cluster.

Similarities and differences in CR management across clusters are related to opportunities and constraints linked to specific biophysical and socio-economic context/drivers in each cluster (Table 1). Biophysical conditions influence the growing season, limiting cropping and CR production in K'obo, Udaipur and Nkayi. Population characteristics exert pressure on resources and CR management differently. Population density is almost 30 times higher in Udaipur than in Nkayi, influencing the amount of grazing land and farm size. The degree of agricultural intensification has a strong influence on CR production. Irrigation and use of pesticides, herbicides and machinery are common in Dinajpur and Karnal, indicating shortages in labour and a higher degree of agriculture intensification. Access to input/output markets differs among clusters, affecting the type of agricultural production. In Kakamega, the high population density has created a local market for milk and so changes in feeding requirements and production practices (e.g. feeding of Napier grass). Finally, local/regional institutions

also influence the ownership and use of CR. In Nek'emte and Nkayi, CR ownership is based on the type of CR: teff and groundnuts are regarded as a private resource while maize is seen as a group- or open-grazing/harvesting resource.

Table 1. General characteristics of study cluster (average of the 8-village cluster).

Characteristics	Clusters						
	Dinajpur	**K'obo**	**Nek'emte**	**Karnal**	**Udaipur**	**Kakamega**	**Nkayi**
Country	Bangladesh	Ethiopia	Ethiopia	India	India	Kenya	Zimbabwe
Population density (persons/km^2)*	624.2	243.5	229.1	569.0	420.4	390.6	21.3
Area (ha)	106	350	113	474	434	531	4606
Households with livestock (%)	88	77	83	88	79	89	69
Main crop	rice-	teff-sorghum	teff-maize	rice-wheat	maize	maize	maize
Households tilling with tractor (%)	100	12	0	100	38	12	0
Households using chemical fertiliser (%)	100	2	95	100	68	80	25
Households using irrigation (%)	100	12	27	99	22	0	10
CR left in the soil (%)	19	0	0	22	5	28	2
CR grazed (%)	0	8	47	0	10	5	53
CR used as stall feed (%)	26	60	20	50	84	24	33
Tropical livestock units (tlu)	203	146	486	1377	523	348	401
Ratio tlu/people (tlu/person)	0.3	0.2	1.9	0.5	0.3	0.2	0.4
Shortage of dry fodder (months per year)	2.9	5.6	8.0	1.1	6.1	4.3	7.8
Shortage of grass (months per year)	4.4	4.3	4.0	.0	3.8	8.1	4.9
Use of dung as fuel (%)	13	33	0	39	10	0	0
No use of dung (%)	74	10	56	56	88	53	26
Use of dung as manure (%)	0	58	26	0	2	4	73

* Calculated based on village area.

Livestock numbers and composition vary across clusters, which influences the demands on CR and feed. The ratio TLU/person ranges between 0.2 in K'obo and Kakamega, and 1.9 in Nek'emte. Buffalo dominates in Karnal, while crossbred cattle are more common in Kakamega and Karnal—which is related to a demand for dairy products. Additionally, clusters might face similar pressure on feed requirements. In K'obo, Nek'emte, Kakamega, Nkayi and Udaipur, villages suffer longer feed shortage periods compared to clusters with higher agriculture intensification (i.e. Karnal and Dinajpur). Related to livestock, use of dung is similar among some regions. In K'obo and Karnal, dung is often used as fuel, while a large part is not collected in K'obo and Nkayi—caused by labour restrictions. In contrast, dung is used as organic fertiliser in Dinajpur, Kakamega and Udaipur.

The differences and similarities of mixed systems and CR management across clusters and villages illustrate that despite the complexity of those systems, farmers in different regions appear to face similar challenges. This is related to specific drivers across clusters and countries. Additionally, although livestock production systems are also diverse, livestock are an important component of the whole farming system in all the clusters, supplying traction, manure, food and cash. Furthermore, the growing use of CR as feed and fuel confirms an increasing pressure on biomass, favouring short-term livestock production over long-term improvement/maintenance of soil productivity. The implementation of mulching in smallholder mixed systems in SSA and SA needs to consider the specific context of farming. The preliminary results of this study suggest that famers, villages or even clusters with similar resources and market options might require a similar set of approaches to conserve their soils, specifically mulching. Clusters with a low grain and stover productivity would need to increase biomass production to cover human and livestock demands in the short term first, before implementing mulching in their fields— long term sustainability. Clusters with an increasing demand for livestock products would need to increase both quality and quantity of CR and fodder. Yet, increasing biomass production will depend on the existence of input/output markets and a set of institutions/policies to support it. If farmers can neither cover their basic food/feed demands nor see a short-term benefit of conservation practices, it is unlikely that such practices are going to be implemented in smallholder mixed systems in SSA and SA in the near future.

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A decision support tool for optimizing integration of specialty crop enterprises in grain production systems

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Keywords: sustainability, livestock, cabbage, woody florals

Introduction

Agricultural production in the Midwestern US is highly concentrated with 85% percent of cropland acreage planted to only corn and soybeans (NASS, 2006). Crop specialization has improved the productivity and market efficiency of grain based commodity crops, but maintaining profitability has become increasingly difficult as input prices continue to rise while grain prices fluctuate substantially (Dimitri et al., 2005). In addition, limited diversity has resulted in a number of negative environmental and social consequences. Diversification is one alternative to help farming operations become more sustainable and survive in today's unpredictable climate. Crop diversification and livestock integration can result in a series of synergisms and complementarities among farming system components, leading to more balanced nutrient and pest management cycles (Altieri and Rosset, 1996), greater farm income (Barbieri and Mahoney, 2009), and reduced income variability and risk (Helmers et al., 2001). Dramatic shifts away from the production of corn and soybeans are unlikely as farmers possess the skills and equipment to produce these crops. However, the integration of livestock or specialty crops as supplementary enterprises could help grain producers obtain the benefits of diversification. Our research was undertaken to determine the feasibility of integrating various supplemental enterprises into a traditional Midwestern corn-soybean rotation system. The objective was to identify supplemental cropping alternatives that have agronomic and market feasibility, would contribute to the environmental and economic sustainability of the operation, fit in during times of low labor requirements for corn and soybean operations, and not require substantial additional specialized machinery or knowledge by the farmer.

Materials and Methods

A model of a typical farming unit in eastern Nebraska was developed and detailed enterprise budgets established for each alternative enterprise based on values obtained in 2002. Data to generate the model and enterprise budgets were obtained from local growers for corn-soybean activities and researchers conducting field trials at the university research farm for supplemental crop enterprises. Enterprise budgets included accounting of the labor needed to perform each individual activity, when it needed to take place, and compensation for the farmer's labor. The four farm options considered were: 1) a base farm with a 256 hectare corn-soybean rotation; 2) the base farm plus crop residue grazing by cattle (*Bos taurus* L.); 3) the base farm plus either winter wheat followed by fall-planted cabbage (*Brassica oleracea* L. var. *capitata* L.) or spring-planted cabbage followed by oilseed sunflowers (*Helianthus anuus* L.); 4) the base farm protected by shelterbelts that included woody species selected for production of decorative floral stems, referred to henceforth as the agroforestry alternative. A Linear Programming (LP) model was developed to evaluate the alternative enterprises and determine the optimal allocation of the farm's acreage to maximize net profits given agronomic, labor and market constraints. The initial LP model focused on the labor constraints of one full-time farm producer and was performed with and without subsidy payments. Analysis of the agroforestry alternative was conducted with and without market constraints. Availability of an additional full-time farm operator or part-time seasonal labor, and a greater share of Nebraska and Midwestern woody floral markets were included in subsequent sensitivity analyses.

Results and Discussion

Fluctuating grain prices, changes in government subsidies, and growing concerns about soil and environmental quality have stimulated interest in changing land use practices (Smith and Young, 2000). Integration of supplemental crop enterprises can increase farm profitability as well as improve the agronomic and environmental sustainability of the operation (Dagliotti et al., 2005; Cittadini et al., 2008). However, farmers will adopt a new cropping system only if it is perceived to provide a net economic benefit relative to a currently used system in terms of lower production costs or higher returns (Zentner et al., 2002).Computer based land use models offer a low-risk, cost effective means to evaluate the feasibility of alternative production scenarios and provide suggested optimal decisions regarding land use. To aid growers in their decision making process concerning the integration of supplemental enterprises, detailed enterprise budges of a traditional corn-soybean operation and four alternative farming scenarios were evaluated in a linear programming model and the optimal crop allocation to maximize profitability was determined. Without crop subsidies an average farm of one section (256 ha) in eastern Nebraska operated with a net deficit of $4,753 (Table 1). Grazing stalk residues with livestock increased returns by $3,840, but did not change optimal crop allocation. Integration of winter wheat-fall cabbage was the most profitable single alternative, providing a net return of $34,503 with only 8.1 ha allocated to the supplemental crop enterprise. The spring cabbage-sunflower alternative also improved profitability, but was constrained by labor allocated to corn-soybean production. The agroforestry system was the second most profitable single alternative, but was limited by market constraints imposed for woody floral crops. When all options were considered simultaneously, acreage was allocated to each of the enterprise alternatives and the farm received a net return of $40,637. The addition of part-time seasonal labor increased acreage allocation to the spring cabbage-sunflower and woody floral enterprises and the farm received a net return of $86,758. Diversification of Midwestern grain farms through integration of supplemental specialty crop enterprises can increase profitability, as well as reduce reliance on agricultural subsidies and contribute to social and ecological sustainability. The intention of this paper is not to suggest that the specific specialty crop enterprises outlined have broad implications for adoption, but to highlight the potential to improve profitability and sustainability through enterprise diversification. Our linear programming model provides corn-soybean growers with a practical decision support tool to evaluate the feasibility of integrating new supplementary enterprises with adaptability and available market opportunities given fluctuating grain and input prices, and labor and market constraints.

Table 1. Optimal acreage allocation and annual net return for a 256-hectare farming enterprise (2002).

Enterprise alternatives	Grazing	Market constraints	Land allocation (ha)†	Net return ($) without subsidies	Net return ($) with subsidies
Corn-soybean alone	no	no	CS: 256	-4,765.44	21,480.96
Grazing considered	yes	no	CS: 256	-925.44	25,320.96
Winter wheat/fall cabbage considered	yes	no	CS: 247.90; WW/FC: 8.10	34,502.72	60,754.79
Spring cabbage/sunflower considered	yes	no	CS: 254.54; SC/S: 1.46	3,489.66	29,686.05
Windbreak and woody florals considered	yes	no	CS: 254.96; WB: 3.75; SC: 0.30	13,052.45	38,883.63
Windbreak and woody florals considered	yes	yes	CS: 254.96; WB: 3.75; SC: 0.10; GW: 0.13; BR: 0.02	4,174.37	30,011.95
All options considered	yes	no	CS: 243.54; WW/FC: 7.88; SC/S: 0.54; WB: 3.75; SC: 0.29	49,152.07	74,971.60
All options considered	yes	yes	CS: 243.54; WW/FC: 7.88; SC/S: 0.54; WB: 3.75; SC: 0.10; GW: 0.13; BR: 0.02	40,637.44	66,456.97
All options considered with part-time labor	yes	yes	CS: 233.23; WW/FC: 8.32; SC/S: 10.2; WB: 3.75; SC: 0.10; GW: 0.13; BR: 0.02	86,758.25	111,443.93

†CS, corn-soybeans; WW/FC, winter wheat-fall cabbage; SC/S, spring cabbage-sunflower; WB, windbreak; SC, scarlet curls; GW, goat willow; BR, bailey redtwig

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Opportunities and challenges for the adoption of Conservation Agriculture in maize production areas of Laos

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Introduction

In developing countries, market integration and the commoditization of agriculture are often associated with rapid land use intensification, a simplification or standardization of the agricultural systems and increased economic and ecological risks (e.g. market fluctuations, pests, soil erosion). Conservation agriculture (CA) is considered as a key alternative for intensifying agricultural production while maintaining or restoring key ecosystem services. However, important questions have been raised regarding the potential of CA in a context of smallholder agriculture (e.g. Erenstein, 2003; Bolliger et al., 2006; Giller et al., 2009). The practice is often deemed knowledge- and capital-intensive, hence incompatible with smallholder farming. For Giller et al. (2009), dissemination should concentrate on "socio-ecological niches" where CA is the most likely to be adopted by smallholders. Soil erosion issues, good access to farm inputs and markets and the presence of smallholders with sufficient land, labour and capital would constitute key criteria for identifying these niches. This paper focuses on two main research questions: "To what extent can CA compete with more conventional forms of agricultural intensification in a context of smallholder farming?" and "What is the value of a 'socio-ecological niche' approach to the dissemination of CA?"

Materials and Methods

The data derives from field studies conducted in two regions of Laos: southern Sayaboury Province and north-eastern Xieng Khouang Province (Slaats and Lestrelin, 2009; Lestrelin et al., 2011; Lestrelin et al., forthcoming). These studies assessed the socio-economic impacts of CA practices promoted by two agricultural research and extension initiatives. Research involved quantitative and qualitative surveys on changes in livelihood, land use and farming systems among 2,300 sample households in 30 villages targeted for CA experimentation and dissemination.

Results and Discussion

Since the mid-1980s, the government of Laos has promoted a gradual liberalization of the national economy. Among the set of reforms advocated, the replacement of shifting cultivation by intensive market-oriented agriculture was recognized as a key stage in the transition towards a market economy. As a result of market integration and policy incentives, total annual maize production increased tenfold between 2000 and 2009 – from 117,000 to 1,130,000 tons. This transition represents an important contribution to the national economy. In 2008, agriculture accounted for about one third of the country's GDP and maize ranked first in volume and second in value among the agricultural commodities exported. At the forefront of this process, Sayaboury Province has become the first maize production zone of the country and an important supplier of the Thai animal feed and food processing industry. Xieng Khouang Province constitutes the fifth production zone and exports essentially to Vietnam. The maize boom has had very important consequences for land cover, land use and smallholder agriculture in the two provinces. Over the past decade, it has led to agricultural expansion (forest and fallow conversion), a generalization of ploughing practices and an increased use of pesticides. With the transition from shifting cultivation to intensive hybrid maize monoculture, agricultural productivity has increased considerably while rural poverty has receded. However, a growing number of farmers are now confronted with land degradation issues (e.g. soil erosion, lowland siltation, weed pressure and chemical pollution), excessive production costs and indebtedness. Four main agroecological zones can be distinguished according to accessibility, market integration and capital outflows from early transitional areas to pioneer areas (Figure 1): (i) a zone long engaged in intensive agriculture and characterized by important land degradation issues, distress diversification (e.g. diversification of the commercial productions or re-emergence of subsistence crops) and mixed farming systems; (ii) a zone with degrading lands covered by intensive market-oriented monoculture and characterized by strong debt loads; (iii) a zone with productive lands engaged in a process of commoditization and intensification of agriculture; and (iv) a zone with productive lands covered by extensive subsistence-oriented agriculture. They correspond to successive stages in a historical pattern of land use intensification.
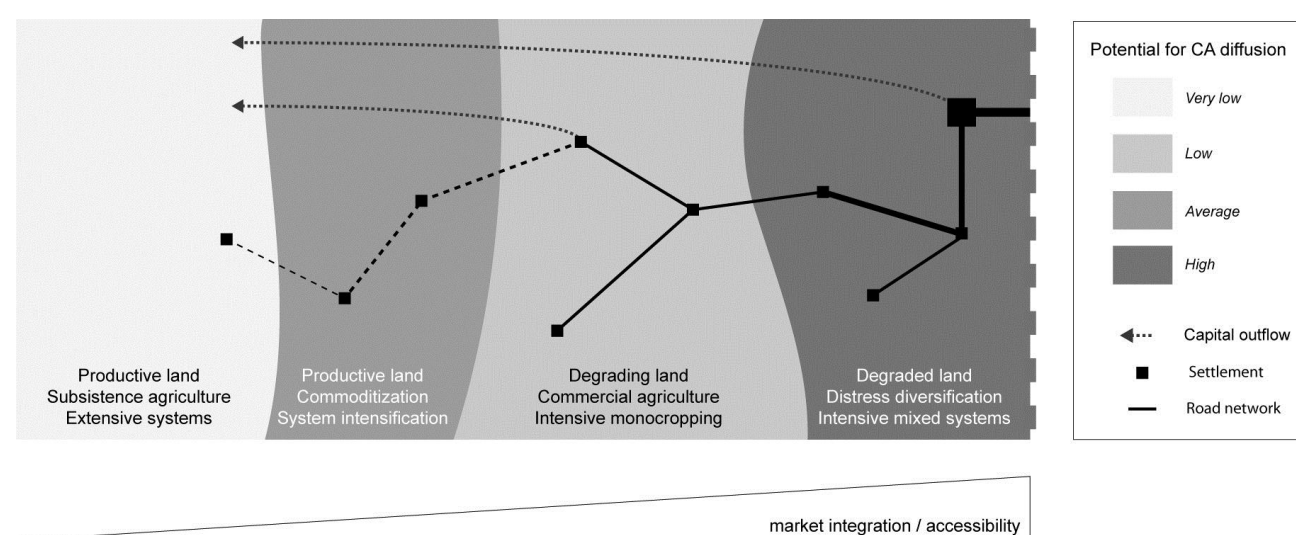
Figure 1. Agroecological transition stages and potential for adoption of conservation agriculture.

Three main direct seeding mulch-based cropping (DMC) systems have been experimented in the study areas: maize monocropping with residue management (proposed as a first step towards agroecological systems), maize – rice-bean intercropping, and biannual rotation maize – rice-bean. Funded through a 4-year extension programme, dissemination efforts have been particularly important in Sayaboury. As a result, adoption by smallholders has generally been much higher than in Xieng Khouang. Common patterns emerge nonetheless when looking at CA adoption across the two study regions (Table 1). First, in each target province, one village was surveyed where virtually all farming households had shifted to CA in 2008. More generally, in degraded areas long engaged in intensive agriculture, CA dissemination efforts have had stronger impacts than at any other stage of the agroecological transition. Farmers have also been more willing to

experiment with complex CA systems based on intercropping and crop rotations. In contrast, where market integration was more recent, limited land degradation, important agricultural incomes and well-established service provision systems (e.g. combining ploughing and pesticide application services) have imposed considerable limits to the diffusion and long term adoption of CA. At an earlier stage of land use intensification, DMC maize monocropping was an attractive option for smallholders willing to engage in market-oriented agriculture with a limited increase in production costs. Finally, in subsistence areas, the diffusion of CA has been significantly hindered by the limited capacity of smallholders to invest into required technologies and inputs.

Table 1. Adoption and abandon rates in the two study areas and four agroecological transition stages.

Agroecological transition (stages)	Sayaboury Province (21 villages, n=2084)			Xieng Khouang Province (9 villages, n=270)		
	Adoption[*] (2008)	Extent of CA[♣] (2008)	Abandon[♠] (2004-2008)	Adoption[*] (2008)	Extent of CA[♣] (2008)	Abandon[♠] (2006-2008)
Productive lands Subsistence Extensive systems	-	-	-	4%	76%	8%
Productive lands Commoditization Intensification	40%	50%	30%	27%	61%	11%
Degrading lands Commercial agriculture Intensive monocropping	13%	31%	54%	13%	32%	55%
Degraded lands Diversification Intensive mixed systems	41%	65%	30%	-	-	-
Total	**24%**	**53%**	**36%**	**12%**	**53%**	**21%**

[*] Percent of farming households
[♣] Percent of total farmland among CA farmers
[♠] Average abandon rate between year n and year n+1 of CA practice

Conclusion

Responding to the first research question, these findings suggest that, with an appropriate timing and adequate research and extension endeavours, CA can compete with ploughing-based agricultural intensification – and this, even in a context of smallholder farming. In the maize production zones of Laos, critical windows of opportunity for intervention were, first, at an early stage of commoditization and intensification of agriculture and, second, at the latest stages of land degradation and economic diversification. In the first instance, CA dissemination and technical support may allow smallholders to engage in more sustainable agroecological transition pathways. In the second instance, CA represents an economically- and ecologically-sound alternative to conventional intensive agriculture. The concept of "socio-ecological niche" put forward by Giller et al. (2009) can certainly prove useful for characterizing areas where particular types of CA can offer advantage and are more likely to be adopted by smallholders. However, local socio-ecological systems are not just spatially diverse; they are highly dynamic and constantly reshaped by broader political, socioeconomic and biophysical driving forces. In that sense, rather than locating potential 'hotspots' for dissemination, the most important challenge for CA researchers and practitioners lies in identifying the key moments for intervention along specific agroecological transition pathways.

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Reducing the cost of complexity for greater farming systems change

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Keywords: embodied innovations, precision agriculture, conservation tillage, convenience

Introduction

Complexity consumes management time, attention and labour. This has a cost (Kingwell 2010). Simplicity, ease and convenience are therefore highly valued by modern farmers. The remarkable rate and level of adoption of disease and herbicide tolerant crops provides evidence of this (Piggott and Marra 2008). These non-pecuniary benefits or costs can have a large influence on the overall relative advantage of a technology for growers and it is likely that they will become more important as farm size increases and management demands increase. In Australia, ABARES (Hooper and Levantis 2011) use an index of land use intensity that integrates crop and livestock activity to show trends towards increasing land use intensity per hectare in major grain growing regions since the 1990's. This typically reflects increasing cropping frequency and in some cases a shift from wool to more intensive prime lamb production. In addition, farmers are facing increasing demands from other aspects of the farm business such as marketing and regulatory requirements.

Introducing a new practice to a farming system usually involves, at least in the short-term, increasing management demands (Pannell et al 2006). However, some practices and technologies offer benefits that do not involve large information and learning requirements. The benefits of such technologies are part of the technology and are obtained relatively simply through its direct use. An example of an embodied technology is a disease tolerant crop variety. In contrast, some technologies do not have embodied benefits and require information, learning and knowledge for the benefits to be obtained. An example of technology that is not embodied is a decision support tool or new soil test. These deliver their benefits to farm productivity, not by direct use, but indirectly through improved decisions and subsequent implementation by the farmer. It follows that where a farm or farmer has greater management capacity, whether it is through greater skill, knowledge or access to expertise, their ability to gain benefits from non-embodied technologies can be greater (Waibel and Zilberman 2007). The nature of embodied innovations means that they are often able to be successfully delivered through the commercial sector. In farming systems research and extension we are not often dealing with simple embodied innovations (Ekboir 2003).

An example of a technology involving complex knowledge demands before full farm productivity benefits can be gained is provided by Gray (2010). His insightful description of the information and knowledge requirements involved in the development of no-tillage cropping in Canada includes mechanical innovations, agricultural knowledge, manufacturing scale, on-farm capital and prices in a chain of drivers. While some drivers of the value of the innovation such as grain and fuel prices were external to the innovation process, others are internal to the innovation development process e.g. the evolution of local farmer conservation tillage organizations, the emergence of specialist cropping consultants, researcher expertise. These all contributed to accumulating stocks of knowledge and information that increased the potential benefit to be gained by using the innovation and thereby eventual widespread adoption. It was a knowledge-intensive process and extended over decades. It would not have been required for a typical embodied technology.

In this paper results from a study of agricultural innovation adoption by Australian grain growers are used to examine the role of learning and information-related constraints and opportunities to reduce their impact on practice change. Data on the diffusion of no-tillage systems in Australia is presented and the drivers compared to the conceptual framework presented above. An analysis of an information-intensive innovation currently in the early stages of diffusion, variable rate technology, is then presented with comparisons made with precision agriculture technologies with more embodied characteristics. The aim is to 1) identify aspects of complexity and information intensity affecting farming systems change and 2) identify opportunities for research and development to address management capacity constraints in a way that enables greater use of beneficial practices.

Materials and Methods

The study draws upon data on precision agriculture (PA) and cropping practices from a study of grain growers from across major grain growing regions of Australia. Interviews were conducted by phone in 2008 as part of a larger study of factors influencing adoption of cropping practices. The farmers were randomly selected from a comprehensive commercial farmer database. Of all suitable households with a primary cropping decision maker contacted, 14% refused to complete the survey. Data were collected from 1170 primary cropping decision makers on farms cropping greater than 200 ha in a typical season. The questionnaire was developed to be as quantitative as possible to allow for cross-region regression analysis. A relatively broad definition of no-till seeding was used in the study based around seeding with low soil disturbance (points or discs) and no prior cultivation. Precision agriculture-related practices include yield mapping and use of variable rate fertiliser on paddock zones.

Results and Discussion

After three decades, the diffusion of no-tillage systems in Australian agriculture is now reaching a plateau in many districts. The information-intensive nature of the process has been demonstrated not only in the adoption process (D'Emden et al 2008) but also in the ongoing extensive use of the technology. The factors significant in explaining no-till use in logit models demonstrate the range of knowledge requirements, with understanding of herbicide efficacy, disease management, seeding reliability and soil moisture retention all represented. Higher education is significantly associated with a greater rate of adoption. Use of a paid farm consultant is significant in explaining both adoption and extent of use. In most regions the use of consultants is more than twice as likely among no-till users.

Some precision agriculture technologies such as GPS-guidance do not have high knowledge requirements and can readily contribute to simplicity and convenience of farm operations. Autosteer is an example of an embodied innovation that allows direct benefits (e.g. reduced overlap, reduced operator fatigue) and has been widely adopted (Robertson et al 2011). However, use of PA technologies for site-specific management is still in the early stages of adoption with less than 10% of growers found to be using variable rate fertiliser with yield mapping. Growers using yield mapping (and using variable rate fertiliser with yield mapping) are more likely to use consultants but it is not a strong association. This is because most growers use a consultant, but not one that provides precision agriculture expertise. In regions where well-understood and highly observable soil variation (e.g. in a dune-swale land system) has allowed for more simple 'convenient' zoning there has been strong advisory support for spatial management and there has been greater early adoption of variable rate application technology.

Before the majority of potential PA adopters apply PA technology to spatial management, a greater proportion of advisors will need to be supporting its use. Some non-embodied technologies generate increased demands for purchased inputs that can then lead to the commercial sector offering increasing levels of advisory support. This was the case for no-till, where demand for herbicide inputs increased, which supported an increasing supply of crop advisors. In the case of variable rate fertilizer, a likely scenario is no major increase in purchased fertilizer inputs (Robertson et al 2011).

After more than 20 years we still see very different levels of use of no-till between districts. In the same way we should expect to see very different peak levels of variable rate technology use between regions in the future. A RandD challenge is to identify where the greatest potential for highly profitable use of in-paddock spatial management is likely to be, based on the type and level of inherent within-field variability. This will allow investment in development of more embodied technologies and support services to be better targeted. Whilst many of the technical PA hardware-software complications are likely to be overcome soon, it will always be the case that variable rate technology requires ongoing information analysis and decision-making to gain value from it. By nature it is information intensive and potentially complex so 1) rapid adoption rates should not be expected; 2) a major role for advisory and support services will be important. However, opportunities exist for research understanding and technology to reduce data and information processing demands required to gain benefits from variable rate technology.

Convenience and simplicity for farm managers are likely to be an increasingly important determinant of the relative advantage of new practices. As a result, the complexity of innovations and the demands on management time and attention will increasingly determine peak adoption, not just the time to adoption. This places increasing demands on research, not just extension. One way for agricultural research to meet these demands is to look for opportunities to internalise additional stages of the innovation development process. RandD aimed at facilitating an active role for advisors can also lead to reduced complexity costs for a particular innovation. Research that generates innovations with greater embodied knowledge and reduced management demands for farmers is likely to be of increasing value and impact.

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Robustness of livestock farmers to climate variability: a case study in Uruguay

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Keywords: resilience, variability, response

Introduction

Increased awareness about climate change has motivated farmers, researchers, and policy makers worldwide to design "climate robust farming systems" that may be at the same time productive and sustainable in face of climatic risks, including climate change (Meinke et al., 2006). The terms stability, resilience, robustness, resistance, among others, are used widely in the literature to refer generally to the capacity to respond to risks, but often with unclear meanings and sometimes conflicting definitions (Grimm and Wissel, 1997). Operational definitions and quantitatively measures for these concepts are urgently needed in order to design climate robust systems and empirically compare systems with different robustness levels. Furthermore, it is relevant to understand how robustness is affected by technological and structural features of farming systems such as farm size, resources, inputs (Reidsma et al., 2007). In this paper we propose operational indicators to quantify robustness dimensions at the farm level and test the hypotheses that structural and technological features of farms impact climate robustness using past data from a group of livestock farms in Uruguay.

Materials and Methods

We used data from the FUCREA farm network in Uruguay, which includes around 350 livestock farmers. We selected 7 livestock farmers that had reported production and economic information relatively continuously for 30 years located in the north-west of Uruguay ("Queguay Chico-Soto CREA Group", years 1973 – 2003). Systems had mixed beef cattle and sheep full cycle to finishing grazing natural pastures on Basaltic soils. The farm output variable analysed was total equivalent meat production (beef + lamb + 2.5×wool) in kg/ha (hereafter referred as EMP).

Two dimensions of response to climatic risks were quantified: variability of EMP over time and robustness to drought. Variability was measured by standard deviation (SD), variance coefficient (VC=100×SD/mean), 90% range (R90=95th percentile – 5th percentile), coefficient of variability (CV=R90/median), and root mean square error of regression of EMP over time (RMSE). Correlations among these measures were calculated, and also with mean EMP in the period.

Using the actual rainfall time series of the official local Meteorological Stations (Salto), as well as simulated forage yield results of natural grasslands using the Century model (Baethgen et al., 1994), we identified fiscal year 1988 as the most severe meteorological drought of the period. Most farmers experienced a reduction in EMP either in 1988 or 1989. Robustness was measured by the ratio of the observed minimum EMP (either in 1988 or 1989) over the predicted EMP by the regression of the five years before the drought. Therefore, robustness in this context is a measure of the sensitivity to drought (more robust farms are less sensitive to drought, therefore are able to maintain higher EMP).

We regressed EMP, variability and robustness against the following technological and structural variables: soil productivity index (relative to national average, CONEAT), area under grazing, percent area in improved pastures, livestock stocking rate (livestock units/ha), and sheep to cattle ratio. A principal components analyses was performed to further explore the relationships among the variables: robustness, variance coefficient, grazing area, improved pastures, EMP, stocking rate, and sheep to cattle ratio.

Results and Discussion

Variability measures SD and R90 were highly correlated (r=0.96), and also were CV and VC(r=0.95), but RMSE was poorly correlated with all the previous (r<0.6). Therefore SD, CV, and RMSE could suffice to characterize the variability. There were no significant association between variability and mean EMP, although as the mean EMP increased there was a trend for increasing variability measured as SD and RMSE (but not VC).

Robustness ranged from 0.64 to 1.13; therefore, some farmers reduced their EMP in the drought year by 64% while others increased their EMP 13%. This indicator was more correlated with average pre drought beef production (r=0.60), stocking rate (r=0.60), area in improved pastures (r=0.52) and soil productivity index (r=0.49), and negatively correlated with sheep to cattle ratio (r=-0.32) and grazing area (r=-0.31). This suggests that in these mixed systems beef cattle are more responsive to climatic signals than sheep. It also suggests, as expected, that the resource base of the farm (soil, improved pastures) is relevant to determine sensitivity to climatic variability.

EMP was positively correlated with robustness (r=0.43), which suggests that more productive systems may be more robust. Robustness was positively correlated with variability measured as RMSE (r=0.50) and STD (r=0.36) but negatively correlated to VC (r=-0.22). The relationship between variability and robustness therefore should be studied further.

Three principal components explained 88% of total variance. The first eigenvector was loaded on productivity variables (EMP, improved pastures, stocking rate, 57 % of variance), the second eigenvector was heavy loaded on variability (variance coefficient, 20% of variance), and the third eigenvector was heavily loaded on robustness (11% of variance). This suggests that robustness may be affected by both productivity and variability. Figure 1 represents the first two eigenvectos, showing that farms with either high or low productivity (principal componemce 1) have less variability (principal component 2) than farms in the middle range of productivity (Figure 1).

These results are based on few farmers with long history of records, and therefore only trends are reported. We were not able to detect any statistical significance out of these case studies. Rather than conclusive evidence, this results are suggested as hypothesis to further test. The purpose of this paper was to propose a methodology and potential analyses in this extremely relevant area of research. This methodology is being tested in larger datasets in order to be able to determine whether farm structural and technological characteristics are strongly associated with robustness to climate variability.
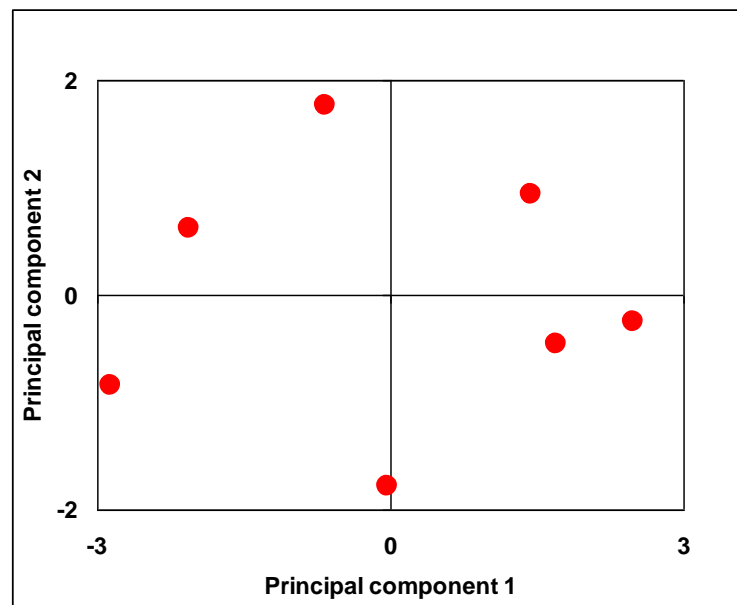
Figure 1. First two principal components for the analysis including 7 variables (robustness, variance coefficient, grazing area, improved pastures, equivalent meat production, stocking rate, and sheep to cattle ratio) for 7 livestock mixed grazing farming systems in Uruguay.

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Agricultural adaptation to climate change: acknowledging different frames

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Introduction

Adaptation to climate change is an ambiguous topic (Orlove, 2009). Central to debate is how "additional" or different, climate change adaptation is relative to pre-existing efforts to manage climate variability (Fankhauser 2010). This question is particularly pertinent within agriculture, as there is an unusually high degree of experience in adapting to natural climate variability and other uncertainties (Crane et al 2011). Research suggests that part of the reason there is ambiguity about climate change adaptation and, in particular, about how novel or serious a challenge it represents, is because there are numerous subsidiary issues involved, which different people frame in different ways (Fünfgeld and McEvoy 2011, O'Brien et al 2007, Pelling 2011, Orlove 2009, Spence and Pidgen 2010, Pielke 2005, Nisbet 2009, Hulme 2009). This paper identifies and reviews three such subsidiary issues for climate change adaptation in agriculture in order to improve the clarity of debate. Drawing on the Australian situation and bringing together insights from a range of relevant literatures, it discusses the divergent views that exist on the following topics and their implications for how climate change adaptation is approached. These are: how anthropogenic climate change relates to natural variability; how success in adaptation is defined; and the relevance of different forms of knowledge (farmer experience versus science) for directing climate change adaptation.

Materials and Methods

A selective interdisciplinary literature review was conducted to complement the dominance of agronomy, climate science and economics in current discussions of climate change adaptation in agriculture. This involved three main avenues. First, relevant discussions of climate change adaptation within the adaptation, climate science, development studies, disaster risk management, resilience science and global change literatures were identified and explored in order to identify some key questions posed by and about climate change adaptation. Second, the implications of these key questions (discussed below) for agriculture were considered by reviewing existing literature on climate change impacts and adaptation in the sector. Third, relevant discussions of agricultural change in the rural sociology, geography and agricultural extension literatures were incorporated to develop a broader perspective of the agricultural adaptation challenge. A total of 213 papers were reviewed.

Results and Discussion

How the climate change adaptation challenge is being approached within agriculture is shaped by different perceptions on key inter-related subsidiary issues, three of which are discussed here.

One, the relationship between climate variability and climate change is not clear cut and is understood in different ways by different people (Hulme 2009). In particular, there are two contrasting views which contribute to conflicting understandings of climate change adaptation. One is what is termed here as the 'scalar perspective' (Figure 1a) in which climate change is understood as an all-encompassing envelope. Perpetuated by global climate models and adopted by many agricultural scientists, this 'top down' approach focuses on the climatic effects of future climate change as the starting point for adaptation. Associated with the 'scenario approach' to, or 'scientific framing' of, climate change adaptation identified by Wall and Smit (2005) and O'Brien et al (2007) respectively, this view generally leads to an adaptation approach based on climate modelling, forecasting and formal risk management tools. It helpfully highlights the "temporal big picture" that agriculture needs to adapt to and within, but can unhelpfully downplay non-climatic factors (Hulme 2011, O'Brien et al 2007). The other approach is the 'experiential perspective' (Figure 1b) which adopts an actor point of view in which climate change is a weak, uncertain and politicised signal nested in among existing climatic conditions and numerous more proximal and pressing concerns. Climate change adaptation here is primarily concerned with addressing current 'start of pipe' (cf Kelly and Adger 2006) sources of vulnerability, including how 'deficient' a given population's adaptation to existing climate risks (e.g. drought) and other risks (e.g. terms of trade) (Pelling 2011, Burton 2011, O'Brien et al 2007). This perspective usefully highlights the multi-factorial "contextual big picture" that agriculture needs to adapt to and within, but risks overlooking the need for anticipatory or transformational change in response to the long term pressures of climate change.

A - A scalar interpretation:
Climate change as envelope

B - An experiential interpretation:
Climate change as signal
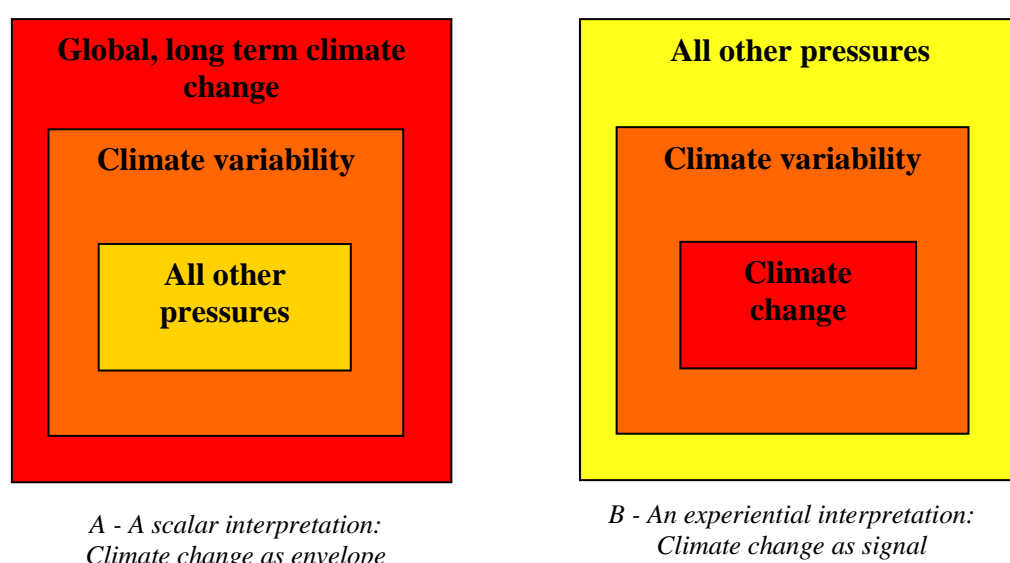
Figure 1. Contrasting images of the relative positioning of climate change and climate variability. A. A scalar perspective of climate change and variability in which climate change is an envelope. B. An experiential perspective in which climate change is a signal nested within more proximal concerns. **(Source: authors)**

Two, the apparent successfulness of adaptation is also a matter of perception, shaped in large part by the temporal scale of analysis. What in one view may seem adaptive may in another appear as maladaptive (Adger et al., 2005). Related to the perspectives on climate change mentioned above, a near-term versus a long-term focus favours different adaptation strategies. For example, a focus on adapting to the emerging conditions within a farming season favours a reactive, incremental, farm-scale approach to adaptation. Both approaches are a continuum, are legitimate and involve trade-offs (Rickards and Howden 2011). Of concern is that some farmers' existing responses to climate variability and extremes are merely a form of coping (short term survival) rather than adaptation (long term improvement), with far-reaching negative consequences for them and the environment. For example, some farmers may survive a period of drought by exploiting resources such as their health of the quality of their soil, which reduces their ability to adapt to subsequent stressors and reduces their ability to avoid destructive measures in the future. Being on such a 'coping cascade' (*cf* Pelling 2011) is therefore not adaptive in the long term. At the same time, suggested adaptations to long term climate change are also not adaptive if they sacrifice farmers' ability to cope in the short term. Recommendations such as making decisions that are 'robust' (adequate) over a range of climate conditions rather than optimised to most likely conditions (Wilby and Dessai 2010) must take into account the costs they impose on farming households (eg financial costs, learning costs, opportunity costs) and whether these households have the capacity to cope with these, given their concurrent need to survive in the short term in order to eventually adapt to the long term.

Three, the forms of knowledge that should form the basis for adaptation is also contested. Climate change poses a double-edged epistemological challenge for agriculture. On the one hand, the highly scientific nature of climate change knowledge and the profound uncertainty that climate change introduces means that farmers' experience-based knowledge may no longer be a reliable guide to what to expect or how to manage their systems (Hayman and Alexander 2009). This downgrading of the value of farmer knowledge seemingly creates a classic case of science deficit, for which 'climate literacy' training and decision-support tools such as seasonal forecasting are sometimes represented as the appropriate answer. On the other hand, the reliability of the science as a guide to management decisions is also questionable due to the high level of uncertainty that characterises many details about climate change impacts (Hulme et al. 2009). It may be that rather than turning to forecasting tools, farmers are better off accepting the future is more uncertain and refining the adaptive approach to decision making and learning that many are already familiar with (Crane et al. 2011). The result is that there is significant ambiguity about what form of knowledge should guide adaptation in agriculture (and beyond). In addition, climate change involves far more than climate and requires an unprecedented level of interdisciplinary research (Howden et al. 2007). To the extent that these points are accepted, the breadth of the climate change adaptation challenge is expanded to include not only farming systems but also our knowledge systems.

Overall, agriculture is both highly experienced and vulnerable when it comes to adapting to climatic change. The degree to which previous experience with adapting to climate variability and other pressures is an advantage or limitation for its adaptation to climate change hinges in part on the consideration of the influence of conflicting perceptions and information in order to fully explore the implications of any possible course of action. Lack of clarity about the breath of issues adaptation involves and the different perspectives people hold on these issues is a barrier to effective coordinated action. This paper tries to identify and discuss issues of ambiguity that require consideration as climate change adaptation increases in prominence and importance.

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Whole-farm models: a review of recent approaches

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Keywords: whole farm systems modelling, economics, optimisation

Introduction

In recent times there has been a proliferation of whole-farm models (WFMs) to address a multitude of questions in agricultural systems. Janssen and van Ittersum's (2007) review of whole-farm models concentrated on mechanistic positive models that used constrained optimisation, and are ideal for ex-ante research evaluation. They did not cover non-optimisation models, which are more compatible with farmer decision-making where results need to be discussed within the context of the assumptions and representativeness of the farm. They also focussed on industrialised countries and since their review there has been a proliferation of WFMs for developing country situations. These often have the objective function of maximising food security and need to account for unique features of smallholder farms such as: household food requirements, the contribution of off-farm income, the ownership of livestock as a significant capital and cultural "asset", the utilisation of communal lands, and the economic implications of home consumption of farm production versus market purchase. Janssen and van Ittersum's (2007) review also did not cover issues of spatial explicitness, representativeness, and coupling with biophysical simulation models.

This paper takes the perspective of researchers, working at the plot and field level, who wish to the scale their results to the farm level to estimate the impact of management interventions on a farm business. The methods and approaches for extrapolation of management from the paddock to the farm scale vary, and researchers need guidelines on types of approach, tradeoffs between comprehensiveness and complexity; the degree to which seasonal variability is accounted for; interactions between activities (a particular issue for mixed farming systems); and soil type or land-use unit heterogeneity.

This paper will document current approaches and develop a typology, using a review of recent papers published on WFMs, and describe strengths and weaknesses of various approaches. This analysis will be used to formulate some preliminary guidelines to match the most appropriate WFM approach to the issue or the objective of the modelling.

Methods

Papers using WFMs published in the journal *Agricultural Systems* between 2006 and 2011 were classified according to a range of criteria. A total of 53 studies utilising 42 models were analysed.

Results

A wide range of approaches are used:

- Constrained resources. Models differed between those with a primary economic emphasis where constraints on labour, machinery or expenditure were evaluated (68%), versus those with a stronger biophysical emphasis (often based on simulation) and usually without any constraints on inputs, which were supplied exogenously to the model.
- Dynamics – within year, between years. Models with livestock only accounted for within-year dynamics (28%) because of the need to reconcile feed supply and demand on a seasonal basis, whereas those with a crop-emphasis concentrated more on between-season variation (8%). There were 43% of studies that accounted for both and 8% neither.
- Accounting for seasonal and price variation. A total of 13% of models accounted for price variation only, 17% for seasonal variability only and 21% for both. No models were described where an assumed or actual distribution or sequence of prices was used. Many models used a sequence of years to calculate a long-term mean without analysing the shape of the distribution.
- Mixed farming or monoculture. A number of models were applied to mixed crop-livestock systems (49%), although few linked the two types of activities and most treated them as discrete enterprises (74%). Household models in the developing world also linked crops and livestock because of the need to account for livestock utilising crop residues and the use of manure on croplands.
- Spatial heterogeneity. Half of the models specified spatial heterogeneity in land-use units within the farm and associated productivity and suitability to crop and livestock activities both in developed (Kingwell and Pannell 1987) and developing world (Giller et al. 2006) situations.
- Real vs "representative" or typical farms. 75% of studies used representative farms, although farm surveys were used commonly to specify what was representative. Where farm surveys were used it was often in the context of an attempt to assess the regional impact of a scenario by aggregating the impacts at whole-farm level (e.g. Cleassens et al. 2008). Surprisingly, few models varied key characteristics of the representative farm in sensitivity analyses.
- Objective – profit, risk, natural resources, social outcomes. Household models built to address issues for smallholder farmers in the developing world (21% of studies) all had a model objective of maximising food security. All models built for industrialised countries had maximising profit as the objective and a significant number (21%) had profit and some measure of environmental impact, such as energy use, greenhouse gas emissions, soil carbon or nutrient losses. One had a "social" objective of maximising labour use. Significantly, only one study within the review period had risk reduction as part of the model objective function.

Discussion

The insights gleaned from this review lead us to arrive at three dominant types of approach to WFMs based on methodology, scope and target domain. These have become reliable methods, based on their dominance in the literature.

Static optimisation in industrialised agriculture

In industrialised agriculture, because there is greater flexibility and technical knowledge, systems can be modelled according to static optimisation approaches. In contrast, in the developing world there are important social limitations that need to be taken into account. Static optimisation approaches represent the biological, physical, technical and managerial relationships of a farm and allocates available

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resources and recommends decisions in order to maximise the objective function of whole-farm profit, subject to resource, environmental and managerial constraints. Seasons are not explicitly described, nor are variations in price but the model can be run with a range of parameter values to assess the influence on the profit-maximising mix of enterprises and the level of farm profit. Strengths of the approach are that temporal interactions between enterprises can be captured and interactions between production activities within a year can be simultaneously considered in enterprise selection. The most well known example of this type is the MIDAS model, which has been used extensively in the analysis of mixed crop-livestock farms in Australia to inform research priorities and farm management to some extent. Models are commonly based on representative farms within a defined region and in some contexts the spatial heterogeneity is important because of differential performance of activities on the various land units found on the farm.

Household models in developing world agriculture
Notable models include IMPACT (Herrero et al. 2007), NUANCES, and IAT (Lisson et al. 2010). Spatial heterogeneity is often accounted for e.g. soil fertility gradients and variable land types. As economic performance of smallholder households is highly dependent upon resource constraints, accounting for resource endowments of farmers is an important feature of these models, and is usually informed by farmer surveys. Both optimisation and non-optimisation approaches have been used over short and long time frames. Some household models used process-based simulation models to generate appropriate input–output coefficients that are then fed to the farm model, while others used summary functions derived from more detailed models.

Biophysical simulation
This approach emphasises detailed specification of biophysical processes, using process-based simulation (e.g. Guimarães et al. 2006). Farm inputs are supplied exogenously, often informed by farm surveys. The advantage of this approach is greater specification of management options, particularly accounting for seasonal variability. Such approaches do not seem to have been applied to spatially heterogeneous situations, perhaps due to the increased complexity of the computational task, nor developing country situations due to data demands. The drawback of such approaches is that resource constraints on production activities (e.g. labour, machinery) are not imposed even though they may be accounted for in the costs of production in the farm financial model.

Conclusions

The 52 studies demonstrate the diversity of approaches being used to address whole-farm production, environmental and economic issues and the emergence of a focus on smallholder households in the developing world. Models with a more economic emphasis accounted for constrained resources, while those with a biophysical orientation focussed on dynamics of processes. A notable deficiency in many studies was sensitivity analysis around prices, seasonal conditions and farm configuration. The focus on most studies is still policy guidance and research prioritisation, with few studies attempting to engage with farm managers.

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Nitrogen is essential to capture the benefit of summer rainfall for wheat in Mediterranean environments of South Australia

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Keywords: terminal drought, critical period, grain number, nitrogen, rainfall, co-limitation

Introduction

In a worldwide context of agricultural intensification, cropping systems in Mediterranean-type environments have been reducing the frequency of long-fallow in a shift to continuous cropping (Rischkowsky et al. 2004; Ryan et al. 2009; Sadras and Roget 2004). The focus of this paper is the short summer fallow between successive winter grain crops in environments of South Australia with winter-dominant rainfall. Our aims were to (i) estimate wheat yield response to summer rainfall, (ii) explain yield responses in terms of capture and efficiency in the use of radiation and water, (iii) explore the incidence of the amount and disposition of stubble on storage of summer rainfall, and (iv) assess the interaction between summer rainfall and nitrogen supply.

Materials and Methods

We used trickle irrigation to manipulate summer water supply in two factorial experiments combining water and stubble treatments, and three factorial experiments combining water and nitrogen supply (Table 1).

Results and Discussion

Addition of 50 to 100 mm of water increased soil water content at sowing between 8 and 46 mm in relation to controls that only received the background summer rainfall (10-74 mm). Yield gain from additional water input in summer declined from 1.1 t ha^{-1} to zero when the yield of non-watered controls increased from 2.0 to 7.8 t ha^{-1}. Where yield response was related to a single resource, water or nitrogen, capture of radiation and water were major drivers of growth and yield response. Where yield response was related to the interaction between water and nitrogen, both capture and efficiency in the use of resources were important.

Improvement in the capture and storage of water derived from tillage and stubble management depends on topography, soil type, rainfall pattern and evaporative demand (Gregory et al. 2000; Kirkegaard and Hunt 2011). Under our environmental and management conditions, amount (0 to 5 t ha^{-1}) and disposition (standing or flat) of stubble did not affect the amount or distribution of water in soils and had no detectable effect on grain yield.

High nitrogen rate was critical to capture the benefits of additional summer water and reciprocally high water supply was required to capture the benefits of nitrogen fertilisation; this highlights the resource co-limitation for wheat production in these environments. In a water x nitrogen factorial, crops with either low nitrogen or no additional summer water supply had radiation use efficiency ~ 1.6 g MJ^{-1}, biomass per unit evapotranspiration ~ 33 kg ha^{-1} mm^{-1} and yield per unit evapotranspiration ~ 15 kg ha^{-1} which increased to 1.9 g MJ^{-1}, 40 kg ha^{-1} mm^{-1} and 18 kg ha^{-1} mm^{-1} in crops with both additional water and high nitrogen.

Across experiments and treatments, grain number accounted for 88% of the variation in yield (Figure 1a). Grain number was proportional to crop growth rate between stem elongation and anthesis; crops with high nitrogen produced 116 ± 5.0 grains per unit crop growth rate and their low nitrogen counterparts 99 ± 4.6 (Figure 1bc).

The label "terminal drought" to characterise Mediterranean environments has lead to an undue emphasis on water conditions after anthesis. Building evidence from Mediterranean environments worldwide highlights the importance of grain number as the main source of variation in yield and therefore the critical period between stem elongation and anthesis where both water and nitrogen supply are critical.
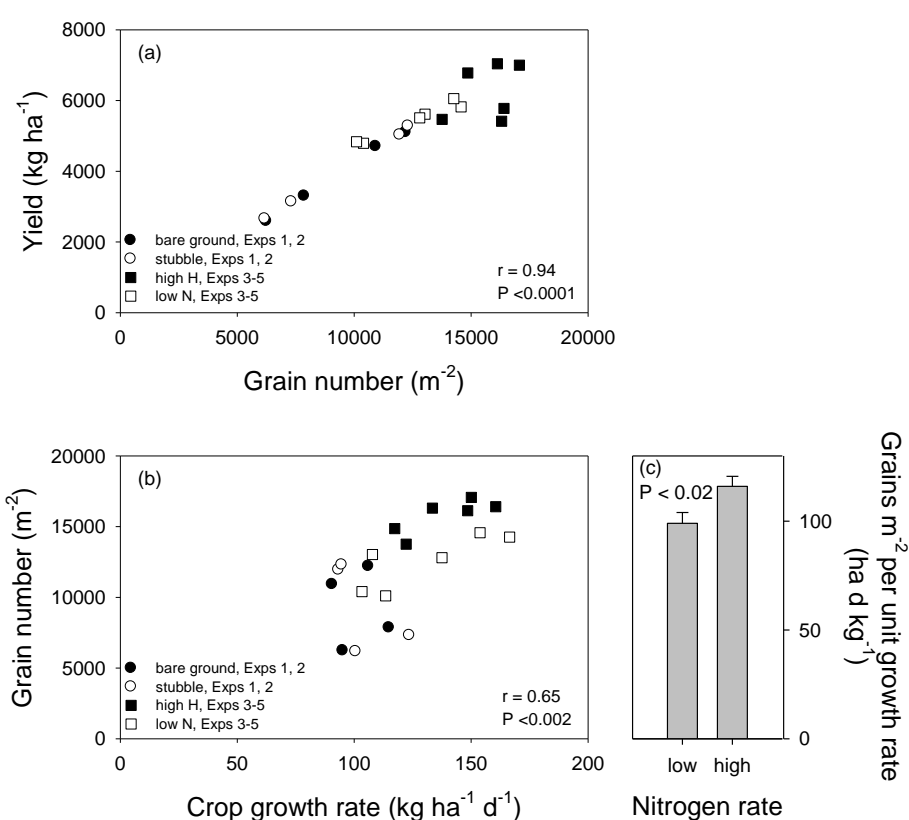
Figure 5. Relationship between (a) yield and grain number and (b) grain number and crop growth rate between stem elongation and anthesis for data pooled across five experiments. (c) Grain number per unit growth rate as affected by nitrogen supply; data pooled across Experiments 3-5, which included the factorial combination of water and nitrogen supply. Error bars are one standard error of the mean

Table 1. Summary of experiments. Experiment 1 was conducted in 2009, and Experiments 2-5 in 2010. All experiments included the factorial combination of water treatments and either wheat stubble (Exp. 1-2) or nitrogen treatments (Exp. 3-5). Experiments 1-3 were located at Hart (33° 45' S, 138° 26' E), experiment 4 at Roseworthy (34° 31'S, 138° 41'E) and experiment 5 at Spalding (33° 30' S, 138° 36' E).

Exp.	Water treatments	Stubble[A] or N treatments[B]	Sowing date	Rain[C] (mm)
1	**Control:** background rain (10 mm) **+50mm:** background rain + 50 mm in 1 event at 11/2 **+100mm:** background rain + 100 mm in 1 event at 11/2	**Control:** bare ground **Stubble 1:** 2 t ha^{-1} standing **Stubble 2:** 2 t ha^{-1} flat **Stubble 3:** 5 t ha^{-1} flat	8/5	a.129 b.26 c.111 d.266
2	**Control:** background rain (74 mm) **100mm/1:** background rain + 100 mm in 1 event at 1/2 **100mm/2:** background rain + 100 mm in 2 events at 1/2 and 1/3 **100mm/3:** background rain + 100 mm in 3 events at 1/2, 1/3, 22/3	**Control:** bare ground **Stubble:** 2.4 t ha^{-1} standing	3/6	a. 132 b. 88 c. 90 d. 310
3	**Control:** background rain (74 mm) **+100mm:** background rain + 100 mm at 12/2	**Low N:** 20 kg N ha^{-1}* **High N:** 70 kg N ha^{-1}	3/6	a. 132 b. 88 c. 90 d. 310
4	**Control:** background rain (34 mm) **+100mm:** background rain + 100 mm at 23/2	**Low N:** 0 kg N ha^{-1} **High N:** 160 kg N ha^{-1}	3/6	a. 85 b. 149 c. 37 d. 271
5	**Control:** background rain (41 mm) **+100mm:** background rain + 100 mm at 24/3	**Low N:** 0 kg N ha^{-1} **High N:** 100 kg N ha^{-1}	6/5	a.112 b.167 c.163 d.442

[A] Experiment 3 was established on 2.4 t ha^{-1} standing wheat stubble, Experiment 4 on 2 t ha^{-1} canola stubble and Experiment 5 on 8.6 t ha^{-1} wheat stubble burnt before sowing.

[B] Differential nitrogen treatments were established at late tillering in experiments 3-5. There were two sources of nitrogen common to all treatments soil inorganic nitrogen at the beginning of the experiments (range 93 to 140 kg N ha^{-1}) and 11-18 kg N ha^{-1} applied as DAP at sowing.

[C] Rain between a. sowing and stem elongation, b. stem elongation and anthesis, c. anthesis and maturity, d. sowing and maturity.

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Does landscape heterogeneity modulate the trade-off between production and biodiversity?

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Introduction

There is empirical evidence that the proportion of land uses and their spatial arrangement can affect the long-term dynamics of bird species in agro-landscapes (Benton et al. 2003). Modifying the proportion of land uses, through the conversion of some intensive land uses into extensive ones often involves a trade-off for production (Sabatier et al. 2010). Acting on the spatial arrangement of land uses to increase the heterogeneity of landscapes without altering the proportion of land uses, could help to reconcile production and biodiversity in agro-landscapes. Theoretical and empirical studies propose various hypotheses linking landscape characteristics to biodiversity (Brotons et al. 2005). They distinguish between compensatory and complementary land uses, depending on the nature of the various habitats generated by each land use. The mechanism of compensation occurs when one land use only provides a part of the resources to the species considered, e.g.. The mechanism of complementation occurs when each of the two land uses is partially favourable to a species, i.e. each of them favours a single stage in the life cycle. Several land uses are then necessary in the landscape to provide all the resources to a species. In such a context, it is likely that along with the proportion of land uses, their spatial arrangement, and thus the landscape structure, strongly affects the mechanisms of complementation. The objective of this study was to assess to what extent biodiversity can be enhanced by altering landscape structure, without reducing agricultural production.

Materials and Methods

We developed a spatially explicit model that represents a grassland landscape made of different types of fields exploited for beef cattle farming. This agro-ecosystem is both a feeding resource for cattle and the habitat of a grassland bird species the lapwing (*Vanellus vanellus*). The landscape is composed of 64 fields, represented in a lattice grid of 64 square pixels of 4 ha. The model includes discrete time dynamics on a monthly time step with a two-year timeline. It links the grassland dynamics of a set of fields to the dynamics of a population of lapwings. Both dynamics are adapted from Sabatier et al. (2010). The grassland dynamics sub-model simulates grass growth, controlled by grazing or mowing in each field. The bird sub-model simulates the dynamics of a lapwing population in response to the direct and indirect effects of grazing and mowing on bird demographic parameters. It includes the juveniles' movements between the various fields in the month following hatching. In grazed fields, grazing has a direct negative effect on the lapwing's average brood size through the destruction of nests by cattle trampling. It also has an indirect positive effect on the juvenile's survival which depends on short grass heights. In mowed fields, only grass height impacts the juveniles' survival. We simulated landscapes composed of pairs of complementary land uses and more complex landscapes consisting of three land uses (Table 1). These three land uses corresponded to "productive grazing", "ecological grazing" and "spring mowing". This functional classification of land uses was derived from Sabatier et al. (2010), where land uses were identified based on differences in impacts on the key stages of bird life cycle (Table 1). For each pair (or threesome) of land uses, we used Neyman-Scott processes to simulate a set of landscapes with different proportions of land uses and different levels of clustering. Each simulated landscape was characterized by the proportion of land uses, by an index of landscape structures and by its ecological and productive performance. The ecological performance was the total lapwing population. The productive performance was given by a grazed grassland production index that corresponds to the number of days for which cattle feeding was provided by grasslands. The higher this index, the greater the forage production of the landscape will be. It was expressed in livestock unit days per ha of grazed pastures (LU days/ha). This index is a linear function of the proportion of grazed grasslands.

Table 1 Different land uses taken into account in the model and their qualitative effects on the demographic parameters of lapwings

Landscapes	Land uses	Impact of land uses	
		Fecundity	Survival
Two complementary land uses	Mowing	+	-
	Productive grazing	-	+
Three land uses	Mowing	+	-
	Productive grazing	-	+
	Ecological grazing	+	+

Results and Discussion

In landscapes with two complementary land uses, simulations showed a non-monotonous effect of the proportion of mowing on bird population sizes (Figure 1). The best population sizes were obtained for intermediate mowing proportions. For a given mowing proportion, variance in the range of population sizes was wide. The residual variance of population sizes was then explained by the landscape structure (Figure 1). High levels of structure indices, and thus high complexity of spatial arrangement of land uses, favoured the bird populations. This result illustrated the importance of interfaces between different land uses when they generated complementary habitats for birds. In landscapes made of three land uses, a strong trade-off existed between productive performance and ecological performance (Figure 2). The fact that, for a constant mowing proportion, the relationship between the grazed land uses proportion and the productive performance was linear, means that there was a strong relationship between ecological performance and the proportion of the two types of grassland. There was nevertheless a large part of variance that was not explained by the proportion of land use. For a constant proportion of ecological pastures (e.g. 10%; +/- 1% in the example in Figure 2), this residual variance was strongly explained by the landscape structure. For a constant proportion of land uses, an increase in the complexity of spatial arrangement of land uses was therefore a way to improve the ecological performance of landscapes without losing on the productive dimension (Figure 2). Our results showed that an increase in the complexity of landscape structure could favour mechanisms of complementation between habitats. Due to limited data availability, the model was partially validated. Therefore, outputs should not be considered as quantitatively exact predictions but rather as criteria for the comparison of simulated landscapes, aimed at testing the complementary hypothesis. Modulating the spatial arrangement of land uses therefore seems to be a promising way to improve trade-offs between production and conservation. Such

approach is now being taken into account in European conservation policies. However, working on larger spatial scales means bringing together several actors to implement wildlife friendly management. The "mosaic management" scheme introduced for wader conservation is a good example of such territorial management. Today, coordination tools are developed under this scheme in order to facilitate synergies among farms (Melman 2010). However, it is still unclear which spatial arrangement can be attained when all farm constraints are taken into account. We conjecture that all levels of landscape structure cannot be envisaged from an agricultural viewpoint. As many obstacles still hinder the efficiency of schemes targeting optimal levels of heterogeneity for biodiversity, considerable efforts are still needed to develop tools for coordinating different actors' efforts.
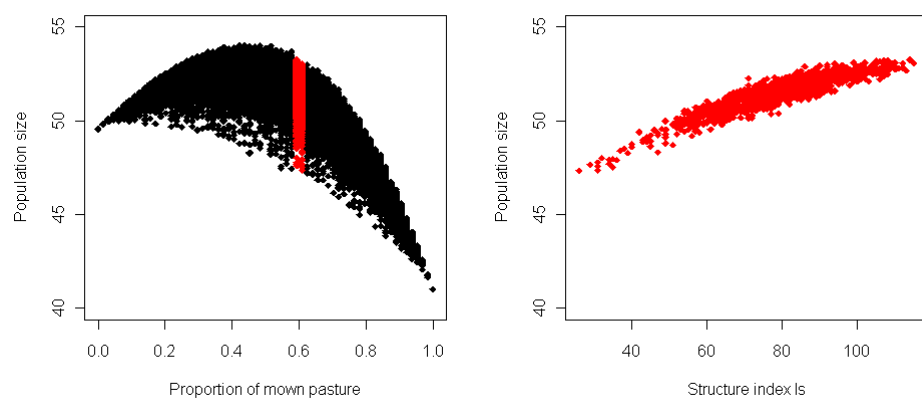
Figure 1 Effect of the proportion of land uses (left) and structure on the ecological performances of 38,100 grassland landscapes made of two complementary land uses. Landscapes in red were composed of 60% (+/- 1%) of mowing.
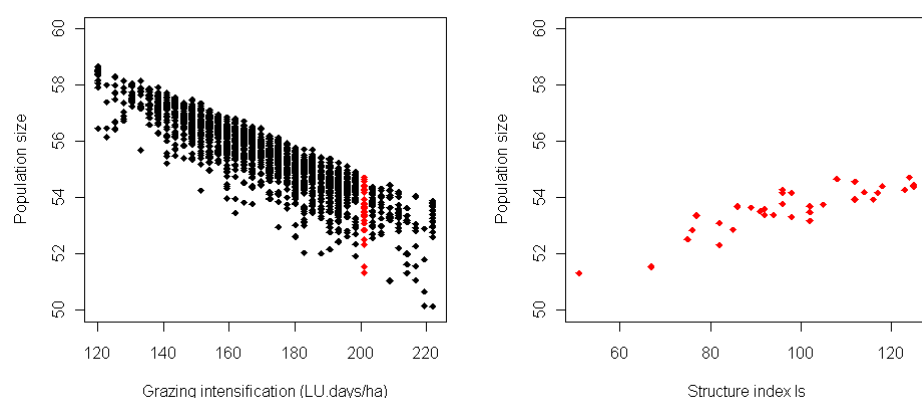
Figure 2 Trade-off between ecological and productive performance of 22,356 grassland landscapes with three land uses (left) and effect of the landscape structures on the ecological performance (right). Mowing proportion is set to 39% (+/- 1%). The landscapes in red correspond to landscapes composed of 10% (+/- 1%) of ecological pasture. The grazed grassland production index has the property of being a linear function of the productive grazing/ecological grazing ratio.

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Farm typologies and resilience: The diversity of livelihood strategies seen as alternative system states

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Keywords: sub-Saharan Africa; household diversity; transformability; socio-ecological systems

Introduction

In complex, dynamic and spatially heterogeneous systems interactions take place across spatio-temporal scales that lead to emergent properties and self-regulatory mechanisms (Holling, 1973). African smallholder agroecosystems are a good example of such complex socio-ecological systems. In spite of the multiple threats they face– whether endogenous or exogenous – several regulatory feedbacks prevent these systems from collapsing. Often different buffering mechanisms operate at community level that emerge from collective action, local rules or traditions, regulating the utilisation and conservation of common natural resources (e.g., Meinzen-Dick et al., 2004). Alternative livelihood strategies built on strong rural-urban connectivity play also a major role in the resilience of these systems (e.g., Andresson, 2002). The impact of human agency through management of natural resources often overrides the net effect of major biophysical processes. Seen under the light of the alternative-states theory, human impacts on natural resources and community strategies to sustain their livelihoods exhibit dynamics in time that are frequently non-linear and irreversible. Measures to prevent further degradation of natural capital and human well-being in African human ecosystems, or to restore these through development interventions, need to embrace non-linearity and irreversibility as inherent properties of these systems. In other words, to recognise the thresholds in relevant system attributes beyond which systems may switch between alternative – desirable and undesirable – regimes.

Resilience and transformability

The address of Walker et al. (2010) to the GCIAR Science Forum of 2009 proposed practical definitions of general and specified resilience, and of transformability for use in the design of new natural resource management in the developing world. These authors define general resilience as the capacity of a social ecological system to deal with shocks, without the need to specify the nature of such shocks or the state variable in the system that is affected, as would be the case for specified resilience (i.e. resilience of what, to what?). Transformability refers to the capacity of systems to change when confined in untenable situations, when alternative re-configurations of the current system are not possible or ineffective. It implies introducing new components and processes, or even changes in the scale at which the system operates. On the basis of these concepts I hypothesise that the diversity of livelihood strategies in rural Africa can be described as alternative system states which dynamics exhibit non-linearity, irreversibility, hysteresis and transformability. The objective is to examine cases of non-linearity, irreversibility and thresholds in African agroecosystems in view of better informing natural resource management strategies and interventions to preserve livelihoods in rural communities.

Household diversity seen as alternate system states

Resource degradation and the concomitant degradation of rural livelihoods in Africa are often assumed to follow a continuous, reversible trajectory in time. This assumption justifies categorising households according to their level of resource endowment (e.g. poor, mid-class and wealthy). This assumption has also led to the idea that a certain threshold of resource endowment should be crossed for households to reach higher welfare equilibriums (i.e. a tipping point in terms of asset holdings) (cf. Tittonell et al., 2010). Households that undergo a contraction of their natural resource, financial and human capitals become increasingly vulnerable and susceptible to poverty traps. Impoverishment often involves liquidation of capital assets, including land or livestock to cover immediate expenses, loss of social credit, and frequently a thorough reconfiguration of livelihood strategies. The labour force of impoverished households is sold cheaply to wealthier ones, thereby reinforcing the gap between both. Children from impoverished households may be removed from school, reducing even further their opportunities to step out of the poverty trap. On the other extreme, well-to-do households exhibit different livelihood strategies that may not necessarily rely on agricultural assets. Their way out of agriculture may be contemporaneous, or through investments in higher education for the next generation.

The diversity of possible livelihood strategies and development pathways in a densely populated region of western Kenya has been categorised through a typology that distinguished five rural household types. This typology, which was later corroborated across a wider range of agroecosystems of East Africa (Tittonell et al., 2010), differentiates households pursuing basically three main livelihood strategies, which may be described as by Dorward (2009) to include, hanging-in, stepping-up or stepping-out. Figure 1 shows the five household types placed in a two-dimensional plane defined by levels of resource endowment and 'performance' in terms of indicators of well-being – i.e. income, food security, investment capacity, etc. Households of type 3, 4 and 5 may be distributed along a curve that represents a low welfare equilibrium (System state I): increasing resource endowment allows increasing performance up to a certain level P' (moving from T5 to T3), and vice versa (from T3 down to T5). The poorly endowed households of type 5 are 'hanging-in' at meagre levels of well being, with several feedback mechanisms confining them to very resilient poverty traps. The point [P'; R'] corresponds to a threshold of accumulated asset holdings that may allow investments to be able, in the short or the long term, to 'step up' to a higher welfare regime (System state II: T2 households) (cf. Figure 1). Resource contraction along the high welfare regime may reduce performance down to a certain level P''. The point [P''; R''] corresponds to a degree of impoverishment that often forces wealthier households to 'step out' of farming through engagement in off-farm activities, totally or partially, in order to preserve their level of well being (T1 households). Resource contraction may take place through liquidation of asset holdings after a drought or to face the costs of funerals, through asset subdivision due to inheritance, or when household members face long lasting health problems that compromise their labour force, or their social and financial capitals, etc. Success in preserving levels of well being when stepping out of agriculture depends on educational levels, financial capital and opportunities (e.g. to find wage jobs in urban areas, to start a business, etc.). Often the step out of agriculture may be temporary, or partial, when part of the incomes obtained off-farm are reinvested in agricultural assets (notably in acquiring livestock). Obviously households of type 3, 4 or 5 may attempt to step out of agriculture from different situations defined by P and R levels, but a distinction is made between families that pursue an off-farm strategy (T1) from those that are 'expelled' from agriculture when unable to sustain a living in rural areas. I circumscribe the concept of stepping out (T1) to cases in which off-farm strategies are a choice, and off-farm activities become the major component of total income.

In search of thresholds and tipping points

One of the challenges here is to identify the measurable variables or indicators that best reflect alternate system states of farming systems, i.e. those that should be plotted on both axes of Figure 1. I examined sets of data corresponding to the case studies from western Kenya

mentioned above and propose, for example, total cropping area as the controlling variable and income as an indicator of performance (Figure 2A). The theoretical, hand-drawn lines in Figure 2 A give an indication of two possible alternate regimes corresponding to low and high welfare equilibriums. Households of type 1 are those that have stepped out of agriculture to engage in off-farm activities to earn >60% of their income. Although they may continue growing small areas of food crops for self-consumption, their main livelihood strategy excludes them from the general trend in the relationship between resources (land) and performance (income). Households of type 2, the wealthiest, grow cash crops and practice a more intensive agriculture that integrates cropping and livestock activities, and that relies on external inputs and additional labour. In Figure 2 B, the ratio of available land to household labour was used as an indicator of resource endowment, and per capita income as an indicator of performance. In spite of the differences discussed, most of the households surveyed lived with less than US$1 per capita a day – a commonly used poverty threshold. However, such functional categorisation of household diversity allows for the identification of the most vulnerable, as well as those that may be most responsive when targeted with agricultural development investments.
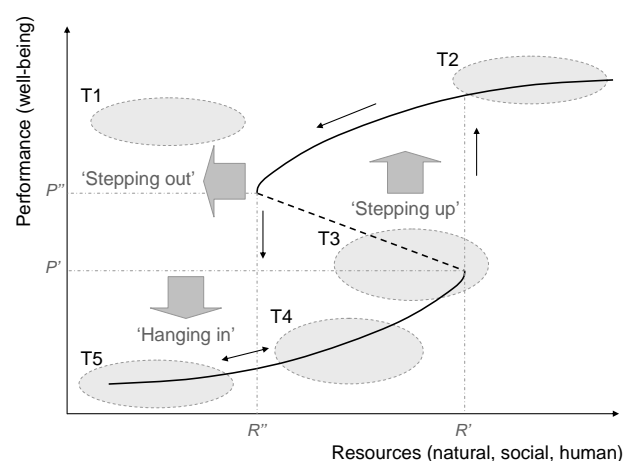
Figure 1: Theoretical representation of the position of five household types (T1-T5) that are common in East Africa in a two-dimensional plain defined by resource endowment and performance (in this case, 'well-being'). Full lines indicate two alternate system regimes.
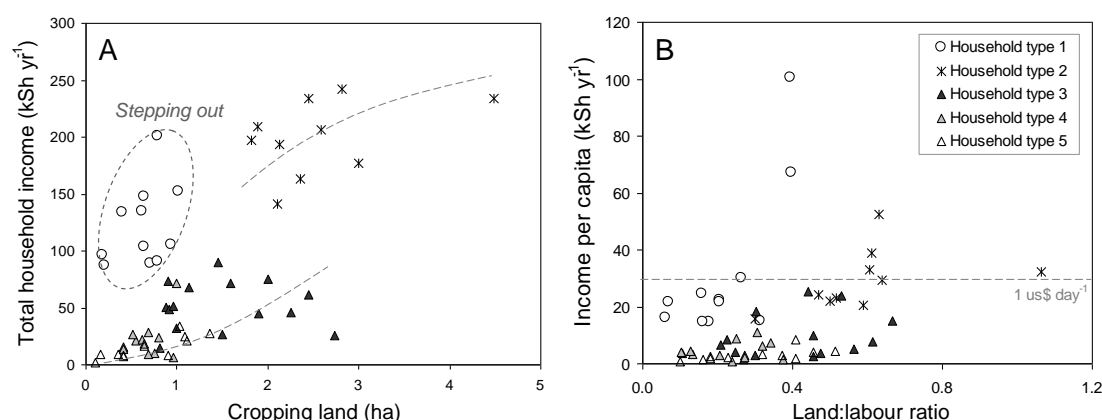
Figure 2: Possible indicators of resource endowment and performance from a survey of households in western Kenya. See text for explanation.

For the concept of alternate system states to become operational in the identification of pathways out of poverty, relevant indicators of regime shifts must be identified. For example, under the agroecological and market conditions of western Kenya, households would need at least 1.8 ha (about 4 acres) of cropping land to step onto a higher welfare regime (cf. T2 households in Figure 2 A). However, households of type 3 may exhibit cropping areas, land:labour ratios and levels of agricultural productivity similar to those in type 2, but yet remain on a lower welfare regime. Significant differences between these two household types can be seen in: (i) the type of livestock activity, (ii) the presence of cash crops (tea, coffee, tobacco), and (iii) access to credit. This is an indication that regime shifts require not just more resources, but also (or rather) qualitative changes in the physical configuration and financial strategies of the farm system. Further examples of this type should be examined in the light of informing natural resource management strategies and interventions to preserve livelihoods in rural Africa.

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Is there an ideal farming system to maximise stored soil water in the Eastern Australian, Vertosol dominated, semi arid sub tropics?

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Introduction

At the height of the millennium drought in Australia, CSIRO as part of the Agricultural Production Systems Research Unit (APSRU) was approached by four commercial agronomist based in the semi-arid subtropical farming region of Walgett, north-western NSW, Australia, to help answer the question: Are the current farming systems used in Walgett suitable to the environmental conditions or are farmers in the area trying to follow a system designed for a much wetter environment?

The dominant cropping soils of the Walgett region are Grey Vertosols (Chan et al., 1988) with plant available water capacities (PAWC) ranging from 150 to 250 mm. Despite having a summer-dominated rainfall the majority of crops produced are winter cereals; however, more recently, increased areas of winter pulse and oilseed have been planted. Summer cropping is used mainly to manage disease and weeds. The annual average rainfall is 478 mm that falls in a 60:40 split between summer and winter cropping period. The region is dominated by high summer temperatures 63 days > 35°C and clear cool winters 22 days with minimum temperatures < 2°C (BOM, 2011).

The key to growing winter crops on Vertosols in summer rainfall dominated regions is the ability for the soil to store water. Rotations and management decisions that improve the soils ability to infiltrate and store water drive the system. Critical questions posed include; How much water needs to be stored? When does waiting for more water negatively affect whole farm profit? What is the chance of achieving a profitable yield given a known soil water content at sowing? This paper outlines how these questions were answered.

Materials and Methods

Simulation modelling using APSIM (Keating et al. 2003), statistical modelling using R (R Development Core Team, 2007) of patch point meteorological data (Jeffery, 2001) and practical local knowledge of farmers and consultants living in the region were used to question and analyse current and alternative cropping practices. Initial work used interrogation of long-term meteorological records to identify how much in-crop rainfall should be expected and the degree of variability of rainfall. Using simulation modelling, the amount of water stored in the soil after the growth of a wheat crop and before planting of the next crop was calculated. Futher simulation studies looked at the probabilites of achieving yields based on varying soil water contents at sowing.

Results and Discussion

The initial rainfall study highlighted how misleading averages could be, the average in-crop winter cropping rainfall was 198 mm, but the coefficient of variation around this mean was 43% this combined with the episodic nature of rainfall in the sub-tropics highlighted the importance of stored soil water, to carry crops between episodic rainfall events and supplement crops in low rainfall years.

A simulation analysis of winter wheat crops was used to identify how much soil water is needed to improve crop yields. The general consensus is the more stored soil water at sowing the better, however, the time taken to accumulate water will effect crop choice and timing. Wheat growth was simulated with different starting water conditions for 100 years to produce an array of yields. These yields were presented as the average percentage yield increase compared to the rain fed yield (Figure 1).
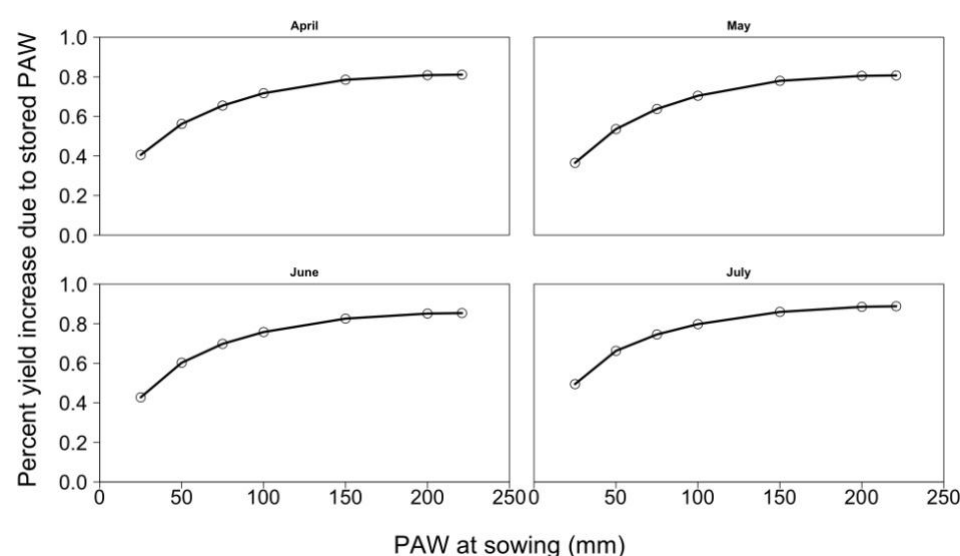
Figure 1 The percent yield increase as a result of increasing stored soil water at sowing. Simulations conducted on a typical Grey Vertosol with 225 mm (PAWC) sowing occurred on the 15th of each month. The starting water contents were 25, 50, 75, 100, 150, 200 and 225 the base rainfed simulation had 10mm of soil water at sowing.

At each of the four wheat sowing dates the point of inflection where the return for more stored sowing water diminished, occurred between 75 and 100 mm. A similar result was also observed for chickpea. This suggests that in this environment accumulating around 100 mm of stored water was the most efficient.

Summer rainfall in Walgett averages 266 mm. With a fallow efficiency of 20 % (Wockner and Freebairn, 1990) an annual winter crop should have 53 mm of stored soil water. However, to account for rain accumulated and unused during the previous crop a simulation

analysis was completed to calculate how much soil water could be accumulated between two winter crops. On average 96 mm of soil water was accumulated after a wheat crop and 82 mm after a chickpea crop. Chickpeas produce less stubble, and evaporative losses are higher. Despite the average accumulation of soil water being close to the desired 100 mm the chances of regularly achieving this target are quite low. The probability of exceedence (Figure 2) shows a ~35% chance of storing 100 mm and a 60% chance of storing more than 75 mm. This result again highlights the variability of rainfall in this environment. Delaying sowing does not improve the probabilities, holding off until spring to sow a summer crop only increases the stored water supply on average to 113 mm and the probability of capturing 100 mm to 50%.

Designing a cropping system for the Walgett region is difficult, because the episodic rainfall patterns, high evaporation and potential for extreme temperatures prevents the adoption of a fixed rotation or base crop that will return reasonable yield in the majority of seasons. Flexibility, knowledge of the environment and a good understanding of the farm business are the only way to manage crops in this environment. The risk of a crop failure or low returning crop, is high, increasing the importance of management to reduce downside risk before chasing potential yields. The use of tools like simulation models that link current quantifiable parameters (current volume of soil water) with historic climate files to predict historic yields are one way to help decide if it is worth planting a crop now or waiting for the next season. However, timely access to these tools is not always available. An alternative is to capture simulation output for a region within a simple figure that can be used as a guide. Rainbow charts (Whish et al. 2010) help consider the risk of a planting decision (figure 3) and when combined with climate forecasting, local knowledge and experience, and the individual farms ability to withstand a loss and ensure the farming system remains flexible.
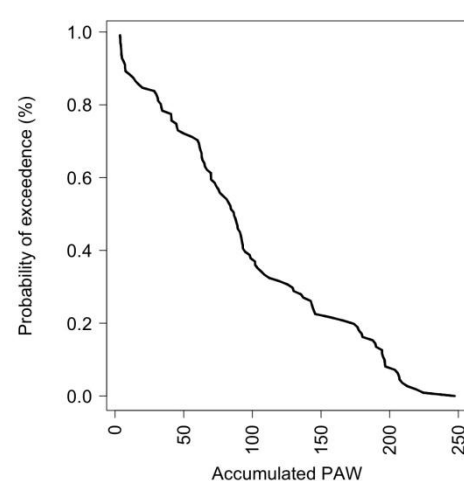
Figure 2 Probability of exceedence for water accumulation within the soil following a may sown wheat crop.
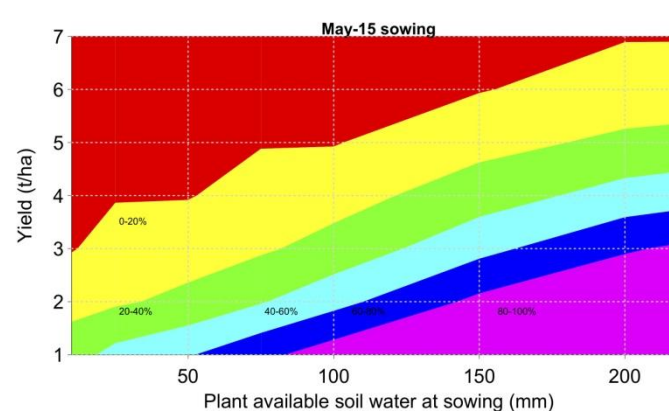
Figure 3 Rainbow chart for a May sown wheat crop in Walgett sowing 150mm of stored soil water at sowing has > 80% chance of achieving a 2tonne yield.

Is there an ideal farming system for the Walgett region? Yes, but it does not revolve around a predefined set of crops selected to maximise the conversion of water into grain, while minimising disease and weed pressures on the system. This region has a highly variable climate and requires flexible management that responds to change in water, weeds, and disease pressures. To effectively manage this system, decisions need to work both at the paddock and whole farm scale. Diversity of crops across the farm help manage both the inter-seasonal and intra-seasonal variability, spreading risk and ensuring cash flow, while accommodating paddocks being fallowed to accumulate water.

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Soil organic carbon accumulation in Conservation Agriculture: a review of evidence

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Keywords: Soil Organic Carbon (SOC) sequestration, Conservation Agriculture, no-till, tillage agriculture, climate change

Introduction

Concerns about rising atmospheric carbon dioxide (CO_2) levels and climate change mitigation efforts have prompted considerable interest in recent years on world's soil carbon content: world's soils are estimated to have a high sink potential for carbon sequestration, not only in terms of their large carbon content, but also because soil organic carbon (SOC) is particularly responsive to modification through agricultural land use. However, the likely negative environmental impacts of the current tillage-based agriculture should not be assumed to be the same as the actual environmental effects that would occur under alternative agricultural systems. Much of the dominant traditional tillage agriculture (TA) in industrialised as well as developing countries is based on mechanical soil tillage with no organic matter mulch cover. This kind of agriculture is considered to decrease soil organic matter, increase soil compaction, flooding and erosion, especially in regions of higher or erratic rainfall, thus depleting soil quality and accentuating the cost of soil restoration. Further, tillage is highly energy-consuming operation that uses large amounts of fossil fuel per hectare (ha) in mechanised systems. In manual small scale systems, tillage requires high amount of human energy input and adds to the drudgery of farming. On the other hand, Conservation Agriculture (CA) is an agro-ecological approach to resource-conserving agricultural production that aims to achieve production intensification and high yields while enhancing the natural resource base. CA comprises the simultaneous application of three principles: i) minimum mechanical soil disturbance (with no-till or strip till and direct seeding); ii) permanent organic matter soil cover (with cover crops and/or crop residues); and iii) species diversification through crop associations and rotations (involving annual and/or perennial crops including trees).

Scope and Approach of the Review

The reported study was conducted using a multi-disciplinary analysis with the aim to developing a clear understanding of the impacts and benefits of the two aforementioned types of agriculture with respect to the CO_2 fluxes and carbon pools, and examining if there are any misleading arguments at present in the scientific literature and highlight the evidence that exposes their flaws. This paper draws primarily on scientific papers published in leading peer-reviewed journals and the work of the Plant Production and Protection Division (AGP) of the Food and Agriculture Organization (FAO) working group on CA. A meta-analysis of the correlated literature has been undertaken and the cropping systems and research protocols followed by the researchers have been examined to explain any discrepancies.

The study shows that when no carbon sequestration or even carbon loss are related to non-traditional agricultural systems, they are most frequently associated with: i) soil disturbance, ii) monocropping, iii) specific crop rotations, iv) poor management of crop residues, v) soil sampling extended deeper than 30 cm. In reality, CA is a broader agro-ecosystem management concept that requires compliance with the three abovementioned interrelated criteria. Most of the world's agricultural soils have been depleted of organic matter and soil health over the years under TA-based systems, compared with their state under natural vegetation. This degradation process has proved to be reversible and the main ways to increase soil organic matter content and improve soil health seem to be: i) keeping the contact and interactions between mechanical implements and soil to an absolute minimum, ii) using effective crop rotations and associations, and iii) returning crop residues as carbon source to the soil. The implementation of these practices can help restore a degraded agro-ecosystem to a sustainable and productive state. However, SOC sequestration is generally non-linear over time (Freibauer et al., 2004) and the effectiveness of conversion of TA to CA depends on many variables: for example, soil carbon sink strength increases most rapidly soon after a carbon-enhancing change in land management has been implemented, and reduces with time as the stable SOC stock approaches a new equilibrium (Smith, 2004). Even though some authors report significant increase in microbial activity soon after transition to CA, fuller advantages of CA can usually be seen only in the medium- to longer-term run, when CA practices become well established within the farming system. To provide an idea of the time scale, Smith reports that the period for European agricultural soils to reach a new steady state level, after a carbon-enhancing land-use change has been introduced, is approximately 100 years.

The study discusses the effectiveness of using average rates for estimating carbon sequestration at the global level. In reality, there are different carbon pools in the soil undergoing transformation from the undecomposed form to decomposed stable form. The carbon sequestration potential of any soil, for the carbon pool considered, depends on the vegetation it supports (chemical composition of organic matter), soil moisture availability, soil mineralogical composition and texture, depth, porosity and temperature. Therefore, when addressing carbon sequestration, rates should always be referred to specific carbon pools, as each carbon category has highly different turnover rates. Further, the study examines the skeptical positions maintained by some researchers on CA's potential to offer productivity and ecosystem service benefits in dryland agricultural environments. Drylands' major limiting factors are i) water deficiency, which is often worsened by unsustainable tillage-based land use practices, and ii) degraded soils, i.e. low fertility, associated with low levels of organic matter and nitrogen and soil life. One of the immediate effects of CA practices on soil moisture in semi-arid and arid regions is the improved capture and use of rainfall through increased water infiltration and decreased evaporation from the soil surface, with associated decreases in runoff and soil erosion compared to TA fields.

With regard to the carbon budget, it should be noted that in CA systems in general the use of machinery is characterized by lower farm power requirements and the number of passes across the field is reduced relative to TA systems. This translates into less fuel consumption, lower working time and slower depreciation rates of equipment per unit area per unit of output. Additionally, with reference to residues restitution, when plant residues accumulate *in situ*, as under CA, the carbon fixed in vegetation through photosynthesis is potentially available as a net gain to the soil. In contrast, when the separation of plant residues from the harvestable components and their transport between fields is done by the use of machines, the energy cost and the CO_2 released from fossil fuel combustion would need to be calculated. Also, the need for energy- and carbon-expensive nitrogen fertilizers can be reduced over time by the use of leguminous cover crops. Firstly these crops can directly influence the quantity of the carbon to be sequestered. Further, rotating or intercropping species with a variety of rooting depths and morphology helps to distribute organic matter throughout the soil profile.

Lastly, the study reviews the effect of a shift from TA to CA on the carbon budget of main active green house gases (i.e. CO_2, methane, nitrous oxide). This, along with sensible nitrogen management, reduces emissions and promotes SOC accumulation throughout the whole soil profile (Pisante et al. 2010). The lack of general consensus in the literature in this respect is largely due to two main reasons. First, it takes time to change soil composition at depth, while the superficial layer is more responsive to land management changes. Besides, when the carbon-enriched top layer (through fertilization) is turned upside-down, carbon concentration at the depth affected by ploughing may be higher than under CA. It should however be observed that, when turning the soil over, the recalcitrant carbon from deeper layers becomes exposed to rapid oxidation and mineralization at the soil surface, favouring SOC depletion in the top soil over time.

Results and Discussion

This paper concludes that terrestrial sequestration of carbon can efficiently be achieved by changing the management of agricultural lands from high soil disturbance practices to low disturbance. CA allows agro-ecosystems to store more CO_2, emit less and all in all improve the ecosystem functioning and services, such as avoidance of runoff and soil erosion. These in turn result in: i) more aquifer recharge and regular stream flow from groundwater throughout the year and reliable yields of water from wells; ii) enhanced soil productive capacity and crop productivity; iii) less erosion and chemical loading, hence less sediment deposition and pollution downstream. The combined environmental benefits of CA contribute to global environmental conservation which also provides a low-cost option to help offset green house gases emissions (Lal, 1998).

The main incentives for farmers to shift to CA are related to productivity and economic rather than environmental sustainability, i.e. improving farms' competitiveness and cutting some of the most relevant production costs thereby increasing profit margins. With CA less or smaller tractors can be used and fewer passes over the field done, which also result in lower fuel and repair costs (FAO, 2001). In addition, over time, less N-fertilizer and pesticide are required for the same output.

But then why are there still so many farmers using the plough? This review of the evidence shows that where TA is deeply rooted in the cultural background, and there is a lack of knowledge about CA principles and systems, it is particularly difficult for farmers to switch over to producing crops without ploughing or tilling. The shift to CA has been achieved where: i) pilot farmers have been informed of the system and convinced of its benefits by experience, ii) training on correct land management and implementation, as well as technical support to early adopters have been provided, iii) adequate support policies (e.g. funding through carbon sequestration contracts with farmers) have been implemented. With regard to policy support, according to the European Conservation Agriculture Federation (ECAF), in Europe, where CA does not exceed 1% of the agricultural cropland, things have slowly begun to change because the Common Agricultural Policy (CAP) since 2004 has been promoting sustainable agriculture systems for food safety and environmental sustainability but does not link environmental services to specific production systems. For SOC credits to become a structural part of the solution to mitigate climate change, short-term increases in SOC pool would need to be commodified and traded based on both on-site and off-site societal benefits. An example of a carbon offset scheme for agricultural land use has been in operation in Alberta, Canada. Alberta province, which has a strong agriculture-based economy that also has the highest green house gases emissions in the country, first adopted a climate change action plan in 2002, which since 2007 includes the implementation of a no-till based crop production system protocol on agricultural lands as an opportunity for direct and indirect reductions of green house gases emissions through carbon offset trading with industry.

These important lessons learned from around the world regarding the high potential for carbon sequestration with CA systems and the associated opportunity for carbon trading should be taken into consideration in any climate change mitigation strategy for the future.

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Decision support systems in practice: some observations

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Keywords: decision support, models, risk assessment

Introduction

Observations on the application of a range of learning and decision support tools mainly dealing with soil and water conservation, water quality and climate risk management in Queensland's semiarid tropics grain producing areas are presented. These observations, while clearly subjective, are offered to support discussion toward development of better risk assessment and decision support tools for farmers.

Our experience comes from being part of teams measuring hydrology and water quality, and developing models and decision support tools such as: PERFECT (Littleboy et al. 1992; APSIM (McCown et al. 1996); Howwet? (Freebairn et al. 1994); Howoften? (Glanville et al. 1997); Howleaky? (McClymont et al. 2011) and "action learning tools" such as a rainfall simulator to demonstrate effects of soil cover on runoff and erosion (Cawley et al. 1992). Some personal observations on how a range of decision support systems have been used follows.

Simplicity and transparency

The simplest things generally work best, and the simpler the better. This requires that the essence of an issue needs to be distilled. A good example is the French and Shultz water use efficiency (WUE) model. It was reported as been relevant to southern Australia. However it relevant wherever water is a major limiting factor in most seasons. The concept is useful for estimating crop expectations and as a review or benchmark tool. WUE has been readily accepted and used by farmers across a wide range of geographies yet some scientists regard it as being too simplistic. Another example is the application of a simple rainfall lookup program, *Howoften?,* which requires the user to formulate their issue as a simple probability question - what is the chance of x rain falling in y days between two dates? The program simply makes the exploration of rainfall records efficient. I a short interactive session, many "what if" questions can be asked. The program does not aim to give a definitive answer, but rather provides a means for efficient exploration of historic rainfall data.

The easier a model or decision support tool is to use, the more chance it has of being used. It does not take much complexity to put people off! Our simplest tools are the most used and with minimal on going support.

The more comprehensive a DSS aims to be, the more complex and less transparent it will be, and the greater the support it requires.

Active demonstrations and physical models are generally more effective than computer based models. As a collector of hydrology and erosion data for 20 years, it is hard to admit that an active simulated rainfall demonstration over a morning can have as much impact on farmers as the results from 10 years of field research.

A rapid cycle of question and answer, allowing for iterative convergence on an insight into a systems variability and responsiveness seems to be a common denominator for an effective learning approach. Computer based tools allow for many "what ifs" to be explored without any risks being taken.

Employ Ockham's Razor ruthlessly – the simplest explanation is generally the best. The Pareto principle is Ockham's best friend; look for the 20% effort that gets 80% of the gain. Also see Ward's (2006) "simplicity cycle". This is particularly important in developing new tools where time and resources are limiting.

Who says the world has to be complex?

Increased complexity seems to be a common pathway for scientists. A common criticism from within scientific ranks is that an approach is too simplistic. This should be taken as a compliment as it indicates you are on the right track. It is a natural tendency for scientists to go for the more refined approach. This sounds reasonable as we attempt to push the barriers of ignorance back, but in the end, the addition of complexity (or parameters) does not necessarily result in an improvement in prediction or explanation. This comment is about overparameterising models. Why use a 10-parameter model when 2 parameters will do nearly as good a job? This is not to say there is not a role for detailed models –there clearly is, but model complexity needs to match the question being answered. For example, you cannot expect a simple WUE model to have any useful opinion on row spacing or crop nutrition.

Uncertainty and complexity. It's common to hear scientists say that farming is a very complex business. Our experience suggests that farmers don't find farming complex as they are well skilled in putting information into context for their particular circumstances. What does challenge farm decision making though is uncertainty: in weather; markets; and outcomes of agronomic practices.

Pragmatic water balance can provide a lot of information on the gross elements of an agricultural system. Basically, water balance models are integrators of weather, plant and management interactions.

There is a view that many models should be termed "instructive" rather than objective or mechanistic. There use should be restricted to exploring systems, with less literal or absolute interpretation given to their output. This is a hard pill to swallow for modellers but it may be the true home for most models. If a model is used and the user does not have a feel for what the answer should look like, beware! That means; don't use a modelunless you have a knowledgeable person to support you or you are aware of the inner workings of the model. This is one of the golden rules for using models. Regardless of model complexity, there is always plenty of scope for misuse. Maybe the developers are not modest enough when indicating limitations?

Acknowledge stakeholders as experts

In farming systems, the farmer is clearly the best expert, and expert farmers generally use a range of other experts to support them. It is worth remembering who has the greatest vested interest in problem solving and acknowledge their expertise Being useful to decision makers requires getting into their shoes. For any decision support tool to be useful it needs to provide information that is relevant to at least

one decision –this means we need to be explicit about which decision, when this decision needs to be made, and presented in a form that is accessible when the decision point arrives. How many decision points are there in agriculture? We suspect not that many. For example, in the northern grain belt, there are three key periods; winter crop, early summer and late summer crops planting periods. While each season is different, after a few years, the number of new situations or key questions arising decreases. The main issues will have been dealt with at least once, with seasonal adjustments needed each year.

When planning a decision support activity, ask the user what they want, and cross-examine until you get what is needed. We are often too quick to pick up on the popular, and easily tractable, rather than put ourselves into a challenging position. For example, what are the chances of a group of scientists "consulting" with farmers likely to find that the farmers needs coincide with their own special discipline? How do we really take ourselves away from our comfort zone? – We don't have an answer to this question!

There is no replacement for the expert. If it's a systems issue, this means several experts and possibly a synthesiser are needed. Without any formal models or decision support tools, experts can always give a well-informed opinion. This opinion is generally based on many experiences, which capture far more elements of an issue than is possible through a formal or coded system. Without the expert, models can be dangerous or at best misleading.

Local ownership –things developed close to home are generally the most focused and used. We have observed that when a group does not develop something, they will not use it. This was the case for some of the very effective nutrition "wheel calculators" and is even more the case for computer based tools.

Scientists are generally slow adopters of new technology that has not been developed by them! The same is also true of extension specialists and consultants.

Modesty and limitations

Risk awareness" has a role where auditable systems are not appropriate or palatable. Simple paper based risk awareness tools can be used as a framework for engaging farmers in a non threatening manner that encourages learning rather than regulation. A one page check list can be as useful as a 50 page Best Management Practice manual or simulation model. Gaming is a very powerful approach to learning. Models have a role to play here, but are not often used, and when used, they are sometimes used with too much emphasis on the model being correct, rather than instructive. A gaming approach becomes powerful when it creates an environment of risk taking, without serious consequence, but with strong feedback and interaction between players.

The enhanced availability of near real-time weather data for many locations opens up the possibility for using a range of analysis tools to explore probabilities. If we believe that the best source of probabilities for future events lies in past records, then things have never been easier. A decline in interest in a DSS tool may be a sign of success rather than failure, indicating that available lessons have been learnt.

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Farmer innovation: seeder fabrication and uptake of zero tillage in Iraq

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Introduction

The viability of dryland cropping in northern Iraq is threatened by drought, reduced yields, increasing costs and environmental degradation. Whilst many countries have developed more productive, profitable and sustainable conservation cropping systems based around zero tillage (ZT), Iraqi systems have changed little, remaining heavily dependent on cultivation. In conventional cultivation (CC), farmers plough 1-2 times with 2-2.5m wide chisel or disc ploughs drawn by 70- 120 hp tractors which can plough 20 ha day$_{-1}$; each cultivation uses about 8 litres of diesel and costs US$12-16 ha$_{-1}$. Crops are commonly planted using modified disc plough seeders with little control over seed placement, or conventional tine seeders including the Australian made John Shearer brand previously commercialised in the region, as well as the locally made RAMA duplicates. Cropping profitability has been reduced, especially since 2004, as diesel, spare parts and labour costs have risen. Soil structure has declined, and soils, if dry, became powder-like after ploughing.

ZT was first introduced into Iraq and evaluated in farmer field demonstrations during the 2006-07 cropping season under an ACIAR-AusAID project, based at ICARDA in Aleppo, Syria to improve crop production in the northern Iraqi province of Ninevah, a large contributor to national wheat and barley production. Rising expenses, less revenue due to drought and soil degradation made ZT appealing to farmers; several had visited ICARDA in 2006/2007 and were impressed with the early ZT trials. In the first season in Iraq, results from demonstrations in farmer fields were encouraging, as crop performance was generally better with ZT than CC. In a replicated trial/demonstration under supplementary irrigation (SI) on Jalili's farm in 2009-10, OmRabi durum wheat yielded 1.74 t ha$_{-1}$ under CC and a significantly (P=0.01) higher 2.29 t ha$_{-1}$ under ZT (LSD = 0.24 t ha-1).

Initial zero-till development and use of local seeders

The main constraint to zero-till adoption in Ninevah was the availability of effective and affordable ZT seeders. Indian made ZT seeders, initially brought into Iraq by the project, were excellent for early evaluations but too small (1.8m wide), light and prone to breakage; with relatively large areas, farmers needed wider and more robust seeders. A leading farmer (Sinan Jalili), took the initiative to convert a 20 tine, 3.6m wide John Shearer seeder (Plate 1), set at 18cm row spacing. This was done by cutting the existing John Shearer tine shanks and adapting Baker boot style openers (Plate 2). The whole conversion cost US$800. In the 2007-08 season, this modified seeder was used to establish ZT demonstration plots (4 ha) for the project on the Jalily farm. In 2008-09, encouraged by good crop performance and an obvious reduction in expenses, the area seeded with the modified ZT seeder was increased to 250 ha of rainfed crops.

In 2009-10, the modification and improvement of tines continued, following farmer participation in a ZT machinery training course held at ICARDA in April 2009 in collaboration with Dr Jack Desbiolles of the University of South Australia. During this training, tine and opener design options and field performance issues were discussed, and examples of zero-till John Shearer tines fitted with narrow point openers were displayed. This approach was appealing to farmers because it did not require alteration of the valuable John Shearer seeding tines. Two different opener prototypes were designed using an ACAD software and manufactured locally; a knife blade (Plate 3) for harder soils (rake angle 65°, width 14mm), and a spear head blade for lighter soils and more soil throw (rake angle 45°, width 14mm). Maximum tine breakout force was measured using a horizontal hydraulic jack attached to a scale (Plate 4) and set to 750 Newton for single-spring and 950 Newton for double spring tines. Press wheels (25 cm diameter, 3.5 cm width) were manufactured in gangs of four (Plate 5) and attached to the fourth tool bar of the seeder (Plate 6). The tine and opener prototypes were tested in the field by measuring depth and width of furrows, backfill percentage and distance of soil throw. The effectiveness of press wheels in covering and packing seeds and shaping the seed row was also tested. The modification cost for a seeder was US$1250, and the local Rama seeders of two more farmers in the group were modified for ZT. Using the three modified seeders, the area cropped in 2009-10 by the three farmers was 1250 ha. Tine breakout force, with spring adjustment in the "maximum attainable" setting, was effective in the hardest soils encountered. Seeding depth was 3.5-5 cm, furrow tilling depth was 8-10 cm, and seed covering in dry soils was complete. Seeding started in early November and continued through December. There were no problems with handling stubble or sticky soils, due to previous drought in 2008-09 and delayed rains during seeding. Seed germination was uniform (Plate 7) and moisture was visibly harvested and conserved in the furrows. The season was dry and, whilst yields were constrained in rainfed areas, ZT without stubble retention yielded better than CC fields. The group held the first ever field day arranged by farmers in Ninevah on 20 February 2010 to present ZT concepts and ZTCC comparisons to fellow farmers. In the demonstration plots, it was clear ploughing did not add benefits to the crop performance under either supplementary irrigation or rainfed conditions, but most importantly ZT was more economic because of no ploughing costs.

Expanding seeder upgrades and ZT demonstrations

In 2010-11, the project encouraged further development and provided support to the farmer group for extending the conversion of seeders to another 18 farmers in Ninevah. The development of ZT conversion kits was focused on the John Shearer seeder because it is widely used by farmers and has a proven durability, good under-frame clearance, multiple tool bars, good stubble handling capacity, changeable tine-row spacing (18, 27, 36 cm) and adjustable tine breakout force. The conversion kits were simple, affordable and made locally, to facilitate installation and maintenance. The group supervised the whole process, providing guidance in the factory on tine and opener specifications, and instructions to farmers on tine and press wheel setting up process. The area sown with farmer-modified ZT seeders was 5000 ha across three areas in the province. Due to previous dry seasons, stubble was mostly removed from rainfed plots, with some retained under SI systems. Rain came at the beginning of December, and some farmers encountered tine and press wheel problems in wet soils. There was heavy stubble on some SI fields and two farmers experienced stubble flow problems which were solved by redistributing tines on three rather than two tool bars, increasing tine distance along the bar from 36 to 54 cm, and lifting the seed box 30cm to maintain free flow of seed and fertilizer to the furthest tines. Press wheels did not have mud scrapers which caused difficulties in wet soils and also suffered dust problems in bearings before rain. Farmers were pleased with the diesel and time savings and the method of conversion, which did not alter

the original tines but required only replacement of sweeps with points and calibration of tine breakout force and press wheel pressure, and were also impressed with the uniformity of established seed rows (Plate 8).

The group went further by fabricating a 2.3m ZT tine seeder for small farmers, to act as a prototype for further expansion of ZT technology. It has a robust frame of three tool bars (Plate 9), a reclaimed seed box and metering system, and new seed cups, seed hoses, tines, ZT openers and press wheels, all easily pulled by a 70hp tractor (Plate 10). It was used to sow 30 hectares, and achieved uniform germination, good seedling establishment, good tillering and spike production (Plate 11) despite limited rainfall and hot days in March. In on-going development, the group also manufactured a new-style tine to provide more options for ZT seeders (Plate 12).

Plate 1: Local 3.6 m John Shearer seeder

Plate 2: First prototype ZT opener
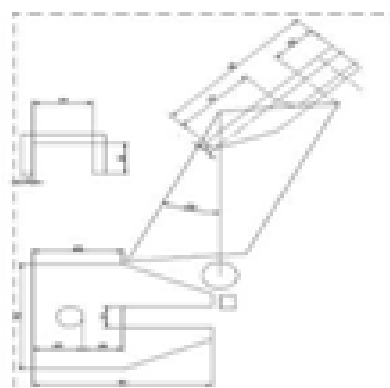
Plate 3: Early design of knife blade opener

Plate 4: Local testing of tine breakout force

Plate 5: Locally made gang of 4 presswheels

Plate 6: Local 3.6 m seeder converted for ZT with press wheels

Plate 7: Good early germination with ZT under SI

Plate 8: Good early establishment under ZT

Plate 9: Fabrication of local 2.3 m ZT seeder

Plate 10: Local 22.3 m ZT seeder operation

Plate 11: Excellent crop sown with local ZT seeder

Plate 12: New generation ZT tine to expand ZT seeder options

Conclusions

Awareness and experience of ZT, and availability of effective and affordable ZT seeders are keys to adoption of ZT. The direct involvement of many Iraqi farmers in ICARDA training and study visits gave them the necessary starting knowledge-base of ZT and local ZT seeder manufacture, which had been pioneered in Syria. Iraqi farmer group efforts and success in converting conventional seeders to ZT increased awareness and provided the opportunity for a large number of Ninevah farmers to try ZT with minimal cost. The area sown with modified seeders in Ninevah has increased from 250 ha by one farmer in 2008-09 to 5000 ha by eighteen farmers in 2010-11, which is a promising initial uptake. The group work to fabricate a small ZT seeder and a more advanced ZT tine enhances the foundation for local manufacture of effective ZT seeders anad w ider applicability to small farmers. The new ZT system, a radical change from heavy cultivation, wl nileed on-going monitoring and adaptation to understand and solve machinery, crop and system problems as they emerge in Iraq, as has been done in countries such as Australia, where ZT has been used for over 30 years and is now adopted in the various statesby up to 90% of cropping farmers. In an important 2011 development, the farmer group established the "Mosul Society of Conservative Agriculture" to further encourage and support conservation cropping development in Ninevah.

Initiating sustainable agricultural systems through Conservation Agriculture in Mozambique: preliminary experiences from SIMLESA

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Introduction

In the last decade, conservation agriculture (CA) has been identified as a key tool to reverse long term soil degradation and low crop yields associated conventional cropping systems (Derpsch and Friedrich, 2009). Mozambique being an agricultural based economy with almost 85% of the rural population practicing low external input subsistence agricultural systems (TIA, 2003, Bias and Donavan, 2003), the use of conservation agriculture and adoption of best practices (Karuppanchetty, 2007) has a strong potential to boost yields and sustain food security. Although CA has been promoted in Mozambique since the late 1990s, through pioneering initiatives funded by Sassakawa Global 2000 and others, there is still a long way to go in order for CA to be internalized and mainstreamed among the country's farmers. To reinforce these early initiatives to improve crop yields among smallholders, CIMMYT in partnership with the Mozambican Institute for Agronomic Research (IIAM) have since August 2010, been implementing SIMLESA1, a research initiative aimed at promoting a sustainable intensification of maize–legume cropping systems for food security in Eastern and Southern Africa. This paper highlights experiences gathered during this first season of implementation focussing on the successes, challenges, lessons learnt and insights on the future.

Materials and Methods

Exploratory CA trials were established through SIMLESA in 6 communities distributed within three provinces (Manica, Tete and Sofala) of Mozambique. The process used to achieve this is described below. Representatives from research and extension departments gathered in a planning meeting in Aug 2010 in Chimoio from which potential participating districts were nominated. To reduce these to six districts, criteria for selection was agreed upon based on attributes such as agroecology, accessibility, potential to boost yields using CA, potential for maize legume systems and availability of secondary data including meteorological data. Proposals for various maize-legume systems and the CA treatments to be tested were developed and later finalized through community awareness meetings held with farmers in the target communities.

Extension and research staff working with farmers in the target areas, were formally trained on CA in a one-week course in which the principles of CA were addressed together with practical step by step procedures for implementing the trials. Community awareness meetings were conducted in each of the six communities (following the CA training course) in which farmers identified their production constraints and proposed solutions to address these. The role of SIMLESA[2] in addressing these issues was highlighted and provided the entry point for CA initiatives. Plans for exploratory trials were elaborated and six host farmers plus a research community of five farmers were elected by other farmers using a secret ballot method. Following these preparatory steps field implementation started. Each community was composed of six trials ideally within 1-2 km of each other and each farmer trial represented a single replicate of six treatments. All implementation activities were supervised and monitored by the local extension staff.

Results and Discussion

Farmer selection

Criteria for selection of host farmers included openness, innovativeness, willingness to host the trials for at least 3 years, acceptance to criticism and being honest. Although highly participatory and based on the secret ballot approach, the selection to host trials differed from site to site and depended very much on cultural habits with some gender biases. For example in Tete and Manica sites, the process seemed to be more supportive of women with one to three women being selected to host trials per site and an average of two women participating in CA committees (Table 1). In contrast, women never featured among the elected farmers in Sofala (Gorongosa) where the gender issue was evident with men clearly overpowering women. Although meant to ensure ownership and identification with the project the approach in some situations eg Gorongosa, led to selection of the same people already hosting trials from other initiatives, a problem only corrected after lengthy discussions. Research committees selected to manage the trials in some communities were also completely dysfunctional in some communities but very instrumental in others.

Table 1: Gender characteristics in CA trial host farmers and research committees by community

Province/district	Farmers selected to host trials by community		Farmers in Local Research Committees		Total
Male	Female	Male	Female		
Sofala: Gorongosa-Canada	6	0	5	0	11
Manica: Chinhadombwe	5	1	3	2	11
Manica: Sussundenga Sede	5	1	3	2	11
Manica: Sussundenga- Rotanda	5	1	2	3	11
T ete: Angonia-Cabango	3	3	3	2	11
T ete:Angonia-Chiphole	5	1	2	3	11

Implementation

The study found that success on implementation starkly depended on the motivation of the local extension worker as well as the interest of the local farmers. It was apparent that the quality of CA implemented, highly depended on the extension workers knowledge, motivation, resources put at their disposal and their workload or commitment to other initiatives. It also became clear that the existence of other projects with different approaches also led to confusion among both the extension staff and farmers. On the other hand farmers were motivated by the resources availed to them through the project such as inputs and equipment (Jab planters, direct seeders) which they considered as very useful tools due to their ability to make the sowing easier and less time consuming. However, complaints over bad

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[2] SIMLESA – is a research initiative funded by the Australian Government through the Australian Center for International Agricultural Research (ACIAR)

functionality, unavailability on the local market and the high cost of the equipment were major constraints to famers interested in adopting the initiatives.

Challenges encountered

The first six months of implementation revealed complex challenges. Amongst others the unavailability of residues to apply in the CA plots was considered labour intensive and impractical by some farmers. Termite infestation was also a deterrent to residue application for example in Manica. Weed management also proved a serious challenge with some farmers calling for the use of pre-emergence herbicides in addition to glyphosate while others avoided hand/hoe weeding on plots treated with herbicides. Jab planters and direct seeders were considered very useful tools provided they were properly manufactured. Training of extension agents was also another challenge with some lacking hands-on practical experience and were poorly motivated. Despite efforts to ensure resources flowed to frontline staff, lack of transport for monitoring trials also affected quality of CA implementation.

Future Outlook

Extension agents should be very well trained to understand the concepts and practices of CA so that they are capable of training farmers. The project should also consider using farmers from previous projects that succeeded in using CA to train other farmers. Exchange visits could thus prove to be an effective tool towards creating farmer awareness and equipping them with practical skills based on 'seeing is believing'. In future efforts will need to be taken to reach more farmers by working with other partner organizations working in the same communities so as to scale out more effectively. Special attention will thus be given to: (1) strengthening extension agents understanding and skills on the design and implementation of CA practices so that they are capable of effectively train and assist local farmers; (2) Improve regular monitoring and assistance to frontline implementation teams (3) There is a need to create more participatory learning platforms by strengthening the establishment and functioning of local CA committees, create the right environments for farmer-to-farmer extension, promote exchange visits (4) Bring in more local service providers who would help not only to cut costs incurred in the process but also facilitate scaling out by improving local farmers access to inputs – seed, pesticides, fertilizer and equipment, and also access to output markets.

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Integrating Conservation Agriculture (CA) into formal education systems

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Keywords: accredited CA qualifications, model curriculum, quality CA, open-source courseware

Introduction

In southern Africa, as in most parts of the world, CA education and training is conducted almost entirely outside the formal frameworks of education management systems that are governed by laws and regulations that determine the nature and scope of National Qualification Frameworks (NQFs) and their associated National Qualification Authorities (NQAs). Typically these formal frameworks require precise definition of job titles and accurate descriptions of the associated professions and occupations. These have to be registered within national standard occupation classification frameworks, which are based on international standards used for labour market analysis in respect of both equity and skills development policy and legislation. Rather logically, a titled occupation is the first step that determines the nature of the learning required to attain competence in the relevant occupation. This determines the curriculum to be followed, which, in turn, specifies the nature of the teaching required to earn NQA-accredited qualifications.

In blissful ignorance of the iceberg of formal education structures, systems, protocols and procedures of which the paragraph above is the merest tip, development agencies and projects have, during approximately the past two decades, pursued strategies to 'mainstream' CA through education and training efforts that:
a. expect graduates to accept 'qualifications' that are meaningless in formal economies that frame their personal career paths; and which,
b. are ever, but forlornly, hopeful of affecting pro-CA policy and institutional changes in spite of hamstringing these intentions and key decision processes by operating in frameworks that are operationally incomprehensible to the policy makers who shape the institutions required to mainstream CA in the formal education systems of national economies.

To reverse the situation outlined above, the option of integrating CA into formal education systems was first mooted in a paper presented at WCCA 4 in New Delhi (Putter et al. 2009). It turned out to be a far more complicated challenge than originally anticipated due to fundamental NQF changes, including a very welcome pedagogical policy shift to constructivist theory. However, the remainder of this paper will first describe the pedagogy of holistic CA education and then report on the current status of the work by the Conservation Agriculture Academy (CAA) on integrating CA in the South African NQF as an essential first step to also integrating CA into the Transnational Qualifications Framework (TQF) for southern Africa under the auspices of SADC—a TQF that became a reality during 2010 within the framework of the Virtual University for Small States of the Commonwealth (VUSSC); see Commonwealth of Learning (2010).

Materials and Methods: Holistic CA Education Philosophy and Pedagogy

The foundation of the CAA's strategy to integrate CA into formal education systems is based on a core idealism—an orthogonal paradigm perspective, that commits the CAA to enabling and empowering personal ecological literacy, i.e. *ecolacy* after Garret Hardin. This ecolacy requires humanity to internalize three key concepts, namely that we must at all times live within the limits of the earth's carrying capacity, e.g. by not liquidating natural capital such as soil organic matter (SOM), and disposing of it as income; that we can never change 'only' one thing; and that we cannot foresee the unintended consequences of our actions.

Consistent with the exhaustive and authoritative review of 'the new culture of agriculture' by Coughenour and Chamla, (2000), the CAA views CA systems as innovative socially constructed learning systems, i.e. '…farmer-managed socio-technical production systems' wherein the primary construction site is an ecotope (*sensu*: Haber 1994), that is, a unique farm, a *'...concrete ecosystem at a given and defined site'*. To the CAA, the central character of the plot and the nexus of the constructivist process is a farmer—an applied ecologist, who is embedded within a local community of practice (CoP), which usually includes one or more local farm advisors. This cluster constitutes the primary, local social network that generates the driving, innovating autopoiesis (*sensu*: Maturana and Varella 1973 and 1992), lived as:
a. *practical innovation*—principally by farmers who, for about 60 years, invented, adapted and validated the three principles of CA in the first place;
b. *communicative action* and '*validity claims' sensu* Habermas (1990 and 1991) and;
c. *social learning* in Communities of Practice, which, according to Wenger (2000)*, are* Social Learning Systems: the crucibles of learning and the theatres where accredited qualifications, namely the CAA's Diploma in CA Systems Management, will be earned.

These key ecological imperatives and the critical definition of CA systems as social constructs, resulted in three predicating lemmas for the design of accredited CA courses and qualifications.

Avoiding systems sub-optimization: the process whereby overall systems performance becomes sub-optimal as soon as any one sub-system is optimized in its own right, has to be avoided. Giller et al. (2009) make this error when they insist that the three principles of CA cannot be applied simultaneously in most African smallholder farming systems. This argument is predicated on the obviously false premise that (A) these farmers cannot in any way whatsoever, (i) reduce the degree of soil disturbance, (ii) improve soil organic matter, nor (iii), increase organic soil cover; and/or (B), that small interactions among these interdependent parameters cannot set a cumulative, spiral of positive synergy in motion that will improve CA systems performance and resilience. This kind of thinking is also inconsistent with the concept of '*quality CA practice'* as emphasised by Ceratti (2003) during WCCA2.

Replacing top-down, linear instructionist thinking and empowering local innovation systems and networks: traditional extension approaches, including the soft-instructionism embedded in 'lead-farmer' tactics and off-farm pilot-plot demonstrations will be replaced by on-farm constructionism at all sub-systems and at all systems levels. Accordingly, the kind of relationship between farmers and facilitating extension agents that is central to the Farmer Field School (FFS) approach and its benefits (Davis et al. 2010), will be adopted as the central, *in situ* interaction critical to outsider efforts to mainstream CA learning, practice and accredited qualification. Thus, the 'new

mainstreaming of CA' process as envisaged by the CAA will engage and empower clusters of innovative farmers in national CA farmers' associations to fulfill their nascent potential to become local innovation networks—CoPs enabled to function as hubs in national networks of adaptive CA innovation.

Functioning as an open-society, open-source wiki: the CAA's intellectual property rights regime is committed to copyleft, global public license principles as the core ethic underpinning development and use of shared information and knowledge assembled as open-source curricula and course materials. It is through this global *wiki* process that the CAA will catalyse, facilitate and enable the emergence of a communal, open-society, protected, global CA knowledge commons—an evolving CA Knowledge Ecosystem (CAKE).

Based on the above, three windows of opportunity for integration CA education and training into the SADC-region's NQFs and TQF education ecosystem, exist, namely:

A. School-level insertion and integration (exit level 4) of CA into School Leavers Certificates would largely focus on existing courses and subjects, i.e. curricula; e.g. by providing CA-expository 'units' that would make it easy and convenient for teachers to change the pedagogical landscape of teaching agriculture.
B. Post-school Diploma and Advanced Certificate education and training (exit level 5), which, critically relevant to CA mainstreaming, includes in-service Vocational Training. *This is the level and 'band' wherein the CAA is developing a dedicated, accredited CA Diploma in CA Systems Management*—a qualification earned through in-service vocational training that implements the NQF/QCTO three-pronged approach wherein theory (T), practice (P) and experience (E) are three equal dimensions. Extension agents working on-farm with farmers in reciprocally constructivist, adaptive CA implementing applied research would earn this Diploma by conducting Farmer Field Schools for two cropping seasons. Participating farmers could earn and accumulate level 2-4 (high school level) credits towards accredited level 2-4 school-leaving certificates.

C. University level (exit levels: 6 [BSc], 7 [MSc] or 8 [PhD]), courses and qualifications are exempt from the 'unit standard' requirements at lower levels in NQFs. This allows more flexibility in course design and accredited qualification development. Accordingly, for exit level (6), either a stand-alone BSc (CA) course and qualification package could be developed or CA could be inserted into existing courses and qualifications in modular or non-modular manner. At exit levels 7, offering an MSc (CA) and exit level 8, i.e. PhD research-based thesis completion, creating opportunities to make CA the 'major' subject and focus, would require little if any adaptation of existing graduate study frameworks at most universities.

Result and Discussion: Accredited Courseware and Qualifications

Working with its key partners, namely DAFF, the ARC, EcoPort and UFH, the CAA's strategy is to insert a fractal wedge—a standard, level 5 CA Diploma into the South African formal education framework. This would, in turn, conveniently facilitate recognition within the SADC TQF and in its 33 adhering States of the Commonwealth. For this purpose, the CAA is a registered Quality Development Partner (QDP) and Assessment Development Partner (ADP) within the national QCTO structure. This CAA x QCTO alliance will frame the establishment during 2011 of a registered and defined CA occupation within the national Organising Framework for Occupations (OFO). This legal definition and specification of an occupation is a compulsory first step to the subsequent design of qualifying courseware and following accredited qualification. Therefore, it is anticipated that the CAA will be in a position to accept enrolments for its first, in-service, season-long, FFS- and CoP-based courses during the 2011/12 cropping season.

The CAA has initiated a CA curriculum design *wiki* through the FAO CoP-L forum to build a virtual global academy of collaborating authors to develop shared learning resources, model courseware and CA qualification templates. Basic, primary information; e.g. technical CA information and course organising structures; e.g. syllabi and curricula, will be accumulated, shared and developed at different levels for use in school-, college- and university-level qualifications. Because no one of us is as smart as all of us, a *wiki*-approach to sharing information would avoid duplication in the resulting warehouse of CA knowledge and CA Knowledge Ecosystem. Thus, curricula and resources developed through global collaborative authoring into a broad, technical consensus, could underpin their promotion and recommendation as baseline standards that could enable independent projects and institutions to adapt these model resources to award accredited CA-specific qualifications branded and underwritten by their own 'centres of excellence'.

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From plough to no-till: the Bernese farmer-to-farmer incentive soil support program

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Introduction

Intensive farming as currently practiced is driven by the need to increase production, which in turn means increasing energy consumption. The result is harmful impacts on natural resources worldwide.

Sealed surfaces and eroded soils, waterlogging, deep wheel ruts in fields and forests, soil settlement resulting from loss of organic matter, and distinct plough pans are unmistakable signs that soil is being compacted by inappropriate ploughing and frequent use of heavy machines, often under unfavourable soil conditions. In order to increase soil carrying capacity, the Canton of Berne has adopted a strategy that calls for ploughless cropping systems to protect the soil: conservation agriculture. Thanks to long-term no-till agriculture, cropland can become as structurally stable, and revitalized with soil fauna, as the soils in pastures. Since 1 August 2009, air and water have also been included in the Canton of Berne's "Soil Support Program" together with measures to restore organic matter and apply liquid manure. Environmental goals established at the federal level are thus being actively and comprehensively addressed. Agriculture in future will need to be based on food and fodder production that maintains resources to the greatest extent possible with minimal use of non-renewable energy sources. This will only be achievable through a reorientation of land management and economical use of the soil resource. The strategy for dealing with soils takes a problem-solving, holistic approach in light of the highly differentiated intensity of soil use in the Canton of Berne. Four conceptual steps are based on this approach: recognizing harmful impacts on the soil, measuring and assessing them, developing strategies for dealing with them, and implementing measures.

Material and Methods

Physical, biological, chemical and agronomic data have been collected in the context of the cantonal soil monitoring (KABO) at 18 sites since 1994. After conclusion of the second sampling round, comparison with the first sampling, and hence with the development of soil fertility, was of particular interest. Moreover, many changes in cropping have been made in the past 15 years, such as increasing use of pastures as ecological compensation areas, conversion to no-tillage, and partial reduction of the livestock population. In addition to consideration of the temporal factor, comparisons were made between pastures and cropland, production according to the proof of ecological performance (ÖLN) and according to guidelines for organic farming (BIO), and cropping systems using no-tillage and ploughing. Soils in pastures are generally more structurally stable than soils on cropland. This is evident in terms of greater total pore volumes, higher saturated water conductivities, and lower bulk densities. In particular, higher organic matter contents have a positive impact on soil parameters and nutrients. Cropland that is regularly ploughed tends to develop greater bulk density, especially in the subsoil, and hence water and air balance are severely limited. Reference values – according to the proposal established by the Swiss Soil Society – were often exceeded for selected physical soil parameters.

In particular, the (rear) tractor wheel – in conjunction with the usual slip – has an especially heavy physical impact on the soil during ploughing. When tillage is abandoned, long-term no-till agriculture can develop stable soil structure on cropland comparable to that on pastures, with high earthworm populations, a large number of macropores, high water conductivity, and air permeability. No-till agriculture makes it possible to achieve the goal of greater carrying capacity on cropland. This is all the more important given that 50% of the field operations take place under soil conditions that are too wet, and that cropland is travelled area-wide by vehicles more than twice as frequently as pastures, i.e. 6.8 times annually.

Results and Discussion

In order to maintain soil fertility, the "no-tillage" and "plough" cropping systems have been compared and developed further, with crop rotation and exclusive use of mineral fertilizers and no fallow periods, on the "Oberacker" long-term field trial at the Inforama Ruetti in Zollikofen near Berne since 1994 (Sturny et al., 2007).

These studies so far have confirmed that a long-term no-till system is an alternative to the conventional plough system, and is ready for application in agricultural practice. No-till agriculture requires an overall strategy, with appropriate crop rotation including crop residues and cover crops, as well as targeted application of chemical inputs. Abandoning the mouldboard plough makes the soil biologically more active and gives it a more stable structure. Water can infiltrate more easily, reducing the risk of erosion and guaranteeing that water and nutrient supplies are more even. Organic matter content in the topsoil increases, leading to continual replenishment of nitrogen, with greater duration during the vegetation period. Phosphorous and potassium exist in a more available form to plants. Six years after switching to this system, yields tended to be larger with identical fertilizer amounts in the no-till system – with 10% less energy input and 20% less ozone formation. Problems such as rising energy costs, cropping practices that harm the soil, loss of nitrogen, and climate warming call for long-term solutions. Despite the requirements of ÖLN, additional measures are necessary to improve and stabilize soil structure, reduce erosion, and maintain soil fertility in the long term. No-till agriculture can make a substantial contribution in this respect. Adaptations in crop rotation, including cover crops, seeding techniques, and nitrogen fertilizers can help to optimize cropping. Farmers have been made aware of cropping systems that conserve the soil since 1996, and have received financial support during the transition phase (Schwarz et al., 2007). Today about 5% of the cropland in the Canton of Berne is under no-till agriculture. Knowledge transfer preferably takes place in successful show-and-tell among those interested in application of these systems.

The farmer-to-farmer approach (Fry, 2009) helps to bridge the gap between agricultural and environmental institutions and measures by:
1. Establishing an accompanying group with all relevant actor groups to induce a learning process.
2. Developing short films in collaboration with these actor groups since film is an ideal means to record farmer know-how which is usually spread verbally. Fundamental elements of nonverbal communication are transported by pictorial language. These allow a high degree of identification.

3. Triggering discussions within farmer networks as well as among policy makers. A consolidated view indicates that farmers can take up arguments much more easily from successful colleagues (same profession, same culture, same language).

The Canton of Berne's "Soil Support Program" launched by farmers and soil experts pursues a comprehensive and sustainable problem-solving approach to soil protection at the interface of water and air. It is based on voluntary participation and allows for financial incentives for implementation of different measures related to cropping systems that protect the soil (mulch-till, strip-till or no-till; offset ploughing in organic farming), soil development and cropping measures (crop rotation, soil cover over winter, undersown crops, abandonment of herbicides, manure composting) and ammonia-reducing techniques for the application of liquid manure (umbilical application system, soil-conserving undercarriages). This catalogue of measures is part of the program concept which, together with educational and extension components, constitutes an overall farmer-to-farmer approach, along with impact monitoring based on KABO that includes plant protection and immission measurements. Following completion of the project in 2015, these measures should be economically feasible without additional incentives and be pursued further.

While experiments demonstrate results in favour of no-till, the overall performance of, and knowledge about, no-till is still inadequate. No-till is therefore actively being promoted in different Swiss cantons. In Berne, Aargau, Fribourg, and Lucerne farmers receive financial assistance to apply no-till over a sustained period of years. To further promote no-till in Switzerland the Swiss Soil Conservation Association named "SWISS NO-TILL" was established (www.no-till.ch). The members are mainly farmers and contractors, but also extension agents, researchers, and teachers. SWISS NO-TILL provides a platform to disseminate knowledge about no-till, and is also actively involved in research projects.

Conclusions

Even though no-till provides many advantages as compared to conventional plough tillage, there are still a few unsolved challenges remaining. These are summarized in Table 1. The incentives for farmers to change to a no-till system are numerous. Tillage costs associated with fuel, machines, and labour can be saved. There are also ecological arguments including reduced soil erosion due to improved soil structure, through encouraging the propagation of earthworms that can play a role in the farmer's decision. Various aspects have lead to a domino effect and increasing adoption of no-till in certain regions of Switzerland. These aspects are: reliable and good quality consulting services, conclusive results, close collaboration with research, word of mouth advertising and publicity. Ultimately: "Change is first denied, then vehemently opposed, finally accepted as being selfevident." (Crabtree, 1997)

Table 1. Challenges of the Swiss no-till system and possible solutions.

Challenges of no-till	Possible solution
☐ Develop risk of mycotoxins	→ Crop rotation
☐ Require substantial amounts of nonselective herbicides	→ Cover crops (that freeze off)
☐ Novel, expensive no-till technology	→ Requires corporate ownership and utilisation
☐ Lack of know-how	→ Learning by doing
	→ Knowledge exchange among experts
	→ Need for research (notably plant nutrition)

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Impact and adoption of conservation agriculture in Africa: a multi-scale and multi-stakeholder analysis

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Introduction

Conservation Agriculture (CA) is increasingly promoted in Africa as an alternative for coping with the need to increase food production on the basis of more sustainable farming practices. CA is specifically seen as a way to address the problems of soil degradation resulting from agricultural practices that deplete the organic matter and nutrient content of the soil. It aims at higher crop yields and lower production costs. Yet, success with adopting CA on farms in Africa has been limited (Kassam et al., 2009).

The European Commission has recently funded a collaborative project, CA2Africa (www.CA2Africa.eu), that seeks to better understand the reasons for the limited adoption of CA in Africa by analysing past and on-going CA experiences, in order to assess under which conditions and to what extent CA can strengthen the socio-economic position of smallholder farmers in Africa. A better comprehension of where, when and for whom CA works best, and how CA should be configured in different settings will enable the identification of knowledge gaps for future research, development and promotion of CA in Africa.

Materials and Methods

The project brings together the major research players involved with CA in Africa to share, assess and learn together with multiple stakeholders from a number of case studies on CA. These experiences will be shared during a series of workshops in the five project regions in West, North, East and Southern Africa and Madagascar. CA is analysed and understood using a conceptual framework that distinguishes three scales of analysis: field, farm and regional scales (Figure 1). Each scale has its own analytical tools and/or models. The performance of CA at field scale may be assessed with conventional experimentation and using crop/soil models such as APSIM or DSSAT. At farm and village scales, trade-offs in the allocation of resources (e.g. cash, labour, land, nutrients) become important in determining how CA may fit into a given farm. Trade-off analysis can be done using bio-economic farm or household models or with biophysical dynamic simulation models coupled with optimisation algorithms and objective functions representing farmers' priorities (Affholder et al., 2010). Land-use problems and competing uses for crop residues among different types of farmers also require analysis at the village scale, at which negotiations for land use and resource allocation take place. At a regional scale, i.e. the context or external environment, factors such as the marketing infrastructure and the institutional dimensions become important (Ehui and Pender 2005). The project examines all three scales and their interactions, with emphasis on the most relevant linkages to explain CA adoption or refusal.
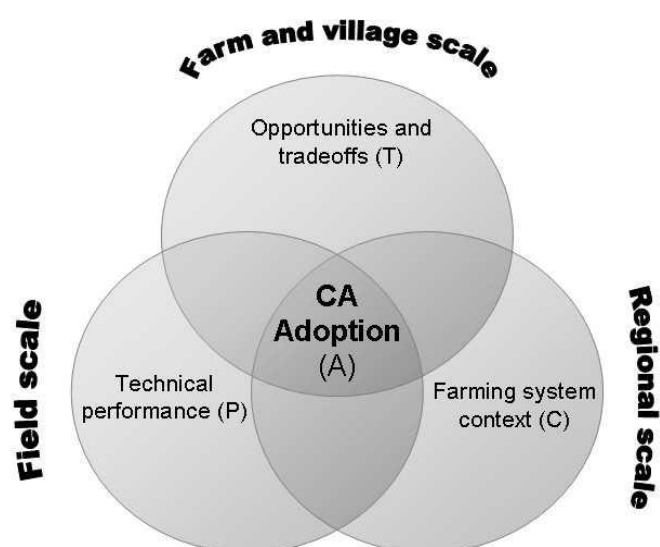
$$\text{Adoption} = \text{Performance} + \text{Tradeoffs} + \text{Context} + (P \times T \times C)_{\text{interactions}}$$

Figure 1. Conceptual representation of the determinants of adoption of conservation agriculture. Adoption (A) is conditioned by its technical performance (P), subject to the opportunities and tradeoffs (T) that operate at farm and village scales and constrained by different aspects of the context (C) in which the farming system operates including market, socio-economic, institutional and policy conditions defining the innovation system and the variability inherent to the physical environment (e.g. climate change).

Major constraints for adoption/challenges for research and development

Some reasons for limited CA adoption that were preliminarily identified from the case studies include: 1) crop yield benefits from CA usually occur in the long term, while associated costs are immediate; 2) there are strong trade-offs with other activities at the farm level and above; 3) the poor functioning and access to (input) markets and credit facilities; 4) the knowledge-intensive nature of implementing CA; and 5) the promotion of CA as a package with little consideration for the diversity of farmers and local practices.

CA is undoubtedly an option that can result in substantial benefits for certain types of farmers in certain locations (Giller et al., 2009). However, benefits from CA at field level do not necessarily overcome the (economic) constraints at farm scale, and many of these benefits are only realized in the longer term (Rusinamhodzi et al., 2010). CA profoundly alters the flow of resources (nutrients, labour and cash) at the scale of the farm and above, and hence strong trade-offs exist when implementing CA. For example, the retention of crop residues on the soil surface as mulch competes with their use as fodder. Indeed, animal feed is often in critically short supply and takes precedence in many farming situations in Africa. The promotion of mulching in CA systems has therefore to be done concurrently to the promotion of fodder production and improved methods of crop residue harvesting, storage and feeding. Protecting the crop residues from free grazing through e.g. fencing of the plots, requires renegotiation of the traditional rules or local by-laws.

The increased amount of labour required for weeding with CA may outweigh the labour-saving gained by not ploughing the soil unless herbicides are used to control weeds. The reallocation of labour, especially to weeding, often is implying more work for women. Weeding is labour intensive and farmers may find the use of herbicides attractive, but often lack the cash to invest in them. In many regions, development of better markets is needed before farmers can invest in herbicides, seeds, fertilizer and no-till equipment. In general, there is in many parts of Africa a need for (market) support for smallholders in order to create economic incentives to invest in agriculture.
Overall, the ex-ante identification of opportune situations for implementing CA is a challenge that demands active research and development from a multi-scale, multi-stakeholder and interdisciplinary perspective. It must consider the multiple scales at stake as represented in Figure 1, in which technical performance (i.e., the field scale) is but one of the determinants of adoption. At each scale, difficulties might emerge that impede, slow down or even reverse the process of CA adoption.

CA-related innovation and adoption processes

Given the complexity and knowledge-intensive nature of CA systems and the need to tailor CA practices to local conditions, a strong capacity in problem-solving around CA among farmers, development agents and researchers is required. Development and adoption of CA is a dynamic iterative innovation process, involving interacting agronomic, socio-economic and cultural factors that are specific for the local conditions and institutions. Production objectives and constraints, and risk attitudes of farmers on the one hand, and the expected benefits and costs of implementing CA on the other hand are two important aspects that influence adoption. Farmers in Africa often attribute a substantially higher value to immediate costs and benefits than those incurred or realised in the future, due to the immediate constraints of production and food security that they face. Yet, many of the benefits of employing CA are only realised in the longer term. Farmers adapt and implement CA technologies with their own understanding of the principles, their aspiration and possibilities to integrate it into their farming systems, and their actual access to knowledge, advice and resources. Most CA projects, however, tend to focus heavily on agronomic, field-scale matters, often to the detriment of dealing properly with issues arising at other scales or being of a different nature. Priority is often given to "demonstrating" CA rather than to reinventing or adapting it in a participatory manner to the local context, even though the use of local group-based learning approaches such as 'farmer field schools' is increasing. Also, interventions tend to place little attention on the need of support system to make the necessary inputs and small equipment available to farmers e.g. in village shops. Overall, the experiences with CA development in Africa teach us that no blueprint or silver bullet exists, and no dogmas or rigid prescriptions will do.

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Mainstreaming Conservation Agriculture: *challenges* to adoption, institutions and policy

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Keywords: Conservation Agriculture, productivity, ecosystem services, adoption, institutions, policy

Sustainable Production Intensification with CA

Conservation Agriculture (CA) is underpinned by a set of core agro-ecological principles that enable producers to intensify production sustainably while minimizing or avoiding negative externalities. CA is able to support and maintain ecosystem functions, and services derived from it, while limiting interventions, required for intensifying the production, to levels which do not disrupt these functions. Thus intensification with CA allows harnessing efficiency (productivity) gains as well as ecosystem benefits. CA offers benefits to all producers, whether they operate on small or large scale of farm size, and to all types of soil-based systems of agricultural production, and to society at large (Pretty, 2008; Friedrich et al., 2009; Kassam et al., 2009; Pretty et al., 2011):
(i) Higher stable production, productivity and profitability with lower input and capital costs; (ii) Capacity for climate change adaptation and reduced vulnerability to extreme weather conditions; (iii) Enhanced production of ecosystem functions and services; (iv) Reduced greenhouse gas emissions.

CA translates into a number of locally-devised and applied practices that are work simultaneously through contextualised crop-soil-water-nutrient-pest-ecosystem management at a variety of scales. According to FAO (2008), the adoption of CA has resulted in savings in machinery, energy use and carbon emissions, a rise in soil organic matter content and biotic activity, less erosion, increased crop-water availability and thus resilience to drought, improved recharge of aquifers and reduced impact of the variability in weather associated with climate change. It can also result in lowered production costs, leading to more reliable harvests and reduced risks.

However, CA represents a fundamental operational change to agricultural production systems and the producers, requiring a wider awareness of ecosystems and the services they offer so that these are least disrupted when altered or used for agricultural production. The benefits of CA provide an indication why many farmers are adopting CA systems and why CA deserves greater attention from the development and research community as well as from government, corporate and civil sectors. However, not all synergistic interactions in the CA system are fully understood. In general, scientific research on CA lags behind farmers' own discoveries. This is partly because CA is a knowledge- and observation-intensive, comprising an interlinked set of practices that does not lend itself to easy scientific scrutiny through short-term research and reductionist approaches. Similarly, knowledge and service institutions in the public and private sectors tend to be aligned to supporting conventional tillage-based production systems. Further, there is limited policy experience and expertise to assist in the transformation of conventional tillage systems to CA systems for small and large farmers in different ecologies and national contexts.

Consequently, more enabling policy and institutional environments are needed to promote and sustain development and adoption of CA. The principles of sustainable production intensification based on an ecosystem approach form the basis for good and (biologically) sustainable agricultural land use which includes the realisation that erosion of soil is a *consequence* and not a prime cause of land degradation. It indicates the need to respect and make best and careful use of agro-ecosystem processes, rather than simply replacing them with synthetic inputs and artificial interventions.

Adoption, Institutional and Policy Challenges

The key limiting factors on CA adoption and up-scaling are lack of knowledge, expertise, inputs (especially equipment and machinery), adequate financial resources and infrastructure, and poor policy support (Friedrich and Kassam, 2009; Friedrich et al., 2009). Where a country or state is not currently generating the knowledge needed for transforming towards CA, it must rely on successful experience outside its borders and support a network of on-farm operational research by pioneer farmers, backed by public advisory services, NGOs and research establishments. The engagement of the agricultural machinery sector is necessary to facilitate the supply of needed equipment.

Social capital is used as a term to describe the importance of social relationships in cultural and economic life. The term includes such concepts as the trust and solidarity that exists between people who work in groups and networks, and the use of reciprocity and exchange to build relationships in order to achieve collective and mutually beneficial outcomes. Social capital is thus seen as an important pre-requisite to the adoption of sustainable behaviours and technologies over large areas. Where social capital is high in formalized groups, people have the confidence to invest in collective activities, knowing that others will do so too. Farmer participation in technology development and participatory extension approaches have emerged as a response to such new thinking.

Policy support and cohesion to meet these aims is critical as most governments have a variety of institutions involved in natural resource management (e.g. Agriculture, Forestry, National Parks, Energy, Water). The fragmented nature of their mandates often inhibits full effectiveness. On the other hand a commonality of underlying concern with the care of land, underpinning policy cohesion, will facilitate the needed interdisciplinary collaborations to be undertaken with farmers and other land-users.

Agricultural development policy should therefore have a clear commitment to sustainable intensification. All agricultural development activities dealing with crop production intensification should be assessed for their compatibility with ecosystem functions and their desired services. Tillage-based production systems do achieve some production objectives, but in many situations will not fulfil the requirement of long term sustainability and enhanced ecosystem services. Any environmental management schemes for agriculture (e.g. certification protocols, payments for environmental services) that do not promote the emulation of CA principles and practices and effects are unlikely to be economically and environmentally sustainable in the long run. This does not mean that non-CA alternatives based on tillage agriculture cannot be considered in new developments but when they are being planned for deployment, the results in terms of output, productivity and ecosystem services may be suboptimal.

Technology and Knowledge Challenges

A major bottleneck for successful adoption and up-scaling of a different production practice such as CA is often the lack of knowledge and experience about the new production system. Site specific research and on-farm testing is needed to assist farmers in responding to system changes such as in nutrient requirements, pest, disease and weed problems as well as for options of green manure cover crops to be incorporated into the crop rotations. The fastest development of suitable technologies is usually achieved through groups of innovative and pioneer farmers who exchange their experiences through specific networks, and thus build social capital.

A particular bottleneck for wide adoption is the unavailability of suitable equipment for CA. While on small scale CA can be undertaken without special tools by just using a narrow hand hoe or planting stick, the full benefits of labour saving and precision work can only be achieved using special equipment or tools. Equipment exists at all mechanization levels and sizes, but local unavailability for the farmers in most parts of the world is a real constraint. Even where this equipment, such as no-till planters, is available, it often requires a considerable initial investment for the farmer. These bottlenecks can be overcome by facilitating input supply chains, working with local manufacturing and contractor services, or sharing equipment among farmers.

What can be done to address the challenges?

Governments should make a firm and sustained commitment to encourage and support CA, expressed in policies which are consistent and mutually reinforcing across the spectrum of government responsibilities, including the mainstreaming of CA in public advisory, research and education services and sufficiently flexible to accommodate variability in local ecological and socioeconomic characteristics. Financial and structural assistance to farmers can be justified by recognition of the public good value of environmental and socioeconomic benefits generated by CA.

CA is knowledge intensive and those who promote it or practice it require training. Learning about the new way of farming will be required not only by farmers, but by all stakeholders in agricultural production, including research and education, extension and training, comprising not only the agronomy but also the nature, existence and handling of the new technologies and equipment options.

National and international knowledge systems must increasingly align their work in research, education and extension to helping to promote CA systems and practices. Research in particular must help to solve farmer and policy constraints to CA adoption and spread and must go beyond academic and reductive comparisons and analyses of different systems. The greater impact that can result from the adoption of CA as a matter of policy and good stewardship is that agriculture development in the future everywhere will become part of the solution of addressing national, regional and global challenges including poverty, hunger, resource degradation, land, water and energy scarcity, and climate change.

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Conservation Agriculture: perspectives from Salamieh District, Syria

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Introduction

This paper broadens the role that conservation agriculture (CA) has, outside the realm of profitable agricultural production practices, sensitive to a range of environmental concerns and sustainability, to one of a catalyst for social development in fragile rural environments. Our focus is upon a rural district in central Syria, where increased frequency of drought and depleting groundwater tables continue to pose hardship for its residents and its economy. We argue that increasing water productivity and efficiency is a necessary, but not sufficient measure, to sustain agricultural livelihoods and rural communities. Instead, a fundamental shift in land use paradigms is required, and when appropriately designed, will implicitly lead to increases in water productivity and efficiency, in addition to other beneficial aspects of enhancing profitability and the productive capacity of the land that can spur agricultural, social and economic development. Our discussion is broadly applicable to those economies where regulatory environments restrict cropping patterns, where the vagaries of weather and poor historical production choices have diminished soil productive capacity, where there are strong crop-livestock interactions, and where civil society has been slow to take root.

Background

Salamieh District is situated in the centre of Syria and covers approximately 5,000 sq km with an estimated population of 244,000. Close to half of its arable land base is barren steppe land (*badia*), but of significant importance for transient Bedouins, who rely on sheep flocks for sources of income and security. The majority of the district's arable land base is rain fed, but a small amount (8%) utilises limited groundwater for its irrigation needs (MARR 2007). Overall, irrigated farm land has decreased from 40,000 hectares in 1960 to approximately 9,000 hectares in 2007 (ibid) and is largely due to a previous legacy of a national cotton policy. In conjunction with increased frequency of drought, one clear impact was depleted groundwater resources, and despite prohibitive legislation, the number of new wells continues to rise.[3]

In addition to a need for securing rural livelihoods, drilling of new wells is attractive given that (i) groundwater is not priced (or taxed) and (ii) that pumping costs are subsidised through a national policy on diesel, which was aimed at assisting citizens in lowering heating costs, but which has had a spill over effect on (sub-optimal) agricultural land use practices. The choice of land use and water use is inextricably linked in this regard, as every land use decision is implicitly a water use decision. The inherent complication in the Syrian context is that agricultural land use is guided by national policy, which stipulates the mix of crops that are permitted for production within pre-defined agro ecological zones.[4] However, given significant shifts in rainfall patterns and increasing frequency of droughts, these zones have, today, largely lost their relevance. Where groundwater is available, opportunities for production of lucrative crops are pursued by farmers who generally turn a blind eye to the ordinances. Where groundwater is scarce or depleted, manual application of irrigation water, delivered via tanker, sustains livelihoods for olive and nut producers, who are unable to produce cereals on marginal land. Some would argue that lessons learned from other countries facing water shortages, particularly in relation to water user groups and farmer associations, would be directly relevant and applicable to Syria. The inherent problem, however, is restrictions on the formation of interest based groups (even non-political) and this stems from a historical security concern within the region. With limited options for cropping, restrictions on social organisation, and continued environmental degradation, the agricultural sector continues to face a downward (environmental, economic and social) spiral.

Options for Development

From a national policy perspective, one important agenda item for much of Syria's agricultural landscape is one of how to secure rural livelihoods in those environments where drought continues to limit agricultural productivity. This challenge is made much trickier when agricultural production is strongly interlinked with livestock production, and where soils have low levels of soil organic matter and lack of any signs of soil biota. Estimates suggest that 26% of rural families in Salamieh district rely upon the livestock sector for their main source of livelihood (AAS, 2009). While livestock may not be the primary source of income for the majority of rural households, they continue to remain important assets and stocks of security, even in small numbers. Barley, therefore, plays an important role in the prevailing crop-livestock system, but incentives for production are dependent upon the agro-ecological zone in which the farm is placed. More specifically, livestock production is stronger in zone 4, relative to zone 3, given stronger edicts on cropping patterns. The natural result is that in the production of barley, straw is the primary product of interest in zone 4, and seed a joint product. The reverse is true in zone 3. Given the importance of barley, there has been much research on new drought tolerant seed varieties, which also have the desired benefit of greater straw yields. This is particularly true in Syria, where ICARDA is actively engaged with regional governments in this area. With the frequency of agricultural droughts and dry spells likely to increase, new drought tolerant seed varieties continue to be in strong demand. While this is a natural response to environmental constraints, the inherent problem is that in Syria, reliance upon the promise of new seed varieties entrenches the mindset, that restrictions on cropping patterns are an effective mitigating response to drought and environmental degradation.

CA has shown, in other contexts, to be a robust practice in mitigating disasters and in reducing the impact of drought and floods (Kassam et al. 2009). Early attempts at introducing CA practices in Syria have shown positive results, irrespective of seed varieties, but have also been challenging in a number of respects (Piggin, 2010). Acceptance of the first principle related to minimum soil disturbance has not represented significant challenges, and this, in large part, can be ascribed to the immediate economic benefits that a no till practice provides. Increasing adoption of the second and third principles relating to a permanent ground cover and crop rotation has, however, been limited. Risk of fire from using straw as a permanent ground cover has often been raised by farmers, and government extension agents, as a reason for non-adoption. We find this argument unconvincing. Field interviews suggest that the lack of willingness to lay

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[3] Well numbers had grown from an estimated 2300 in 1980 to 6100 by 2003. AKF estimates that close to 60% of these wells were dry in 2003.

[4] Salamieh district lies within three zones. Zone 2 is based upon a norm of annual precipitation exceeding 300 mm per year. Zone 3 is based upon a norm of 250mm to 300mm per year. The norm for Zone 4 is between 200-250 mm per year and Zone 5, the badia (steppe lands) is based upon a norm of less than 200 mm annually. Barley, wheat, summer vegetables and tree crops are permissible in zones 2 and 3, while only barley is permitted in zone 4. Any form of cultivation is prohibited in zone 5.

down barley and wheat straw as well as residues from cover crops, as permanent ground cover, is rather based upon a *perceived* economic value of straw and other biomass to be much higher as forage (which increases in a drought year), relative to ground cover.[5] Benchmark CA fields have been initiated by Aga Khan Foundation (AKF) in Salamieh district, but it is too early to report upon economic calculations of relative value for straw and cover crop biomass in competing applications. What is clear, however, is that the applicability of CA in drought prone areas, with strong crop-livestock interactions, will be tested by the economics of relative value of straw and other sources of biomass in competing applications. In general, areas with high livestock to land ratios will likely represent challenges for all three CA principles, whereas no-till farming is likely to be adopted in any environment.

We have raised three important challenges to the adoption of CA in Salamieh district, which we feel are representative for much of Syria: governmental regulations on cropping patterns (regulatory), alternative uses for ground cover (perceived economic), and a demand for new drought tolerant seed varieties (systemic). A fourth, and perhaps more binding constraint on CA adoption, has been an overwhelming drive for adoption of *modernised* irrigation systems (drip and sprinkler as opposed to surface). Existing programmes, such as those initiated by AKF, have documented impressive gains in both water productivity and water use efficiency. Yet, while modernised irrigation systems offer the promise of increased water productivity and water use efficiency they neglect the importance of a farming systems approach. In parallel with these water initiatives, therefore, AKF is also engaged in operational research aimed at identifying 'optimal' crop mixes under (i) the current system of national edicts and (ii) in an environment where farmers are potentially free to choose from an available set of crops that respect environmental constraints.

The two problems at hand, optimality of crop mix, and efficiency of water use, cannot be adequately addressed without first defining an appropriate land use management system. It has been well noted that there are clear social and environmental benefits to be found from the adoption of CA (Kassam et al. 2009) In the case of Salamieh district, and Syria more generally, CA provides a unique and additional opportunity to influence agricultural policy, through greater cooperation and partnerships between government extension services, Ministry of Agriculture (MoA) research stations, and individual farmers. Although this poses a difficulty, in that it almost defies the status quo in Syria, coopting the government into an operational research agenda, while concurrently working with lead farmers on demonstration fields, has the potential for influencing agricultural policy *with* the MoA and from *within* the MoA. In the absence of a transparent system for forming interest groups in Syria, due to national security concerns, this avenue for influencing agricultural policy comes closest in spirit to what a civil society agenda would hope to achieve.[6]

For CA to deliver on its many promises over the long run, its core philosophy and underpinnings must become institutionalised, rather than being touted as an available option. This is particularly true in the face of drought, where reactive policies that appear to be benevolent, are often harmful to long term growth and to the natural environment. In sum, this paper argues that there needs to be a significant rethinking of the role of agricultural innovation, at least in terms of drought mitigation, and that alternative production paradigms, such as CA, can serve as vehicles through which the multi functional role of agriculture in economic and social development, including environmental enhancement and well being, is harnessed to its fullest extent. While this claim is broadly applicable, in the Syrian context, mainstreaming sound environmental practices is going to require a significant rethinking of agricultural education (vocational and higher education), agricultural research, public and private agricultural services and with enabling public policy support.

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[5] In rainfed areas, the relative tradeoff is between straw as ground cover and direct grazing. This is particularly true in a drought year, where the barley stand may not be harvested due to poor yield, and direct grazing is provided to livestock producers through seasonal land rental contracts.

[6] The Aga Khan Development Network defines civil society as the sum of human endeavour, in structured non- governmental organisations, that aim to impact positively, all the key forces which condition people's quality of life.
Oral Presentations

A preliminary evaluation of furrow inflow rate and cut-off time on the performance of smallholder raised bed farming systems

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Keywords: efficiency, uniformity, subbing

Introduction

Irrigated raised bed farming systems in north-west Pakistan are characterised by short furrow lengths (30 to 100 m), narrow bed widths (65 to 75 cm furrow spacing) and blocked ends. Wide beds (typically 130 cm furrow spacing) have recently been introduced and shown (Akbar et al. 2007) to produce agronomic benefits but are not in common usage. In general, 5 to 10 furrows are concurrently irrigated from small head channels with the time to cut-off determined by flow arrival at the end of the furrow and/or furrow filling. Management is often poor with varying furrow inflow rates, frequent overtopping of beds, problems with wetting front penetration (i.e. subbing) into beds and the potential for substantial deep percolation losses (Akbar et al. 2007). The purpose of this study was to evaluate the irrigation performance of narrow and wide raised bed systems under farmer managed conditions and to identify the potential to improve performance using simple irrigation management strategies.

Materials and Methods

Three irrigated raised bed fields (furrows 80 to 90 m in length) located in Mardan, north-west Pakistan were observed during the summer season of 2010. Each site had a similar sandy clay loam alluvial soil classified as a Fine Usteric Camborthid (Hassan et al., 2005) and a slope of 0.002 m m^{-1}. Cotton was grown at one site and maize at the other two sites. The target soil moisture deficit prior to irrigation was 60 mm within the top 60 cm depth at each site. Furrow conditions varied between the sites due to differences in farming practices, crop and growth stage. Hence, there were differences in furrow compaction (due to wheel trafficking), weed infestation and the surface roughness of furrows (due to manual weeding) between the trial sites. Two raised bed sizes (NB = 65cm and WB = 130cm furrow spacing) with four irrigations were observed at each site. The furrow dimensions, furrow inflow rate (Q), distance and time of water advance along the furrow at multiple points and the time to cut-off (T_{co}) were measured in each furrow and event.

The measured field data was used to calculate the infiltration characteristic for each furrow and irrigation event using IPARM (Gillies and Smith, 2005). This data was then used to parameterise the surface irrigation model SIRMODIII (Walker, 2003). Calibration of SIRMODIII was achieved by adjusting the manning's roughness coefficient until the simulated advance time matched the measured advance time. The calibrated model was then used to evaluate the irrigation performance. The performance indicators were application efficiency (E_a) which is the ratio of the water stored in the root zone and the water received at the field inlet; requirement efficiency (E_r) which is the ratio of volume of water stored in the root zone to the pre-irrigation root zone soil moisture deficit; and distribution uniformity (DU) which is the average infiltrated depth of water in the lower one quarter of the field divided by the average infiltrated depth of water over the whole field. The calibrated model was subsequently used to evaluate two irrigation management optimisation strategies: (a) T_{co} optimisation using the measured inflow and (b) optimisation of both T_{co} and Q simultaneously. Optimisation was based on $E_r \geq 85\%$ and water arriving at the tail end. The aim for these criteria was to ensure adequate subbing, to use in season rainfall effectively and to avoid any dry sections of the field. Practically applicable inflow rates up to 5 L s^{-1} per furrow were evaluated.

Results and Discussion

The furrow inflow rate under farmer management was 52% higher (on average) in WB than in NB systems (Table 1). However, the advance time to the end of NB fields was only 16% longer (on average) than WB. All furrows in WB were trafficked where as only every second furrow was trafficked in NB systems. Hence, WB furrows were generally observed to be more highly compacted and smoother than NB furrows. There were also higher weed infestations in NB furrows than in the WB furrows which would increase flow resistance and advance times.

Table 1: Impact of irrigation management optimisation (based on $E_r \geq 85\%$ and flow reaching furrow end) on current irrigation performance of three sites with two bed sizes (values in brackets are standard deviations).

Site	Bed Size	*Strategy	Q (L s^{-1})	T_{co} (min)	E_a (%)	E_r (%)	DU (%)	Inflow (m^3/ha)	Water saving# (%)
1	NB	Current	3.0 (0.2)	39 (2)	50 (6)	100 (0)	90 (6)	1206 (147)	
		1	3.0 (0.2)	32 (4)	59 (12)	99 (0)	80 (3)	1029 (210)	15
		2	5.0 (0.0)	14 (1)	90 (11)	93 (2)	86 (7)	725 (114)	40
	WB	Current	4.9 (0.0)	33 (2)	72 (4)	99 (1)	77 (2)	828 (55)	
		1	4.9 (0.0)	21 (0)	99 (0)	89 (1)	92 (3)	542 (5)	35
		2	5.0 (0.0)	20 (1)	100 (0)	85 (1)	94 (4)	514 (6)	40
2	NB	Current	1.6 (0.1)	34 (3)	92 (8)	83 (7)	66 (7)	556 (85)	
		1	1.6 (0.1)	38 (3)	86 (0)	88 (1)	61 (1)	620 (6)	-11
		2	0.5 (0.0)	115 (7)	89 (8)	87 (2)	69 (21)	590 (36)	-6
	WB	Current	2.7 (0.1)	35 (1)	99 (1)	77 (0)	84 (8)	465 (5)	
		1	2.7 (0.1)	38 (0)	98 (1)	87 (0)	82 (5)	531 (5)	-14
		2	1.5 (0.0)	68 (0)	99 (1)	87 (0)	89 (12)	521 (0)	-12
3	NB	Current	2.4 (0.4)	37 (1)	68 (9)	99 (1)	73 (1)	880 (113)	
		1	2.4 (0.4)	24 (2)	98 (1)	91 (6)	94 (1)	555 (42)	37
		2	2.3 (0.0)	23 (2)	99 (1)	90 (6)	93 (2)	547 (48)	38
	WB	Current	3.0 (0.2)	34 (1)	99 (1)	83 (7)	75 (9)	504 (48)	
		1	3.0 (0.2)	36 (2)	97 (2)	87 (1)	75 (8)	541 (3)	-7
		2	2.5 (0.0)	41 (1)	99 (1)	92 (9)	84 (12)	517 (6)	-3

The E_a of the farmer managed irrigations ranged from 50 to 92% in NB and from 72 to 99% in WB systems (Table 1). However, E_r was generally higher in NB (83 to 100%) than in WB (77 to 99%). Therefore, subbing problems in WB systems may, in part, be attributed to applying insufficient irrigation water. The effect of bed width on uniformity of application varied with DU lower at site 1 in WB compared to NB but higher in WB than in NB at sites 2 and 3.

The relationship between E_a and E_r is site specific and dependent on the soil infiltration, furrow inflow rate and field length. For each site and bed configuration, it is possible to identify a combination of inflow rate and time to cut-off which maximises both E_a and E_r (e.g. Figure 1). For example, using NB at site 3 (Figure 1a), it is possible to achieve an E_a and $E_r > 85\%$ using a Q = 1 L s^{-1} and T_{co} = 80 mins. However, using the WB system at site 1 (Figure 1b), similar performance can be achieved using either Q = 1 L s^{-1} and $T_{co} \sim 140$ mins or Q = 2 L s^{-1} and $T_{co} \sim 80$ mins.   However, the water application strategy required to optimise the irrigation performance appears to be site (ie. soil and infiltration characteristic) specific. Improving performance at site 1 would result in water savings of up to 40% on both NB and WB systems (Table 1). However, optimisation of irrigation performance at site 2 would require the application of up to 14% more water to ensure adequate E_r and DU in both NB and WB systems. At site 3, up to 37% water could be saved in NB systems through improved water management but in the WB system up to 7% more water is needed to be applied to satisfy E_r.
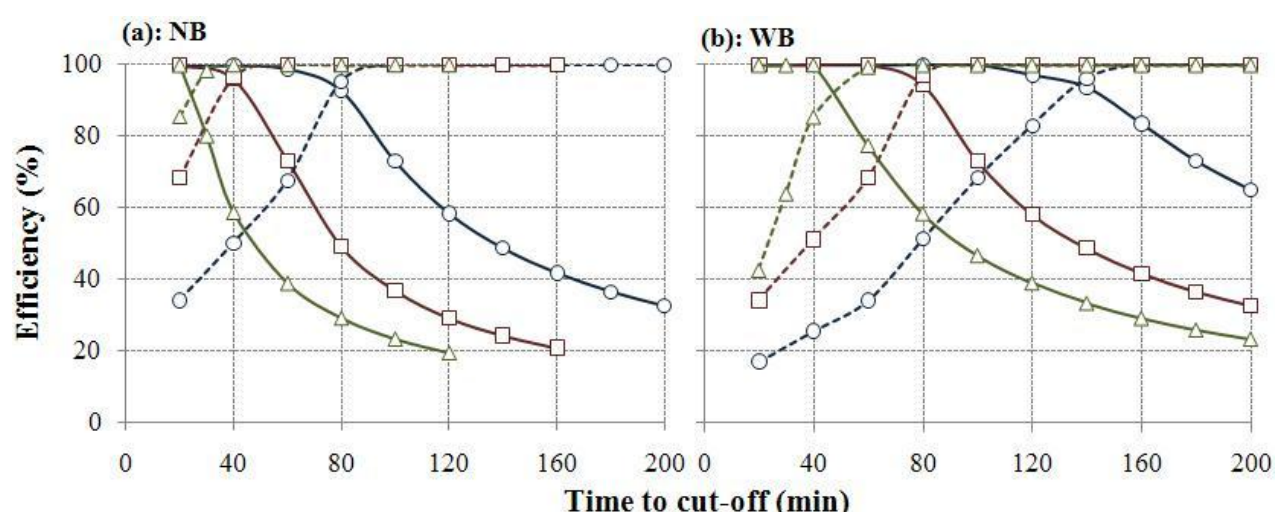
Figure 1: Example for NB and WB (Site 3 = 90 m field length) showing the effect of T_{co} and Q ($\circ$ = 1, $\square$ = 2 and Δ= 2.5 L s^{-1}) on E_a (——) and E_r ($\square$ $\square$ $\square$) during irrigation 1.

This work raises the prospect of significantly enhancing water use productivity of raised bed farming systems in north-west Pakistan through improved irrigation management. Importantly, the management strategies identified in this research may be implemented without incurring substantial changes to infrastructure, machinery or labour. However, further work is required to confirm the benefits across a wider range of soil types and irrigated field layouts.

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Conservation tillage systems for peanut cultivars in rotation with sugarcane and pastures in Brazil: effects on yield pod and root growth

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Keywords: no-tillage, *Arachis hypogea* L., residue, crop rotation.

Introduction

The area of peanuts(*Arachis hypogaea* L.) in Brazil is approximately 120,000 ha, of which 80 % are concentrated in Sao Paulo State. In general, peanut has been grown in rotation with sugarcane or pasture, respectively 60% and 30% of the area and the cropping system is characterized by conventional tillage and adoption of short season cultivars (Bolonhezi et al., 2005). The green harvest sugarcane system, as opposed to pre-harvest burning, is now practiced on almost 50% of the 5,6 million ha cultivated in Sao Paulo State. Due to the large amounts (on average 15 Mg ha^{-1} of dry matter) of residue left on the soil surface after green cane harvest, tillage costs can increase up to 30 % compare to burning. Pastures provide an opportunity to increase the peanut area by using this legume, and integration with livestock, in what are are known as sod-based rotations. No-tillage systems are used for different crops on more than 26 Mha in Brazil, but conservation tillage for peanuts are not widely used because of doubts about soil compaction, efficiency of digging and herbicides. The first question in relation to soil compaction is about peanut root distribution, because the traffic of harvesting machinery on sugarcane, and cattle on pastures certainly increases bulk density of the soil surface. Bolonhezi et al. (2007) reported no statistical difference in peanut pod and kernel yield, and number of pods and pegs, between the conservation and conventional tillage following green harvested sugarcane. But this information is insufficient to develop a package of no-tillage technology for peanut, specially for new cultivars. The aim of this study was to determine the effect of conservation tillage on the yield and root development of Brazilian peanut cultivars grown under sugarcane and pasture residue.

Materials and Methods

Five field experiments were carried out from 2003 to 2005 in two different types of soils, an Oxisol and an Ultisol, situated in Ribeirão Preto and Mirassol cities in Sao Paulo State. A split-plot experiment with four replications was used with main types of conventional tillage (moldboard plowing followed by two applications of disk harrowing), reduced tillage (chisel plowing after spraying with 3.6 kg a.i. ha^{-1} of glyphosate), and no-tillage (crop residues on the soil surface after spraying glyphosate). Sub-plots were the peanut cultivars IAC-Tatu (Valencia market-type, erect growth habit, red seed coat, maturity range around 100 days after planting) and IAC-Caiapó (runner market-type, prostate growth habit, pink testa, maturity range more than 135 days). The sowing dates of the experiment in rotation with sugarcane and pastures were 1st Dec in 2003 and 2004, (Ribeirão Preto) and 14th Jan in 2005 (Mirassol). Prior to the trial, soil chemical characteristics were determined (0-20 cm) according to van Raij et al. (2001, Table 1). Basic fertilization in the sowing furrows consisted of 16, 70, and 40 kg ha^{-1} of N, P, and K, respectively. Treatment assessments included agronomic characteristics (yield pod and grain, plant stand, number of pods), dry root biomass and soil attributes. Conventional soil core-sampling (COR) methods were used and peak flowering (Fujiwara et al. 1994), and samples taken at 0,10 m intervals to a depth of 0,7 m using a metal cylinders with known dimensions. Data were subjected to ANOVA using ESTAT (UNESP, 1992), and means were separated using a Tukey t-test at P<0.05.

Results and Discussion

Four out five experiments showed no statistical difference in pod yield and just one showed significant interaction between cultivars and peanut yield. Considering all the soil profile (from the top to 0,70 m) and both cultivars, the dry biomass of root was higher (P≤0,05) in no-till (0,12 mg cm-3) than in the reduced (0,08 mg cm^{-3}) and conventional tillage (0,04 mg cm^{-3}). Cultivar IAC-Tatu showed significantly higher root dry biomass (0,09 mg cm^{-3}) than IAC-Caiapo (0,068 mg cm^{-3}) at 60 days after planting. The distribution of root system showed that almost 45% of biomass is concentrated from 0,10 to 0,20 cm in conservation tillage, but root was observed below 0,60 m only in no-tillage. Other measurements (not reported here) demonstrated that the no-tillage system reduced the CO_2 flux from the soil and soil increased soil moisture (12% higher) and nodulation.

Table 1. Chemical properties of surface soil (0-20 cm) of three experimental sites used for a sugarcane and pasture experiments in Sao Paulo State, Brazil.

Location	Residue	pH	O.M.	P (resin.)	K	Ca	Mg	H + Al	CTC	V
		CaCl$_2$	%	mg dm^{-3}	--------------mmol$_c$ dm^{-3}-------					%
Ribeirao Preto	Sugarcane	5.0	3.1	36	1.3	27	7.0	48	83.6	42
Ribeirao Preto	Pasture	5.1	3.2	17	1.5	22	12	34	69.8	51
Mirassol	Pasture	5.4	1.0	11	2.4	15	7	13	37.0	65

In conclusion, conservation tillage rotations including sugarcane, peanuts and pasture appear to be the way to reduce costs with acceptable yield and sustainability, independently of peanut cultivars. The next steps will be to study similar rotations in which the peanut is grown each two years.

Table 2. Mean pod yield (kg.ha^{-1}) of peanut cultivars IAC-Tatu ST and IAC-Caiapó, in differents soil managements under sugarcane and pasture at 3 sites, with 12 replications/site.

Soil Management (M)	Ribeirão Preto			Pindorama	Mirassol
	00/01	03/04	04/05	03/04	04/05
Conventional	1783	3249	2256	3167 a	1962 a
Reduced Tillage	1925	3440	2597	3157 a	1436 b
No-Tillage	1756	3450	2054	2812 b	1643 ab
F-probability	2,7 ns	0,48 ns	3,4 ns	9,0 *	11,7 *
L.S.D. (Tukey 5%)	238	744	641	292	346
Cultivars (C)					
IAC-Tatu ST	1647 b	2956 b	1940 b	2924	1643
IAC-Caiapó	1996 a	3797 a	2664 a	3165	1717
F-probability	20,2 **	33,8 **	46,6 **	3,2 ns	0,77 ns
L.S.D. (Tukey 5%)	175	327	240	308	224
Interaction M x C					
F-probability	1,8 ns	1,6 ns	0,7 ns	1,6 ns	4,99 *
C.V. Manegements	8,5	14,4	18,2	6,3	13,5
C.V. Cultivars	10,4	10,5	11,3	10,9	14,5

* e ** significant respectively to 5% and 1% of probability; ns,not significant, letters compare meanswithin each year
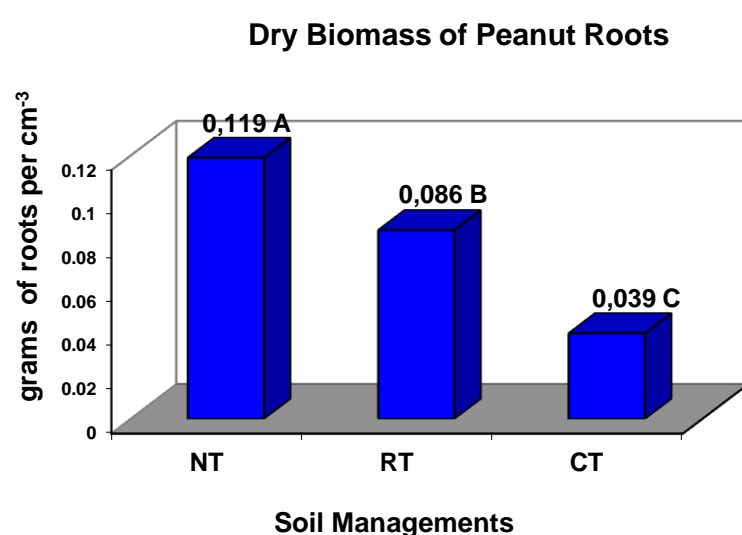
Figure 1. Dry biomass of peanut roots in different genotypes and soil managements under sugarcane residue.

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Sustainable Agriculture under climate change in the Aral Sea Basin: introducing legumes in crop rotations

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Keywords: mungbean (*Vigna radiata* (L.) Wilczek), common bean (*Phaseolus vulgaris* (L.)), regulated deficit irrigation, alternate furrow irrigation

Introduction

Perhaps the most extreme contemporary example of the potential negative impacts of agriculture is the drying of the Aral Sea due to the expansion of irrigation networks in the Soviet era. Climate in the region is hot and dry, and agriculture is highly dependent on irrigation. The predominant system in Uzbekistan consists of rotations of cotton planted in the spring (April –May) with winter wheat planted around the cotton harvest (October – November). In this paper, we build on our experience and research done in the region to suggest changes in the prevalent agricultural system to improve food security, sustainability and resilience. Considerable efforts and resources have been allocated towards new forms of water governance at the inter-state level to water user associations. We believe that in addition to such measures, changes in the cropping system are necessary, specifically to lessen Uzbekistan reliance on cotton. Introducing legumes as double crops following the harvest of winter wheat (from July to October) can provide a first transition step towards greater crop diversification which does not interfere with the State prescribed quotas on cotton and winter wheat. Appropriate investments in the repair of the irrigation and drainage infrastructures are also urgently needed.

Current Challenges

Once the fourth largest inland water body, the Aral Sea level has dropped 17 m and has lost more than 74% of its area and 90% of its volume. It is now divided into three parts, the Small Aral Sea in the North, and two large basins (Eastern and Western) in the South. It has been estimated that the amount of water inflow that would be required to restore the Aral Sea to its original size is 50 km^3 $year^{-1}$, a little less than half of the total annual renewable available water (Bortnik, 1999; Micklin, 2000). At the moment, inflows into the Sea are approximately 4 to 5 km^3 $year^{-1}$ from the Syr Daria river into the Small Aral Sea, and from 0 to 7 km^3 $year^{-1}$ for Amu Darya into the Large Aral Sea (Micklin, 2007). Since such an increase in inflow into the Sea is unattainable considering the importance of agriculture (and therefore of irrigation water) in Central Asian economies, many have accepted the death of the Aral Sea as it once was (Aladin et al., 2005). In the North, the Kazakh authorities with the help of the World Bank have constructed a dam to retain water in the Small Aral Sea. This has allowed a considerable increase in the Small Aral Sea level, a decrease in salinity and the resurrection of the commercial fisheries with the current inflows. In the South, Micklin and Aladin (2008) have suggested to retain the water in the Western Aral Sea, which is deeper and thus has lower evaporation losses. They predict that the maintenance of the western Aral Sea would necessitate slightly more than 8 km^3 $year^{-1}$, a much more attainable goal.

Furthermore, land degradation is now obvious throughout the basin. It is estimated that between 1990 and 2000 the proportion of the irrigated area affected by salinization has increased from 25 to 50% (EC-IFAS, 1999; Savoskul et al., 2004). Water is used to leach the salts out of the soil, but this in turn increases the salinity of the drainage water and its quality decreases for downstream uses. In order to leach salts away successfully drainage systems are necessary. Unfortunately, although 93% of the irrigated area has installed drainage, 32% of the open ditches are out of order, 46% of the subsurface drainage systems are no longer functional and all of the vertical drainage systems are broken (Dukhovny et al., 2007).

At the same time, climate change is introducing a new level of uncertainty. The limited information available points to predicted temperature increases of 1.5 to 2.75°C (Ragab and Prud'homme, 2002). Precipitations are also predicted to increase, but the increase in evaporation due to higher temperatures might more than offset higher rainfall and result in lower soil moisture. In addition, glaciers in the Himalayas are an important source of water for the two main rivers. There is evidence from modelling (Savoskul et al., 2004) and from satellite data (Khan and Holko, 2009) that the inflows have been increasing in recent years, but that the snow depth and snow cover area have decreased. Thus, it becomes urgent that new agricultural systems be adopted to decrease irrigation withdrawals, and ultimately decrease the dependence of agriculture on irrigation water.

Possible Solutions

On-farm water saving technologies will play an important role in improving the sustainability of agricultural systems in the region. Surface irrigation is the most widely used irrigation technique and will likely remain so in the future. Technologies such as regulated deficit irrigation and alternate furrow irrigation are appropriate and do not demand capital investments. Through regulated deficit irrigation, growers allow some degree of water stress to be experienced by the crop in order to allow an increase in the area irrigated (Pereira et al., 2002; Kijne et al., 2003). Alternate furrow irrigation consists in supplying water to every second furrow, possibly alternating furrows between irrigation events to encourage root growth (Kang et al., 2000). Both of these techniques have been shown to increase substantially the water use efficiency in cereal crops. We have also demonstrated that both of these techniques, separately but particularly in combination, can be used to grow legume crops (common bean and mungbean) after the harvest of winter wheat in Uzbekistan (Webber et al., 2006; Bourgault et al., submitted (a)): in 2004, yields of common bean were not significantly decreased from reducing irrigation events from 5 to 3, while yields of mungbean were highest with a single irrigation event at flowering. Water consumption for these two crops were 1500 and 2200 m^3 ha^{-1} for mungbean and common bean respectively including a pre-planting irrigation. In comparison, average water consumption for winter wheat and cotton are 4790 and 7070 m^3 ha^{-1} respectively (EC-IFAS, 1999). In another experiment, we grew a soybean crop (also after the harvest of winter wheat) with approximately 2500 m^3 ha^{-1} (Bourgault et al., submitted (b)).

Horst et al. (2007) have demonstrated water savings of 44% or 3900 m^3 ha^{-1} in cotton by using surge-flow irrigation (where irrigation water is delivered in interrupted high-rate pulses) with alternate furrow irrigation. If such savings were realized over the entire cotton growing area (approximately 1 million ha), and assuming that part of this water would be diverted to another 1 million ha in (for example) mungbean production, this would still leave 2400 m^3 ha^{-1} (or 2.4 km^3 $year^{-1}$) of water saved for ecological purposes. Such calculations are obviously crude and simplistic, but they do point to real opportunities for the improvement of agricultural water use efficiency and crop diversification.

The diversification of agricultural products and a shift from cotton towards less water-intensive and more salt tolerant crop have been suggested before (Kotlyakov et al., 1992; Spoor, 1993). Growing legumes and exporting them could represent a real alternative to cotton for foreign currency for the Uzbek government. Export markets could be developed and boost the agricultural sector, but will require state intervention and political will. The current system for cotton is well organized from the legacy of the communist system and could be modify to include other non-perishable crops such as dry grains. There exists a small but growing international market for mungbean used for sprouting or processing. Australian farmers have started growing mungbean recently but most of this production is only suitable for processing. Mechanized agriculture cannot at this moment compete with the quality obtained by hand harvesting. As such, Uzbek mungbean would have a market advantage. Spoor (1993) suggested the development of fruit and vegetable export markets and we agree (especially with grapes and watermelon). However, this system would likely require considerable investment and infrastructure (for refrigeration, for example), and would be complicated by the large number of individuals growing these on household plots rather than collective farms.

Another solution (a favourite of the lead author) would be to increase substantially the number of mulberry trees growing on edges of agricultural fields to reduce waterlogging and salinity problems. These are also used to grow silk worms. Unfortunately, we have not been able to access enough data to support our claim, but we believe there is an untapped potential in silk production. In 2004, we have been able to buy silk fabric in 'plain' colours from a local factory for about $5 m^{-1} (which was considerably more expensive than the traditional colourful designs which sold at $1.5 to $2 m^{-1}). With its rich history and central location in the Silk Road, Uzbekistan could find an interesting angle to market its silk fabrics on the world market.

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Using Conservation Agriculture to improve water use efficiency in wheat crops on the Branson farm in South Australia

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Keywords: Farming System, Carbon Farming, No-Till, Controlled Traffic, Precision Agriculture.

Introduction

The 1200 ha Branson farm is located between Stockport and Giles Corner in the lower north of South Australia. Annual rainfall is 475mm which predominantly falls in the winter months; growing season rainfall (GSR) is 350mm which falls from April to October. As such, the farm is in the high rainfall zone for cropping in South Australia.

The Bransons have been early adopters of new technology throughout the generations. The farm was an early adopter of superphosphate, the ley farming system, which included the growing of pasture legumes, and improved weed control with herbicides. When the present owner/manager and author took over the farm in 1990, grain legumes were introduced into the rotation and minimum tillage was adopted. In 1997, yield monitoring was introduced, and following the purchase of new sowing equipment, all crops have been sown with No-Till since 2002. In 2004 with the purchase of very accurate GPS equipment (RTK 2cm), Controlled Traffic (CT) was introduced to the farm with all major farm machinery being driven using autosteer technology. In 2005, the author won and completed a Nuffield Scholarship where he studied overseas for 18 weeks looking at Conservation and Precision Agriculture. In 2006 a handheld Greenseeker ® was purchased and used with Nitrogen Rich strips (Raun et al., 2002) to fine-tune Nitrogen (N) applications. Also in 2006, a full Precision Agriculture (PA) fertilising program was developed with all Phosphorus (P) based fertilisers being Variable Rate (VR) applied. In 2010, a set of CropSpec ® sensors were purchased which have enabled the introduction of VR N application. The Branson farm is now one of the leading farms in Australia in the adoption of new cropping technologies into the farming system.

The author believes that improving soil health and structure holds the key to improving water use efficiency (WUE) which leads to improved farm profits and benefits the farm environment. He has designed his farming system by using worlds best farming practice to achieve this.

This paper discusses the achievements made to date on the Branson farm in increasing the WUE of wheat crops through the adoption of new cropping technologies. Two periods are of particular interest in this paper. The first, from 1990 to 2001, was the period in which the farming system changed to include growing grain legumes and the introduction of N based fertilisers. The second, from 2002 to 2010, was the period in which new cropping technologies, including No-Till, CT and PA techniques, were introduced to the farming system.

Materials and Methods

From numerous benchmarking exercises, wheat yield has been identified as a key driver of farm profitability on the Branson farm. A way of mapping wheat yield gains over time is to use the actual yields achieved divided by the French and Schultz potential yield calculation (French and Schultz, 1984). The result reflects the percentage of potential wheat yield obtained given the actual growing season rainfall, the key driver to wheat yield in rainfed cropping systems. The French and Schultz potential yield calculation determines attainable wheat grain yield per unit of water use (i.e. 20kg grain/ha/mm). The calculation requires the GSR minus soil water evaporation (assumed by the model to be 110mm) to be multiplied by 20kg/ha. Here, GSR was calculated from the actual April to October rainfall plus half the rainfall in the months of March and November, and the value obtained by dividing the actual yield by the potential yield referred to as 'percent potential yield'.

Five year rolling average yields and percent potential yields were calculated and trend lines fitted to the data using simple linear regression in MS Excel.

Results and Discussion

Percent potential yield on the Branson farm increased from 64% in 1990 to 91% in 2010 (Figure 1). Over the same period, potential yield decreased from 5.1 to 4.85 t/ha due to a decline in GSR. The improvement in percent potential yield can therefore be attributed to improved WUE associated with changes to the farming system. Of note is the fact that the gains in WUE achieved on the Branson farm greatly exceed the small increase achieved in the district as a whole, which on average sits at 50 to 60% percent potential yield (Stephens, et al., 2011). No-Till has been adopted by the leading farmers in the district who are experiencing gains, but CT, PA and other new technologies are mostly not adopted.
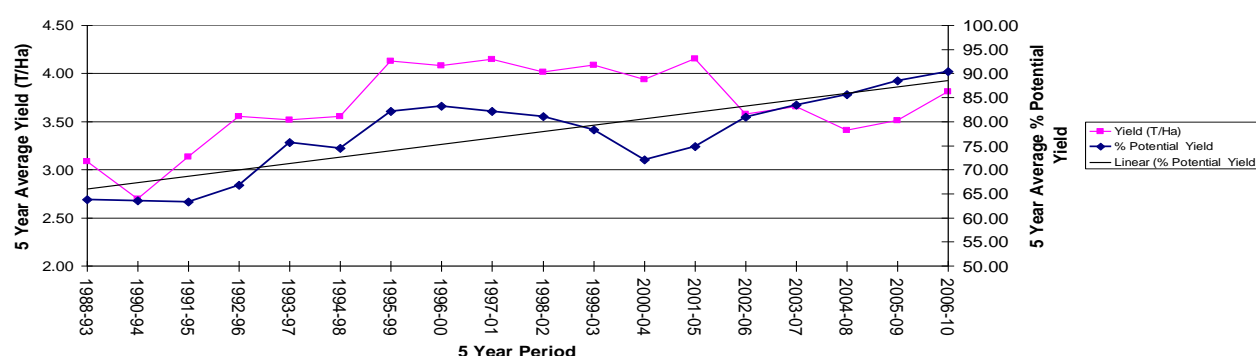
Figure 1. Five year rolling average wheat yields and percent potential yields from 1990-94 to 2006-2010 on the Branson farm.

Over the years from 1990 to 2001, the farm rotation changed to include the cereal break crops of field peas and faba beans, and the oilseed crop of canola with the aim of reducing cereal root diseases such as CCN, Rhizoctonia, and Haydie. During the same period, N based fertilisers were introduced to improve crop nutrition, and stubble retention was enforced. Most of the leading farmers in the district adopted

these farming system changes, some faster than others. Analysis of this period (Figure 2) shows that the percent potential yield trend line from smoothed 5 year averages increased from 66% (1988-93) to 81% (2001-05). This is equivalent to a 1.1% annual increase in WUE.
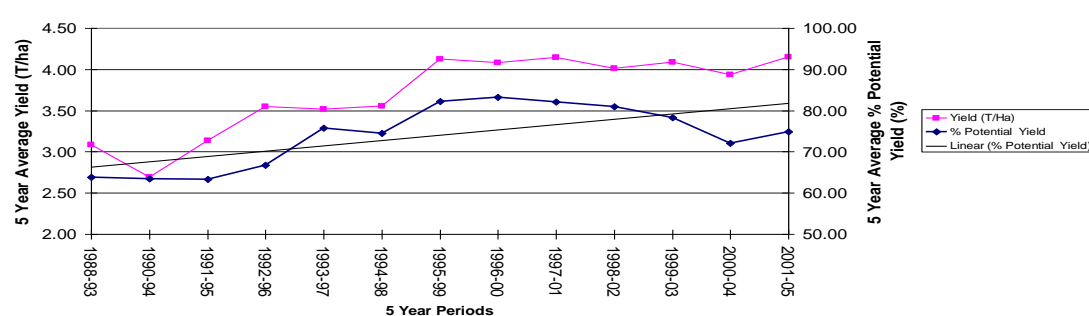
Figure 2. Five year rolling average wheat yield and percent potential yield from 1988-93 to 2001-05 on the Branson farm

In the period from 2002 to the present, No-Till, application of additional animal manures, growing more high carbon crops and the continuation of stubble retention has led to an improvement in the soil structure. In addition, more effective nutrient cycling, especially of N, seems to be occurring with less N needing to be applied for the same outputs. Both these gains are consistent with results obtained overseas (Reicosky, 2005; Lafond et al., 2008) in which improvements in soil structure and nutrient cycling have been attributed to extra carbon being added to the soil using the above farming practices; CT has decreased soil compaction (Webb et al., 2004). Overall, the improvement in soil structure from the above farming system changes has led to more water and nutrients being available to the crop to grow and produce grain. Thus, Figure 3 shows that percent potential wheat yields have increased at a rate of 2% per year for the period 2002-06 to 2006-10 and now sit at 91%. This is equivalent to an annual increase in WUE of 0.9% following the adoption of new cropping technologies in the farming system if the gains in the first period are maintained, but could be more if they had slowed.
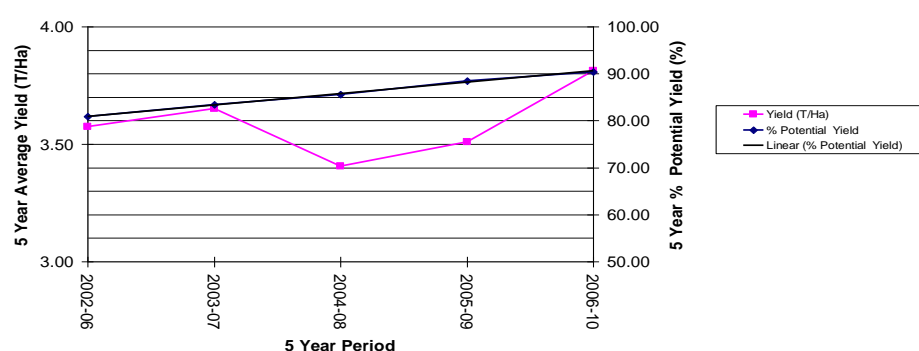
Figure 3. Five year rolling wheat average yield and percent potential yield from 2002-06 to 2006-2010 on the Branson farm

It is concluded that the adoption of Conservation Agriculture and PA has led to increased wheat yields on the Branson farm well in excess of the district average. It has also led to an improvement in farm profits and the farming environment.

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Innovations for relay planting of wheat in cotton: a breakthrough enhancing productivity and profitability of cotton-wheat systems of South Asia

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Keywords: cotton-wheat system, direct drilling, relay seeding, planting machinery

Introduction

In South Asia, the cotton-wheat (CW) rotation used over ~4.5 M ha could be improved to provide major gains in wheat production from the region. This occurs because wheat planting is often delayed by 20-44 days due to late picking of cotton, and subsequent tillage and field preparation operations for wheat planting. Sowing wheat after 20th November in this region reduces the productivity at the rate of 1.0-1.5 % per day (Nasrullah et al 2010), reducing average yield after cotton by > 0.5 t ha^{-1}. Stapper and Fisher (1990) have also pointed out that wheat planted after cotton harvest in general faces an unfavourable temperature regime and smaller window for growth and development, leading to lower yields (CRI 1993). This is made worse by delayed planting.

Innovation is needed to overcome the problem of delayed planting of wheat in the cotton-wheat cropping system, and studies on relay planting of wheat in standing cotton under zero tillage have shown promising results (CRI 1992). The timely planting of wheat without any penalty on cotton crop can be achieved through relay planting in standing cotton using innovative planters. In this study, two approaches were used to develop and deploy an innovative wheat plants for the cotton-wheat production system and facilitate direct drilling of wheat in standing cotton to improve timeliness, productivity and profitability.

Materials and Methods

An innovative 2-wheel tractor-based self-propelled relay seeder with seed-cum-fertilizer attachment (Figure 1) was developed in collaboration with Amar Agro Industries, Ludhiana, India. The prototype seeder, powered by a 7 HP diesel engine, is capable of direct drilling wheat along with fertilizers in three rows (20 cm spacing) between two rows of standing cotton (67.5 cm apart). To evaluate the prototype, a study was conducted for 2 consecutive years (2009-10 and 2010-11) on sandy loam soils at 4 and 11 locations respectively in cotton-wheat dominated areas of Bhatinda (between 30.11651 to 30.15897 N and 74.88904 to 74.92802 E) Punjab, India.
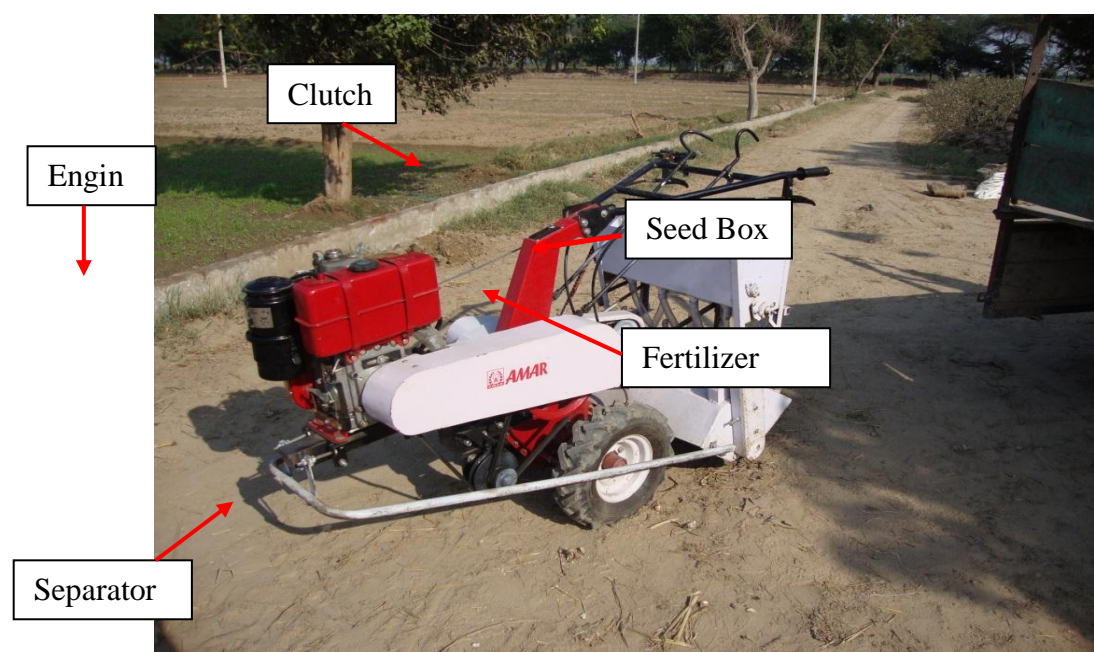
Figure 1. Innovative 2-wheel tractor based self propelled relay seeder

In year 1, four and in year 2 three wheat planting methods were compared in terms of yield and profitability of wheat production under cotton-wheat rotation. The planting methods included; relay seeding of wheat in standing cotton using self propelled relay seeder without tillage (T_1), relay seeding of wheat in standing cotton with manual drill without tillage (T_2), relay seeding of wheat in standing cotton as broadcasting with minimum tillage (T_3) and seeding of wheat crop after the harvest of cotton crop and by conventional tillage practices, using 4-wheel tractor drawn drill (T_4). After the third picking of cotton, farmers usually apply a last irrigation to cotton in first week of November which also provides the pre sowing irrigation for relay-seeded wheat. All other agronomic practices were kept same in all the treatments except the method of seeding. A uniform dose of nutrients (125 kg N, 62.5 kg P_2O_5 and 50 kg K_2O ha^{-1}) was applied in all the planting methods. All the phosphorus, Potash and 50% N was drilled at seeding and the remaining 50% N was applied after the harvest of cotton (at first irrigation). In conventional practice, the seeding was done after harvest of cotton following conventional tillage practice. For statistical analysis, locations were considered as replications and hence the data were subjected to analysis in a Randomized Block Design (RBD).

Results and Discussion

Yield data given in Table 1 confirms the results of farmers' participatory field trials, indicating that the conventional practice of wheat cultivation after harvest of cotton delayed wheat planting by 20-44 days leading to significant yield penalty. This data shows that among different methods of relay seeding, direct drilling using the innovative relay seeder produced the greatest yield benefit. Further, with relay seeding, the yield gains were higher (0.8 to 1.4 t ha^{-1}) in 2009-10 compared to 2010-11 (0.5 t ha^{-1}). This was mainly due to greater wheat yield loss due to terminal heat in cotton-wheat districts of Punjab in 2009-10 (> 22 % according to Gupta et al, 2010), whereas the growing

season was prolonged, and relay seeding advantages relatively less in 2010-11, due to more favorable weather and temperature during reproductive and grain filling stage.

Among different methods of relay seeding, maximum yield gains were recorded with the innovative relay seeder, which had the additional advantage of placing seed and fertilizers in band compared to other methods of relay seeding. The average (over 2 years) wheat yield advantage with relay seeding using the innovative relay seeder was 0.98 t ha^{-1} (24.9 %) compared with conventional practice of planting wheat after cotton harvest. Economic analysis of average results from these two years indicates significant gains in net returns (US$ 150 to 405 ha^{-1}) with relay seeding of wheat compared to conventional planting practice and maximum gains were with innovative relay seeder (Table 1). The results of this study also suggests that if relay seeding technology were adopted over 4 Mha that measure alone would produce additional over 2 Mt of wheat in the region, and contribute significantly in food security in South Asia. In view of the potential of this technology and range of farm size in the cotton-wheat region, efforts have already been made to develop a high clearance platform for 4-wheel tractors and an initial prototype has been developed in collaboration with Rajar Agriculture works, Ludhiana, Department of Farm Machinery and Power, PAU, Ludhiana and John Deere (Figure 2).

Figure 2. High clearance platform for 4-wheel tractor

Table 1. Wheat grain yield and net returns under different planting methods under cotton-wheat system

Treatments	Wheat grain yield (t ha^{-1})			Cost of cultivation (US$ ha^{-1})	Net profit (US$ ha^{-1})	B:C ratio
	2009-10	2010-11	Mean			
T$_1$	4.97a	4.84a	4.91a	430	1353a	3.15
T$_2$	4.51a	-	4.51a	430	1123b	2.61
T$_3$	4.39a	4.64a	4.52a	430	1124b	2.61
T$_4$	3.52b	4.33b	3.93b	463	978c	2.11
Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by the Duncan's multiple range test (DMRT)						

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The effects of minimum and conventional tillage systems on maize grain yield and soil fertility in western Ethiopia

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Introduction

Ethiopian soils, formed from old weathered rocks, are naturally low in fertility. Moreover, crop production is constrained by non-sustainable cropping practices, particularly repeated plowing and hoeing, which result in loss of soil fertility (Tolessa, 2010). The objectives of the present study were to evaluate the effects of tillage system, residue management and nitrogen fertilization on maize grain yield in western Ethiopia and the effects of the integrated management practices on some soil fertility parameters.

Materials and Methods

A five-year experiment on integrated soil management practices was conducted at five sites in western Ethiopia. The experiments were laid out in a randomized complete block design with three replications. Three tillage systems (MTRR = zero tillage with residue retention, MTRV = zero tillage with residue removal and CT = conventional tillage) and three N fertilization levels (recommended rate of 92 kg N ha^{-1} and 25% less and 25% more than this rate) were combined in complete factorial arrangement. Experimental plots were kept permanent to observe the carry-over effects of the treatments over years.

For the MTRR and MTRV treatments, the soil was disturbed only to place the seed in the soil at the time of sowing. In contrast, for CT treatments the soil was plowed three times prior to sowing to obtain a suitable seedbed. Penetrometer resistance, soil pH, organic C, total N, extractable P and exchangeable K were quantified to establish treatment effects on the Nitisols.

Results

At all sites there were no significant differences in grain yield between MTRR and MTRV in the first two years and both were significantly superior to CT (Figure 1). However, in the final two years of the experiments, there was no significant difference between MTRV and CT, but MTRR yielded significantly more than both. Grain yield was significantly higher with 92 kg N ha^{-1} than with 69 kg N ha^{-1}, but there was no further response with 115 kg N ha^{-1} regardless of tillage system. Hence, the recommended fertilization rate of 92 kg N ha^{-1} for conventionally tilled maize was also found adequate for zero tillage maize in western Ethiopia. The only negative aspect of MTRR in comparison with CT was a decline in soil pH and a higher penetrometer resistance of the soils (Figure 2). After five years both organic C and total N content were significantly higher in the MTRR soils than the CT soils. Similarly, the extractable P and exchangeable K contents of the MTRR soils were higher than that of the CT soils.

Table 1. Effect of different tillage systems and nitrogen fertilization on maize grain yield in western Ethiopia

N level (kg ha^{-1})	Tillage system (T)			Mean
	MTRR	MTRV	CT	
69	5953	5595	5210	5586
92	6513	6173	5868	6185
115	6953	6450	6227	6543
Mean	6473	6073	5768	
LSD$_{(0.05)}$	T or N = 394	T x N = ns		
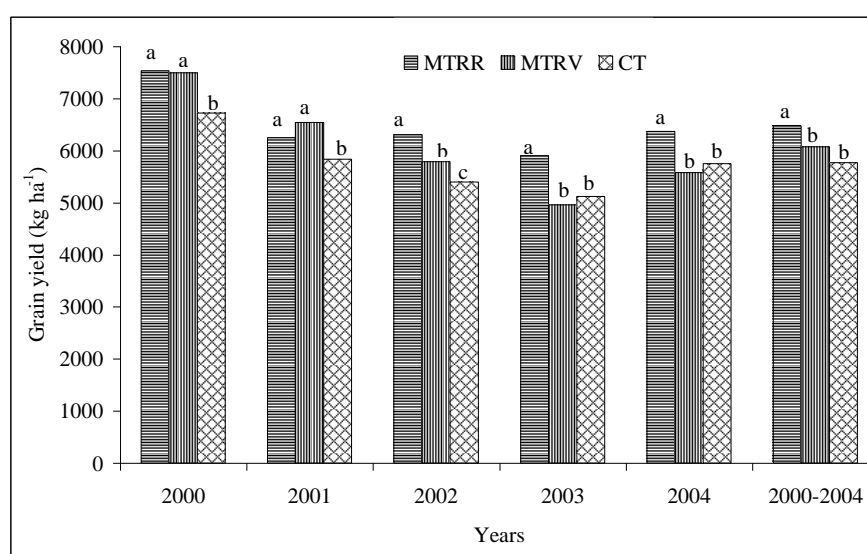
Figure 1. Mean grain yield of maize as affected by different tillage systems and residue management.

Conclusions

On average, MTRR increased grain yield by 6.6 and 12.2 % as compared to MTRV and CT, respectively. When crop residues are removed, it takes at least three years before adverse effects on grain yield reductions become evident and when crop residues are retained on the surface, it requires at least three years before the beneficial influence on grain yield are realized. As reported by some researchers (Lal, 1976; Kang and Yunusa, 1977) grain yield response to minimum tillage when the residues are retained depends on the gradual build-up of soil fertility. Nitrogen fertilization requirements for minimum tillage maize appear to be similar to those for the conventionally-tilled crop. These findings are in agreement with that of Triplet and Van Doren, 1969; Moschler et al. 1972; Legg et al., 1979; Thomas and Frye, 1984). Hence, MTRR can be successfully practiced for sustainable maize production in Ethiopia.
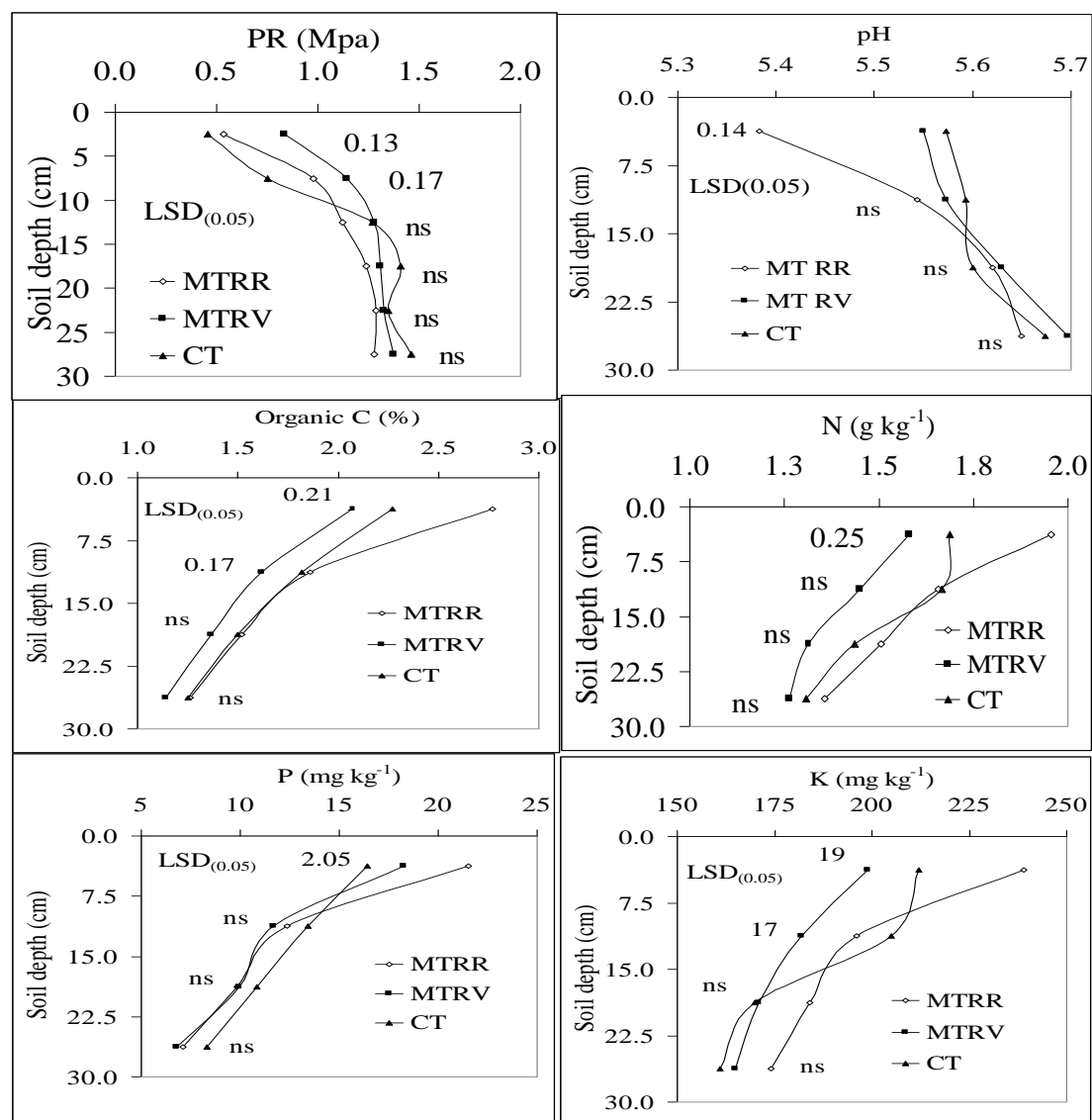
Figure 2. Effect of tillage system on penetrometer resistance, soil pH, OC and NPK content o soil in western Ethiopia

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About the necessity of adequately defining no-tillage - a discussion paper

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Introduction

What is no-till farming? This seems to be a simple question, but 40 years after its introduction in practical farming neither the scientific community, nor teaching institutions, nor the farming industry have yet agreed on a clear definition of this crop production system. There is still confusion about planting system methods that are included or excluded when using the term no-tillage. In other words there is a very broad interpretation and understanding of no-tillage and how it should be performed. But although almost everyone understands that no-tillage farming is agriculture without tillage, this is not precise enough when it comes to define a system with the aim of having comparable research results. It has been shown that low disturbance no-tillage will yield different results when compared to high disturbance no-tillage in terms of carbon and water losses (Reicosky, 2011). A no-tillage system where crop residues from the previous crop have been removed, burned or eaten by livestock will yield different results from no-tillage with full retention of crop residues (Wall, 1999, Sayre et al., 2006). We also know that long term no-tillage research will produce different results than one year or short term no-till as well as disregarding adequate crop rotations will compromise the results of a no-tillage system. Often no-tillage is defined as a production system with minimal soil disturbance not taking into account that for many farmers in Europe minimal soil disturbance means not using the plough while it means invisible no-tillage seeding for experienced no-till farmers in the US or in South America.

Therefore it is extremely important to formulate a science based and explicit definition of the no-tillage system if consistent and comparable results are to be achieved among the research community. Often conflicting and contradicting no-tillage research results are the consequence of using local jargon and definitions by different researchers causing misunderstandings of how no-tillage should be put into practice. For this reason, it is necessary to find a consensus for an accurate description and definition of no-tillage. If this cannot be achieved soon, then we will continue to "flounder" and have conflicting and contradicting research results in no-tillage at the national and international level.

Description and definition of the no-tillage concept

No-tillage or zero tillage is a conservation farming system in which the seeds are placed at proper depth directly into untilled soil that has retained the previous crop or cover crop residues. It is also referred to as no-till. It is considered to be the important element in Conservation Agriculture. Special no-till seeding equipment with discs (low disturbance) or narrow tines/coulters (higher disturbance) open a narrow slot into the residue-covered soil which is only wide enough to put the seeds into the soil at proper depth and cover them with soil. The aim is to move as little soil as possible in order to preserve the surface residues and to reduce potential weed seeds from reaching the soil surface to germinate. No other soil tillage operation is done. The residues from the previous crops will remain largely undisturbed at the soil surface as mulch. Seeding systems that till and mix more than 50% of the soil surface while seeding cannot be defined as no-tillage (Linke, 1998, Sturny et al., 2007). If the whole machine width of soil is disturbed even superficially, then according to CTIC (2011), the system is defined as mulch tillage. A successful no-tillage system has to have adequate weed control. Weed control in no-tillage is performed through the adoption of appropriate crop rotations including the use of adapted, aggressive species of cover crops or crop associations, mechanical non soil engaging tools like the knife roller and also by applying appropriate herbicides. Adequate nutrient management, including replacement of nutrients exported by crops that are in short supply in the soil and integrated pest management are parts of the system. Some of the environmentally-relevant effects of no-tillage, such as erosion control, improvement of water quality, increased water infiltration (leading also to reduced flood hazard and greater dry season flows), climate related consequences (through carbon sequestration in the soil and lower emissions of other GHGs), will become important only after several years of continuous, uninterrupted practice, generating substantial off-farm benefits for society (Landers et al., 2001). Returning enough plant biomass to the system year by year is a condition for all these environmental benefits to become effective.

In Australia no-till and zero-till are considered to have similar meaning although no-till refers to one pass seeding into previously untilled soil with knife-points while zero-till refers to one pass seeding with disc openers (Ashworth et al., 2010). Zero-tillage denotes a higher quality no-till system involving disc seeders, with capacity for full residue retention.

The success of no-tillage as a conservation production system, embraced by Conservation Agriculture, is based on its continuous, permanent usage, similar to a permanent pasture (Sturny et al., 2007) and on direct biological diversification through crop rotation and cover crops associated with non disturbance of soil. Indirect diversification also occurs especially in the soil micro- and meso-biota, but also in the surface fauna, such as birds and mammals. The system mimics nature where soil loosening is performed by roots of plants and soil fauna as well as by diversified biological activity. Special requirements of the system must be satisfied to avoid failures and the necessary steps towards a successful transition to no-till need to be followed (Duiker and Myres, 2006, Derpsch, 2008). The fact that the soil is not tilled and remains permanently covered with crop residues leads to reduced soil erosion, to soil sequestration of atmospheric carbon, to increased biological activity in the soil, to better conservation of water, to better efficiency of applied nutrients and increased nutrient availability from biological activity, to improved energy efficiency (Sturny et al., 2007) and to higher economic returns through time (Derpsch et al., 2010). Moreover, no-till is the only farming system known today that fully meets the requirements of a sustainable agricultural production even under extreme soil and climate conditions.

The **key principles** on which no-tillage is based are the same that have been defined by FAO (2011) to characterize Conservation Agriculture and are in this case rigorously implemented.
- **Continuous minimum mechanical soil disturbance** (not more than a narrow slot is opened in the untilled ground to deposit the seeds and no other soil tillage is done).
- **Permanent organic soil cover** (full plant residue retention from previous crops and living plants that provide cover of the entire soil surface continuously).

- **Diversification of crop species growing in sequence and/or associations** (this is mainly being achieved in practice by the use of crop rotations, cover crops and crop associations).

The rigorous application of these principles in the no-tillage system implies that the additions of crop residues to the system must be at least greater than the output due to oxidation processes of organic matter.

In summary, no-tillage or zero tillage is a conservation farming system in which the seeds are deposited into untilled soil that has retained the crop residues from the previous crop by opening a narrow slot, trench or hole only of sufficient width and depth to obtain proper seed coverage. No other soil tillage is done (adapted from Phillips and Young, 1973 and Köller and Linke, 2001). All aspects of the above description of the no-tillage system are considered to be implicit in this definition.

No-tillage is being adopted on more than 100 Million ha worldwide (Derpsch et al., 2010) and on about 70% of arable cropland by countries like Brazil, Argentina, Paraguay, Uruguay, Australia and New Zealand. From 1999 to 2009 the technology has expanded at an average rate of 6 Million ha per year (Derpsch et al., 2010). The main reasons for the rapid expansion are savings in time, labour and fuel, reduced soil erosion, improved water use efficiency and greater nutrient efficiency, which lead to higher profitability and continued progressive profitability for sustainability. This increasingly popular production system deserves an adequate international definition to be agreed on in order to avoid conflicting and contradicting research results in future!

Equivalent terms to no-tillage /zero tillage in other languages are; Spanish: Siembra Directa or Labranza Cero. Portuguese: Plantio Direto na Palha. French: semis direct.

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Conservation Agriculture, aggregate stability and the organic carbon distribution in soil aggregates

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Introduction

Agronomic practices, including tillage, residues management and crop rotation, are crucial determinants of the quantity of carbon retained in the soil. The soil organic carbon (SOC) distribution in soil aggregates controls the sequestration or release of C within a given agricultural system. Macro and micro-aggregation are important for SOC storage and turnover. Declining SOC contents in agro-ecosystems are important in the global C budget, as less C is sequestered in the soil. In the central highlands of Mexico farmers apply generally conventional tillage with maize monoculture and removal of crop residues for fodder. In 1991, a rain-fed field experiment was therefore set up at the International Centre for Maize and Wheat Improvement (CIMMYT) in the central highlands of Mexico to investigate the effect of different management practices, i.e. ZT or CT with or without residue retention and maize-wheat rotation or monoculture, on soil degradation and yields. The present study reported on the long-term effects (16 years) of contrasting management practices on aggregate size distribution, and carbon distribution in three aggregate fractions during a cropping cycle of a soil cropped with maize and wheat in Central Mexico.

Materials and Methods

The study was conducted at El Batán Experimental Station of CIMMYT, situated in the semi-arid, subtropical highlands of Central Mexico, in a Cumulic Phaeozem. The experiment was set up in 1991, sixteen treatments were applied in a randomized complete block design with two replicates. Three management factors were analyzed: 1) tillage (zero tillage (ZT) or conventional tillage (CT)), 2) crop rotation (wheat and maize monoculture (M) or/and maize-wheat rotation (R)), and 3) residue management (with (+r), or without (−r) crop residues). Undisturbed samples were taken from the 0-5 and 5-10 cm soil layers and separated in micro-aggregates (< 0.25 mm), small macro-aggregates (0.25 to 1 mm) and large macro-aggregates (1 to 8 mm), wet sieving was used to determine aggregate stability and separate different size aggregates, 20 gr dried soil wet sieved through a column of sieves with a mesh opening of 4.75, 2.0, 1.0, 0.5, 0.25 and 0.053mm submerged in a cylinder of distilled water and driven up and down at 60 cycles per minute. The fractions held in the sieves were collected and dried at 105 ∘C for 18 h. The carbon content of each aggregate fraction was determined with a C autoanalyzer (TOC-5050A –Total Organic Carbon, Shimadzu©).

Results and Discussion

Zero tillage combined with crop rotation and crop residues retention resulted in a higher proportion of macro-aggregates. In the 0-5 cm layer, plots with a crop rotation and monoculture of maize and wheat in ZT+r had the greatest proportion of large stable macro-aggregates. The plots with CT had the largest proportion of micro-aggregates (Table 1). The combination of ZT plus residues retention favored aggregate stability. The commonly used practice in the study area of CT-r with monoculture of maize, resulted in poor structural stability. Blanco-Canqui and Lal (2007) found that in soil with ZT, an increased amount of surface residues increased the proportion of aggregates > 5 mm, reduced the percentage of micro-aggregates. The 0-10 cm soil layer, in all treatments, had a greater proportion of small macro-aggregates compared to large macro-aggregates and micro-aggregates. In the 0-10 cm layer of soil with residues retention and maize or wheat, the greatest C content was found in the small and large macro-aggregates, except in the CT treatment with crop rotation where it was similar. No such effect, however, was found in the micro-aggregates. The large macro-aggregates in the 0-5 cm layer of soil cultivated with wheat in rotation and where the residue was retained contained significantly more C than where it was removed, but not in the wheat monoculture. ZT promoted aggregate formation, mainly in the 0–5 cm layer, compared to CT and this effect was related to greater soil organic C accumulation in ZT than in CT (Zotarelli et al. 2007). In the plot cultivated with maize the C in the small macro-aggregates contributed most to the total organic C, except in the 0-5 cm layer of the ZTR+r plot where the major contribution came from the large macro-aggregates (Figure 1). In the plots with residue removal, the micro-aggregates contributed more C to the total organic C than in plots with residue retention (Figure 1A). In the plot with wheat 0-5 cm layer, the C in the large macro-aggregates of the ZT treatments contributed more to the total organic C in the soil than in the CT treatments, while the opposite was found for the small macro-aggregates (Figure 1B). Stewart et al. (2008) stated that the C sequestration capacity of a soil is determined mainly by the protection of C in the aggregates. It can be hypothesized that the negative effect of tillage was greater for large macro-aggregates than small macro-aggregates. The abundance of small macro-aggregates might be the result of the breaking up of large macro-aggregates and/or the physical and chemical characteristics of small macro-aggregates makes them more resistant to break up by tillage, then the C of small macro-aggregates contributed more to total organic C than large macro-aggregates (Figure 1). The proportion of the micro-aggregates in all treatments was small and they had the lowest organic C content.

We concluded that zero tillage with residue retention and monoculture of maize or rotation with wheat was the most attractive system to maximize C retention in the aggregates of the top-soil, under the experimental conditions (Figure 2). Our results showed that the retention of C in the top-soil depends mainly on the C content in the small and large macro-aggregates of the 0-10 cm soil layer.

Table 1. Aggregates distribution (%) in soil with zero tillage (ZT) or conventional tillage (CT), rotation (R) and monoculture (M), with residues (+r) or without residues (-r) at CIMMYT's El Batán (Mexico).

0-5 cm soil layer	Maize			Wheat		
Treatments	1-8 mm	0.25-1 mm	<0.25 mm	1-8 mm	0.25-1 mm	<0.25 mm
ZTM+r	33.5	48	19	46	34	20
ZTR+r	42.5	41	16.5	39	41.5	19.5
CTM+r	24.0	54	22	15	55	30
CTR+r	25.5	50.5	24	25	49	26
ZTM-r	14	58.5	27	43.5	33	22.5
ZTR-r	21	54	25	32	45.5	22
CTM-r	8	56	36	10	65	25
CTR-r	9	64	26.5	14	58	28
LSD [a]	11	24	3	18	14	18
5-10 cm soil layer						
ZTM+r	22.5	57	21	39	43	18
ZTR+r	22	51	27	28	49	23
CTM+r	19	63	18	35	45	20
CTR+r	19	60	21	28	48	24
ZTM-r	14	63	23	35	46.5	18.5
ZTR-r	19	57.5	23	22	56.5	21.5
CTM-r	11	61.5	27.5	22.5	54.5	23
CTR-r	8.5	58.5	33	16.5	62	22.5
LSD [a]	14	16	17	23	8	14

[a] $p < 0.05$ level based on least square difference grouping (LSD)
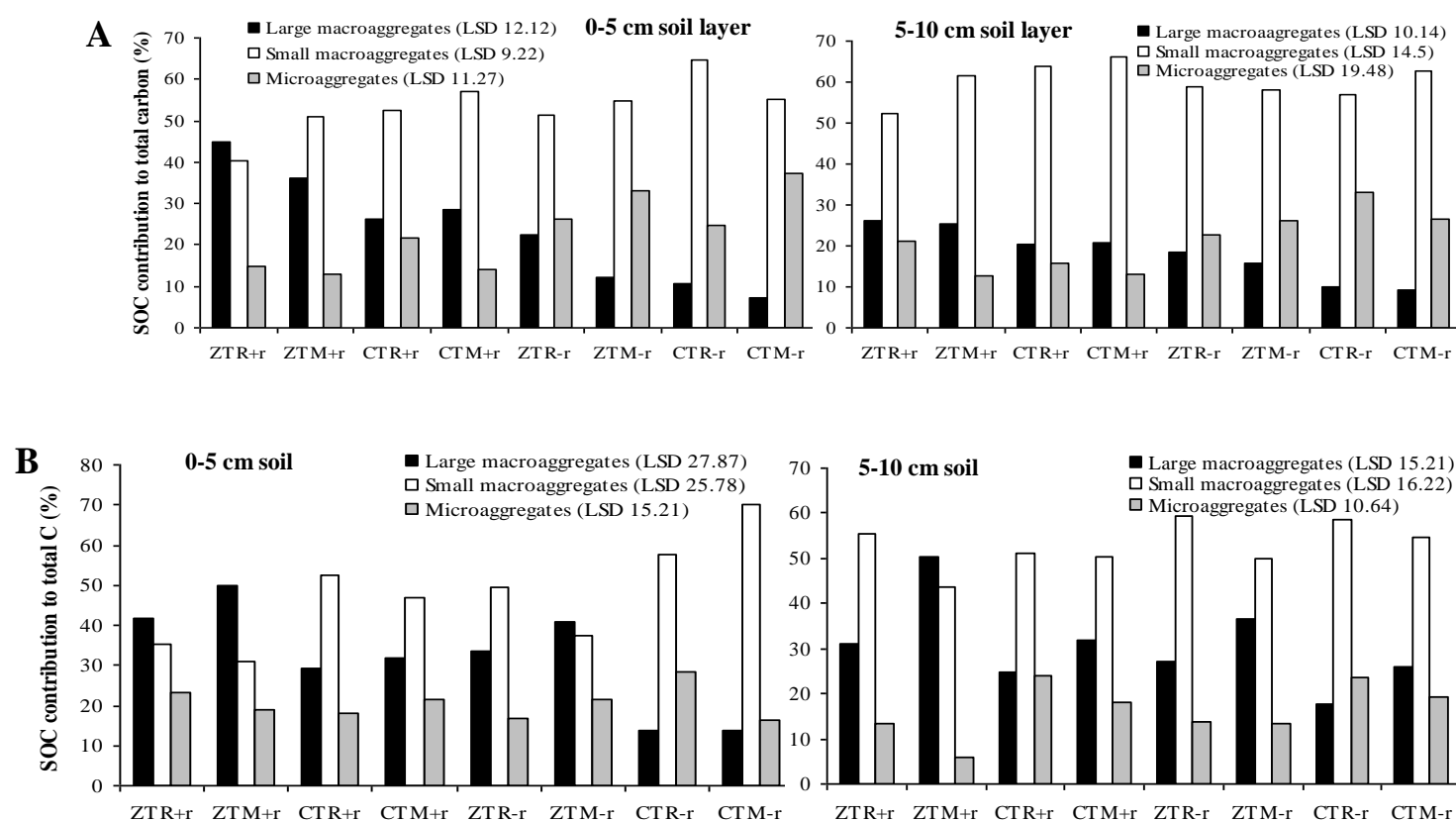
Figure 1 The contribution of the C in the different aggregates to total organic carbon of the soil sample in soil **A)** cultivated with maize, **B)** cultivated with wheat, zero tillage (ZT) or conventional tillage (CT), rotation (R) and monoculture (M), with residues (+r) or without residues (-r) at CIMMYT's long-term tillage sustainability trial at El Batán (Mexico)
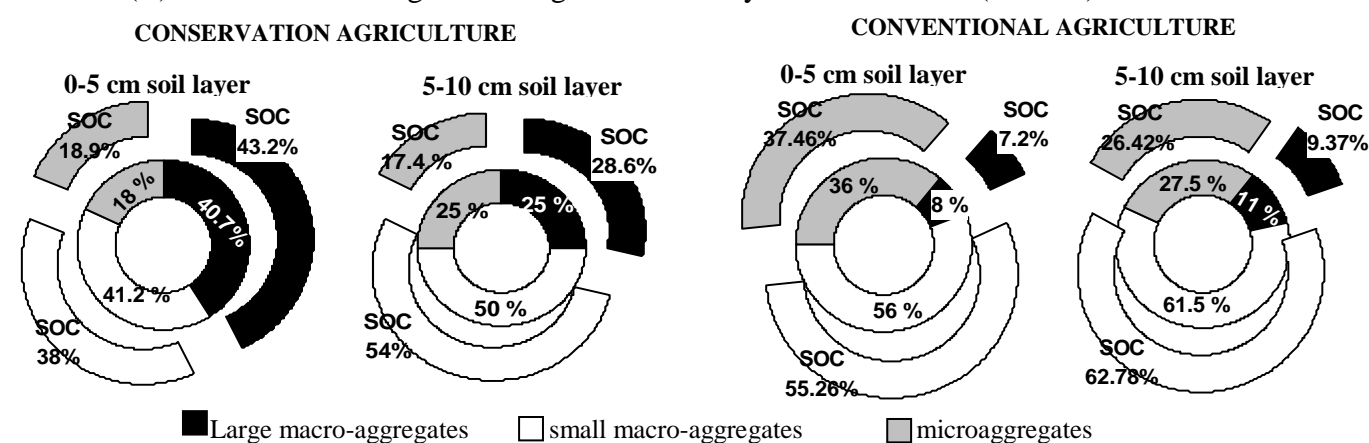
Figure 2 The aggregate size distribution and carbon contribution in three aggregate in conservation and conventional agriculture and at CIMMYT's long-term tillage sustainability trial at El Batán (Mexico)

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Happy Seeder technology: a solution for residue management for the sustainability and improved production of the rice-wheat system of the Indo-Gangetic Plains

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Introduction

The rice-wheat system of the Indo-Gangetic Plains, occupying 13.5 M ha, is critical for food security in the region. Productivity of rice and wheat has recently stagnated and declined owing to climate change and reduced soil productivity, posing a serious threat to the sustainability of the rice-wheat cropping system (Ladha et al. 2009). Hence the major challenge is to increase the productivity to meet the growing food demand without adverse environmental impact. Combine harvesters have recently been introduced, with exponential growth in mechanical harvesting of wheat in the better endowed rice-wheat growing area of NW India especially, Punjab, Haryana and western Uttar Paradesh. In these combine harvested areas, managing heavy loads of rice residues is the major issue. Farmers generally burn rice residue prior to wheat sowing as the cheap and easy option for residue management, but burning leads to losses of soil organic matter and nutrients (especially N, P, K, S and C), and creates environmental pollution (particulates and greenhouse gases) (Singh et al. 2007). The Happy Seeder technology provides an alternative to burning for managing rice residues and allows direct drilling of wheat in standing as well as loose residues (Gathala et al. 2009). Both on-farm and on-station trials were conducted to evaluate the feasibility of direct-drilling of wheat in the presence of heavy loads of rice residue using the Happy Seeder and the effects of tillage and residue management methods on crop productivity and soil physical properties.

Materials and Methods

The on-station experiment was conducted on sandy loam from 2007 to 2010 at the research farm of Sardar Vallabh Bhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India. This was part of large experiment with multiple objectives. In this paper we are presenting results of three treatments varying in tillage and residue management methods. The experimental design was randomized complete block design with three replications, using permanent experimental plots measuring 6 x 20 m. The treatments included: 1) conventional tilled wheat (CTW) after conventional puddled transplanted rice; 2) zero-till wheat without rice residue (ZTW) after zero-till dry direct seeded rice and; (3) zero-till wheat drilled directly in the rice residues retained as soil surface mulch using Happy Seeder technology (ZTW-HST) after zero-till dry direct seeded rice. The observations were taken only during the wheat crop. At crop maturity, wheat yield and yield parameters were measured. Wheat canopy temperature was measured daily in all the three treatments. Soil physical properties i.e. soil bulk density, soil aggregation, penetration resistance, and steady state infiltration were measured after harvest of each wheat crop. In addition, soil temperature at 5 cm depth was monitored daily (0700 hr and 1600 hr) during the wheat growing season. In addition the performance of the ZTW-HST system was also evaluated in farmers fields in participatory trials. A total 61 on-farm trials were conducted in three years. Data were subjected to analysis of variance (ANOVA) and treatment means were compared by Tukey's honest significant difference test.

Results and Discussion

Grain yield: Treatment x year interaction was non-significant for wheat grain yields (set out in Table 1), so the data were pooled for all three years. On-station wheat grain yield of ZTW-HST was 10% and 9% higher than CTW and ZTW, respectively. A similar trend was observed in on-farm trials with 3% higher yield in ZTW-HST than CTW. Gathala et al. (2011a) also observed higher wheat yield under zero-till compared to conventional till.

Soil physical properties: After three years, the percent water stable aggregates (WSA) of size >0.25 mm, steady state infiltration rate, and bulk density were affected by tillage and residue management methods (Table 2). WSA% was highest in ZTW-HST (63%) followed by in ZTW (57%) and CTW (52%). Similarly, steady state infiltration rate was higher in ZTW-HST and ZTW (0.314 to 0.372 cm hr^{-1}) compared to CTW (0.237 cm hr^{-1}). Both percent WSA and infiltration rate improved in zero-tillage treatments (ZTW and ZTW-HST) and decreased in conventional tillage (CTW) with time, from the initial value. After three years, soil bulk density was affected by tillage and residue management methods at all depths (Table 2). The surface bulk density (0-5 cm) was lower in CTW and ZTW-HST as compared to ZTW. The lower bulk density of surface soil in ZTW-HST compared to ZTW suggests that residue retention as mulch helps in minimizing soil compaction. In contrast, sub-surface (11-20 cm) bulk density was lower in ZTW-HST compared to CTW because of compaction caused by trafficking of machines used during tillage operations (Gathala et al. 2011b). Soil temperature trend was similar in all the three years, therefore average weekly data are presented (Fig 1). The 0700-hr soil temperature was highest in ZTW-HST, lowest in CTW and intermediate in ZTW, while at 1600-hr, the trend was reversed. The ZTW-HST moderated surface soil temperature by 3 to 7°C. These results suggest that zero-till (ZTW and ZTW-HST) buffered soil against temperature fluctuations better than conventional tillage. This is likely to have a positive effect on soil micro-flora, water and nutrient availability, and plant growth (Gathala et al. 2011b).

Canopy temperature: Canopy temperature was similar in all treatments up to 143 days after sowing (March 20), however later during the grain filling stage, residues in ZTW-HST lowered the canopy temperature by 2-3 °C over the other treatments (ZTW and CTW) (Fig 2). This could be attributed to higher soil moisture availability in ZTW-HST due to the presence of surface residue mulch which may lead to a higher transpiration cooling effect. The lower canopy temperature in ZTW-HST may help in prolonging the grain filling period and may also help in combating the emerging deleterious issue of terminal heat during this period.

Conclusions: Our results indicate that ZTW-HST can improve wheat productivity by improving soil physical properties and regulating canopy and soil surface temperature.

Table 1: Wheat grain yield under different tillage and residue management methods.

Treatment	On-station		On-farm[*,**]	
	------------t ha^{-1}-----------			
CTW	4.13	b	4.67	b
ZTW	4.18	b	4.77	ab
ZTW-HST	4.55	a	4.83	a
ANOVA	-----------*p value*-----------			
Treatment	0.014		0.041	
Year	<0.001		NS	
Treatment *year	NS		NS	

* No. of farmers: CTW=61; ZTW= 29; and ZTW-HST= 36
** Adjusted mean yield calculated using SAS mixed model procedure

Table 2. Effects of tillage and residue management methods on percent water stable aggregates (WSA), steady state infiltration and soil bulk density after three 3 year of rice-wheat rotation.

Treatment	% WSA (>0.25mm)		Steady state infiltration rate (cm hr^{-1})		Soil bulk density (Mg m-3)							
					0-5 cm		6-10 cm		11-15 cm		16-20 cm	
CTW	52.35	c	0.237	b	1.48	b	1.57	b	1.76	a	1.80	a
ZTW	57.44	b	0.314	a	1.59	a	1.64	a	1.70	b	1.77	b
ZTW-HST	62.61	a	0.372	a	1.52	ab	1.63	a	1.69	b	1.76	b
Initial	*53.30*		*0.263*		*1.52*		*1.65*		*1.73*		*1.74*	
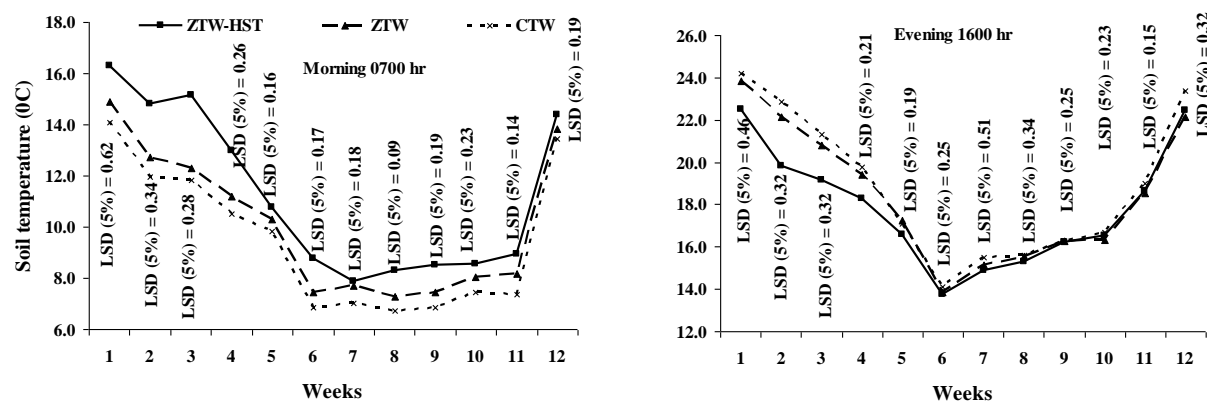
Figure 1. Effects of tillage and residue management methods on surface (5 cm) soil thermal regime
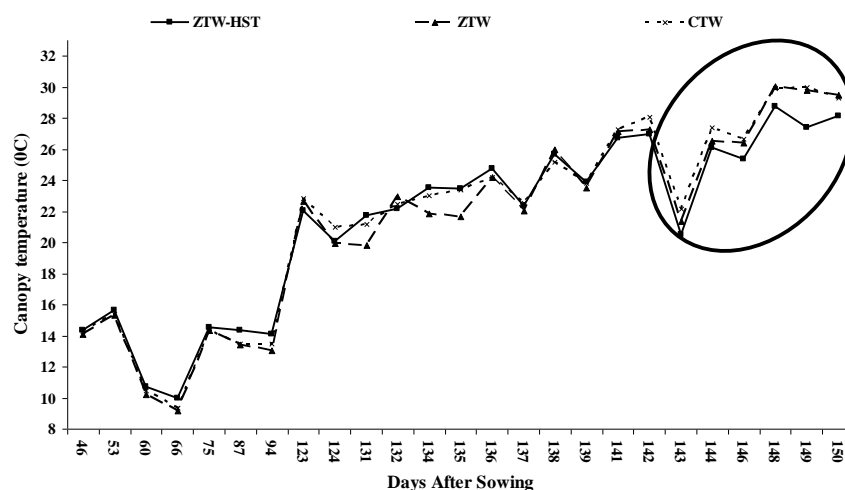
Figure 2. Effects of tillage and residue management methods on wheat canopy temperature.

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A novel perennial pasture and winter wheat conservation agriculture intercrop system for central USA

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Introduction

The USA's federally funded Conservation Reserve Program (CRP) has largely been successful in restoring many critical ecosystem functions to millions of acres through the conversion of vulnerable croplands to diverse perennial plant communities—primarily to perennial grass and forb plantings. CRP contracts, however, on as much as 6.5 million hectares (ha) are now expiring. Aside from leaving the land idle and economically unproductive as it was during the contract period, land owners typically have two options for managing post-contract CRP lands. Grazing or haying the perennial grass vegetation may be the best option for maintaining environmental benefits following contract expiration (Glover et al., 2010), but can offer low economic returns. Another option is to convert the land back to annual cropland for greater economic return. In the past, nearly 66 percent of post-contract CRP grasslands have been converted to annual cropland with roughly 30 percent remaining in perennial cover (USDA-ERS, 2005).

Studies of the effects of perennial grass on soil quality have illustrated a wide range of benefits (Karlen et al, 1999; Glover et al., 2010). Unfortunately, these benefits may be quickly lost once perennial grasslands are converted to annual cropping (Randall et al., 1997; Culman et al., 2010; DuPont et al., 2010), especially when tillage is used to kill the perennial cover (Culman et al., 2010). Direct conversion to no-till annual cropping (direct seeding) maintains some of the soil quality benefits of perennial grasslands but requires high chemical inputs and results in decreases in active soil carbon levels and changes in soil food web structure and function (DuPont et al., 2010).

The post-CRP contract dilemma of accepting lower economic returns from grazing or haying the perennial cover or accepting the loss of environmental benefits under annual cropping could be resolved by pasture-wheat intercropping (PWI). Pasture-wheat intercropping has been adopted by about 1000 growers in Australia as a means of conserving resources and increasing profits. Using the combination of perennials and annuals to integrate livestock and cropping operations on the same landscapes has improved profitability, increased management flexibility and maintained environmental benefits of continuous living plant cover.

To our knowledge, no studies of PWI systems used in the USA have been reported in the scientific literature. Here we report results of the impacts on soil health, productivity, crop quality, and profitability of PWI, grass hay production (HAY), and directed seeded annual crop (NT) systems.

Materials and Methods

This project included two research sites that had been in native vegetation, primarily warm-season grasses, for more than 20 years. Each site had three production treatments replicated three times: 1) warm-season meadow (dominated by big bluestem, *Andropogon gerardii*) for hay production (HAY); 2) no-till (NT) annual rotation of soybeans-wheat-sorghum; and 3) pasture-wheat intercropping (PWI) system. Each experimental plot was 4.5 m wide and 9.5 m long (43 m^2). The project consisted of four areas of study: **1.** soil characteristics; **2.** yield characteristics; **3.** economic inputs; and **4.** plant community composition. Yields of hay and grain were determined annually and enterprise budgets developed for each of the systems. Plant species composition and relative abundance was measured each year in early July.

Results and Discussion

Pasture wheat intercrop systems consistently achieved yields of 1.7 to 2.0 tons ha^{-1} of wheat with applications of 112 kg ha^{-1} of nitrogen fertilizer. These yield levels are economically competitive with no-till wheat monocultures, which require higher herbicide inputs and do not produce an additional hay crop following wheat harvest. Even on very poor sites, PWI systems produced 2.7 tons ha^{-1} grain yields with 224 kg ha^{-1} nitrogen fertilizer rates. Typical yield levels for NT systems were roughly 672 kg ha^{-1} greater.

Soil health, particularly in terms of increased levels of active soil organic carbon, improved in all managed systems compared to soil health in the hay production plots (unmanaged CRP plots). Hay yields were also higher in the PWI plots than in unmanaged CRP plots.

Plant diversity of PWI plots did increase but generally resulted in negative impacts on wheat grain yield. Increased presence of cool-season perennial grasses increased diversity but competed heavily with early season wheat growth, which consequently significantly reduced grain yields.

Presence of tan spot disease (as indicated by % of flag leaf affected) was greater in PWI systems (54%) compared to NT systems (19%). Greater disease presence likely resulted from the wetter, cooler canopy conditions due to greater shading and ground cover in PWI plots. The increased disease pressure indicates that identification of suitable varieties with strong rapid growth and disease resistance will be important to the long term success of PWI systems.

The greater availability of nitrogen in the PWI system, however, resulted in higher crude protein content (5.8%) compared to that measured (4.8%) in hay harvested from HP systems. The percent of neutral detergent fiber was not significantly higher in PWI systems despite the presence of the wheat straw.

Analysis of the economic performance of the pasture-wheat intercrop(PWI), no-till wheat monoculture (NT), and hay production (HP) systems, based on 2009 prices, indicate that using post-contract CRP lands simply for hay production would not cover production and land costs (Table 1). The NT and PWI systems provide net positive returns of $50 and $82 ha^{-1}, respectively. Despite lower wheat yields in the PWI system, the subsequent hay yield, which is greater than the hay produced by the HP system, increases overall profitability. Lower weed management costs in the PWI offers an additional advantage. The profitability of both systems is highly vulnerable to fluctuations in nitrogen fertilizer costs. The PWI system, because it is a more diversified enterprise, provides greater economic security in years when wheat yields are low.

Table 1. Summary of economic performance of study treatments.

	No-till	Wheat pasture intercrop	CRP grass
Wheat price ($ per bushel)	17	17	0
Hay price ($ per ton)	0	111	111
Yield/acre	0	0	0
Hay (tons)	0	3	2
Grain (bu.)	99	74	0
Revenue/acre	0	0	0
Hay	0	145	111
Grain	692	519	0
Total Revenue/acre	692	663	111
Costs ($) / acre	0	0	0
Seed	27	27	0
Pre-Harvest Machinery	0	0	0
No-Till Planting	34	34	0
Fertilizer Application	12	12	0
Herbicide Application	12	0	0
Fertilizer	0	0	0
Urea	89	89	0
Dap	226	226	0
Herbicide	0	0	0
Glyphosate	77	0	0
Harvest Machinery	0	0	0
Haying	0	29	29
Combine	53	53	0
Land Value (Cash Rent Equivalent)	111	111	111
Total costs/acre	642	581	140
Net return	50	82	(29)

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Comparison of different soil tillage systems, under several crop rotations in wheat production at Central Anatolian Plateau in Turkey

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Introduction

Turkey is a peninsula that located between 26-45 East longitudes and 36-42 North latitudes on the Northern hemisphere. The country consists of seven regions, with varying climate and topography. The Central Anatolian Plateu (CAP), is located in the central part of Turkey with an average altitude of 1,000 m above sea level and surrounded by mountains. Summers are hot and dry, winters cold and snowy and the average annual rainfall around 300 mm. CAP Region has 9Mha agricultural lands, which is 45 % of total cultivated area of the country. About 15 % of land can be irrigated and more than 70 % percent of the land in this region is used for winter cereals cultivation, largely wheat. Besides the low of precipitation, its erratic distribution results in 2Mha of the area in fallow for storing soil moisture, but often managed with excessive tillage.

Wheat fallow is the traditional rotation system with a 14-month fallow wheat harvest until October of the following year. Conventional tillage involves the use of a moldboard plow at 25-30 cm depth as the primary tillage tool followed by multiple trips with secondary tillage tools like disks, harrows,and field cultivators at 10-15 cm. The first fallow tillage is done in late March or April when the soil is suitable for plowing, and the same practice is applied in irrigated or non fallow areas. The main purpose of tillage is to increases yield, is expensive and also has a quite harmful effect on soil properties. Over 4.5Mha of cultivated land in CAP is at risk of erosion and 75 percent of agricultural land has less than 2% organic matter.

The current average conventional practice wheat yield is 2,3 t/ ha in the CAP, and farmers use 35 l/ha diesel and 5 h/ha labor, so the represents 13% of total cost (Balıkçı, 1995). Profitability is a major criterion for evaluating the impact of new system adoption. The aim of a new systen should be to conserve the natural resource, increase productivity and reduce cost. Conservation Agriculture (CA) is increasingly seen as a promising alternative farming practice. CA specifically aims to address the problems of soil degradation resulting from agricultural practices that deplete the organic matter and nutrient content of the soil. It aims at higher crop yields and lower production costs through combating soil erosion, increasing soil water conservation and generally improving soil physical and chemical characteristics, hence soil fertility and high productivity (Aykas et al., 2010). The main objective of this study was to evaluate the effect of tillage and previous crops on wheat yield and profit under CAP conditions.

Materials and Methods

Field experiments were carried out under rainfed and irrigated field conditions at Bahri Dağdaş International Agriculture Research Institute in Konya province. In Konya, the annual mean air temperature is 11.4 ^{0}C, the mean evaporation is 1332 mm and in the growing season (December-July) the mean precipitation is about 300 mm. The soil texture was a sandy loam, pH 7.7, organic matter content less than 1.5%. Treatment effects were compared through an analysis of variance using ANOVA with year effects as random. Partial budgeting techniques were used to calculate the variable costs of production for each tillage system (Uzunlu and Özcan, 1987), including any costs that vary in proportion to the area planted. The wheat prices are the regional benchmark.

The experiments *were established* in 2002 using a split-plot design with tillage management as main plots and rotation treatment as a sub plot, over 4 years. The effect of tillage management and the previous crop on winter wheat yield was determined in 2005 and 2007, after 2 years of the previous crops. Individual plot size was 10 x 8 = 80 m^2 with each plot replicated 3 times. The rotation treatment was depending on irrigation, continuous winter wheat (WW), beans-winter wheat (BW) and sugar beet-winter wheat (SW) croping systems on irrigated, continuous winter wheat (WW), chickpea-winter wheat (CW) and fallow-winter wheat (FW) on rainfed.

The three tillage management treatments were conventional tillage (CT), reduced tillage (RT) and no-till (NT). For CT, mould board ploughing was used after harvesting or in early spring at a tillage depth of almost 25 cm, followed by two cultivator passes just before planting, with a tillage depth was almost 10 cm and sowing with a conventional seed drill. For RT, glyphosate herbicide was applied in early spring or before planting, then rototiller was used, at a tillage depth of almost 10 cm, before sowing with a seed drill. For NT, direct drilling was used without any prior tillage but glyphosate herbicide was applied in early spring or before planting. The first tillage and herbicide applications in fallow were performed in April when the soil is suitable for plowing. Residue was retained on the soil surface of all NT plots. Winter wheat was generally planted at September and was harvested in mid July. Fertilizer application followed locally recommended practice for both *rainfed and irrigated* field conditions, providing the same amount of water on irrigated experiment.

Results

All plant growth was normal without any incidence of disease or pest in any of the treatments in this study.

Rainfed Conditions

Rainfed grain yield of winter wheat ranged from 1072 kg ha$^-$ in 1997 to 1215 kg ha^{-1} in 1999, being effected by variation of annual precipitation. Annual (1 September to 30 June) precipitation was 184 mm and 248 mm in the 1st and 2nd years respectively. There were significant statistical differences in grain yield depending on previous crops. The highest yield wheat yield was recorded in the fallow treatment with 1248 kg ha^{-1} followed continuous wheat and chickpea with 1147 kg ha^{-1} and 1037 kg ha^{-1} respectively. Wheat grain yields were also affected by tillage. The overall average grain yield for NT was significantly greater, averaging 1317, 1207, and 907 kg ha^{-1} for NT, RT, and CT respectively. The results in Table 1 are based on average prices and yields variability in market gross returns reflect different yields and production costs. For the experiment, income from the three tillage systems was different measured by gross returns over variable costs, with CT being less profitable than the other two tillage systems. The alternative tillage treatments, NT and RT, could increase yield and reduce production costs.

Table 1. Wheat grain yield by tillage systems and previous crops, mean market gross returns over production values and variable costs hectare for rainfed condition in CAP region.

Tillage Manegement	Previous Crops	Yield (kg ha^{-1})	Production Value ($*)	Variable Cost ($)	Gross Return ($)
	Fallow	989	305,27	246,67	58,60
CT	Chickpea	796	245,70	173,33	72,37
	Wheat	936	288,91	246,67	42,25
	Fallow	1248	385,22	213,33	171,88
RT	Chickpea	1229	379,35	160,00	219,35
	Wheat	1145	353,42	193,33	160,09
	Fallow	1506	464,85	133,33	331,52
NT	Chickpea	1086	335,21	80,00	255,21
	Wheat	1358	419,17	113,33	305,84

*US $

Irrigated Conditions

Wheat grain yields reached 5531 kg ha^{-1} with grain yield affected by previous crops. The highest wheat yield was recorded in the beans rotation with 5459 kg ha^{-1} followed sugar beet and continuous wheat with 5222 kg ha^{-1} and 2530 kg ha^{-1} respectively. Wheat grain yields were not affected by tillage , averaging 4403, 4415, and 4393 kg ha^{-1}for CT, RT, and NT respectively. All the data obtained from the fields where wheat was grown continuously shows that the continuous WW rotation is not an effective method, whichever soil tillage method is used. The yields in all treatments decreased over the years. For the experiment, gross returns over total costs for the three tillage systems were measured (Table 2.). After sugar beet, CT was less profitable than the other two tillage systems. Continuous wheat is also less profitable than the rotation systems with other crops.

Table 2. Wheat grain yield by tillage systems and previous crops, mean market gross returns over production values and variable costs hectare for irrigated condition in CAP region.

Tillage Manegenet	Previous Crops	Yield (kg ha^{-1})	Production Value ($)	Variable Cost ($)	Gross Return ($)
	Wheat	2950	944,00	246,67	697,33
CT	Beans	5531	1769,92	173,33	1596,59
	Sugar beet	4727	1512,64	173,33	1339,31
	Wheat	2368	757,76	193,33	564,43
RT	Beans	5425	1736,00	160,00	1576,00
	Sugar beet	5452	1744,64	160,00	1584,64
	Wheat	2273	727,36	113,33	614,03
NT	Beans	5421	1734,72	80,00	1654,72
	Sugar beet	5485	1755,20	80,00	1675,20

A four-year period is not sufficient to see all the effects of soil tillage and rotation in these conditions. The three tillage systems were economically not equivalent based on market returns over total production. Economic analysis indicates that producers need to switch from conventional to reduced-tillage or no-till because those systems are more profitable. The no-till treatment with a proper crop rotation appears to be optimal in the conditions of this region.

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The impact of trash management and tillage on soybean productivity in sugar-based farming systems

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Introduction

Sugarcane producers are increasingly moving towards a new farming system based on legume rotations, trash retention, controlled traffic and reduced tillage. Soybean break crops significantly improve subsequent sugarcane productivity (Garside *et. al*. 1999), reducing plant pathogens and increasing numbers of beneficial biota (Pankhurst *et. al*. 2003). Retention of the sugarcane trash blanket produced when the crop is harvested green (the Green Cane Trash Blanket - GCTB) provides soil cover to reduce erosion and improve rainfall infiltration. It also increases soil carbon status (Bell *et. al*. 2001) and provides a carbon source essential for developing a soil microbial community that can suppress cane pathogens (Stirling 2008). Adoption of a reduced till / precision controlled traffic farming system can provide significant fuel and cost savings (Halpin e*t. al.* 2008).

Farmers rarely adopt all components of the new system in one step and dealing with 7-12 t trash/ha from the final cane harvest is a major hurdle preventing change. This is accentuated by the apparent need for multiple tillage operations to alleviate compaction sustained during the cane cycle, making trash incorporation and provision of adequate tilth for legume establishment in the short period between cane harvest and legume sowing difficult. Trash is therefore often burnt or baled and removed from fields to allow a reduction in tillage operations, with other producers employing aggressive tillage equipment such as rotary hoes to reduce the number of tillage operations between cane harvest and soybean planting.

Burning or removal of trash, or use of aggressive tillage equipment to speed trash incorporation and breakdown, reduces the chance of achieving many of the potential soil health benefits that adoption of the new farming system can deliver. Adoption of reduced or no tillage production systems will remain low until there are successful demonstrations of reduced tillage systems. This paper reports one such demonstration.

Materials and Methods

Factorial combinations of three trash management techniques and three tillage treatments were implemented on a 1.25ha paddock after harvest of 3rd ratoon sugarcane cv. Q151 in mid August 2009, prior to sowing a fallow soybean crop. The treatments were replicated 3 times in a randomised block design on a Red Kandosol soil (Australian Soil Classification) at a site approx 10km south of Bundaberg, in the coastal Burnett area of southern Queensland. The experimental unit was 5 cane rows wide by 25m length (39.25m^2).

The trash treatments consisted of either an undisturbed Green Cane Trash Blanket (GCTB), or a trash blanket that was raked and removed via a commercial hay baler (Baled) or burnt in-situ (Burnt), with treatments imposed mid September. Lime was applied at 4t/ha to ameliorate low pH in late September, and tillage treatments were imposed from late September to mid-November. The conventional tillage treatment consisted of two passes with a rotary hoe, followed by a deep ripping (approx. 35cm) and then another pass of a rotary hoe operation. The strip tillage treatment consisted of a coulter ripper with the tynes 70cm apart (35cm either side of the cane stool), followed by a high speed pass with a set of fluted coulters and then a crumble roller on the same zone as the ripper tyne. This provided a tilled zone of 30cm width either side of the old cane stool. The direct drill treatment had no mechanical tillage operations. Cane regrowth in the direct drill and strip till treatments were controlled by herbicide applications.

Soybeans were sown on 24th November using a planter that was specifically adapted to handle the large cane trash levels, with a large coulter followed by double-disc openers. Seed of cv. Fraser was metered via a vacuum plate system, with 83kg/ha used to establish a plant population of 325 000 plants/ha. Group H inoculant was applied to the seed and surrounding soil in the planting drill via water injection at 140L water/ha.

The soybean crop was irrigated by a travelling water winch, with irrigations scheduled once tensiometers at 25cm depth recorded a suction of 40Cbar. Broad-leaf weeds were controlled via herbicide applications (Acifluoren 224g/L and Imazethapyr 700g/kg). Insect populations were monitored twice weekly, with insecticides applied once populations reached spray threshold levels. The crop was desiccated with Diquat 200g/L10 days prior to harvest.

Treatment impact on soybean productivity was determined in two destructive samplings; one at 50% bloom, which occurred 42 days after sowing (DAS) and one when the crop had attained maximum biomass (113 DAS). Final grain yield was determined with a self-propelled small plot header at 148 DAS. Treatment effects on crop height and height of lowest pod were recorded.

All data was analysed using analysis of variance (ANOVA) procedures in the GenStat$^®$ (Version 11.1) statistical package. Significant differences were determined via pair wise testing between means using an LSD when the F test in the ANOVA was significant at P<0.05.

Results and Discussion.

The 2009/10 summer cropping season experienced close to average temperatures. December and January were characterized by dry seasonal conditions (73% and 45% of long-term average rainfall, respectively) whereas February and March were wetter than average (234% and 223% of long term average rainfall, respectively).

While the various trash management treatments provided a large range in trash loads, with the Burnt, Baled and GCTB treatments having 0.7, 5.2 and 14.1 t dm/ha, respectively, trash had no impact on any of the soybean establishment or growth parameters. Conventional tillage significantly lowered soil bulk density to 20cm depth compared to the direct drill treatments (0.931 and 1.150 g/cm^3 respectively) and significant effects of tillage were recorded on a number of crop parameters (Table 1). Crop establishment was significantly impacted by tillage, with strip tillage and conventional tillage establishing 17% and 23% more plants, respectively, than the direct drilled treatment.

There was a trend (p=0.066) for trash management to affect productivity at flowering with both the baled and burnt treatments producing 18% more biomass than in the GCTB treatment (data not shown), but this pattern was not evident later in crop growth. There was a significant tillage effect on soybean productivity at flowering with conventional tillage ≥ strip tillage > direct drill (Table 1). However these treatment effects were no longer evident at the time of sampling for maximum biomass or in grain yield at final harvest.

Table 1: Sugarcane trash management and tillage effects on soybean emergence, biomass, grain yield, plant height and height of lowest pod. There were no significant trash management or trash * tillage interactions for any parameter.

Tillage	Emergence	Biomass – flowering	Maximum biomass	Grain	Plant height	Height of lowest pod
	Plants/ha	t/ha			cm	
Conventional	335 430[a]	1.91[a]	10.81	4.63	78.2[a]	9.2[a]
Strip	318 450[a]	1.66[a]	10.06	4.58	72.8[a]	9.0[a]
Direct Drill	272 452[b]	1.31[b]	10.06	4.52	62.1[b]	7.3[b]
Lsd (0.05)	37 442	0.25	n/a	n/a	5.65	1.4

Despite the lack of treatment effects on crop yield there were significant effects on crop height and more importantly, height of the lowest pod (Table 1). Plants in the direct drill treatment were 16cm and 11cm shorter than in the conventional and strip tillage treatments, respectively. Similarly the height of the lowest pod in the direct drill treatment was 7cm above the ground, whereas in the other tillage treatments it averaged 9cm. The closer the pods are to the soil surface the greater the risk of the pods not being recovered by harvesting equipment and the greater the risk of grain being contaminated with soil and stained. Seed staining by contaminants such as soil are a major impediment in achieving the higher prices available in the more lucrative markets for human consumption.

This experiment demonstrates that there is no negative impact of sugarcane trash retention on subsequent soybean productivity. Similarly, reduced tillage after sugarcane harvest did not impact on soybean productivity, although there were suggestions that reduced plant height and height to the lowest harvestable pod in full direct drill systems may cause some issues with harvestability or grain quality. Commercial evaluation of strip tillage techniques are warranted, as this reduced tillage system effects and offers the opportunity to both improve soil health by reducing frequency and severity of tillage, while still alleviating compaction and maintaining soil cover. This system largely overcame issues of reduced crop establishment and slower early growth seen in the direct drill system, whilst maintaining soybean crop height to facilitate mechanical harvesting. Reduced tillage will become an increasingly attractive option to reduce production costs as fuel prices rise.

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Versatile multi-crop planter for two-wheel tractors: an innovative option for smallholders

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Keywords: bed planting, minimum tillage, strip tillage, zero tillage, power tiller

Introduction

The rapid spread of mechanisation on small farms in Asia has not yet led to the development of a range of low-cost planters for two-wheel tractors (2-WT) that can be used for minimum tillage (Baker et al., 2002). Such planters are needed to develop conservation agriculture (CA) practices on small farms, and in diverse cropping systems they need to be capable of operating in multiple planting modes and with a wide range of crops. The initial 2-WT based developments with zero tillage (ZT); single-pass shallow (up to 60 mm deep) full tillage (SPST), strip tillage (ST) and bed planting (BP) in Bangladesh were reported by Haque et al. (2004 and 2010) and Roy et al. (2009). Despite these promising developments, none of the present planters for 2-WT are capable of planting in all modes of tillage. The aim was to develop a planter that could be used in ZT; SPST; and conventional tillage (CT) with 4 to 8 tillage and 3 to 4 laddering operations by 2-WTs; and to shape permanent beds, when driven by 12-16 HP 2-WTs. A key aim of the development was for a planter on which setting up of blades, row spacing, seed depth and the calibration of seed and fertiliser rates could be accomplished quickly by the operator in the field. Incorporating features from a range of earlier planters for 2-WTs, a Versatile Multi-crop Planter (VMP) was designed with capability for seed and fertilizer application in lines.

Materials and Methods

The VMP was designed with capability for seeding with fluted roller or vertical plate seed and fertilizer meters in line planting for SPST, ST, ZT, BP, and for CT using full rotary tillage. The VMP was powered by a Chinese Dongfeng or Saifeng 12 HP 2-WT. The net weight of VMP is 152 kg and its overall dimensions are length 990 mm, width 1220 mm, and height 840 mm (Figure 1). The VMP is mounted on a 700 mm toolbar attached through side arms and connecting rods to the main handle of the 2-WT. This allows for seeding and fertilizing in four adjustable lines if row spacing is 200 mm and down to a single row in the case of maize sown in 600 mm beds. There is capacity for up to 32 blades attached by 8 brackets to a square shaft. Brackets are made to clamp onto the square shaft by two bolts. Both fluted roller and vertical plate seed meters can be fitted depending on the level of precision in seed placement required. The fertilizer box similar in design to the seed box and is fitted with four fluted meters with four flutes each for delivery fertilizers. Furrow openers are made from 2 mm steel sheet bent to 180 degrees with a round leading edge to help stubble clearance and attached on the toolbar by two U-clamps. A pressing roller is attached behind the furrow openers by a pair of arms. Bed shaping capability is added by bolting to each side of the pressing roller truncated cone set with a flat bar frame. By contrast with the standard rotary tiller that has blades bolted at fixed positions; the VMP has adjustable blade positioning. This was achieved by replacing the round shaft with a square shaft and then designing brackets that can slide across the shaft while holding two or four blades. The sliding of the bracket sideways without blade removal enables row spacing to be adjusted quickly in the field according the crop requirements. Hence the square shaft and brackets designed for the VMP achieve improved flexibility for multi-crop planting on a field-by-field basis. Data on seed and fertilizer rates calibration were determined using the equation of Michael and Ojah (1978). Data on wheel slippage and operating speed; theoretical field capacity; effective field capacity; and fuel consumption were determined according to the methods used by Haque et al. (2004). The VMP was widely evaluated in 16 districts in 1000s farmers fields for several tillage modes: up to four rows of ZT with furrow openers; ST with 16 blades attached on four brackets; SPST; two rows of crops on BP (60 cm) with 32 blades attached on eight brackets, and; CT with 16 blades attached on eight brackets. Initially a fluted roller was used to meter seeds and found to be suitable for delivering continuous seed flow, but not for evenly spaced seed in crops such as maize. However, if continuous seed dropping is preferred, the fluted rollers are satisfactory and cheaper.

Results and Discussion

Among tillage treatments, no significant difference was observed in case of chickpea emergence after seed metering using the fluted roller, however, significant improvement in plant establishment was observed with all one-pass planting methods in case of mung bean and with strip and zero tillage with black gram (Table 1).

Table 1. Established plant population (plants /m^2) using the fluted type seed meter on the Versatile Multi-crop Planter for sowing chickpea, mung bean and black gram with different tillage options in the High Barind Tract, Rajshahi, Bangladesh.

Crop	CT	SPST	ZT	ST	BP
Chickpea	56a	55a	47a	57a	31a
Mung bean	27c	145ab	121b	209a	101b
Black gram	22b	-	99a	93a	52ab

In a row, means followed by a common letter are not significantly different at 1 % level by Duncan's Multiple Range Test.

Field capacity under CT with higher speed (4th gear) was significantly higher at 0.11 ha per hour (Table 2), than for SPST, ST, ZT and BP which fluctuated around 0.06 ha per hour with lower speed (1st gear). Operation of the planter with lower speed for SPST, ST, ZT and BP was useful to make the row straight and allow seed and fertilizers uniform distribution. In the case of CT, the operator can ride to the 2-WT and that decreased the time losses for turning. However, for precise planting operator needs to go slower speed, turn the planter and place uniformly for make the straight row planting that increases the time losses. The SPST, ST, ZT and BP by VMP saved 38, 82, 50 and 13 % diesel fuel over CT (Table 2). Land prepared by VMP saved 50-68 % labour in land preparation, seeding and fertilizer application. The greatest savings were with SPST and ST, followed by ZT and BP (Table 2). The overall operational costs for SPST, ST, ZT, and BP were US$ 19.8, 10.3, 18.1 and 28.8 ha^{-1} which were 52, 75, 23, and 13 % (Table 2) lower than the CT method for chickpea, black gram and mung bean planting. The depreciation and repairs costs were not considered. To date a total of 45 units of VMP have been sold including 6 to international buyers in India and Vietnam; and eight private buyers providing services for planting crops in Bangladesh. Four VMPs service providers have been rented out the VMP to 656 farmers covered total 81 ha of wheat (32 ha in 237 farmers), maize (16 ha in 122 farmers fields), mungbean (13 ha in 101 farmers fields) and rice (11 ha in 80 farmers fields).

Table 2. Effect of tillage mode by the Versatile Multi-crop Planter on fuel consumption, field capacity, labour requirement in land preparation and seeding of chickpea, mung bean and black gram in clay soil at High Barind Tract, Rajshahi, Bangladesh (data in brackets refer to % savings relative to CT).

Tillage type	Field capacity (ha/hour)	Fuel consumption (l/ha)	Labour requirement, (person-hours/ha)	Cost of land preparation and seeding[§] (US$/ha)
CT	0.11a	33.1a	48.1a	41.5a
SPST	0.07b	20.6c (37.7)	15.4c (68.1)	19.8d (52.3)
ST	0.07b	5.83e (82.4)	15.3c (68.3)	10.3d (75.2)
ZT	0.06b	16.6d (49.8)	17.3c (64.0)	18.1c (23.4)
BP	0.05b	28.9b (12.6)	23.9b (50.5)	28.8b (12.7)
Probability (<1% level)	**	**	**	**

[§] Considering variable costs for labour and diesel fuel.

Conclusion

The VMP is a unique multi-functional and multi-crop planter powered by 12-16 hp 2-WT with capability for seed and fertilizer application in variable row spacing using single-pass shallow-tillage, strip tillage, zero tillage, bed planting, and conventional tillage. The square shaft and brackets designed for the VMP achieve improved flexibility for multi-crop planting and capacity for rapid adjustment of row spacing on a field-by-field basis. Planters such as VMP could be used to develop CA practices across a wide range of cropping systems used by smallholder farmers in Asia, Africa and other regions.

Acknowledgements

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Conservation tillage improves soil properties and crops yields in North China

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Keywords: conservation tillage, soil property, yield

Introduction

China has 33Mha arid and semi-arid land which is largely located in the 16 provinces of North China. In dryland farming of these areas, wheat (*Triticum aestivum*) and maize (*Zea mays* L.) are the main crops that are constrained by adverse weather, water shortage and poor soil fertility. In current cropping system, all the crop residues are removed or burned after harvest before mouldboard ploughing. However, these practices have contributed to an exacerbation of soil, water and nutrient losses. The severe land degradation and serious environmental problems have led the Chinese government to emphasize the need for the implementation of farming practices which contribute to the conservation of soil and water. A vital approach is the use of conservation tillage, which is defined as any tillage and planting system that leaves 30% of crop residue on the soil surface after planting. The Chinese Ministry of Agriculture has promoted the widespread extension of conservation tillage since 2002, and by the end of 2009, the conservation tillage area in China was over 3Mha. This paper reports the impacts of conservation tillage on soil properties and crop yields in dryland farming areas in North China.

Materials and Methods

The long-term experiments were conducted at Linfen (1992-2007) on the Loess Plateau one crop/year region, Beijing (2000-2007) of North China Plain (NCP) two crops/year region (2000-2007) and Farming pastoral ecotone at Wuchuan (1998-2008). In all these experimental sites, two tillage treatments were evaluated: conservation tillage (CT) and traditional tillage (TT). TT includes mouldboard ploughing to a depth of 10-18cm, followed by harrowing, hoeing, rolling and levelling. All the residues in the fields were manually removed before ploughing.

Results and Discussion

In northern China, long-term CT was effective in improving soil fertility as compared to TT (Table 1). The mean soil organic matter (SOM) in 0-10cm soil layer for CT was 21.7% and 10.5% higher than for TT in Linfen (after 16 years) and Beijing (after 8 years). In Wuchuan, the mean SOM in the 0-10cm layer was 16.5g/kg for CT after 10 years, which was significantly greater than the 13.4g/kg observed on TT. The SOM difference between CT and TT declined in the deeper layers, but were still significant at 20cm depth. The SOM increases resulting from conservation tillage are attributed to the greater straw input and reduced biological oxidation associated with less soil disturbance. Tillage-induced changes in soil organic N are directly related to changes in soil organic C. In Beijing, total N (TN) in 0-10cm and 10-20cm layers was 24.3% and 18.6% higher for CT than for TT after 8 years. In Linfen, after 16 years, TN in the 0-10cm layer under CT increased by 51.5% compared to TT. Below 10cm, the TN differences were not significant. A similar result was found in Wuchuan after 10 years of CT management. After long-term CT management, the available P was 56.3%, 48.5% and 10.5% higher than under TT in the 0-10cm soil layer in Linfen, Beijing and Wuchuan, respectively. In the 10-20cm layer, the P content was 54.1% and 17.8% lower under CT than under TT in Linfen and Wuchuan, respectively. The topsoil accumulation of P in conservation tillage is attributed to the limited downward movement of particle-bound P in soils and the upward movement of nutrients from deeper layers through nutrient uptake by roots.

Table 1. Soil organic matter, total N and Available P in 0-20cm soil layer for CT and TT in Linfen (16 years), Beijing (8 years) and Wuchuan (10 years).

Sites	Treatment	Organic matter (g/kg)		Total N (g/kg)		Available P (mg/kg)	
		Soil depth (cm)					
		0-10	10-20	0-10	10-20	0-10	10-20
Linfen, Loess Plateau (Wang et al. 2008)	CT	18.2a	11.1a	1.03a	0.67a	35.0a	10.5a
	TT	15.0b	13.8b	0.68b	0.66a	22.4b	22.9b
Beijing, North China Plain (Zhang et al. 2009)	CT	16.5a	15.9a	1.38a	1.02a	20.2a	16.9a
	TT	14.9b	14.0b	1.11b	0.86b	13.6b	13.9b
Wuchuan, farming pastoral ecotone (He et al. 2009a)	CT	16.5a	9.6a	0.52a	0.30a	17.9a	8.3a
	TT	13.4b	7.4b	0.42b	0.24a	16.2b	10.1b

Values within a column in each experimental site followed by the same letters are not significantly different (P>0.05).

In Linfen, Beijing and Wuchuan, bulk density to 30cm depth was 2.2%, 1.2% and 2.8% lower for CT than for TT, indicating long-term conservation tillage can eliminate hard pan, due to the increased soil organic C and biotic activity after long-term CT practice.

Long-term CT can improve the percentage of water-stable aggregates of the largest size class (>2mm) and reduce the percentage of water-stable aggregates of the smallest size class (<0.25mm). In Wuchuan for example, soils under CT contained more macro-aggregates (13%-37%) than those under TT in 0-30cm depth. The percentage of micro-aggregates was 25%-59% greater in TT. The higher macro-aggregates can be attributed to the greater biological activity and a reduction in breakdown of surface soil aggregates in no-tillage and residue cover soils.

Many studies have evaluated the effects of tillage practices on crops yields in North China. For wheat, Chen et al. (2008) showed that the mean (1999-2006) yield of CT being 9.3% greater than that of TT in Loess Plateau. In 3 out of 8 years, CT showed significantly higher yield than TT (P<0.05) (Table 2). In Northwest China, He et al. (2008) showed that the mean (2005-2007) yields in conservation tillage of 5.6% higher than that in traditional tillage. For maize, He et al. (2009b) conducted a 2 years (2002-2003) experiment in Dingxing of North China Plain and found that in the first growing season of 2002, conservation tillage produced yield that were 5.7% higher than on traditional tillage. In the second growing season of 2003, conservation tillage again increased 6.8% of mean yield in comparison with traditional tillage. In Beijing, Zhang et al. (2009) also showed that mean (2004-2007) yield for summer maize in conservation tillage was 138kg/ha (3.24%) higher than that in traditional tillage. The significant contribution under conservation tillage can be attributed to increased soil water storage, combined with the changes in soil bulk density, water stability of aggregates and fertility. Implementation of CT farming practices has been very beneficial in improving degraded soils, as well as promoting food security in North China.

Table 2. Winter wheat yield (t/ha) for conservation tillage (CT) and traditional tillage (TT) in Linfen of Loess Plateau (1999-2006), Chen et al. (2008).

Treatments	1999	2000	2001	2002	2003	2004	2005	2006	Mean
CT	3.27a	2.48a	3.08a	3.68a	3.51a	4.01a	2.71a	4.43a	3.40a
TT	3.79b	1.46b	2.91a	3.52a	3.64a	4.12a	1.91b	3.50b	3.11b

Means within the same column followed by the same letters are not significantly different (P>0.05).

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Crop residues, an effective tool for improving growth of wheat and suppression of some associated weeds

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Keywords: Crop residue, Wheat, Weed, Allelopathy.

Introduction

The primary objective of weed control treatments is to increase the yield per area with minimum expenditure. There is much emphasis on new methods of weed control that are safe and less expensive, and use farm-produced materials. Allelopathy has emerged as an important area of weed research and has been accepted very recently as important ecological phenomena. Allelopathic plants for example sorghum, sunflower and oats, contain a number of allelochemicals that in low quantity act as hormones and in high amount as herbicides (Ali et al., 2004). Allelopathic crop plants not only control weeds but can also enhance crop growth and yield. Sorghum and sunflower are important summer crops in Egypt. After their harvest, large quantities of residues remained in the field and are usually burnt, which leads to further pollution of the agricultural environment. Considering the importance of sorghum and sunflower in cropping systems, we studied the possibility of using sorghum or sunflower residues for weed control in wheat field.

Material and Methods

Allelopathic effects of chopped–sunflower and sorghum shoots and roots on germination and growth of wheat cv. Sakha 69 and three common weeds were determined in a greenhouse at the National Research Centre. After sunflower and sorghum head harvest, uprooted plants were dried at room temperature for 15 days and then chopped into 1-5 cm pieces with an electric fodder cutter. This material was mixed with clay loam soil (w/w) at 2, 4, 8 and 12 (%) preparations. Plastic pots 12-cm diameter and 8-cm depth were filled with this mixture, while control pots were filled with soil only. Fifteen seeds of wheat, ten seeds of wild oats and cannary grass and 5 seeds of burclover were sown per pot in a completely randomized design, with three replicates. Water was added whenever required to avoid water stress. Seedlings numbers were was counted at one-week interval till 60 days after sowing. The final germination of all tested species was calculated. Plants were uprooted at 60 days after sowing and weighed immediately to determine fresh weight, then dried in an oven at 70 ^{o}C till constant weight to record their dry weights (g/pot).

Results and Discussion

Soil incorporation of all residues substantially decreased seedling number and dry weight of wheat and weed species except sunflower root residue on wheat, which produced a slight opposite effect. (Figures1- 4). Residue of both crops exhibited selectivity in their effect on weed species, where sorghum residue inhibited seedling numbers and dry weight of grassy weeds (canary grass) more than sunflower. Sunflower residue depressed broad-leaved weed (burclover) more than sorghum residue. These residues substantially reduced seedling numbers and dry weights of weeds (at 60 days after sowing). Sorghum shoot residues gave greatest reductions in seedling numbers and dry weights of wild oats (43.55% and 62.90%, respectively) and canary grass (72.00% and 73.08%, respectively) as compared with control treatments (Figure 2 and Figure 3). Incorporation of sunflower root residues achieved highest depressions in seedling number and dry weights of burclover (90.14% and 82.76%, respectively), compared to untreated control (Figure 4). Of the allelochemicals identified in crop residues, we found that O-coumaric (stem), m-coumaric (leaf), salicylic (leaf) and cinnamic acids were found only in sunflower (root, stem and leaf) extracts, while protocatechuic (stem) and benzoic acids were identified only in sorghum (leaf and root) extracts.

These results indicate that allelopathic effects differ with plant parts, sensitivity of receiver species and residue concentration, and this might be attributed due to selectivity of various allelochemical compounds and their concentration released from plant residue into soil. Hall et al., (1982) reported that the allelopathic effects of sorghum and sunflower have bean attributed to phenolics, mainly cinnamic acid derivates, ferulic, p-coumaric, chlorogenic and isochlorogenic acids, and their potency is concentration- dependent (Einhellig, 1985), and differs among cultivars (Woodhead, 1981). Selective allelopathic effects of crop residues have also been observed by Leather (1983) and their concentration-dependence by Sorour (2001). More recently, Hozayn (2008) and Hozayn et al., (2011) noted similar effects in wheat and lentils, and some weeds.

Conclusion

This study shows that sorghum and sunflower residues can suppress the growth of some weeds associated with wheat, and this eco-friendly weed management approach depends on the maximum levels of phytotoxins entering into the soil to reduce early growth and development of these weeds. Field studies are needed to evaluate suppressive efficacy of residues under natural conditions, and the allelopathic role of sorghum and sunflower in rotations to manage the spread of these weeds.
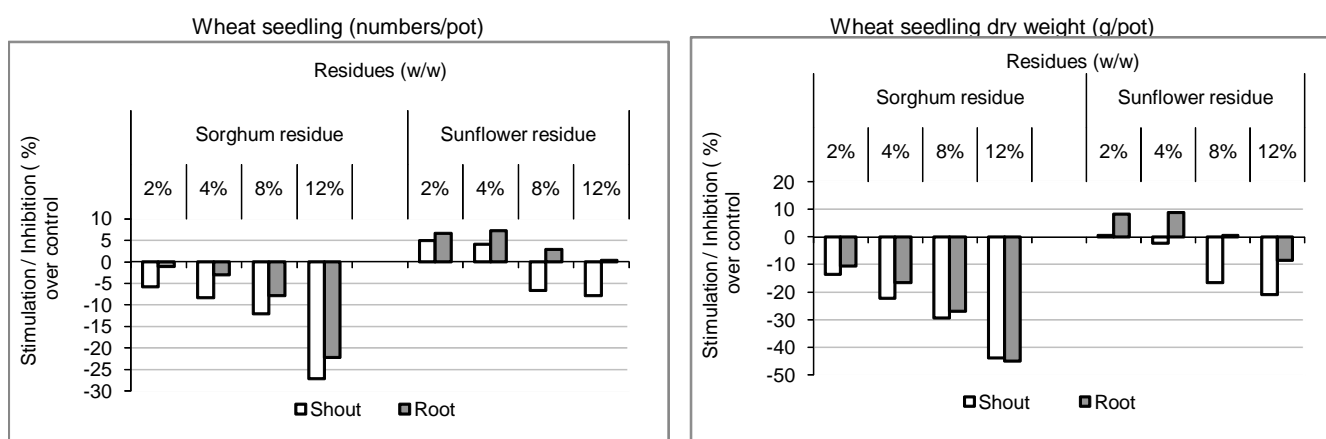
Fig. 1. Stimulation or inhibtion percentage of sorghum and sunflower residues on the growth of wheat at 60 days after sowing.
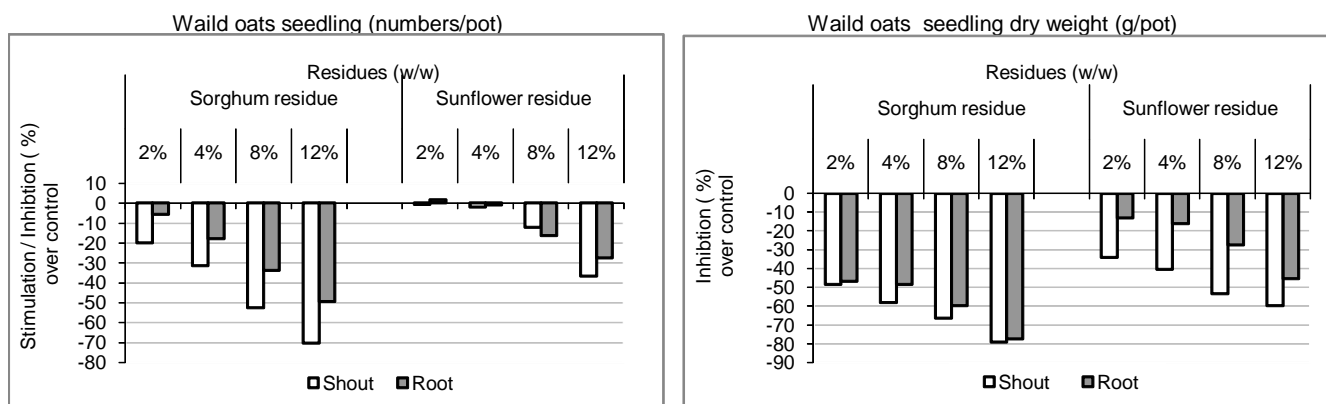
Fig. 2. Stimulation or inhibtion percentage of sorghum and sunflower residues on the growth of waild oats weed at 60 days after sowing.
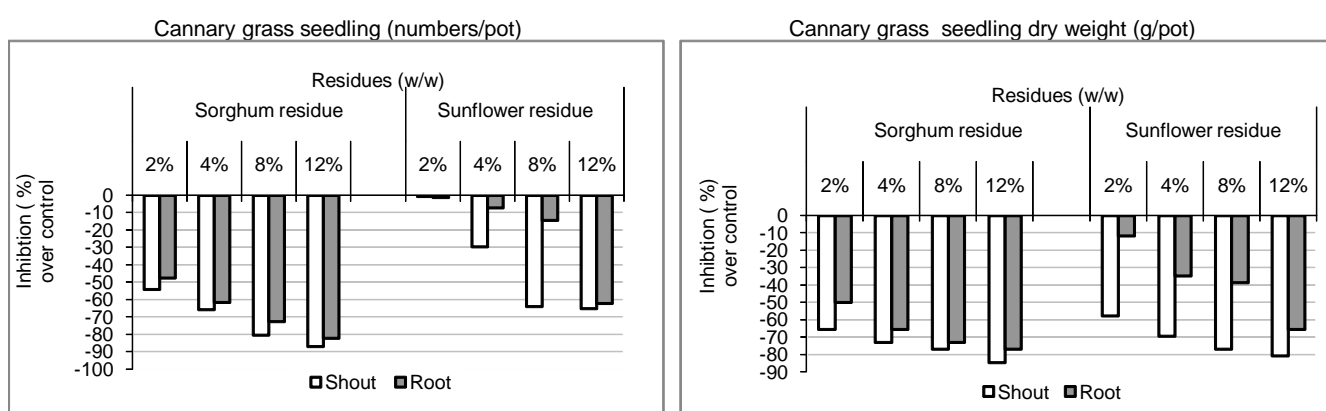
Fig. 3. Inhibtion percentage of sorghum and sunflower residues on the growth of canary grass weed at 60 days after sowing.
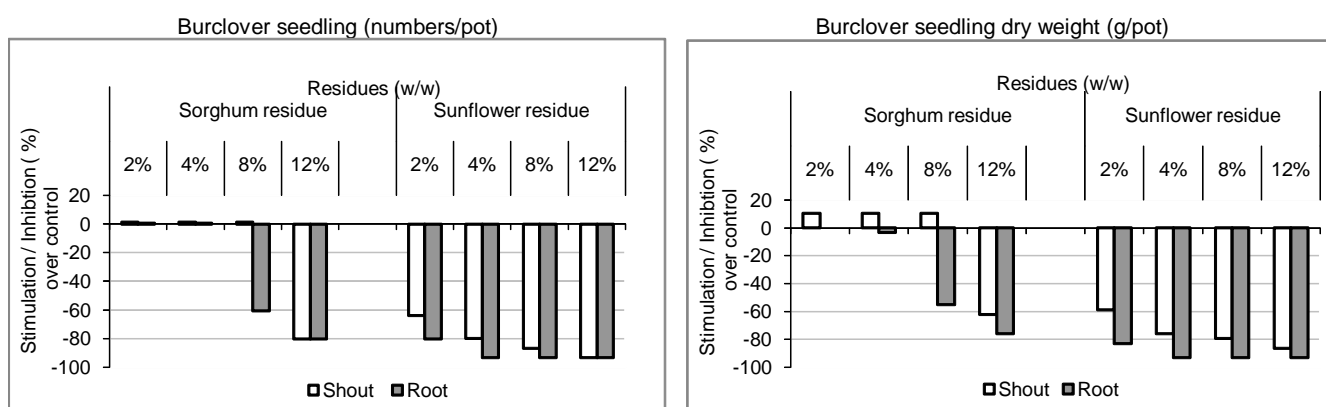
Fig. 4. Stimulation or inhibtion percentage of sorghum and sunflower residues on the growth of burclover weed at 60 days after sowing.

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Advanced design of permanent raised bed machinery in Pakistan

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Keywords: Agricultural Mechanization, PRB machinery, Seeder performance, Pakistan agriculture,

Introduction

In the 1950s mechanical power use was introduced in agriculture of Pakistan in the shape of tube-wells, during the mid 1960s tractor and tillage equipment were launched. Currently, 593,334 tractors are available in the agricultural sector, and 23.8 million hectares of land is under cultivation, whereby one tractor cultivates an average 47.6 hectares. 310,524 tractors (46-55hp) are available to farmers which is 77% of the total. Out of 6.62 million farms, 19.5% are under 0.5 hectares, 16.5% between 0.5 to 1.0 hectares and 21.5% between 1.0 to 2.0 hectares. To fulfil the food requirement of the 173.38 million population of Pakistan the per capita availability of agricultural land is 0.14 hectare, and is going down day by day. Consumption of petroleum production in agriculture sector was 109,400 tonnes in 2008-09. The agriculture contribution to green house gas emission is 39% of which Carbon dioxide contributes 54%, Methane 36%, Nitrous oxides 9% and other gases 1%.

The machinery available on farm is given in Table 1. Keeping in view the above information Pakistan needs conservation agriculture through mechanization supported by Pakistan's available tractor horsepower (46-55 hp) and available farm size. Timely ploughing and seed bed preparation are not possible without tractors. Conservation agriculture means to minimize soil disturbance, maximise retention of previous crop residue and improve crop rotations with maximum profitability. A main attraction of conservation agriculture is cost - effectiveness with up to 15% savings on operational cost.

Table 1: Levelling and cultivating implements owned by tractor owners
(NB: 593,334 tractors are available in the agricultural sector)

	Blade	Culti-vator	Mould-board Plough	Disk Plough	Chisel Plough	Ripper/subsoiler	Rotovator	Disk harrow	Ridger	Laser leveller
Total	233,126	369,866	40,050	29,218	8,514	1,655	47,919	23,764	71,338	2,785
Govern-ment	893	563	224	179	97	7	173	155	107	181
Private	232,233	369,303	39,826	29,039	8,417	1,648	47,746	23,609	71,231	2,604

Tractor mounted Permanent Raised Bed (PRB) machinery was introduced in Pakistan in 1998 by an Australian government funded project. The PRB machinery shows very good results it has two parts namely a bed shaper and a no-till seeder. This machine is a good example of effective mechanization because it saves water, time and labour, improves grain yield and achieves a uniform distribution of seed and fertilizer. After 13 years of promotion, farmers are now familiar with raised bed technology, and are using different types of raised bed machinery while some farmers are using PRB machinery, especially in Khyber Pakhtonkhwah (KPK) and some part of Punjab. The PRB technology has proved its success but in Pakistan, our tractor horse power (46-55 hp) and the small farm size are obstacles to broad use of such machines suffering from high weight and cost. Therefore, we developed an advanced PRB machinery design which is low cost and light weight as well as versatile in its use.

Materials and Methods

After the completion of a three year national project on permanent raised beds, a survey was conducted in all components of the project in Pakistan to evaluate the performance and working of PRB machinery. All farmers agreed that machinery is working very well and its results are very encouraging. They are getting more benefits as compared to traditional farming system. Particularly, 90% farmers related two key observations, namely i) two separate operations (bed making with bed shaper and sowing with no-till seeder) and ii) cost of the machinery (Rs. 320000/PRB machinery set). Pakistani farmers have very small land holdings with low economic affordability of the PRB machinery even with subsidies, petroleum prices are now very high and they cannot easily afford two operations for crop sowing on beds.

Following the survey, an advanced design of PRB machinery (ADPRB) was developed (Figure 1) and this multipurpose machinery responding to the farmer requirements is now tested and approved for distribution. The ADPRB have all abilities of PRB machinery combined in a single operation, it can achieve an adjustable bed size from 90cm (single bed) to 25cm (double bed), plant six rows of wheat and rice and two rows of maize and cotton on a 90cm bed and two rows of wheat and rice and one row of maize and cotton on a 25cm bed. The machinery is capable for maintaining the row to row distance and also plant to plant distance according to the crop requirement (see Figure 2, Figure 3, and Figure 4).

The ADPRB machine comprises four parts, namely i) the front bar with three furrow openers, two blades and one shaft with four cutters (NB: the cutters are used for hoeing on beds between rows of cotton and maize), ii) fertilizer and seed boxes, a shaft with five cutters and one roller, iii) six tines with double disk furrow openers for wheat and rice seed and iv) a precision seed metering system for maize and cotton to maintain plant to plant distance. The blades and cutters are used for renovation and reshaping of beds. The bed renovation and reshaping, sowing of crop and distribution of fertilizer are all performed in a single pass using the ADPRB machine. The cost of this machine was calculated as Rs. 120000, which is affordable for all types of farmers in Pakistan. A study was also conducted on wheat crop sowing with this machine at Gujjar farm, Haripur, KPK. Wheat was sown on raised beds with six rows at the end of December 25th 2010 to assess the ADPRB machine performance and operation.

Results and Discussion

The results show that farmers are now interested in purchasing the ADPRB machine because of its low cost and within the 15 days of display of ADPRB machine 20 farmers placed orders to purchase the ADPRB machine (i.e. 10 from in KPK, 5 from in Balochistan, and 5 from in Sindh) but due to financial constraints, the project is unable to meet the orders. The results revealed that six rows of wheat on 90cm bed germinated very well as shown in Figure 2. Fuel consumption for sowing was also less as compared with previous PRB machinery, the

results also show that grain yield was 2,370 kg/ha as compared with flat sowing on basin irrigation system which was 1,580 kg/ha, a 33% yield increase. The grain yield was very low due to late sowing at the last week of the December 2010; even then the crop on raised beds was better than drill sowing on flat field. Results shows that due to its light weight of the three point linkage mounted ADPRB machine, a 55hp tractor easily operates the machine and the tractor driver is satisfied with its performance. We are now working on some more improvements to the ADPRB machine to make it more efficient. A comparison of the PRB and ADPRB machines is given in Table 2.

Figure 1: View of ADPRB machinery

Figure 2: Six wheat seed rows established on PRB

Figure 3: Maturing wheat crop on six row PRB

Figure 4: Field test of cotton seed dropping

Table 2. Comparison of PRB and ADPRB machine specifications

Inputs	PRB	ADPRB
Bed Making	Yes	Yes
Sowing	Yes	Yes
Renovation	Yes	Yes
Furrow Depth	Adjustable	Adjustable
Seed rate	Adjustable	Adjustable
Number of operations for Renovation and sowing	2	1
Row to row distance	Yes	Yes
Plant to plant distance in cotton and maize	No	Yes
Hoeing in cotton and maize	No	Yes
Weight	350 and 450 kg	175 kg
Cost	Rs. 320000/-	Rs. 120000/-

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Carbon sustainability and productivity of maize based cropping system under Conservation Agriculture practices in Indo- Gangetic plains

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Introduction

Tillage practices contribute greatly to the labour cost in modern intensive agriculture in any crop production system resulting in lower economic returns, especially in developing countries where there is most concern for sustainable production without degradation of the natural resource base (Jat et al., 2008). The traditional practice of growing these crops has limitations such as inconvenient input management when sown by broadcasting: improper plant geometry; uneven plant population resulting in inefficient utilization of space; and plant competition leading to low productivity and input efficiency. Shortage of water, labour and energy resources, together with inappropriate crop management practices and the adverse effects of conventional tillage on the carbon based sustainability index, as well as declining profit margins, are forcing farmers of Indo-Gangetic Plains (IGP) to switch over to conservation agriculture practices. Conservation agriculture with diversified maize-based cropping systems by inclusion of legume crops in sequence helps to overcome the major challenges viz. declining factor productivity and deterioration of the resource base, and also plays a vital role in sustainable agricultural production. Adoption of no-till practice helps in timely seeding of either of the crops, and hence leads to increase in productivity of different maize-based cropping systems. In the present study four cropping system were evaluated under three different tillage and crop establishment practices to assess the system productivity, carbon inputs and outputs and carbon based sustainability index. The study aims to develop conservation agriculture practices to increase the sustainability of the maize-based cropping systems in the IGP.

Materials and Methods

Keeping in view the above mentioned facts a field experiment was initiated during *kharif* (summer) 2008 at the Directorate of Maize Research (DMR) farm, New Delhi. The data reported are from the 2008-09 and 2009-10 seasons of an established long-term experiment. Soil of the experimental field is sandy loam in texture having initial pH 7.8, low in available nitrogen and medium in available phosphorus and potassium. The experiment consisting of three tillage and crop establishment methods viz. (i) Permanent Beds (PB), (ii) Zero Till (ZT), (iii) Conventional Till (CT) with four maize based cropping systems i.e. (i) Maize-Wheat-Mungbean, (ii) Maize-Mustard-Mungbean, (iii) Maize-Chickpea-*Sesbania,* (iv) Maize-Maize-*Sesbania* in three replications was initiated during *Kharif* 2008. In *Kharif and Rabi* season maize hybrid HQPM-1 was sown. In the *Rabi* (winter) season (cv. PBW-343), mustard (cv. Pusa Bold) and chickpea (cv. Gram-P-362) were sown as per treatments. A multi-crop planter and a multi-purpose no-till seed-cum-ferti planter were used for planting of the different crops under investigation. Two rows of wheat, chickpea, mustard, mungbean and one row of maize were planted on the permanent beds having furrow to furrow width of 67cm. In conventional till system, the maize, mustard and wheat were planted after four ploughings whereas chickpea and mungbean were planted after two ploughings.

Sustainability of the maize-based cropping systems under the different tillage management practices was calculated by using the carbon sustainability index, the ratio of difference between total carbon output and input to the total carbon input. Total carbon input was calculated as the sum of the carbon equivalent of all inputs used under different tillage management practices in maize based cropping systems i.e. tillage operation, seed, irrigation, fertilizer, pesticide, harvesting, threshing etc. Total carbon output was computed as the sum of the carbon equivalent of grain, straw and root biomass produced by the crop. Globally prescribed values by different scientists were used for calculation of carbon equivalent of inputs as well as outputs. The carbon sustainability index and carbon efficiency of different tillage practices and cropping systems was calculated as per the formula of Lal (2004) shown below:

$C_s = (C_o - C_i) / C_i$

$CE = C_o / C_i$

where; C_s= sustainability index, CE= Carbon efficiency, C_o= Carbon output and C_i= Carbon input

Results and Discussion

The system productivity in terms of maize equivalent yield was influenced significantly due to different tillage practices and various cropping systems under study. The results revealed that permanent bed planting resulted in maximum system productivity during both the years of investigation compared to zero till and conventional till (Table 1). In permanent beds better aeration and high infiltration rate with less weed infestation and crop root penetration resistance resulted into better plant growth and yield. Among the various maize-based cropping systems Maize-Wheat-Mungbean resulted in maximum system productivity in both the years. This system involves a grain legume which not only contributed to increased yield, but also helps maintain soil health which in turn improves system productivity. The carbon-based sustainability index (CSI) and carbon efficiency (CE) was significantly higher under permanent beds compared to zero and conventional till (Table 1). Both carbon inputs and outputs were markedly influenced by the tillage management practices under study. Across the systems CSI and CE declined in the order of Maize-Maize-*Sesbania*> Maize-Chickpea-*Sesbania*> Maize-Mustard-Mungbean>Maize-Wheat-Mungbean during first year and Maize-Chickpea-*Sesbania*>Maize-Maize-*Sesbania* >Maize-Wheat-Mungbean> Maize-Mustard-Mungbean. Inclusion of two maize crops in a year resulted in higher CSI and CE, reflecting the ability of the crop to sequester more carbon than other crops and resulting in more sustainable cropping, based on CSI. Dubey and Lal (2009) also reported that tillage practices and production systems have significant effects on CSI and CE. The productivity of various crops and their CSI under maize-based cropping sequences having different degrees of correlation ranging from R^2=0.309 in chickpea to R^2=0.991 in mustard (Figure 1).

Conservation agriculture based resource conservation technologies lead to significantly higher system productivity, CSI and CE irrespective of the various maize-based cropping systems. However, the greatest system productivity was achieved maximum under Maize-Wheat-Mungbean when planted on the permanent beds.
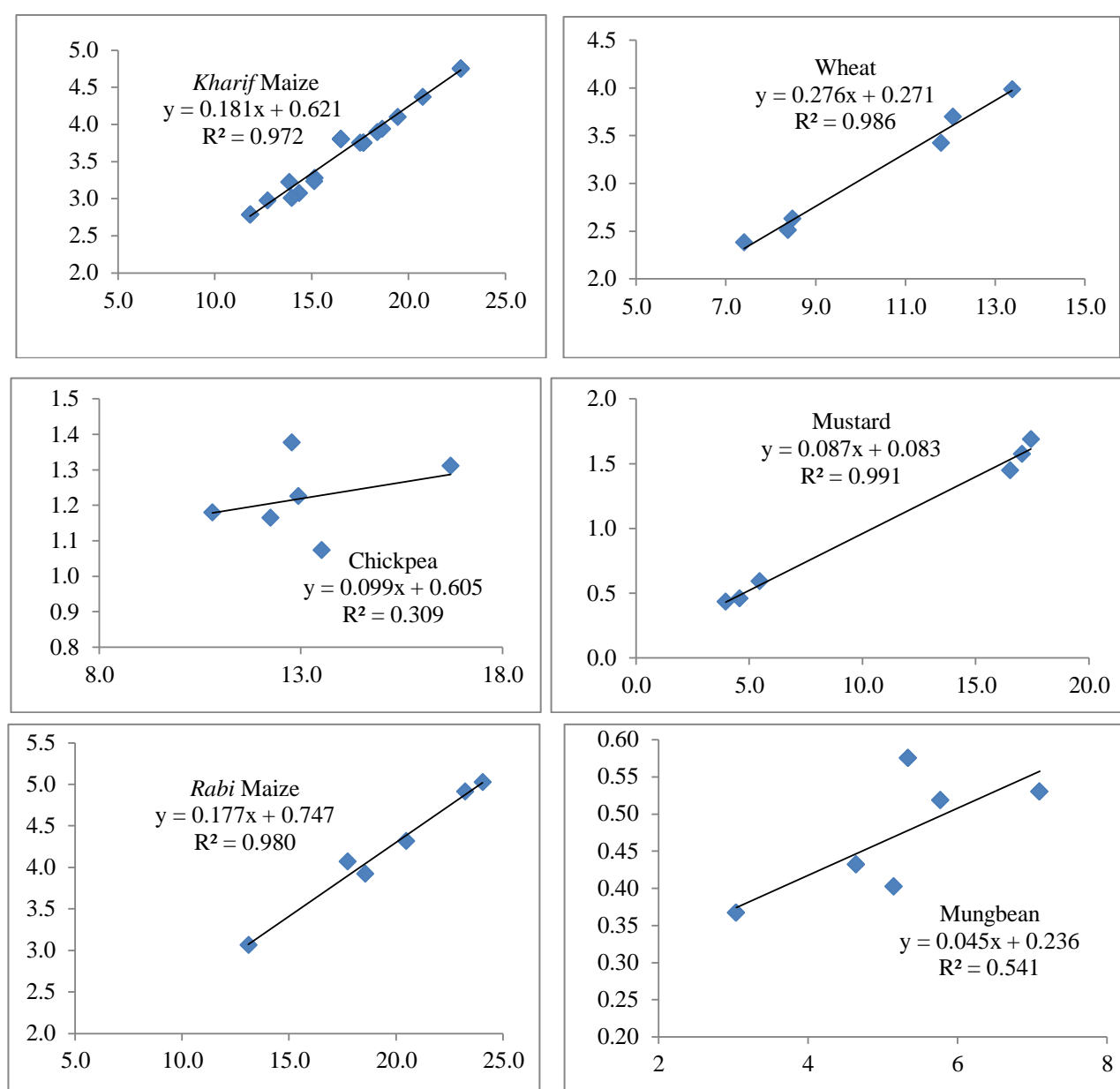
Figure 1. Correlation between crop productivity (Y-axis) t/ha and carbon sustainability index (X-axis) in maize based cropping system under various tillage practices

Table 1. System productivity and carbon sustainability index of different maize base cropping systems under different tillage practices

Treatments	System productivity (kg/ha)		Carbon sustainability index (CSI)		Carbon efficiency (CE)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Tillage practices						
Zero till (ZT)	8146	7661	14.9	13.8	15.9	14.8
Permanent Beds (PB)	8828	8238	16.4	14.2	17.4	15.2
Conventional Till (CT)	7680	7322	13.2	11.7	14.2	12.7
Cropping systems						
Maize-Wheat-Mungbean	8925	10108	11.7	11.5	12.7	12.5
Maize-Chickpea-*Sesbania*	7198	6974	16.3	15.7	17.3	16.7
Maize-Mustard-Mungbean	8687	6026	14.9	10.4	15.9	11.4
Maize-Maize-*Sesbania*	8062	7854	16.4	15.3	17.4	16.3

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Carbon footprint of crop production due to shift from conventional to Conservation Agriculture

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Introduction

Acute shortage of conventional energy sources has led to increasing dependence on non-conventional sources. But the safety concern of nuclear power plants which is thought to be main alternative source of energy, especially after tsunami and earthquakes in Japan during early 2011 which caused great damage to power plants. In developing country like India where 67% of the population depends on agriculture,, contributing 28 % of GDP it becomes necessary to think about either saving conventional sources of energy or producing energy by non- conventional means with highest safety standards. Agriculture in developing countries is already under pressure from growing populations, industrialisation and environmental degradation. Climate change is expected to exacerbate and add to these problems. There is also a need for diversification and intensification of cropping system with lower energy consumption when per capita availability of land is decreasing.

Energy used on farms can be categorised as direct and indirect energy. The energy which is directly required for various farm operations can be termed as direct where as indirect energy is required for production of different farm inputs, such as commercial fertilizers, pesticides, herbicides etc. The amount and type of energy used in agricultural operations affect overall CO_2 emissions and generally CO_2 levels increase with higher energy use. CO_2 emitted either directly from soil as soil respiration or indirectly due fuel or electricity consumption can be curtailed by changing agronomy, nutrient management, tillage/residue management, water management etc. Improved agronomic practices increase yields and generate inputs of carbon residue and can therefore increase soil carbon storage (Follett, 2001). Reports of minimum or no till effects on soil carbon are mixed (West and Post, 2002; Ogle et al., 2005; Gregorich et al., 2005), but conservation agriculture practices of zero or minimum tillage, crop residue retention and cropping system management as key components can conserve energy in crop production.

There is a need to estimate the change in energy requirement for crop production due to shift from conventional to conservation agriculture. Since cereal based cropping systems are the most popular in India an experiment has been planned with different cropping systems in old alluvium non-calcareous non-saline soil of Patna, India, under Cereal System Initiatives for South Asia project.

Methods

To estimate the amount of direct energy needed for crop production the carbon footprint principle has been applied. Carbon footprint is the sum of all emissions of carbon dioxide which were induced by activities in a given time frame. It is the best way to calculate carbon dioxide emissions based on fuel consumption.

Large plots, each of 1900 m^2 have been used in a trial to assess four cropping scenarios with three replications at Sabajpura research farm of Indian Council of Agricultural Research-Regional Council of Eastern Region, Patna (India). Each scenario is a combination of cropping system, crop residue management and tillage operation. Scenario 1 (S1) is the conventional practice followed by most farmers in this region. A small group of farmers now practices recently developed agricultural technology which include zero tillage in wheat (November – April) and puddled transplanted rice during rainy season (June – November). They also take green gram as cover crop during summer season. This is a system that has been practised for scenario 2 (S2). Conservation agriculture practices are used in scenario 3 (S3), where in addition to zero tillage rice and wheat, zero tillage cowpea is grown as a summer legume crop. To meet the growing demand of food diversification and intensification of cropping system a 4th scenario (S4) has also been examined. This has direct seeded rice in the rainy season, potato and maize in winter and cowpea as relay cropping in summer.

Direct use of energy in crop production mainly consists of energy required in tillage and irrigation. When there is a shift from conventional to other agricultural practices there may be a change in energy requirement for crop production. Hence energy consumed in tillage and irrigation was estimated in the four scenarios during rainy and winter seasons. The efficiency of crop production lies in putting less fossil fuel energy into production for a given level of output.

Results and Discussion

During winter 2009-10, equivalent CO_2 emission due to tillage operation was highest in S1 which was 400% more than that of minimum equivalent emission plot of S3 (Figure 1). S4 had significantly more emission than S1 due to mixed cropping of potato and maize. For irrigation it was 20% more emission than S3 (Figure 2). In this case also S4 had highest energy requirement. Wheat yield of S3 was 43% more than S1 where as wheat equivalent yield of S4 was 351% more than of S1. In rice it was found that equivalent CO_2 evolution from diesel consumption for tillage operation in S1 and S2 were at par (Figure 3). Similarly it was at par in S3 and S4. But zero tillage direct seeded rice in S3 and S4 could save 525 and 348% equivalent kg CO_2 ha^{-1} respectively as compared to conventional tillage rice in S1 and S2. Puddled rice in S1 emitted highest equivalent kg CO_2 ha^{-1} for irrigation by electricity which was19 % more than in zero tillage direct seeded rice of S3 (Figure4). S4 had the lowest emission , perhaps due to greater recycling of crop residues. Irrigation water required in S1 and S2 were at par. Highest rice grain yield was found in S4 which was 30% higher than S1.

Fig.1: Equivalent CO_2 (kg ha-1) required for tillage in wheat production in different scenarios during 2009-10

Fig.2: Equivalent CO_2 (kg ha-1) required for irrigation by electricity during wheat production in different scenarios (2009-10)
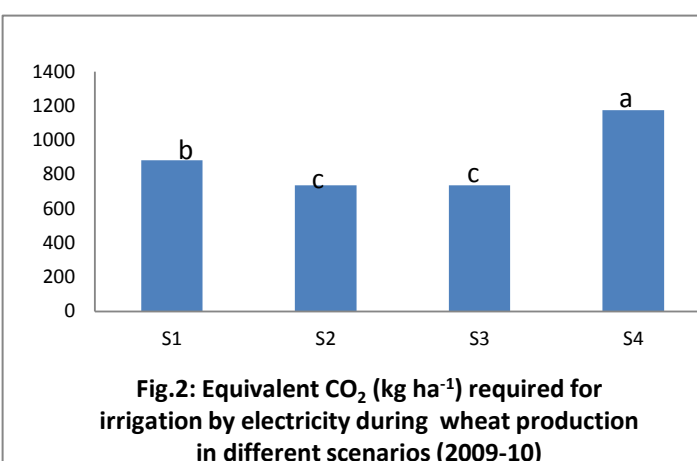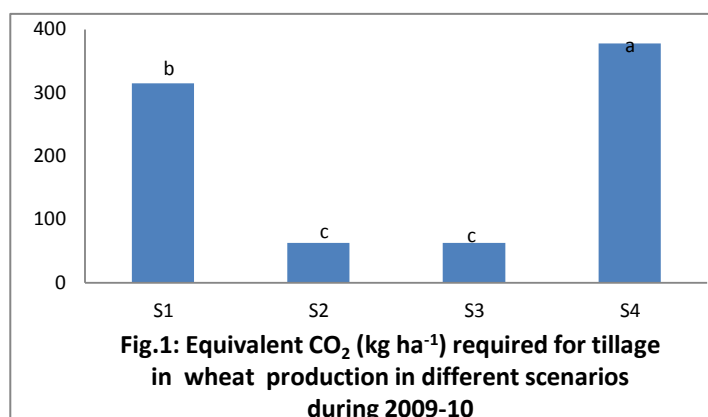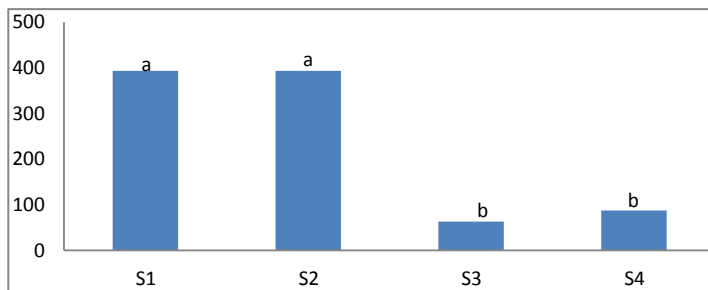
Fig. 3: Equivalent CO$_2$ (kg ha^{-1}) required for tillage in rice production in different scenarios during 2010
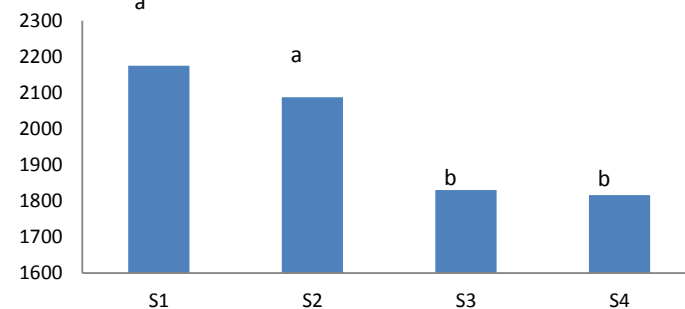
Fig.4: Equivalent CO$_2$ (kg ha^{-1}) required for irrigation by electricity in rice production in different scenarios during 2010

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Improved no-till seeding performance in Northern China using powered-chain residue manager

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Keywords: conservation tillage, no-till seeder, maize residue, powered-chain manager, strip-till seeder

Introduction

Conservation tillage (CT) is defined as a system of planting (seeding) crops into untilled soil by opening a narrow slot, trench or band only of sufficient width and depth to obtain proper seed coverage. No other soil tillage is done (Phillips and Young, 1973). This has been demonstrated and extended by the Chinese Ministry of Agriculture (Gao et al., 1999) in the annual double-cropping (winter wheat - *Triticum aestivum*, L., and summer maize - *Zea mays,* L.) regions of northern China since 1997. No-till seeding of maize after wheat harvest has been achieved with increasing success in these regions and several small–medium-sized no-till maize seeders have been developed for these conditions (Li et al., 2000), but no-till seeding of wheat after maize harvest is still a problem (Gao et al., 2003). No-till wheat seeders, equipped with various kinds of maize residue anti-blocking mechanisms (e.g. strip-choppers, powered cutting discs), were designed to cut through maize stubble (Yao et al. 2009). In annual double-cropping regions of northern China, the strip-till seeder using a powered rotor to till shallow strips ahead of the seed opener is the most widespread option to plant crops into stubble, but with high power consumption and soil disturbance. This approach was shown to reduce soil water storage and retention capacity due to low residue cover on seedbeds (Wei et al., 2005), which does not conform to the principles of conservation agriculture. A power chain unit residue management attachment for a more conventional no-till seeder unit has since been developed to overcome these problems, and this paper reports a comparative evaluation of the powered-chain no-till seeder (PCNTS) and strip till seeder (STS).

Materials and Methods

The new approach is derived from the simple concept of throwing residue aside manually by the fingers, achieved by using rigid fingers welded to the chain of the PCNTS (Figure1a). The complete machine is 1.62-m wide with 6 openers at 0.2-m spacing and 6 powered-chain residue managers 30-60mm above the ground. It is equipped with tine openers to provide a groove 30-50mm wide and 80-120mm deep for fertilizer placement and a double-disc opener with individual-row depth control mechanisms to place seed 40-50mm above the fertilizer (Figure2a). The STS (Figure 1b) is equipped with 6 powered strip-till rotary hoes at 260-mm spacing, to chop the cover crops and till strips of seedbed to 30-50mm below the soil surface (Figure 2b) and create a 120-mm-wide, 100-mm-deep tilled zone. Behind a single narrow tine-type opener, a pair of offset delivery tubes place 2 rows of seed at 120mm spacing and a single, centred delivery tube places fertilizer, 30-40mm below the seed, within the tilled zone. The anti-blocking mechanisms rotate at 320 rpm in the same direction in both seeders. These units were evaluated sowing winter wheat into cover crops in field A near the Zhangziying town (39°41′N, 116°35′E) in plots with a 5-year history of no-till cropping , and in field B in the Daxing district of Beijing, over the 2009-10 seasons with three replicates, respectively. Figure 1(c) and (d), show field "A" with its residue from maize and wheat crops and field "B" covered with freshly chopped maize (3.1kg/m^2). At both experimental sites, average annual rainfall was 600 mm, 80% occurring in summer. The soil type is silt loam, and in the top 20cm layer, soil bulk density is 1.36g/cm^3. The performance of PCNTS and STS was assessed in terms of residue handling ability, soil disturbance, fuel consumption, residue cover after planting, soil moisture in the seed zone after planting and crop yields (Yao et al. 2009; Zhang 2010).
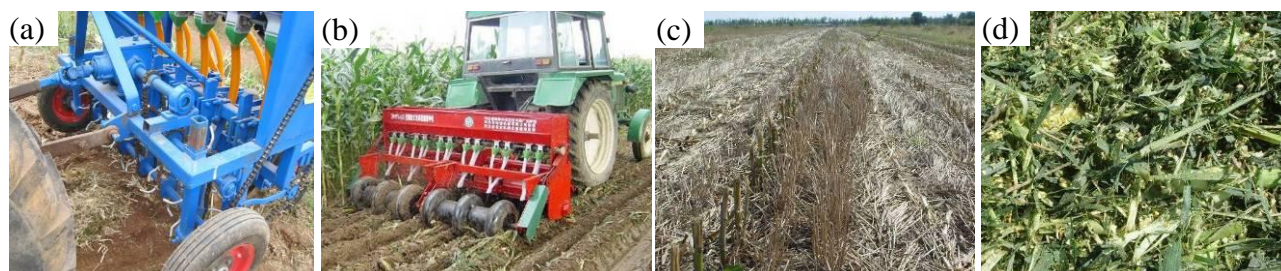
Figure 1. (a) powered-chain no-till seeder (PCNTS), (b) strip till seeder (STS), (c) test field **A**: covered with standing maize and wheat stubbles, (d) test field **B**: covered with freshly chopped maize.

Results and Discussion

In the field A, both seeders operated without blockage at similar velocity (5.3 km/hr), while in field B at a planting speed of 3.2km/hr, slight blocking occurred with both seeders once in the three experimental runs in this high moisture, dense residue. Average seed depth was 38mm after STS planting and 42mm after the PCNTS in field A, and in field B 43mm after STS and 45mm after PCNTS but the differences were not significant(P>0.05) in either case. Fuel requirement of the STS was greater than PCNTS, which used energy to move residue, rather than cut through residue and soil. This difference was significant, and greater in field B (Table 1), with its greater mass/unit area of the green material, but field A represented more typical no-till seeding conditions. Both seeders appeared to have a similar capacity to avoid blockage in heavy residue conditions, but the residue covered area after PCNTS planting was almost 50% greater than that after STS, and the strip of disturbed soil (proportion of width of furrow groove to row space) is smaller by factor of approximately 4. Additional soil movement probably accounts for the greater fuel use of the STS.

Soil moisture is one of the most important factors limiting crop yields, and soil volumetric moisture content in field A for each planter was taken at critical growth period of the winter wheat (Figure 3a). Soil moisture content in the field planted by PCNTS was about 10% higher than that planted by the STS at seedling, heading and filling stages, and 33% greater than the STS at the jointing stage. The wheat yields in Figure 3b show that the yields for PCNTS are 262 and 237 kg/ha more for the STS in field A and B, respectively. These differences are likely to be a consequence of the greater soil disturbance and residue burial produced by the STS. These results show that both seeders can meet the Agro-technical requirements for no-till planting of wheat after maize. Furthermore, the performance of the PCNTS appeared to be a substantial improvement on that of the STS, particularly when judged in terms of compliance with the needs of conservation agriculture.
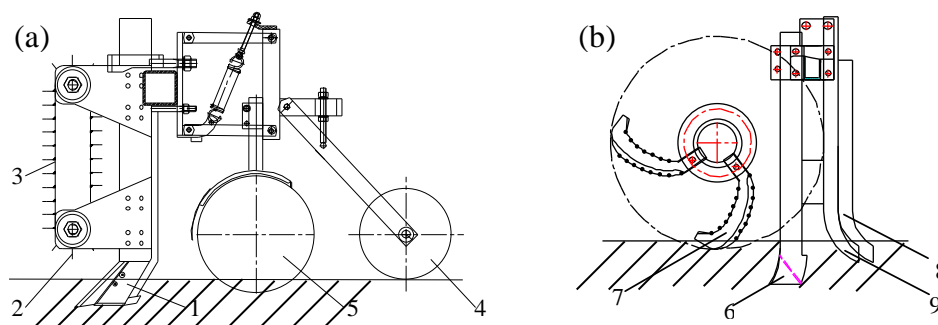
Figure 2. (a) powered-chain residue manager of PCNTS: 1,tine opener; 2,rigid fingers; 3,chain; 4, press wheel; 5,double-disc opener; (b) integrated strip-tillage unit of STS: 6,tine opener; 7,rotary
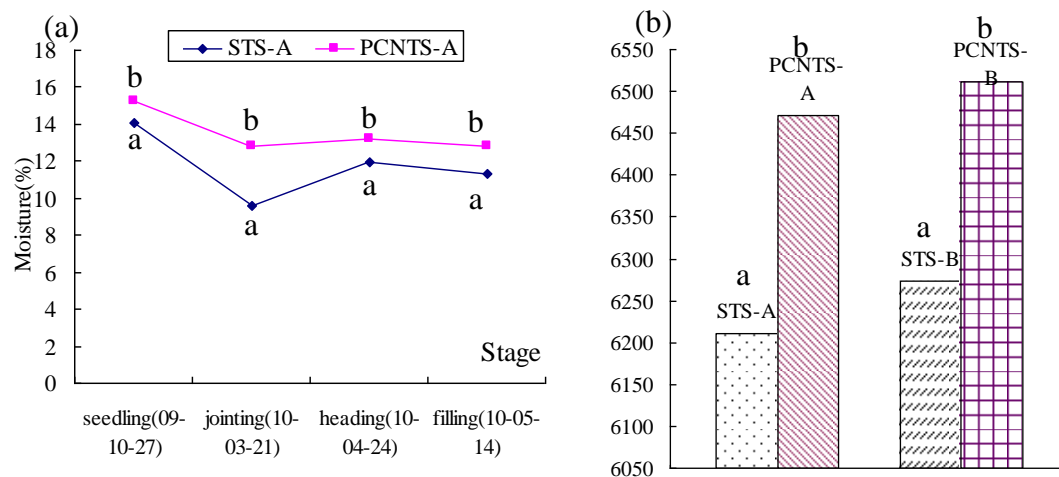
Figure 3. Comparison of the winter wheat yields in field A and B for each planter taken at harvest stage, and soil volumetric moisture content in field A for each planter taken at critical growth period: (a)Soil volumetric moisture content(%); (b) Yield (kg/ha) comparison. Values within a chart in each experimental field and growth stage followed by the same letters are not significantly different (P>0.05).

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No-tillage effects on soil carbon storage and carbon dioxide emissions in northern China

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Introduction

Tillage practices play an important role in the storage and release of C within the agricultural ecosystems' C cycle. Tillage alters the soil organic matter (SOM) decomposition environment by aerating the soil, breaking the aggregates, incorporating residue into the plow layer, and therefore, increasing soil and crop residue contact. The magnitude of CO_2 loss from soil due to tillage practices is highly related to the intensity of soil disturbance caused by tillage. A critical review of the literature indicates contradictory results with regard to tillage effects on CO_2 emissions. Álvaro-Fuentes et al (2007) reported that NT had low short-term soil CO_2 efflux compared with other soil tillage systems (e.g., conventional and reduced tillage) in the semiarid Mediterranean agro-ecosystems. In contrast, higher emissions were reported for some periods and lower for others under NT relative to conventional tillage (David et al., 2009). Monitoring CO_2 emissions and changes in SOC for different tillage treatments is important to identifying the management practices that maintain soil productivity, increase C storage, and contribute to mitigate the greenhouse effects. Therefore, the present investigation was conducted to estimate soil C sequestration and CO_2 emissions under different tillage management.

Materials and Methods

The experiment was carried out in Shouyang County, Shanxi Province, China (37° 32´-38° 6´N, 112º46´-113º 26´E) at 1300 m above sea level. The experimental area is characteristic as semi-arid warm temperate continental climate with a mean annual precipitation of 474 mm, most of the rain falling between July and September. The mean annual temperature is 8.2 °C. The soil is classified as Cinnamon. The experiment was started in 2004 and compared two tillage treatments; i) conventional tillage (CT) treatment, 30 cm deep mouldboard plowing, with all crop residues removed for fodder; ii) no tillage (NT) treatment, all residues of the previous maize crop were flattened and mulched in the field. Maize (cv Jindan34) was planted each year in late April and harvested in early October. Herbicide (2,4-D butylate) and insecticide (40% dimethoate) were applied in August. 150 kg ha^{-1} urea was applied as basal fertilizer and the other 150 kg ha^{-1} urea was applied as top dressing in the jointing stage of maize every year. Soil samples were collected in October 2008. At each sampling position, three cores were randomly taken from 60 cm depth at 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, and 50-60 cm intervals. The soil CO_2 flux was measured using the soil respiration method of Parkinson (1981), where a cylinder static chamber of 20 cm diameter and 30cm height was placed on the soil and the rate of increase in CO_2 concentration within the chamber was monitored with an LI-6400 portable photosynthesis analyzer (Li-Cor Inc.,Lincoln, NE). In our study, measurement of soil CO_2 flux was conducted between 9:00 and 11:00. The soil CO_2 fluxes were measured 6 times in April 25, May 26, July 3, August 8, September 11 and October 10 in 2008.

Results and Discussion

NT increased soil organic carbon (SOC) content over CT by 57% in 0-5 cm depth and by 12% in 5-10 cm depth (Table 1). No significant difference was found in SOC content between NT and CT treatments in the 10-40 cm depths. But there was a slight increase in SOC with NT treatment at those depths. In the 40-60 cm depths, SOC was not different between NT and CT treatments. Comparison of cumulative carbon stocks among tillage systems showed significant ($P<0.05$) tillage effect. At 0–20 cm depth, NT had significantly ($P<0.05$) higher horizon stocks than CT. In the 10-20 cm depth, although tillage effects were not significant on a concentration basis, there were significant tillage effects on mass per unit area basis (7.8% higher in NT for SOC) due to the higher bulk densities in the NT treatment. After 5 years, NT (59.0 Mg C ha^{-1}) had about 11.7% higher ($P<0.05$) cumulative carbon stocks at 0–60 cm than CT (52.8 Mg C ha^{-1}).

The higher SOC concentration in the surface soil layer of NT is attributed to reduced soil–residue interaction which causes lower rates of mineralization. The SOC concentrations declined rapidly in NT soil with increasing depth. The decrease in organic carbon content from surface to subsurface was probably due to the accumulation of organic material on the soil surface under NT. Logsdon and Karlen (2004) found the same trend, which indicates that the use of NT practices altered the vertical distribution of SOC. Soil organic carbon stocks have been identified as a good indicator of carbon dynamics under different management systems (Farage et al. 2007). Unlike SOC concentrations, stocks account for changes in both SOC concentrations and bulk density. Our results are consistent with those of many other authors who have observed the increase of stocked SOC over time for NT in comparison with CT (Hernanz et al, 2009).

Seasonal CO_2 flux ranged from 0.61 to 5.16 μ mol m^{-2} s^{-1} for NT and 1.35 to 4.68 kgμ mol m^{-2} s^{-1} for CT from April to October in 2008 (Figure 1). Based on the flux patterns, the data were divided into three periods, approximately corresponding to the maize growing period: seeding to jointing stage (April 25 to June 30), flowing to maturity stage (July 1, August 31) and maturity to harvesting stage (September 1 and October 10). The soil CO_2 fluxes were significantly higher in the flowing to maturity stage than in the seeding to jointing stage and maturity to harvesting stage. The soil CO_2 flux after tillage operations was significantly affected by tillage systems, with higher soil CO_2 flux under CT than under NT, especially in seeding to jointing stage. Tillage often increases short-term CO_2 flux from the soil due to a rapid physical release of CO_2 trapped in the soil air spaces. Our results are consistent with Dao (1998), who determined soil CO_2 flux following wheat in the 11th year of a tillage study and found the cumulative CO_2 evolved from soil in a 2- month period was much higher for moldboard plowing than for no-tillage. During s flowing to maturity stage, CO_2 fluxes were generally higher under NT than CT. Franzluebbers et al(1995a) attributed increased CO_2 emissions under NT to maintenance of higher soil water content at the soil surface and higher SOC content under NT which favored increased microbial decomposition. Overall, no-tillage management increased SOC storage and reduced CO_2 emission above CT levels under specific maize growing stage of the measurement year.
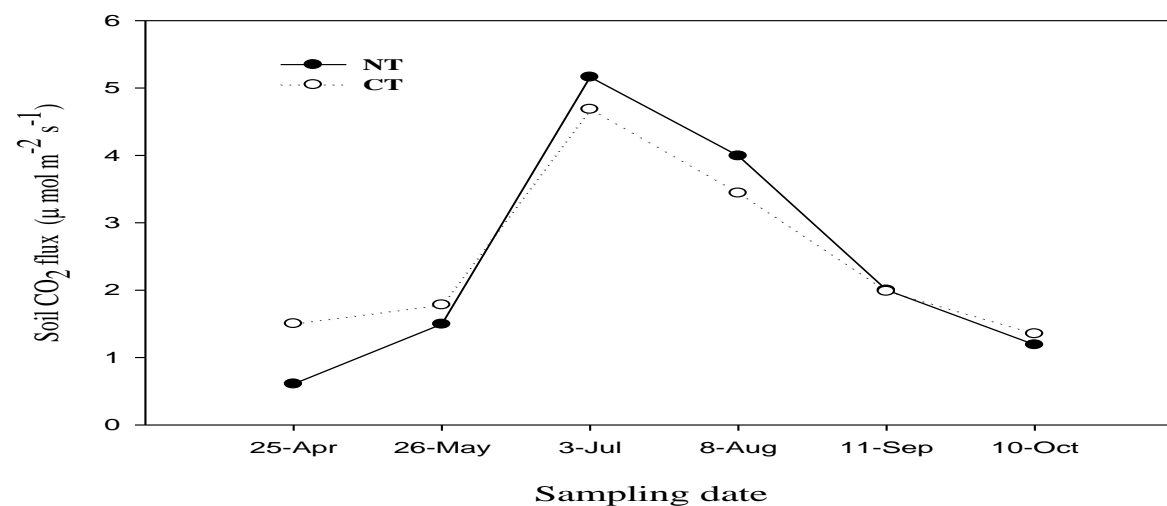
Figure 1 Seasonal changes in soil CO2 fluxes from different treatments in the2008 maize growing seasons.

Table 1. Soil organic carbon contents and stocks under different tillage system at the different depths

Tillage treatment	Depth (cm)						
	0–5	5–10	10–20	20–30	30–40	40–50	50–60
Soil organic carbon contents (g kg^{-1})							
NT	15.7	11.9	10.3	9.3	4.9	3.3	2.5
CT	10.0	10.6	10.9	9.7	5.7	3.3	1.6
s.e.d.(d.f.=4)	0.32	0.22	NS	NS	NS	NS	NS
Soil organic carbon stocks (Mg C ha^{-1})							
NT	10.0	8.1	13.6	12.7	6.7	4.5	3.4
CT	5.4	6.0	12.6	12.9	7.8	6.0	2.2
s.e.d.(d.f.=4)	0.41	0.26	0.28	NS	NS	NS	NS

NS=not significant P>0.05.
NT= no-tillage, CT= conventional tillage

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No-till dryland sugarbeet production in the semi-arid US High Plains

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Keywords: *Beta vulgaris* L., glyphosate-tolerant sugarbeet

Introduction

Irrigation is used for almost all sugarbeet production in the U.S.A. west of Longitude 100° W, where annual precipitation generally falls below 500 mm and climate is characterized as semi-arid or arid. Most growers in this region produce sugarbeet under contract with a cooperative. Growers are typically obligated to deliver sugarbeet roots from the number of irrigated hectares in their contract. Failure to deliver contracted production may result in a financial penalty. In 2007 and 2008, high prices for other commodities relative to sugarbeet made it difficult for some growers to rent sufficient irrigated land to meet their contracted production. At that point in time, the sugarbeet industry questioned whether some contracts could be fulfilled by producing sugarbeet on nonirrigated land (dryland). No research existed on the potential for dryland sugarbeet production in this or a similar climatic region.

The commercial introduction and industry acceptance of glyphosate-tolerant sugarbeet in 2008 made no-till sugarbeet production a possibility. No-till management maintains crop residues on the soil surface, which increases water storage efficiency (Peterson and Westfall 2004, Nielsen and Vigil 2010) and protects the soil from the erosive effects of water (Dickey et al. 1983) and wind (Fryrear 1995).

A number of field studies have been conducted to determine the optimum plant density for irrigated sugarbeet using conventional tillage systems. Yonts and Smith (1997) found sugar yield in western Nebraska was maximized when using a 56 cm row width and when plant densities were between 40,000 and 100,000 plants ha^{-1}. Robinson and Worker (1969) investigated square spacing of sugarbeet in California and found sugar yield was maximized at a plant density of 100,000 plants ha^{-1}. Similarly, Parashar and Dastane (1973) in northern India found sugar yield was maximized at a plant density of 100,000 plants ha^{-1}. However, without irrigation in water-short environments such as semiarid western Nebraska, low plant densities are used in many crops to maximize the water available to each plant (Loomis and Conner 1992). The objectives of this study were to ascertain the yield potential and optimum plant densities for root and sugar yield in dryland no-till production systems for the Nebraska Panhandle.

Materials and Methods

Multiple field studies were conducted each year from 2008 through 2010 for a total of 10 site-years. Two studies each year were located at the University of Nebraska High Plains Agricultural Laboratory ($41^o14'$ N, $103^o0'$ W, 1320 m elevation) located near Sidney, NE (Figure 1). The soil type at these six site-years was a Duroc loam (fine-silty, mixed, superactive, mesic Pachic Haplustolls). An on-farm site was located west of Gurley, NE in 2009 and 2010 ($41^o20'$ N, $103^o05'$ W, 1310 m elevation), where the soil was a Kuma loam (fine-silty, mixed, superactive, mesic Pachic Argiustolls) in 2009 and a Duroc loam in 2010. On-farm sites were also located south of Hemingford, NE in 2009 and 2010 ($42^o15'$ N, $103^o05'$ W, 1330 m elevation), where the soil was a Rosebud loam (fine-loamy, mixed, superactive, mesic Calcidic Argiustolls).

Figure 1. Glyphosate-tolerant no-till dryland sugarbeet production in semi-arid western Nebraska in 2009.

The experimental design was a randomized complete block with six replications and a 2 by 4 factorial treatment arrangement consisting of two sugarbeet cultivars and four target plant population densities. All cultivars were glyphosate-tolerant. Target plant population densities were 2.47, 4.94, 7.41, and 9.88 plants m^{-2} in 2008. In 2009 and 2010, target plant populations were 1.48, 2.97, 4.45, and 5.93 plants m^{-2}. A 50% emergence rate was used to set the seeding rates.

The previous crop was winter wheat at each site for all years. Established plant population densities were determined after final emergence, when plants had 4 to 6 true leaves, by counting the number of plants in the entire length of the middle two rows of each plot. Foliage was mechanically removed immediately prior to machine harvesting the middle two rows of each plot. A harvester-mounted scale was used to measure the pre-wash weight of all harvested roots. Two representative sub-samples of approximately 12 kg each were collected from each plot and sent to Western Sugar Cooperative (Gering, NE) to determine soil tare, sugar concentration, and impurity analyses. Soil tare was deducted from total harvest weight to determine sugarbeet root yield. Sugar yield was estimated by multiplying sugarbeet root yield by sugar concentration within respective plots.

Analyses of variance were performed using the general linear models procedure in SAS (Littell et al. 2002). An α level of 0.05 was used for declaring significant treatment differences. Regression analysis was used to determine yield parameter responses to established plant population density. Linear regression equations were selected unless the quadratic term was significant at an α level of 0.05 and the R^2 was increased by at least 0.05 compared to the linear equation. Maximum predicted root and sugar yields were determined by calculating the first derivative for each regression equation with y = 0. The estimated maximum root or sugar yield value was then inserted for x and the equation solved for y to determine the plant density at which maximum yield was predicted.

Results and Discussion

The data from all 10 site-years were pooled and regression analysis used to estimate root yield response to changes in plant population density. The resulting regression equation: $y = 9.7 + 11.4x - 0.962x^2$ ($R^2 = 0.397$, P < 0.001, n = 477), where y = root yield in Mg ha^{-1} and x = plant population density in plants m^{-2}, was used to estimate a maximum root yield of 43.5 Mg ha^{-1} at a plant density of 5.93 plants m^{-2}. The response curve for the pooled sugar yield data is described by the equation: $y = 1.39 + 2.06x - 0.165x^2$ ($R^2 = 0.448$, P <0.001, n = 477), where y = sugar yield in Mg ha^{-1} and x = plant population density in plants m^{-2}. Using this equation, the maximum sugar yield is estimated to be 7.82 Mg ha^{-1} at a plant density of 6.24 plants m^{-2}, which is 0.31 plants m^{-2} greater than the estimated plant density for maximum root yield of 5.93 plants m^{-2}. This is likely due to the linear increase in sugar concentration with increasing plant population density. In this study, sugar loss to molasses either decreased in a linear fashion or was not affected as plant density increased (data not shown).

Maximum yields require deep, well drained soils, with high water holding capacity and adequate stored water at planting to a depth of at least 1.2 m. Having adequate soil water throughout the top 1.2 m of soil at planting helps to ensure good emergence and root development. Brown et al. (1987) reported that early drought severely affected fibrous root development in sugarbeet and significantly reduced root yields compared to late drought, which was imposed when the fibrous root system was already extensive. In 2010, weather conditions turned dry and hot in July, yet root yields were only slightly reduced compared to 2009, which remained wetter and cooler than normal the entire season, and sugar yield was actually increased at some locations compared to 2009.

As climate change affects surface and ground water resources in the US High Plains, and the volatility of global grain markets increases, no-till sugarbeet production, both under irrigated and dryland conditions, may help to bring some stability to sugarbeet production in this region.

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Upland rice under zero tillage in Brazil: Cultivar performance and soil management for early vigour improvement

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Keywords: no tillage, aerobic rice, Ferralsols, BRS cultivars, termites, furrow compaction.

Introduction

In Brazil, upland (rainfed) rice *aka* aerobic rice is planted on approximately 1.5 M ha. In the 1970s and 1980s, it was a common pioneer crop after deforestation with almost 4.5 M ha planted each year. The average grain yield of cultivars like Araguaia and Guarani ranged from 2.0 to 3.0 t ha^{-1}, but the grain type (long and wide with low amylose content) resulted in a sticky rice after cooking. It was rejected by the consumers once long and slender, non-sticky irrigated rice was introduced in the market. Embrapa's upland rice breeding program started in late 1970s resulted in increased grain yield (currently at approx. 4 t ha^{-1}) and quality standards adjusted to consumers preference (Breseghello et al., 2011). Despite being less labour and energy intensive than flooded anaerobic systems, upland rice is only grown in ploughed or heavy disk harrowed soils in rotation with other grain crops (e.g. soybean) on 200-ha farms or larger. Because of high erosive rainfall, tilled soils suffer from water erosion and become degraded in the mid term. Efforts are being made to grow upland rice under zero tillage (ZT) in rotation with both cash and cover crops. Pasture areas, which covers 48 M ha, mostly under acidic soils demanding recovery, represent another opportunity for the upland rice crop. However, some constraints hinder the adoption of ZT rice. Low early vigour, normally attributed to low nitrate reductase activity, impairs weed competitiveness of upland rice. Soil termites tend to be a large problem in ZT rice. Studies were initiated to tackle those problems, as an attempt to enable the cultivation of upland rice under ZT in acid tropical soils in the Brazilian Cerrado and Amazonia biome. Field experiments started for investigating the potential of modern upland rice cultivars at different row spacing to enable the use of the same ZT planter used for soybean (40-cm spacing), the interaction of seed chemical treatment and furrow compaction on rice plant mortality by termites in the early growth stages, and the effect of cover crops on mulching and soil NO_3^- and NH_4^+.

Materials and Methods

Upland rice cultivars vs row spacing
In Santa Carmen, State of Mato Grosso (transition of Cerrado and Amazonia biome; 2065mm in 6 months; clayey Ferralsol; pH_{H2O} 6.6; 55% base saturation, and medium phosphorus levels), and Santo Antonio de Goias, State of Goias (Cerrado biome; 1343mm in 6 months; clayey Ferralsol; pH_{H2O} 5.2; 65% base saturation, but low phosphorus), field experiments were conducted during the rainy season of 2009 to evaluate the performance of five Embrapa (BRS) upland rice cultivars (Sertaneja, Pepita, Monarca, and Primavera) under ZT and to determine the effects of row spacing (17, 34, 51, and 68 cm) on rice yield. The experiment was established on a 3-year old Brachiaria pasture followed by soybean, fallow, upland rice, and maize mixed with palisade grass (*Urochloa brizantha*). All under ZT. Palisade grass was dessicated with glyphosate (2880 g AI ha^{-1}) and 20 days later the cultivars were sown with a ZT planter. Rice received fertilizers at rates of 70 kg ha^{-1} of N with additional 20 kg ha^{-1} of N as top dressing. The experiment was a split plot randomized design with three replicates.

Furrow compaction vs rice plant mortality by termites
In Santo Antonio de Goias, a field experiment was established to evaluate the effect of ZT planter fitted with chisel (no compaction) or disc (furrow compaction of 1 kg cm^{-2}) on soil mineral N concentration and of the interaction between furrow compaction and seed chemical treatment (thiametoxam 1.4 g AI kg^{-1} seeds; imidacloprid 1.625 mL AI kg^{-1} seeds and; fipronil 0.625 mL AI kg^{-1} seeds) on rice plant mortality by termites (*Procornitermes triacifer*; *Proconitermes* spp; *Syntermes molestus*). Rice cultivar was BRS Sertaneja. Zero tillage was still in transition from ploughed system as it was in its second season.

Cover crop species vs soil ammonium- and nitrate-N, and nitrate reductase activity
In the same field experiment used for termite evaluation, investigations were conducted to evaluate the amount of dry mass of two cover crops sown with a ZT planter in the end of the rainy season (March) and dessicated in the beginning of rainy season (October) of the same year for upland rice sowing 30 days after dessication with glyphosate (1468 g AI ha^{-1}). Cover crops were ruziziensis grass (*Urochloa ruziziensis*) and pearl millet (*Pennisetum glaucum*). Fertilization of N was at sowing time (20 kg N ha^{-1}) and top dressing 40 days after sowing (60 kg N ha^{-1}). Dry mass of cover crop residue and nitrate reductase activity (NRA) in rice leaves were measured base on Beevers and Hageman (1969) at 10, 18, 25, and 37 days after sowing.

Results and Discussion

Yields of all cultivars tested ranged between 2.5 and 6.0 t ha^{-1} in both sites (Figure 1). In Santa Carmen, yields were more contrasting and row spacing dependant than in Santo Antonio de Goias. Yields were similar to ploughed soils (data not shown). Compared to Santa Carmen, higher base saturation of the Ferralsol and less weed population could explain the lower effect of row spacing in grain yield in Santo Antonio de Goias. Yield reduction caused by weed competition at the wide interrow spacing was also reported by Chauhan and Johnson (2011). In the first year under ZT, rice plants were not affected by termite attacks probably due to soil disturbance caused by ploughing previously to ZT adoption. However, in the second year, furrow compaction combined with seed treatment with pesticides showed significant effect on termite attacks (P=0.002; Figure 2). The significant influence of soil compaction alone on tunnel network construction by termites has already been reported in Florida, USA (Tucker et al., 2004). Rice plant mortality was lower in the pesticide treated than in the control plots (Dunnet test α=0.05). The interaction of furrow compaction and seed treatment with pesticides showed higher effect (P=0.002) on termite control than furrow compaction alone. Imidacloprid and fipronil combined with furrow compaction showed best termite control. Dry matter of cover crops was adequate for mulching at both terms in ZT upland rice, but *U. ruziziensis* showed higher mulching effect than *P. glaucum* 30 days after dessication (Table 1). Cover crops showed greater effect on soil ammonium (F_{value}=46.5; P<0.01) than on soil nitrate (F_{value}=26.3; P<0.01), and soil ammonium was larger under *U. ruziziensis* than *P. glaucum* at 25 and 35 days after dessication of cover crops. However, no significant difference in NRA (Table 1) and rice yield was observed (data not shown). Nitrate reductase activity was more influenced by the time of sampling (F_{value}=360,1; P=0.01) than by cover crop residues (F_{value}=10.4; P=0.01).
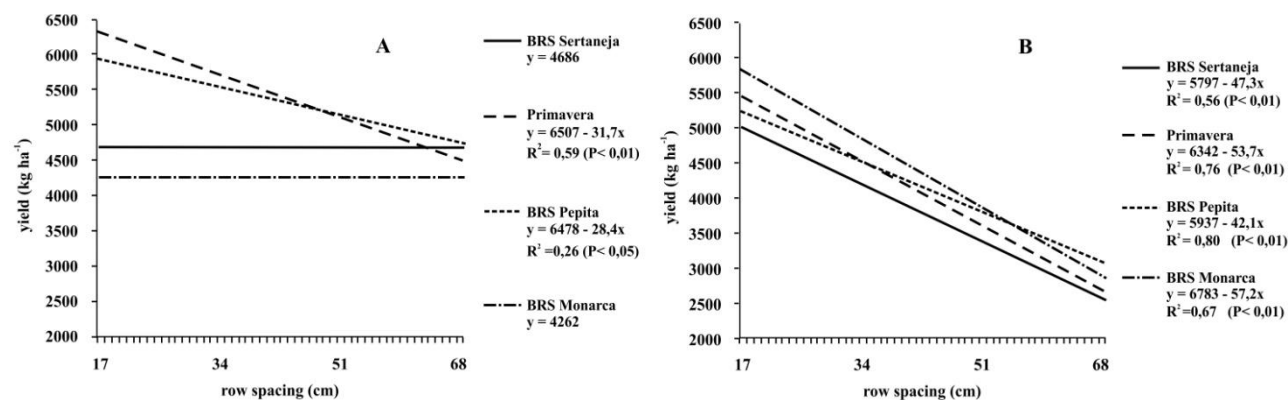
Figure 1. Effect of row spacing on yield of different upland rice cultivars on a clayey Ferralsol under 2nd-year zero tillage in Santo Antonio de Goias (A) and Santa Carmen (B), Brazil.
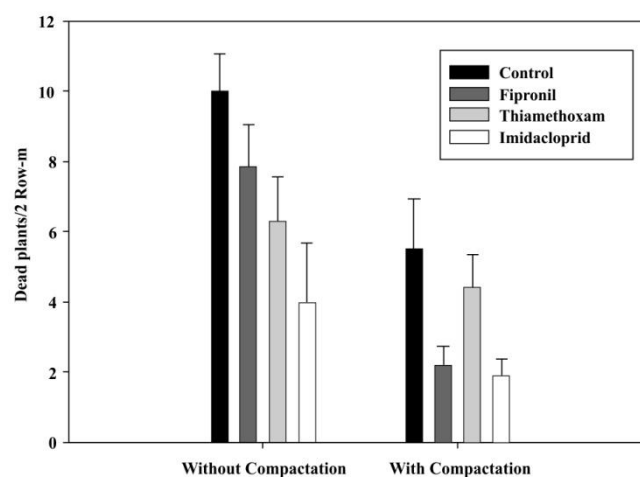
Figure 2. Rice plant mortality due to rootfeeder termites (*Procornitermes* spp. and *Syntermes molestus*) in a clayey Ferralsol under 2nd-year zero tillage.

Table 1. Dry matter (t ha^{-1}) of cover crops, soil ammonium- and nitrate-N (mg dm^{-3} soil), and nitrate reductase activity in rice leaves (NRA; μmole NO_2^- $g^{-1}.h^{-1}$) at different terms after dessicaton of cover crops in a Ferralsol from Santo Antonio de Goias, Brazil.

		Cover crops						
		U. ruziziensis				*P. glaucum*		
DAD*	DM**	NO_3^-	NH_4^+	NRA	DM	NO_3^-	NH_4^+	NRA
10	5.5a	21.9a	2.0a	0.01a	3.4a	47.8a	1.9a	0.01a
18	nd♣	5.8b	3.8a	1.48a	nd	23.4a	2.0a	1.38a
25	nd	23.6a	3.1a	9.37a	nd	22.0a	1.6b	6.78a
37	5.4a	20.8a	4.9a	9.46a	2.8b	19.2a	1.7b	9.05a

*days after dessication   **Dry matter   ♣not determined

♣Means followed by the same letter in a row are not significantly different at P<0.01

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Improving furrow backfill in rotary strip-tillage systems

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Keywords: power tiller, blade shape, rotary speed, strip-tillage drill, clod size, PTOS

Introduction

Strip-tillage is a conservation tillage system defined as a row-crop practice that restricts soil and residue disturbances of the field area to less than 25% (CTIC, 1995) or 33% (Reeder cited in Morris et al., 2007). It consists of preparing strips of seedbed, 50–200 mm wide and 50–200 mm deep, with the soil between the strips not being disturbed and having a protective cover of plant residue (e.g. FAO, 2000). This system has some of the benefits of both the no-tillage and conventional (full soil disturbance) tillage systems (Licht and Al-Kaisi, 2005) and is often used as a transition from conventional tillage to no-tillage.

Two-wheeled tractors fitted with rotary cultivators (commonly known as a 'power tiller') are popular as a soil tillage machine in some developing countries where farm size is small, like Bangladesh where 87% of farm holdings are less than 1 ha. In Bangladesh there are over 350,000 power tillers that are used for soil preparation of more than 80% of cropping area (Haque at al., 2010). Typically, in these small farms crops are sown by manually broadcasting or hand planting seeds. There is a growing trend of farmers adopting power tiller operated seeders (PTOS) which can achieve soil preparation and seeding in one pass. A commonly used PTOS is the Chinese made 2BG-6A, which cultivates 1.2 m wide and plants up to 6 rows of seeds prior to consolidation by a packing roller. In order to capture the many benefits of strip-tillage, researchers in Bangladesh (Esdaile, 2009; Haque et al., 2010; Hossain et al., 2009) have been evaluating modified PTOS to achieve strip-tillage planting of maize, wheat and chickpea.

During the operation of a rotary cultivator, the blades cut soil, carry and throw soil lumps against a shield. Whilst impacts against the shield help soil pulverisation, in strip-tillage it creates the problem of soil scattering to the untilled inter-row areas, which results in less furrow backfill (Lee et al., 2003; Thoma and Collett, 1988). The research studies of Hossain et al. (2009) using a PTOS also found that it did not produce enough soil backfill to adequately cover seeds. The soil entrainment and pulverisation are affected by the shape (mainly width) and the rotational speed of the rotary blades (Hendrick and Gill, 1971). Therefore, the study reported here was conducted to evaluate how, in the context of rotary strip-tillage, the furrow backfill and the soil pulverisation change for a series of blade shapes and rotary speeds.

Materials and Methods

Figure 1 Conventional (left) and improved (right) strip-tillage furrows, using bent and straight

The study was conducted at the Mawson Lakes campus of the University of South Australia in a fallow land with a clay soil (soil moisture 16% dwb, bulk density 1.47 g/cm^3) using a model 2BG-6A PTOS fitted to a 9.0 kW Dong Feng DF12 two wheel tractor. For the tests, the rotor of the PTOS was fitted with two sets of four blades set at a spacing of 390 mm and cutting two furrows. The blades extended to an outside diameter of 340 mm. On one side (left) bent C type blades, commonly used with PTOS were fitted with the bend facing toward the centre of the furrow (vertical face on the outside of the furrow). On the other side (right), a set of four straight C type blades were fitted that were specially designed for the tests with the aim of reducing entrainment and soil throw from the furrow (Figure 1). Each set of blades was mounted to achieve a cutting width of 50 mm. The cutting edge of all blades included a two sided bevel which was sharpened. The rotary cultivator was operated at two speeds of 214 and 500 rpm and at a 0.67 m/s forward speed and 60 mm depth. A randomized complete block design with three replications was used for the experiment. The furrow backfill was measured both by depth of backfill and mass of loose soil per meter length remaining in the furrow after strip-tillage. Samples of soil taken from the furrow were air dried and sieved for three minutes through a nest of sieves of 20.0, 9.5, 5.5, 3.3, and 1.5 mm diameters collecting into a pan. The cumulative percentage of soil (by mass) passing through each sieve was calculated and plotted against sieve opening diameter. The mean mass diameter (D_{50}) was calculated as the sieve opening diameter corresponding to 50% of the soil mass passing through. The uniformity coefficient (C_u) was calculated as the ratio between the diameters D_{60} and D_{10} (Reddy, 2010). The proportion of soil mass remaining in the furrow in the optimum clod size range between diameters of 1.5 and 20 mm was also calculated.

Results and Discussions

The results are shown in Tables 1–2. Data showed the blade shape had a significant effect on backfill and soil pulverisation, while the rotary speed only had a significant effect on relative uniformity (Table 2). These effects were consistent with no significant interaction observed. Table 1 shows that the straight blade provided a much greater backfill of soil in the furrow, as well as a coarser tilth as shown by greater D_{50} values, a slightly greater clod proportion in the optimum size range and a reduced proportion of fines < 1.5 mm. The results correlate with the bent blade carrying and throwing more soil against the rotary tiller shield and hence creating more fines. Also the bent tip would act to cut the soil in the furrow into thin slices, compared with the straight blades which would tend to fracture soil clumps sideways with less entrainment. The bite lengths at 214 and 500 rpm were 47 and 20 mm, respectively. The results showed that the straight blade gave an extra 20 mm of soil height into which seeds could be planted corresponding to over twice the amount of tilled soil mass remaining in the furrow.

Table 2 shows that the increase in rotary speed from 214 rpm to 500 rpm did not have a significant effect on the furrow backfill parameters, except for the uniformity value which improved from 12.5 to 10.5. It would have been expected that as the rotary speed increases and bite length reduces, along with greater impact energies of clods hitting the shield, that smaller and more pulverised clods would result, but such differences - although observed as trends - were not significant under the test conditions.

Overall, considering furrow backfill and soil pulverisation for the test site at Mawson Lakes, the straight blades would be the preferred option over existing bent blades when undertaking strip-tillage using a PTOS due to the improved furrow backfill and lower amounts of fines. As speed did not significantly affect furrow backfill, the higher speed of 500 rpm (normal speed of PTOS) would seem most compatible with less vibrations to the operator. Further work is required to validate these findings across a range of soil types and conditions. The importance of optimising furrow quality parameters should be emphasized in dedicated research alongside promotion of strip-tillage drill technologies.

Table 1: Mean data comparison for blade shape (*NB* Numbers followed by same letters in a column do not differ significantly at $\alpha = 0.05$)

Blade type	Depth of backfill, mm	Amount of backfill, g/m	Mean mass diameter, D_{50}, mm	% mass in clods 1.5 to 20 mm	%mass in clods < 1.5 mm	Uniformity coefficient, D_{60}/D_{10}, C_u
Bent	28.8 a	812 a	2.9 a	60.3 a	37.0 a	10.3 a
Straight	48.7 b	1890 b	4.5 b	63.8 b	28.0 b	12.6 b

Table 2: Mean data comparison for rotary speed (*NB* Numbers followed by same letters in a column do not differ significantly at $\alpha = 0.05$)

Parameter	Depth of backfill, mm	Amount of backfill, g/m	Mean mass diameter, D_{50}, mm	% mass in clods 1.5 to 20 mm	% mass in clods < 1.5 mm	Uniformity coefficient, D_{60}/D_{10}, C_u
214 rpm	39.8 a	1323 a	4.3 a	63.5 a	29.4 a	12.5 a
500 rpm	37.7 a	1379 a	3.1 a	60.7 a	35.6 a	10.5 b

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Short term agronomic gains from Conservation Agriculture in NW China

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Keywords: Loess, permanent raised beds, conservation tillage, sustainable agriculture.

Introduction

Increased water infiltration and reduction in water and wind erosion is achieved through reduced tillage and retention of ground cover (Ma et al. 2006). So there are more than 4,000,000ha in 14 provinces under conservation tillage in China (Hejin et al. 2007). The challenge for Chinese agriculture is to broadly embrace Conservation Agriculture (CA). Wheel compaction problems can be overcome and significant system benefits achieved by the use of CA and controlled traffic farming (CTF) (Tullberg et al. 2007). Permanent raised bed (PRB) cropping gives positive control of surface water, while also providing the physical guidance system needed for CTF. PRB cropping is highly compatible with CA, and its effectiveness is well documented (Bachmann and Friedrich 2003). Changing soil management practices from intensive tillage to PRB alters the partitioning of the water balance, decreasing soil evaporation and increasing transpiration, infiltration and deep percolation, leading to increased yields and WUE (Wang et al. 2004a and 2004b). PRB plus CA is a way to combine profitable agricultural production with improved sustainability, which has been effective in a variety of agro-ecological zones (McGarry 2006). Key constraints to implementation of CA in NW China are the lack of appropriate machinery, the "good farming" mindset of conventional tillage and competition for crop residues. However the impetus for CA is the increasing desertification and severe water restrictions imposed on farmers (Xie et al. 2005).

Materials and Methods

Research and demonstrations were conducted over 3 seasons near Zhangye, Shandan, and Jiuquan in the Black River Basin of Gansu Province PRC. Mean rainfall is less than 150mm/year on a Loess soil, which is frozen to 30cm deep from late November to mid April. Spring wheat is the dominant crop, grown from mid April until late July, although there are considerable areas of other grains and vegetable production.

The research area layout consisted of eight 400m^2 plots, in 2 replicates of 4 treatments; CA PRB, fresh raised bed (FRB), zero till - control traffic (ZT) and conventional tillage (CT). Larger comparative demonstration sites (3000m^2) of PRB, ZT and CT were located near the other cities. A five row zero-till planter was used in PRB, FRB and ZT, while CT was solidly planted with a conventional 8 row tine planter. Fertiliser was applied at planting at an average rate of 217kg/ha N and 205kg/ha P. ZT and CT treatments were flood irrigated, whereas PRB and FRB treatments were furrow irrigated. Irrigation volume was based on replacement of the soil moisture deficit (SMD) for PRB, FRB and ZT, while CT received up to 1.5ML/ha per irrigation event (farmer practice).

Results and Discussion

At the research site poor plant establishment had a considerable impact on treatment yields, but despite 20% less emergence in PRB, its yield at 5.6t/ha was not significantly different to that of other treatments in 2006. In 2007, despite a 10% lower establishment the grain yield of wheat under PRB was 7.1t/ha, compared to CT at 6.4t/ha (Table 1). Poor planter performance, low soil temperature and inadequate seed/fertiliser separation continued to restrict establishment and final yields in 2009, however PRB was not significantly different from CT even with 20% of arable land given to furrows.

Water use by all treatments shown in Table 2, illustrated the substantial water-savings achieved by PRB compared with the other treatments. The lower volumes of irrigation water applied to PRB per irrigation are indicative of increased available water, plant root accessibility, lower soil wetted perimeter and soil water monitoring. Irrigation volumes were quite variable across treatments, but there was a 21% or 133mm saving in irrigation water in 2006 for PRB. In 2007, 39% less irrigation was required for PRB compared with that of CT. Increased competence in the farming system, close water monitoring, as well as improved soil structure maintained water savings (33%) in 2009. Consequently PRB water productivity, in all years, was better than CT, although the differences were small in 2006 (Figure 1) largely due to start up limitations. In 2007 and 2009, PRB WUE values (~15kg/ha/mm) were significantly different to CT at an average of 9.2kg/ha/mm for the 3 seasons.

Crop emergence, yield and applied irrigation water at the demonstration sites followed similar patterns to those found at the research site (data not shown). Total water savings for PRB in 2006 and 2007 at Shandan were 26% and 51%, respectively. Water savings in ZT were 23% and 26%, respectively. In Jiuquan water savings were also around 23%. Yields for all treatments were similar at Shandan, but were slightly lower (7%) than CT in Jiuquan.

During the establishment phase of the research and demonstration sites, crop emergence was poor. This appeared to be a result of the poor performance of prototype planting machinery, operating under difficult conditions of heavy residue, high soil moisture, frozen soil conditions, combined with poor depth control, inadequate seed-fertiliser separation and inexperience with CA techniques. Despite the adverse starting conditions, poor emergence and 20% loss of cropping area to wheel tracks in PRB and ZT, final yield was equivalent to CT in the first year, but considerable improvements were recorded in the following seasons. These yield and emergence results are an improvement on those achieved in a comparison of (non-PRB) conservation tillage with conventional practice in the same area by Ma et al. (2006), and consistent with the results of Hejin et al. (2006). Under PRB conditions less water was used to replace the SMD and coupled with continuous ground cover this reduced total water losses to evaporation and deep drainage.

Conversion from conventional (intensive tillage, basin-flood irrigation) to CA increased wheat yield by 10% in 2007 (2% over 3 seasons) while it provided 6.4ML/ha in total water savings over 3 years.
CA can be implemented in the Chinese rural community without loss of yield and with considerable gains in natural resource conservation, provided that the operational capabilities of the prototype machinery continue to improve.
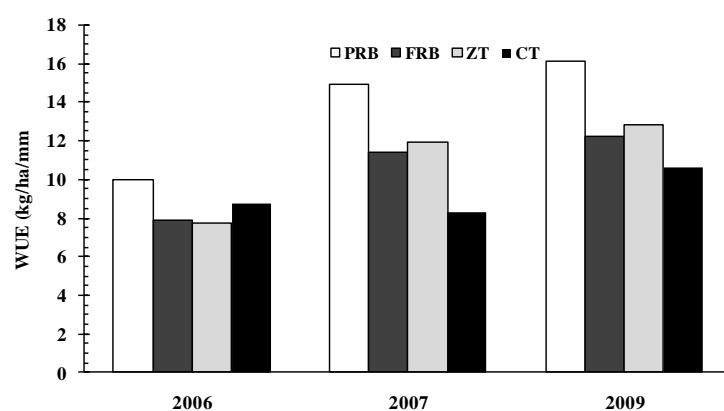
Figure 6. Water Use Efficiency (kg/ha/mm) for wheat in each treatment PRB, FRB, ZT and CT at the Zhangye Research Station for 2006, 2007 and 2009 seasons

Table 2. Crop yield from the 2006-2009 at the Zhangye for the four treatments PRB, FRB, ZT and CT.

Treatment	Yield(kg/ha)		
	2006	2007	2009
PRB	5575[ab]	7132[a]	6680[a]
FRB	5306[b]	6651[b]	5542[b]
ZT	5420[b]	6356[b]	6200[ab]
CT	6088[a]	6458[b]	6520[a]

Note: Yields followed by the same letter are not significantly different within years at P<0.05

Table 3. Irrigation volumes (mm) by date and effective rainfall for 2006 (a), 2007 (b) and 2009 (b) at Zhangye Research Station

	Irrigation Date	21/11/05	22/04/06	1/05/06	16/05/06	23/05/06	6/06/06	22/06/06	2/07/06	Eff Rain	Total
a	PRB	174[*]	79		53		78	113		64	560
	FRB	131[*]	73	88		78	105	132		64	670
	ZT	153[*]	96		77		95	144	69	64	693
	CT	145[*]	89		94		107	140	53	64	698

	Irrigation Date	18/10/06	9/11/06	4/05/07	16/05/07	30/05/07	2/06/07	5/06/07	23/06/07	Eff Rain	Total
b	PRB		180[*]		55		73		95	76	479
	FRB	110[**]	131[*]	36		111			117	76	581
	ZT		185[*]		106			81	85	76	533
	CT	95[**]	177[*]	150		143			137	76	777

	Irrigation Date	31/10/08	3/05/09			5/06/09		26/06/09	Eff Rain	Total
c	PRB	90[*]	99			105		82	37	414
	FRB	122[*]	98			109		86	37	452
	ZT	109[*]	131			104		102	37	484
	CT	180[*]	148			114		134	37	614

Note: Irrigation values followed by [**] indicate tillage irrigations and values followed by [*] indicate winter irrigations. Both irrigations are post-harvest irrigations in preparation for winter and the following production season.

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The effects of soil conservation practices implemented in basal plateau scarp - southern Brazil

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Key words: water conservation practices, tobacco, sediment yield; soil organic carbon

Introduction

Major agricultural production systems on the basalt slopes of southern Brazil includes intensive pig farming in integrated agro-industrial schemes, and the cultivation of grapes and tobacco. Particularly in the case of tobacco production systems, high rainfall intensity associated with periods of soil tillage, together with the region's steep hillsides, leads to wide-scale erosion and declining productivity. Traditional management techniques used by tobacco farmers typically involve conventional soil tillage (CT), the use of large quantities of fertilizers, and intensive application of pesticides. To attenuate this problem, changes in tobacco farming practices have been proposed which involve the introduction of conservation practices such as minimum till (MT) and no till (NT) associated with cover crops. The effects of changes in soil management on soil quality and sediment yield of a small watershed have been studied by the different authors and are summarized in this article.

Materials and Methods

The Arvorezinha experimental watershed was established in 2001 as part of the Program to Combat Rural Poverty in the state of Rio Grande do Sul (World Bank-BIRD). It was part of a watershed monitoring project that used environmental indicators to assess the impact of the Program. The watershed area is 1.2 km^2 and the individual farm size ranges from 5 to 20 ha. Steep slopes are one of the factors leading to high erosion potential in the watershed. The terrain in the upper portion of the catchment is rolling, while in the mid and lower portions the average slope is 9%. The local geology is characterized by extruded basalts. The soils of the watershed are dominated by Chromic Alisols, Haplic Cambisols, and Litholic Neosols. Annual precipitation varies between 1250 and 2000 mm. Despite the relatively even distribution of annual rainfall, erosivity is significantly higher during the months of September and October. This coincides with soil tillage activities prior to tobacco planting, which promotes erosion. During the second year of monitoring, rural extension officers introduced MT which was gradually adopted by the producers. The new management strategies aimed to minimize soil disturbance, promote the use of contour planting, and substitute winter fallow with cover crops such as black oats (*Avena strigosa*), vetch (*Vicia villosa*) and forage parsnip (*Raphanus oleraceus*). MT is characterized by the use of cover crops and contour ploughing and planting. The adoption of MT practices by the farms in the Arvorezinha watershed has been gradual. Responses to soil management changes were evaluated by monitoring key variables related to soil quality, hydrology and off-site aspects such as sediment yield at the watershed level (Minella et al., 2009; Dalbianco, 2009; Mello, 2006; Brilhante, 2009 and Janssens, 2011). The Century and SWAT mathematical models were also used to simulate soil organic carbon (SOC) dynamics (Lopes, 2006) and sediment yield (Uzeika, 2009) considering different scenarios of soil management at the watershed scale.

Results and Discussion

In 2003 and 2004, the rural extension agency (EMATER) actively encouraged producers to adopt soil conservation practices, which led to a gradual shift from CT to MT and NT and these practices were efficient at reducing off-site impacts such as sediment yield (Figure 1). Table 1 summarizes the main results found by several authors carrying out studies in the Arvorezinha watershed. There had been a tremendous reduction in SOC over the course of 80 years when forest land was converted to agricultural land (Lopes, 2006 and Janssens, 2011). One consequence of this was a loss in soil productivity caused by degraded soil structure (Dalbianco, 2009). Studies carried out at the plot, field, watershed scale and mathematical modeling show that the conservation practices introduced by the Extension Service in 2002 are not only controlling off-site impacts, but they are improving soil quality. Another positive result is that farmers continue to voluntarily adopt conservation practices that were initially financed by a government soil conservation program.
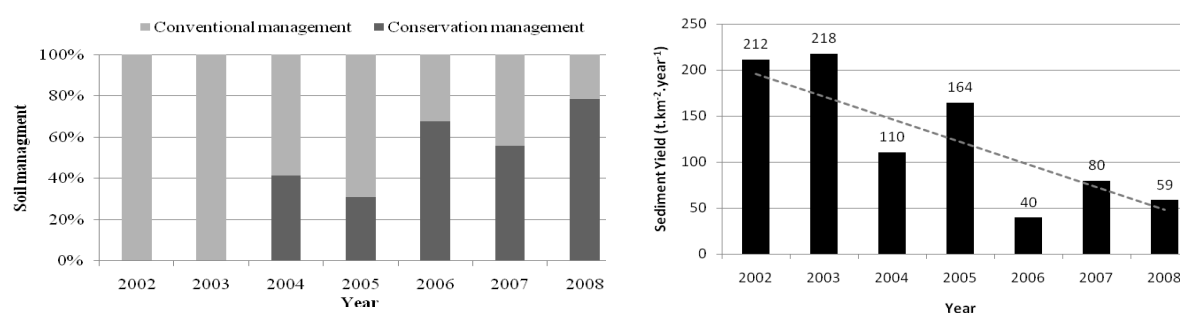
Figure 1 Changes in soil management (left) and sediment yield (right) in the Arvorezinha watershed during the monitoring period

Table 1 Main findings regarding impact of soil conservation practices on soil quality in the Arvorezinha watershed.

Author	Scale	Main results
Mello, 2006	Field	In areas under conservation practices where adopted, erosion and SOC export were reduced. Particulate fraction SOC was more sensitive to the soil conservation practices.
Dalbianco, 2008	Watershed survey	Fields managed under CT had a degraded soil structure, low aggregate stability and low SOC. Soil under conservation practices improved water-holding capacity.
Brilhante, 2009	Plots	Plots under conservation practices improved the soil biota when compared with CT.
Janssens, 2011	Field	Increased biomass in MT resulted in an increase in SOC stocks. High SOC contents were found in concave slopes and low levels in convex slopes due to tillage induced erosion.
Lopes, 2007	Century model-watershed	Conversion from forest to agriculture fields reduced SOC by 60% over 80 years. Scenario with NT and oats-tobacco/oats-corn crop sequence over 50 years would recover the initial SOC.
Uzeika, 2009	Swat model watershed	SWAT model was able to simulate appropriate hydrology but failed to simulate sediment yield when model was not calibrated. Scenario with MT and crop sequence oats-tobacco/oats-corn would reduce by 30% sediment yield over 50 years, when compared with CT tobacco-fallow.

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Conservation Agriculture in dryland agro-ecosystems of Ethiopia

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Keywords: smallholder farmers, dryland agriculture, tillage, mulching

Introduction

Conservation agriculture (CA) has been proposed as an alternative to conventional tillage to sustainably intensify crop production. Key-elements of CA are minimal soil disturbance (minimum or no-tillage), stubble retention, and the implementation of viable crop rotations. Compared to tillage-based agriculture, CA has the potential to decrease soil loss, enhance levels of soil organic matter, increase plant available soil water, and save costs due to fewer or no tillage operations. CA practices have been successfully adopted on intensive, large-scale farms in many dryland regions, where they have become an essential component of sustainable cereal-based farming (Thomas et al., 2007; Lyon et al., 2004). Reported disadvantages include the prevalence of certain weeds, pests and diseases that are difficult to control without tillage, and the high conversion costs for equipment (Lyon et al., 2004).

It has been also proposed that CA is suitable to address agricultural problems in smallholder farming systems of eastern Africa, where productivity is chronically low and mostly declining (FAO, 2010). Historically, subsistence farmers used shifting cultivation to restore soil fertility. This practice was sustainable, though at low levels of productivity, while the human population density was low. With population growth, the demand for food has increased. As a consequence the area, duration and frequency of long bush fallows (10-15 yrs) in shifting systems have declined, and permanent cultivation has become increasingly common. The intensified land use combined with insufficient manure supply and the world's lowest use of mineral fertiliser (FAO, 2008) has deteriorated soil fertility. This is often aggravated by soil erosion. Soil degradation is arguably a greater constraint to crop productivity than climate variability. Crop yields are low even in 'good' seasons as nutrient deficiencies restrict crop responses to available soil water.

Whether or not CA provides benefits for smallholder systems in Africa has been subject to an ongoing debate (Giller et al., 2009). A major criticism is that the socio-economic dimensions of smallholder farms are often insufficiently addressed in existing CA research. For example, poor farmers lack the resources to purchase expensive inputs, which may or may not be available locally. Greater reliance on hand weeding is likely to increase the workload of women and children. In addition, residue retention usually conflicts in farming systems with livestock, where crop residues are a valued feed, other uses includes its use as fuel, and in construction. In Ethiopia, on-farm and researcher-managed CA experiments have been conducted across a range of dryland agro-ecosystems since 2001. This paper reviews the progress made so far and the impact of CA on crop, soil and water productivity. We discuss challenges and opportunities related to the suitability and potential adoption of CA by smallholder farmers in Ethiopia.

Farming systems in dryland agro-ecosystems of Ethiopia

Dryland agriculture is practised in the lowlands and highlands (>1500 m) in semiarid to dry subhumid environments (500-800 mm average annual rainfall). Rainfall is highly variable, which results in high levels of production risk and contributes to food insecurity. The annual rainfall pattern is bi-modal. About 70% of the rain falls during the long-rainy season (June-September).
Rainfall during the short-rainy season (March-May) is mostly too low for growing short-season legume crops. Common soil types are Andosols, Luvisols, Vertisols, and Lithosols. The cropped soils are characterised by low amounts of soil organic matter (<1%), plant available nitrogen (N), and phosphorous (P).

The average farm size is 5 ha, and supports a house-hold of about eight family members. Mixed crop-livestock systems dominate the landuse. Fields are permanently cultivated and fallowing is uncommon. Most of the land is devoted to cereals, primarily sorghum (*Sorghum bicolor*), tef (*Eragrostis tef*) and maize (*Zea mays*). While sole cropping dominates, intercropping with legumes (e.g. *Phaseolus vulgaris, Vicia faba, Cicer arietinum, Lens culinaris*) is also practiced. Traditional tillage (TRAD) involves repeated cultivation (3-5 times depending on the required soil tilth) with the local *maresha* plough (oxen-drawn implement with a single tine) combined with residue removal. Crop residues are collected and stored as dry-season feed resource or grazed *in-situ*. Sorghum and maize straw is valued as fuel for cooking, and for brick making.

Evaluation of tillage practices

Experiments (up to 4 years) conducted showed that CA can reduce soil erosion and runoff (Oicha et al., 2010), increase crop yields (Mesfin et al., 2005; Burayu et al., 2006; Temesgen et al., 2009), soil organic matter, and mineral nutrients (Burayu et al., 2006) in Ethiopian drylands. However, the research also showed that minimum tillage generally outperformed no-tillage (Table 1). This might be related to better soil water infiltration with minimum tillage (Rockström et al., 2007).

Table 1. Comparison of different tillage practices with traditional tillage using the *maresha* plough (TRAD): (+) increase, (−) decrease, and (+/ −) variable response.

Tillage practice	Yield	Soil water	Soil fertility
Minimum tillage	+[1,3,4,6]	+[7]	+[4]
No-tillage	−[1,5]	−[1]	+[1]
Permanent beds	−[2]	+[2]	+[2]
Tied-ridges	+[1,4] −[1]	+[1]	+[1]
Subsoiling (25-30 cm)	+[1,3]	+[1]	−[1]

[1]McHugh et al., 2007; [2]Oicha et al., 2010; [3]Rockström et al., 2007; [4]Burayu et al., 2006; [5]Mesfin et al., 2005; [6]Temesgen et al., 2009; [7]Temesgen, 2007.

Soil compaction with TRAD is common in Ethiopian drylands. In compacted soils, no-tillage without prior soil amelioration (e.g. subsoiling) is not a viable option because poor water infiltration and high surface runoff result in low crop yields (McHugh et al., 2007; Temesgen, 2007). Farmers are generally aware of compaction problems, and prefer strategies that open-up the soil (Rockström et al., 2009). To improve infiltration and reduce run-off in compacted soils, subsoiling (25-30 cm depth, 75 cm intervals) has been tested experimentally. In a dry subhumid environment, subsoiling increased plant available soil water and sorghum yield but also increased the rate of soil loss relative to TRAD (McHugh et al., 2007).

A number of CA implements have been developed. These are modifications to the *maresha* plough that cause minimal soil disturbance. The aim has been to make the CA implements affordable, light and easy to use by smallholder farmers (Rockström et al., 2009; Temesgen, 2007; Temesgen et al., 2009). There is generally little yield benefit from reduced soil disturbance unless the practice is integrated with an adapted soil fertility management including the application of mineral fertilisers and rotations with legumes (Rockström et al., 2009; Burayu et al., 2006).

With minimum and no-tillage, weed control becomes initially a serious challenge. Generally, TRAD and handweeding are cheaper than the use of herbicides. Smallholder farmers do often not have the financial resources and have limited access to credit. Both constrain the adoption of CA practices (Temesgen, 2007). Another important constraint to adoption can be the high opportunity costs for crop residues. While farmers value the crop residues as animal feed, among other uses, research by Mesfin et al. (2005) showed that residue retention (3-6 Mg ha^{-1}) can be effective in improving yields due to higher plant available soil water. However, for mulching to be adopted, the long-term benefits from soil and water conservation for crop productivity need to be greater than the potential losses incurred by not using the residues as animal feed.

A survey including 50 households revealed that farmers appreciate the improved timeliness of planting and the reduced labour with minimum tillage compared to TRAD. This was especially true for farmers who do not own oxen and rely on share-cropping or renting draught power. Minimum tillage is also seen as an adequate option for female-headed households because it is unaccepted culturally for female farmers to plough (Temesgen, 2007).

Considering the complexities discussed above, we conclude that there is no single management practice that can be universally applied in smallholder farms of Ethiopia. Thus, flexible best-bet practices that are tailored to the specific, local conditions are likely to bring about wider adoption. Identifying best-bet practices requires a participatory approach involving farmers from project design through to implementation, and close ties with national extension services.

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Conservation Agriculture for smallholders in Africa: lessons, challenges and the vision

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Introduction

Rising food prices, increasing degradation of the natural land resource base, climate change issues, and increasing production input costs all threaten the livelihoods of millions of poor people as well as the economic and political situation in sub-Saharan Africa (SSA). Climate change is predicted to impact negatively on smallholder agriculture; with yield losses of 20-50% by 2050 (IPCC 2007) for Southern Africa. The 12.7% share of direct emissions from agricultural operations in SSA increases substantially when forests and pastures are also transformed into arable due to consumption pressure. However, agriculture possesses the dual face of also being part of the solution to climate change challenges by innovative interventions to increase the land's ability to sequester CO_2 and reduction of expansive land use through intensification. Smallholder farmers and Africa are net importers of food, diverting scarce foreign exchange, (US$ 16.5 billion in 2007, FAOSTAT 2009), that could have been used for other investments. With the SSA population expected to treble by 2050 (UN Habitat, 2010), demand for more and higher quality foods by the increasing urban population, and given environmental problems such as soil degradation, water scarcity, biodiversity loss and climate change, new and innovative solutions are required to improve food security. Sustainable increase of the productivity, stability, and resilience of production systems through conservation agriculture is the strategy taken by the African Conservation Tillage Network (ACT) and her partners to ensuring food security for the growing rural and urban populations in SSA. ACT collates and shares knowledge and information on conservation agriculture within the Africa –wide network of stakeholders.

Materials and Methods

The lessons are drawn from two case studies of two projects: (i) the Conservation Agriculture for Sustainable Agriculture and Rural Development (CA SARD) which was implemented in 10 semi-arid districts of Kenya and Tanzania from 2004 to 2011, and (ii) Smallholder Conservation Agriculture Promotion (SCAP) project in Burkina Faso, Niger and Guinea from 2008 to date. The targeted beneficiaries totalling 5000 are smallholder farm families, cultivating 1-2 ha in poor agro pastoral and cash crop producer communities. SCAP is financed by the International Fund for Agricultural Development (IFAD) and the French Agricultural development Fund (AFD). It is implemented by ACT with ICRAF and CIRAD. SCAP operates within IFAD financed projects of PICOFA and PDRD (Burkina Faso); PPILDA (Niger) and PADER/BGN (Guinea) in partnerships with National Governments and non governmental organizations. CA-SARD, funded by the Government of the Federal Republic of Germany has been executed by the Food and Agriculture Organization of the United Nations (FAO) and the regional coordination and administration functions were performed by the ACT. Inorganic fertilizers were promoted and used by all farmers in Kenya, by some farmers under the SCAP project and none in Tanzania. Fertilizer, fodder, fruit, live fence and wind breaker trees and shrubs (*Faidherbia albida*; Baobab; *Grevillea; Piliostigma)* are part and parcel of the CA package for the SCAP project. Soil cover has generally been attained by mixed cropping – with relayed and/or slow growing cover crops or shrubs, purposeful crop residue retention, zero or controlled grazing or establishment of cover crops which are non-edible to livestock. Some 800 smallholder farmers in 28 villages under the SCAP project used 31 farmer field schools (FFS) and individual farmer innovators to introduce and adapt innovative CA technologies. The second phase of the CA-SARD project was implemented through 282 FFS involving 8460 men and women farmers. The typical 0.2 to 0.4 ha FFS validation plot is subdivided into 4 to 5 treatments that address the 3 CA principles and aligned to the farmers' key production constraints. Treatments of one FFS form therefore the replicate of another similar FFS. The results presented herein are at a higher generalised regional level rather than details – which are presented elsewhere.

Results and Discussion

Forty seven percent of the trained 8,460 households in the CA SARD project (49% of the FFS members were women) have adopted and are benefiting from the CA technologies while reversing degradation of the environment. The percentage of those practising CA in the SCAP project is about 30%. The total area under CA farmed by those directly reached by the technology through FFS membership has reached 1800 ha. Under CA, smallholder farmers cultivating less than 2 ha, are able to attain sustainably higher yields under CA from the second year onwards in both years of scarce and also normal rainfall; marked improvement in food security and nutrition; less labor (up to 57%) in land preparation and weeding; and the freed up labor and cash is invested for better crop management and enterprise diversification including high value and all year round agriculture such as vegetables, dairy and poultry. ACT has learned together with farmers and partners, that under CA, it is possible to raise 2-3 crops simultaneously (or per year) instead of one. This brings the opportunity to substantially increase land (and labor) productivity without too much emphasis on yields for smallholder low external input systems. Furthermore, for semi-arid areas, CA with external inputs is more profitable but also more risky. The project managed to enhance and support CA equipment artisan and manufacturing capacity by training 8 CA equipment manufacturers from East Africa. These local manufacturers have produced 6200 units of CA equipment, fulfilling the local demands for rippers and subsoilers. The demand for jab planters and direct seeders is not fully satisfied locally and importation (mainly from Brazil) is still undertaken. CA-SARD has been the catalyst for the adoption and promotion of CA by many secondary organizations. These will continue to promote CA beyond the CA SARD lifespan and include the Governments of Kenya and Tanzania which recognize CA at policy level and eight local and International NGOs (such as RECODA, CPAR, WADEC, KENDAT, CARE Tanzania and TIST) that are promoting CA as a result of the CA SARD or SCAP efforts. The capacity of ACT for up-scaling CA in Africa has been substantially improved through the support received from the CA SARD and SCAP projects. ACT's staff numbers have increased by 14; the network has expanded from the Harare office and Nairobi headquarters to West and Central Africa (Burkina Faso) and the East Africa hub (Dar es Salaam); and from coordinating 1 project in 2007 (CA SARD); to 5 in 2011. The ACT website (www.act-africa.org) provides CA information which is accessed by many organizations across Africa; while targeted hard copy publications (posters, leaflets, manuals, information sheets) are constantly produced to satisfy the growing demand.

CA with external inputs is MORE PROFITABLE but also MORE RISKY

CONVENTIONAL (US$ per hectare)		CA WITH INPUTS (US$ per hectare)	
Sub-soiling	0.0	Sub-soiling	31.3
Land preparation (plow/hoe)	46.9	Land preparation (herbicide)	21.9
Seed maize 10kg	35.9	Seed maize 10kg	106.3
Fertilizer (1 bag)	71.9	Fertilizer (2 bags)	143.8
Planting (with hoe)	62.5	Planting (jab planter)	43.8
Stalk borer control	3.1	Stalk borer control	12.5
Weed management (hoe, x 2)	75.0	Weed management (herbicide)	25.0
Top dressing	0.0	Top dressing	6.3
Harvesting	6.3	Harvesting	15.6
De-husking	10.9	De-husking	21.9
Shelling	11.3	Shelling	31.3
Miscellaneous	21.9	Miscellaneous	28.1
TOTAL VC	345.6	TOTAL VC	487.5
REVENUE 12 bags	703.1	REVENUE 25 bags	1,781.3
GROSS MARGIN	357.5	GROSS MARGIN	1,293.8
Cash needed (risked):	**110.9**	**Cash needed (risked):**	**346.9**

Data source: FFS groups – Nakuru District, Kenya

Challenges

The greatest challenge facing wide scale adoption of CA in Africa is the exclusion of the private investors, including entrepreneurial medium scale farmers, whose critical role and resources needs also to be unleashed and brought on board. There are competing uses of crop residues to keep the soil covered with livestock feeds, fuel, building materials and hand crafts. Weeds are a real problem especially during the first years of CA when there is inadequate soil cover, available mechanical weeding options not CA compliant or demand too much labor, soil cover crop seeds are not easily available and the peer pressure that herbicides are not totally safe. Produce prices are usually highly variable, a phenomenon that increases the risks of using expensive inputs. As a result, the African farmer gets punished both ways for over and under production. Risks are aggravated by inadequate development of water resources for supplementary irrigation which leaves most farmers at the mercy of highly irregular rainfall.

Way forward

The experience gained so far is sufficient to support a longer term and large-scale investment effort, moving beyond village level pilot projects into watersheds, thus attaining critical mass in demands for CA services that would address the supply and demand situation for CA implements and market linkages.

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Maize yield increases and stabilization under Conservation Agriculture in semi-arid districts of Tanzania

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Keywords: smallholder farming, direct seeding, ripping, cover crops

Introduction

Frequent crop failures resulting from improper farming practices have entrenched erratic food supplies and extreme poverty in the semi arid areas of Tanzania. The conservation agriculture (CA) intervention aims at promoting practical, short term outcomes to help farmers optimise both their labour output and utilization of existing resources to maximize capture and retention of soil moisture, expand their cropping options while sustainably conserving their farm lands, and reduce the vulnerability of farm incomes. The Conservation Agriculture for Sustainable Rural Development (CA for SARD) phase 1 was a Project funded by the Government of the Federal Republic of Germany and executed by the Food and Agriculture Organisation (FAO) of the United Nations. Regional coordination and administration functions were performed by the African Conservation Tillage Network (ACT). The project aimed to contribute to the promotion of growth and improved food security in Kenya and Tanzania through the scaling up of conservation agriculture as a sustainable land management (SLM) tool. Through an increase in the numbers of CA farmer field schools, the Project was to expand the adoption of profitable CA practices by smallholder farmers in the two East African countries. To facilitate the scaling out process the Project enhanced the supply and availability of CA equipment for farmers by stimulating private sector participation in the manufacture, retailing and hiring of equipment.

Materials and Methods

This paper is based on the findings from samples of six to eight farmer field schools (FFS) from a total of 14 from Arumeru and Karatu Districts in Arusha Region Tanzania for three consecutive years from 2005 to 2007. Names of the FFS with villages in brackets include Ekenyo (Kilimapunga); Ikenya (Ikiushin); Ujamaa (Rhotia Kati); Tumaini (Getamock); Kinara (Tloma) and Upendo (Likamba). The gender mixed farmer groups constituted 20 – 25 smallholder farmers and were formed by voluntary membership to establish learning by experimenting with alternative crop production technologies. Participating farmers were guided by village group facilitators and ARI Selian research scientists to select tillage, weed control and cover crop treatment options considered "best bets" in ameliorating deficiencies in soil and water resources. Selected treatments were as follows: (1) Jab planter, glyphosate weed control, lablab cover crop planted after first weeding, (2) Ripping (ox ripper), glyphosate weed control, jab planting in the ripper furrow, pigeon peas intercrop, (3) Jab planter, glyphosate weed control, pigeon peas intercrop, (4) Ripping, glyphosate weed control, jab planter, lablab cover crop and (5) Farmers practice - ox ploughing, hand hoe weed control. Plot sizes varied from one FFS to another, ranging from 390 to 1440 m^2. The ox ripping treatment was imposed before the first rains when the soil was friable, and to ensure the first rains were harvested with no runoff losses. Field data was collected by the farmers themselves through a participatory monitoring and evaluation approach that incorporated the empowering agricultural ecosystem analysis (AESA). Data was collected on rainfall, labour input for the field operations, soil property changes, crop disease and insect attack/coping strategies, maize grain yield and cover crop grain yield. Recommended agronomic packages in terms of crop spacing and use of improved maize seeds were practiced. However, none of the FFS used industrial fertilizers or manure.

Results and Discussion

Effect of tillage
Ripping with either lablab or pigeon peas as cover crops produced significantly different and higher grain yields (of 1,949 and 2,043 kg ha^{-1}) compared to direct seeding with the jab planter (1,735 and 1,770 kg ha^{-1}) and conventional ox ploughing (1,353 kg ha^{-1}) during the first year of CA (Table 1). This was a relatively dry year with annual precipitation of 528 mm. The trend in yield increase differences continued during the second year with a relatively better rainfall of 755 mm. However, the higher yields in ripped sub-plots were not maintained in year 3 but were exceeded by the jab planter with a substantial soil cover of lablab (1,973 and 1,320 kg ha^{-1} for ripping with lablab and p/peas respectively compared to 2,738 for jab planting with lablab). The ox ploughed plots produced the lowest grain yield throughout.

Effect of cover crops
The direct seeded jab planter treatments produced the second lowest and significantly different yields during year 1. Yield trends changed in year 2 as the interaction of the established cover crops on tillage treatments started to have an effect. While ripped plots with pigeon peas produced the highest yields (3,018 kg ha^{-1} it was not significantly different to others, except the farmers practice), ripping with lablab produced the lowest yield of the tillage and cover crop treatments. The yield increase trends were consistent for lablab which produced and maintained the highest yield of 2,738 kg ha^{-1} in year 3 (in a year with a grand mean of 1,697 kg ha^{-1}) while pigeon peas dropped drastically to 1,320 kg ha^{-1}.

Yield variations across sites
Yields across different FFS varied greatly (from a maximum of 7.6 tons/ha in Rhotia Kati for ripper with pigeon peas to 0.2 tons/ha for the farmers' practice in Getamock), which was understandable due to the differing farmer management skills and the initial degraded status of the fields.

Preferred CA technologies
Participating FFS members were encouraged to choose preferred CA technological packages for implementation in their individual farms. Of the 352 households practicing CA, 206 (64%) are FFS group members while the remaining 146 are non-FFS members enticed by the benefits of CA. The preferred planting/tillage technologies are the ripper (61%) for FFS members; most of them complimented by the jab planter for seed placement, while a few farmers place the seeds manually in the ripper furrow and cover by foot.

Gender implications to CA
Women constituted 33% of the members of the FFS during formation of the groups. Of the total 206 adopters from 8 FFS, 136 (66%) are women. Interviewed farmers in Karatu explained that 90% of their active participants are women who see an opportunity to feed their

families, improve livelihoods and that most of the men are no longer available for agricultural work as they are employed in the tourism industry.

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Does Conservation Agriculture pay? Experiences from Zimbabwe

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Keywords: Cost Benefit Analysis; gross margin analysis, returns to labour, cost benefit ratio

Introduction

The biophysical benefits of Conservation Agriculture (CA) are well-documented. However, for farmers to take up the technology, it must make economic sense. The Protracted Relief Program (PRP) in Zimbabwe has been promoting Conservation Agriculture as a vehicle for poverty alleviation. Questions have been asked of the profitability of CA in the smallholder farmer context. The donors of the PRP program have also been asking questions on whether investments in poverty alleviation via CA have yielded satisfactory returns. This paper is a synthesis of the results of a cost benefit analysis done on the CA being promoted in Zimbabwe in the smallholder farming sector. There are few studies which have considered the economics of CA under smallholder conditions. In the context of our study, CA was centred on the use of hand-hoes for preparing permanent planting stations called potholes or basins. Seed and fertilizer inputs are also part of the CA package being promoted by PRP. In the current study, we hypothesised that CA profitability depends on agro-ecological zone, resource endowment of the farmer and the different components of CA adopted by the farmer.

Materials and Methods

The traditional Cost Benefit Analysis (CBA) model was modified to a financial analysis at household level. Market prices were used to value both inputs and outputs instead of the economic prices that take into account the real resource cost to the nation, and to value output at its real value to the nation, free of distortions, taxes, duties, exchange rate distortions and other impediments. The analysis considered both donor and household capital investments in CA. Household capital included the labour used in all crop production processes associated with CA, weeding both in winter and summer, digging of the basins and all crop management practices till harvest. Donor capital included the cost of training on CA, mineral fertilizers, seed and related costs. All the output produced was valued at the going market prices irrespective of whether consumed or sold. The effectiveness and impact of CA was measured using discounted cash flow analysis where both future costs and returns are discounted to the present day using a discount rate, which effectively introduces an opportunity cost of the capital employed. Indicators such as the Internal Rate of Return and Cost-Benefit Ratios are typically used to measure impact. The analysis compared returns to CA with the five other cropping models obtainable in the smallholder farming sector of Zimbabwe. Crop modelling data from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as well as gross margin budgets were used for the analysis.

Results and Discussion

The modelling results showed large yield variations depending on the quality of the season. In years with good rainfall there is very little difference between CA yields and the optimum farmer practice with fertilizer. Table 1 and Figure 1 give cropping scenarios and modelling results respectively. If a farmer adopts the full CA package the yield potential is 3.3 times that of the farmer practice. Because of several limitations most farmers do not adopt all the components of CA. Commonly adopted options are fertilizer use and timely weeding. Applying adoption proportions and inferences from the long term modelling predictions, average yields were calculated for CA and the five different cropping scenarios (see Figure 2). Cost Benefit Analysis was then undertaken using these yields. Gross margins developed show that with more years of CA on the same field, weed species change as broad-leaf species become more prevalent compared to grasses and labour requirements decrease. Soil fertility increases and these positive changes are reflected in better gross margins per hectare for CA farmers with more than four years experience.

Table 1: Cropping Scenarios Modelled

Cropping Scenario	Description
Normal farmer practice (no access to draft power)	Conventional ploughing, planted mid to late December and a minimum of 2 weedings
Optimum farmer practice (with access to draft power)	Conventional ploughing soon after effective rainfall and two weedings
Optimum farmer practice and microdosing	Conventional ploughing with 28kgs of nitrogen per hectare
CA basins without fertilizer	CA basins with two weeding and no fertilizer
CA basins including fertilizer	CA basins with two weeding and 28kg nitrogen per hectare
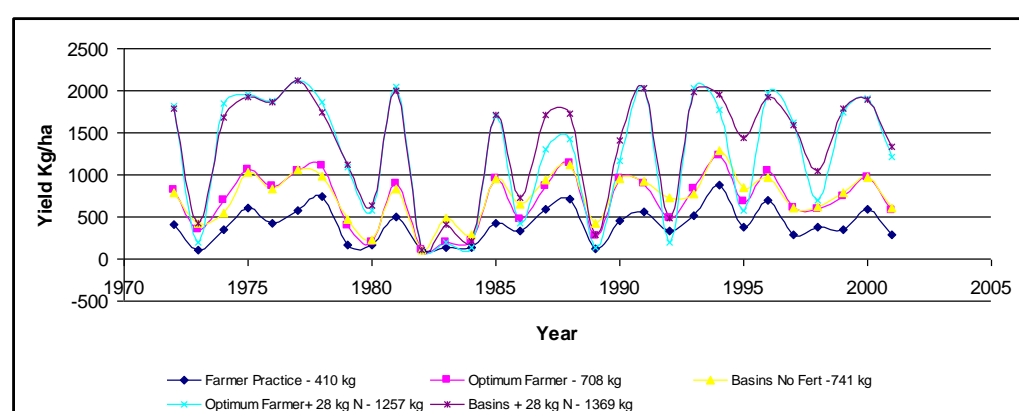
Figure 1: Seasonal Variations in Maize Yields predicted by crop modelling for five scenarios and Matopo Research Station

Labour is commonly cited as the main factor limiting adoption of CA by smallholder farmers. From the gross margin analysis CA has a higher return on labour compared to the farmer practice of planting late due to draft power shortages and no fertilizer application. The cost of producing a tonne of maize was USD239 for the farmer practice, USD146 per tonne for a farmer in the first three years of adopting CA and USD126 per tonne for experienced CA farmers. It is much cheaper to produce a tonne of maize for an experienced CA farmer. The return per labour hour was 9.8US cents for the farmer practice, 10.4 US cents for the inexperienced CA farmer and US15.7 cents for the experienced CA farmer. The return to labour invested in CA is substantial for experienced farmers. The doubling of labour hours,

compared to the farmer practice, in the first three years of adopting CA is a challenge for most smallholder farmers who might be interested in adopting CA. Real CA benefits are long term especially for those farmers willing to adopt the full package. The returns to fertilizer use were much higher for CA (79US cents per dollar invested) compared to 7US cents per dollar invested for the traditional farmer practice. CA is more efficient in the use of mineral fertilizer compared to the farmer practice. A comparison of gross margins by agro-ecological zone showed that in the drier regions with less than 500mm of rainfall annually, the margins were almost the same if not lower than the farmer practice raising questions of the suitability of CA in semi-arid regions.

Table 2: Percentage of farmers practicing basin planting who adopt different components.

Component	Cropping Season					Average
	2004/05	2005/06	2006/07	2007/08	2008/09	
Winter weeding	51	87	76	71	63	70
Application of mulch	40	75	69	70	56	62
Digging of basins	100	99	99	97	89	97
Application of manure	89	88	89	87	80	87
Application of basal fertilizer	71	75	74	66	38	65
Application of top dressing	94	92	92	88	70	87
Timely weeding	94	98	99	96	85	94
Crop rotation	8	13	13	18	19	14
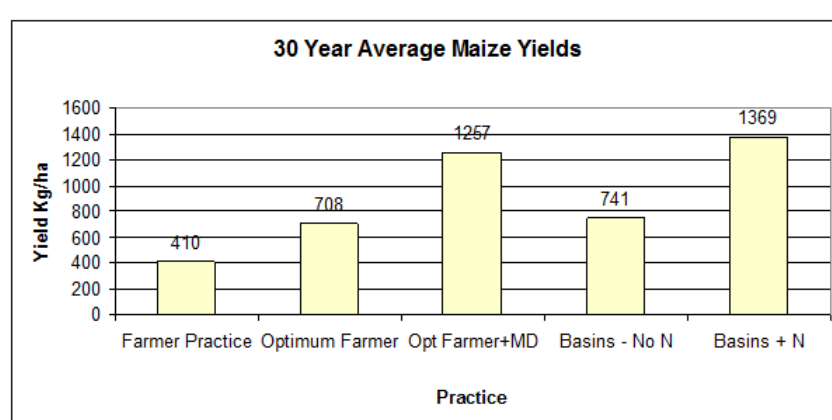
Figure 2: Long term Model Average Maize Yields

Using a discount rate of 12% the cost benefit ratio for CA was 2.3. A cost benefit ratio of 1.0 means that the initial investment is recovered over the life of the investment (25 years in this case) including a return on the capital invested of 12%. Ratios higher than 1.0 imply a return on capital greater that the discount rate used. In that regard CA has a high return on capital invested.

In conclusion CA is a viable option for smallholder farmers in Zimbabwe particularly for those smallholder farmers in high potential areas. CA responds much better to improved soil fertility management as shown by higher returns to mineral fertilizer use. The mechanisation of CA will definitely encourage more smallholder farmers to adopt CA as it will substantially reduce the labour required in the first three years of adoption.

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Termite prevalence and crop lodging under Conservation Agriculture in semi-arid Zimbabwe

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Keywords: maize crop residues, conventional mouldboard ploughing, smallholder farmers

Introduction

Conservation Agriculture (CA) seeks to achieve sustainable and profitable agriculture to improve the livelihoods of farmers through the application of three principles: minimal soil disturbance; permanent soil cover and crop rotations (PFA, 2007). Provision of soil cover through crop residues, among other benefits, ultimately results in a more favourable environment beneficial to soil fauna, which in turn enhances soil fertility. Macrofauna communities, dominated by termites, are the main agents of decomposition of surface mulches (Nhamo, 2007) into humus. The resulting humus plays an important role in soil aggregation, allowing aeration and water infiltration through the structure and channels made by burrowing fauna (Waters and Oades, 1982).

In spite of their known benefits, many smallholder farmers believe retention of crop residues contributes to increased termite prevalence thus increased crop lodging in semi-arid regions. This is more apparent towards the end of the rainy season where resultant lodging contributes to yield losses. On the other hand, some scientists suggest that the application of dry crop residues under CA may actually reduce termite attack on growing crops as they are thought to prefer dry stover as compared to fresh biomass (Nhamo, 2007). This study therefore sought to establish the linkages between termite prevalence and crop lodging at different residue amounts (commonly found in smallholder farmers' fields) applied at the beginning of the rainy season as a surface mulch.

Materials and Methods

This study was conducted in Kadoma district, Zimbabwe. Kadoma is in NR III receiving an annual rainfall range of 650-800 mm, where semi intensive mixed farming is generally practiced. The soils are dominated by kaolinitic fersiallitic red clay soils derived from mafic rocks (Nyamapfene, 1991). *Zea mays* (maize) is the major cereal crop grown hence maize residues were used.

A Complete Randomised Block Design (CRBD) experiment with 4 replicates per treatment was laid out. Four treatments of surface residue cover amounts of (0, 2, 4 and 6 t ha^{-1} under CA) and a control (conventional mouldboard ploughing (CMP) treatment where remaining crop residues are incorporated into the soil), were randomly allocated to plots in each of the four blocks. Maize on CA plots with surface applied residues was planted into 10-15 cm deep basins prepared by hand hoes and manually weeded twice or more per season. Plot sizes of 5 x 6 m were laid out in the experiment with an inter-block spacing of 1m. Three farmer fields were used for analysis in both seasons. Soil monoliths measuring 20 cm x 20 cm x 20 cm depth were used to sample each plot in February 2009 and March 2010 to collect termites. The number of crops lodged by termites were counted in each plot from the 4 replications at harvesting. A combined analysis of variance across sites was conducted using Genstat 6 statistical package, to analyse differences between treatment means. The least significant difference (LSD) at p=0.05 was used to differentiate between statistically different means. Simple Regression analysis was performed to test the relationship between crop residue amounts and crop lodging or yield.

Results and Discussion

Termite abundance/prevalence
Crop lodging
Significantly higher termite numbers at 4 and 6 t/ha of residues under CA compared to conventional mouldboard plough were observed in both seasons (Figure 1). Generally, implementation of the two CA principles (minimal soil disturbance and soil cover), resulted in significantly more termite numbers (2437 termites/m^2) compared to CMP (192 termites/m^2) over the two seasons. Minimal soil disturbance could mean that termites' nesting sites were not destroyed while ploughing increased this disturbance. Nhamo (2007) also found out that gallery construction by termites was more enhanced by conservation agriculture. The results thus support the idea that maize crop residues are a good attractant to termites as they act as a food resource and provide a suitable foraging site of soil fauna and hence influence their activities.
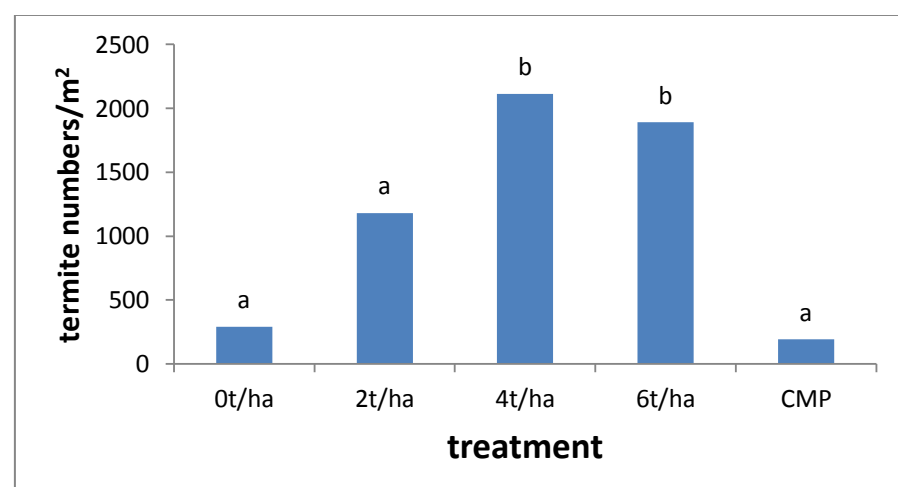
Figure 7: Effects of different residue amounts under CA on termite abundance (numbers per m^2 of soil) compared to CMP over two seasons in Kadoma

Generally lodging was lower under CMP (30.1 %) than CA (44 %). The addition of different residues amounts under CA however had no significant impact on crop lodging (p>0.05, in Figure 2). This could be attributed to the fact that by the time of harvesting (physiological maturity), all the residues applied at the onset of the season had been completely eaten by termites and other soil fauna. Hence, there was no extra food reservoir from the CA plots yet the termites were already attracted to the fields. The lower % lodged plants in CMP could

also be attributed to the fact that tillage had disturbed their channels since this has a bearing on the survival and reproduction of soil fauna (Kladiviko et al., 2007).

Crop yield
CA had significantly higher maize grain yield (2 900 -3 348 kg/ha) compared to CMP (2117 kg/ha). An increase in crop residues resulted in a positive but insignificant increase in grain yield (Figure 3).
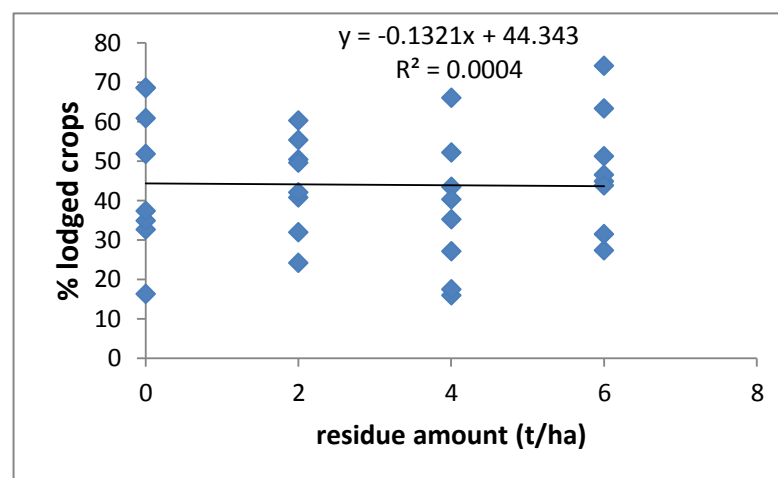
Figure 8: The correlation between different residue amounts under CA and % lodged plants in Kadoma for season 2008/9 to 2009/10. (p>0.05)
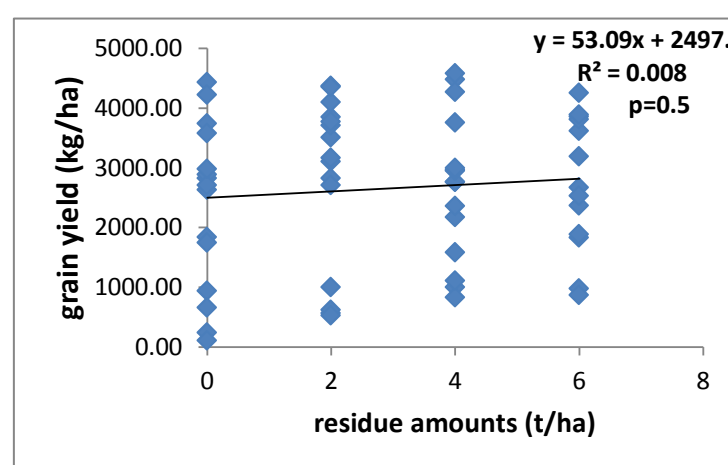
Figure 9: Relationship between crop residue amounts and grain yield (kg/ha) in Kadoma over two seasons

Conclusions and Recommendations

High crop residues exceeding 4t/ha under CA, increased termite numbers compared to CMP. This therefore confirms and provides scientific evidence to the farmers' opinion that addition of crop residues attracts more termites. CA thus suffers from this setback in termite prone environments where its use leads to increased crop lodging. The study also proved that addition of crop residues at the beginning of the rainy season under CA in termite prone environments, does not necessarily reduce crop lodging to an appreciable extent, but rather a shift from CA to CMP results in significant reduction in crop lodging. This therefore disqualifies the notion that addition of residues minimises crop lodging as termites would prefer dry matter and leave the crop. This is so because by the time of physiological maturity, all the residues would have been finished in termite prone environments. Thus termite control measures may be required under CA if termite levels reach pest proportions to minimize crop losses due to lodging.

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Experience in low cost CA farming systems with small scale farmers of north eastern Tanzania

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Keywords: Conservation agriculture, mechanisation, animal-drawn implements

Introduction

From the early 1980s, Tanzania including the north-eastern zone of the country has been experiencing occasional agriculture droughts as a result of erratic rainfall, poor rainfall distribution, lack of good management of rainwater and inadequate diversification of crop production. About 60% of Tanzania is semi arid, and therefore subjected to occasional droughts and food shortages. Such areas are not utilized to their potential due to inadequate technology in rainwater management and conservation tillage. In order to exploit their ecological potential other than rainwater management, appropriate soil and moisture manipulation are important.

About 60-70% of farming in the area is estimated to be mechanized where tractor implements and animal drawn implements are used while the remaining portion is done by hand hoe. Farming in this area results in heavy destruction of soil structure, depletion of soil fauna and loss of soil moisture. The area is a typical representative of the whole country because it harbours the same climatic ecological zones,
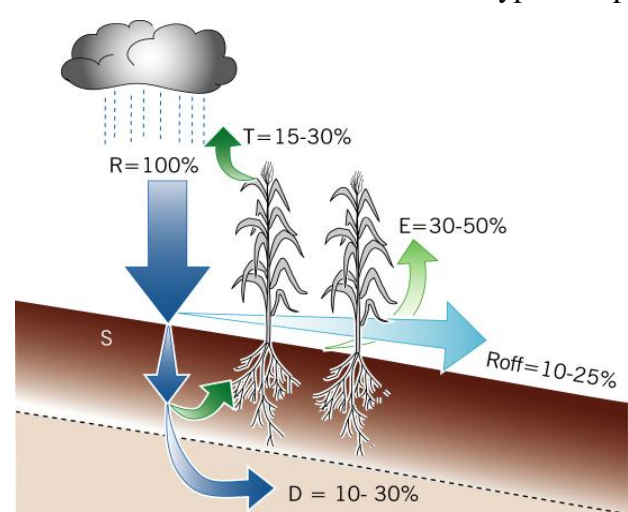
Figure 1. Partitioning of rainfall on farmers' fields in drought prone savannahs in sub-Saharan Africa (after Falkenmark and Rockstrom, 2008)

starting from the steep slopes of Mt Kilimanjaro about 5000 meters above sea level down to 500 meters above sea level. Soils are well drained and light volcanic, but can easily be eroded. These highland areas are highly populated followed by the midlands and the least populated is the lowlands. The average rainfall per annum ranges from 1000 mm in the highlands to 450 mm (very erratic and unevenly distributed) in the lowlands. In the highlands, a wide range of coffee and banana plantations are incorporated with trees for shade provision; where livestock keeping is intensive. The plantation practice also applies in the midlands but which is very sparsely cultivated and where livestock keeping is semi intensive, while in the lowlands extensive grain production is found, with maize being the major crop. Improper land management in all ecological zones involving conventional tillage is the major cause among others that has led to:

- Restricted plant roots penetration in the soil
- Washed away of plant nutrients
- Low moisture holding capacity
- Poor distribution of plant nutrients

Surprisingly, despite the frequent occurrence of water scarcity, there is in most years more than enough water to produce a good crop. A major problem is that large volumes of water in the farmer's field is lost by the crop due to land mismanagement and the erratic character of tropical rainfall. Figure 1 shows the average partitioning of rainfall on resource poor farmers fields in semi-arid farming systems in sub-Saharan Africa. Of the total rainfall in a growing season, only 15–30 % is used as productive green water, i.e., to support crop growth. Up to 85 % is lost as surface runoff, soil evaporation, and deep percolation. On degraded soil, up to 95 % of the rainfall is lost, and only 5 % flows as productive green water producing a yield of some 400 – 500 kg grain food per hectare.

The lowlands is much affected by the above mentioned situation and this paper narrates the experience gained from the small scale farmers in this area whereby they've increased 60% of their crop harvest with the application of CA farming systems and techniques as well as reduced their labour use.

Materials and Methods

The use of low cost animal drawn implements for deep tillage (e.g. the *Magoye* ripper – See Figure 2) is used to break the soil compaction by creating small channels whereby rainfall runoff water is checked; all trapped water is concentrated in the lines and percolates into the soil. Tilling the field is done well in advance before the rainy season starts or soon after crop harvesting to ensure the first drop of rain and thereafter is caught and stored into the soil for seed germination and plant growth. After ripping; farm yard manure/rock phosphate is applied into the lines and covered partially by soil. Dry planting is done into the lines depending on the desired spacing a farmer might choose, but the commonly used for maize production is 30cm plant to plant and 75cm apart from line to line. Two maize seeds are planted per hole but at knee height, the seedlings are thinned to remain one.

The undisturbed area between the lines is covered by crop residue (left in the field from the last season harvest) as mulch or planted lablab beans (*Dolichos lablab),* as cover crop for maximum moisture retention and nitrogen fixing. Shallow weeding and hand weed picking is done. Slashing is done (by hand slasher) between the planted lines, if mulch or cover crop is not applied. tilling is repeated at the same spot each season without disturbing the untilled areas.

Results and Discussion

In north-eastern Tanzania, on the semi-arid savannahs of Arusha, Arumeru and Babati districts, the use of conventional implements in ploughing the land both powered by engine or animal drawn has resulted in severe land degradation. Rainfall is bimodal, with the main rainy season for crop production being the *Masika* (or long rainy season) between March-June. Most farmers do not cultivate a grain crop during the short *Vuli* rains falling between November-January. Average rainfall is 420 mm for Masika rains. Variability is very large, with a range from 180 – 680 mm (and a standard deviation of 140 mm).

Development and adoption of conservation farming systems, based on minimum or no-till principles, started over more than two decades ago, has to date been adopted at a large scale by farmers in Latin America, North America, Australia and parts of Asia (Benites at el. 2002). Commercial farming systems in north-eastern Tanzania have adapted CA farming practices of late, while disc ploughing has been

abandoned in favour of tractor drawn chisel ploughs to achieve rain runoff water harvesting and also savings in diesel costs in line with minimal land tillage.
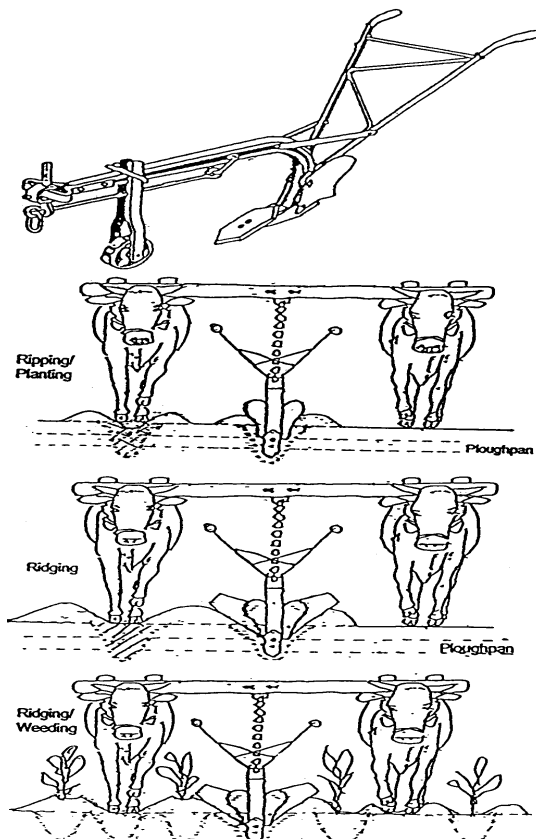
Figure 2. *Magoye*-based operations with Oxen (The *Magoye* Ripper is attached to the common plough beam and comprises a flat sharp chisel at the bottom. Two draught animals pull the implement by use of a yoke 210cm long making a space of 75cm between rows which can easily accommodate subsequent weeding by draught animals. - Drawings by J Rockstrom).

The use of the *Magoye* ripper with draught animals has reduced time and labour cost spent per unit area, to almost half of the time used in conventional ploughing by animal drawn mouldboard ploughs. This technique has been realised by small scale farmers because it enables them to prepare their fields in time to go with the unreliable rainfall distribution. The little rainfall harvested by this technology is exploited by the crop through its roots.

Application of mulch and cover crops on the field soil surfaces reduces the loss of moisture by evaporation, thus the assurance of moisture retention. Leguminous crops planted as cover crops maintain and increase soil fertility by fixing nitrogen into the soil. Farmers were conventionally achieving an average of 1 t/ha grain yield in the past, while now can get an average 3.9t/ha of maize. The cost of crop production in conventional farming compared to CA shows that with less resource costs incurred, CA also fetches more profit (see Table 1).

Table 1. Cost-benefit analysis comparing gross margin and net farm income (per acre) under conventional and conservation farming in semi-arid Arusha and Arumeru districts, Tanzania (NB: Tanzania Shillings, 1000 Tshs = 1 USD)

	Conventional		**Conservation Farming**	
Gross Output	(1.4 t/acre)	69564	(1.9 t/acre)	96843
Total Variable Costs		79000		76000
Gross Margin		-9436		20843
Total Fixed Costs		2500		3000
Net Farm Income		**-11936**		**17843**
		(-12 USD/year)		*(+18 USD/year)*

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The contribution of rainfall erosivity, soil cover and organic carbon to soil loss and run-off under CA on a fersiallitic red clay soil in Zimbabwe

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Keywords: Rainfall energy, soil erodibility, soil erosion

Introduction

Historically the switch of land use to agriculture has accelerated soil erosion. Soil erosion in general is influenced by four physical factors ie Vegetation (soil cover), Climate (rainfall), Soil (erodibility) and Topography (Slope). In Zimbabwe acceptable soil loss target levels thought to best match soil formation rates range from 3 to 5 t/ha/yr based on guidelines of the Soil Loss Estimation Model for Southern Africa (SLEMSA) (Elwell, 1982; Elwell and Stocking, 1984). The use of conventional mouldboard ploughing system (CMP) widely practised by about 70% of Zimbabwe's smallholder farmers is thought to be the main contributor to land degradation associated high sheet erosion resulting in huge losses of soil, nutrients and water through run-off (Elwell and Stocking, 1988). Among others one of the key benefits of conservation agriculture is its capacity to reduce soil loss and run-off to sustainable levels mainly through its effects on the vegetation(cover) and soil (erodibility) erosion factors (Vogel, 1993). Unfortunately not many studies have been carried out and reported in Southern Africa to compare the contribution of such erosion factors to soil loss and run-off under conventional and conservation Agriculture systems. This study thus evaluated the effect of rainfall energy or erosivity, soil cover and organic carbon on soil loss and run-off on a fersiallitic red clay soil at Hatcliffe, Harare, Zimbabwe measured over 3 cropping seasons.

Materials and Methods

Erosion research studies were carried out at Hatcliffe, Harare (grid reference 17° 42' S and 31^o06' E, +/_ 1 500 m above sea level) over 3 cropping seasons from 1993/4 to 1995/6. The site has a unimodal rainfall season and deep, well-drained, red clay soils, classified under the Zimbabwean System as Fersiallitic soils, Harare 5E.2 series (Thompson and Purves, 1978; Nyamapfene, 1991). Erosion research plots installed in 1980 on 30 x 10 m rectangular run-off plots (Hudson, 1957) with a general south-east facing slope of 4.5 percent, were used for measuring daily soil loss and run-off following each rainfall event. Rainfall energy or erosivity was determined from measurements of rainfall intensities achieved using an autographic rain gauge from which rainfall energy was calculated using the Hudson Index for each rain event. Soil mulch and crop cover was measured weekly using a crop cover instrument (Elwell and Wendelaar, 1977). Soil organic carbon was measured from composite soil samples collected annually from each plot within a depth of 20 cm. Soil moisture was determined weekly from 1994/5 using gravimetric and neutron probe methods.

The two tillage systems, mulch ripping (MR) and conventional annual mouldboard ploughing (CMP), laid out in a *completely randomized block design* with three replications, were continuously grown to maize throughout the study period. CMP is a land preparation method using an animal drawn mouldboard plough and mimicked the farmer practice in this study while the second tillage system, *mulch ripping* (MR), was a conservation agriculture (CA) system involving the retention of crop residues on the surface and minimum soil disturbance achieved using an oxdrawn ripper on 90 cm rows. No crop rotation was practised hence the third of the three principles of CA was not observed (Kassam et al., 2009) . Data was analysed using regression and analysis of variance.

Results and Discussion

As expected the results of the study show that CA maintained higher levels of soil cover throughout the three seasons studied (Figure 1). The effects of this soil cover due to mulching on dissipation of rainfall erosivity was more important during the early part of the season (Oct-Dec) than later (Figure 2a) thereby suggesting that the erosion process under CMP was driven more by detachment of soil particles by raindrop impact during this period and later by sediment transport during the mid to later season phases. On the other hand in MR, both detachment and transport capacities were kept in check by the mulch and crop cover throughout the season thereby resulting in significantly lower soil loss and run-off from CA. Overall significant but different (p<0.001) linear relationships were obtained between rainfall erosivity and soil loss showing that CMP was more sensitive to rainfall erosivity than CA, thereby emphasizing the importance of soil cover in keeping erosion under control (Figure 2b). Using multiple regression analysis the results showed that the most dominant factors influencing soil loss were in decreasing order of importance rainfall erosivity (t_{prob} =51.2, *p*<0.001), % soil cover (t_{prob}=10.57,*p*<0.001), top soil moisture content (t_{prob}=4.06; *p*<0.001) and soil organic carbon status. (t_{prob}=0.02; *p*=0.987). The effects of rainfall energy, % soil cover and moisture content on soil loss were significantly influenced by the type of tillage system employed while soil organic organic carbon was not. For example soil loss tended to increase with soil moisture under CMP while under MR it was not important. The results of the study illustrate the importance of taming the erosive power of high intensity rain storms experienced under tropical conditions through the use of live or dead mulches for soil cover as high storm erosivities exceeding 1400 Joules/m^2, were measured during the 3 year period. Immediate benefits of reduced soil erosion from the provision of soil cover in CA thus emanated from its capacity to neutralize rainfall erosivity and in particular during the early part of the season when soil cover due to the crop is at a minimum. Benefits of soil organic carbon to soil erosion although known to be important (Elwell, 1986; Chivenge et al., 2007), did not significantly influence measured soil losses relative to rainfall energy, soil cover and top soil moisture content.
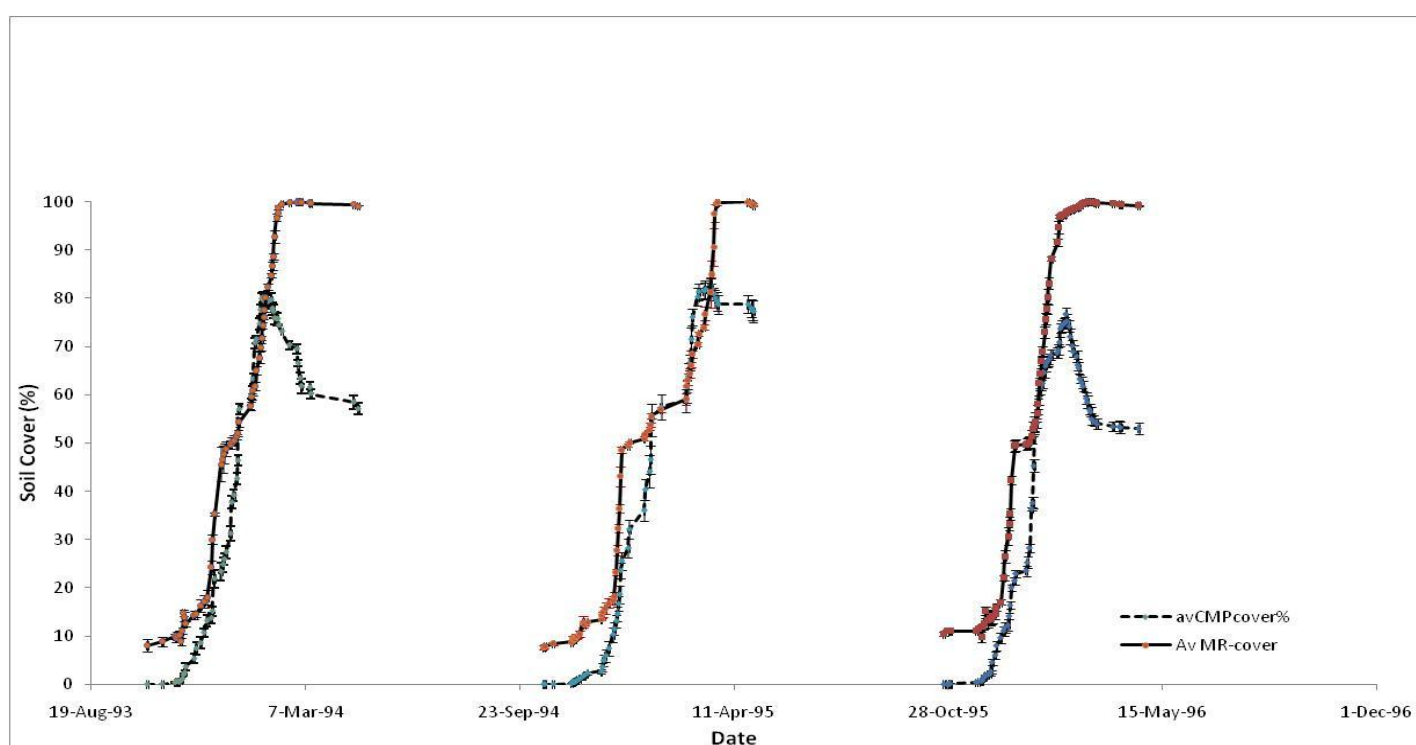
Figure 1. Soil Cover (%) changes comparing CMP and MR over three seasons at Harare. CMP= Conventional M'board Plough, MR= Mulch Rip. Error bars denote +/- SE of mean
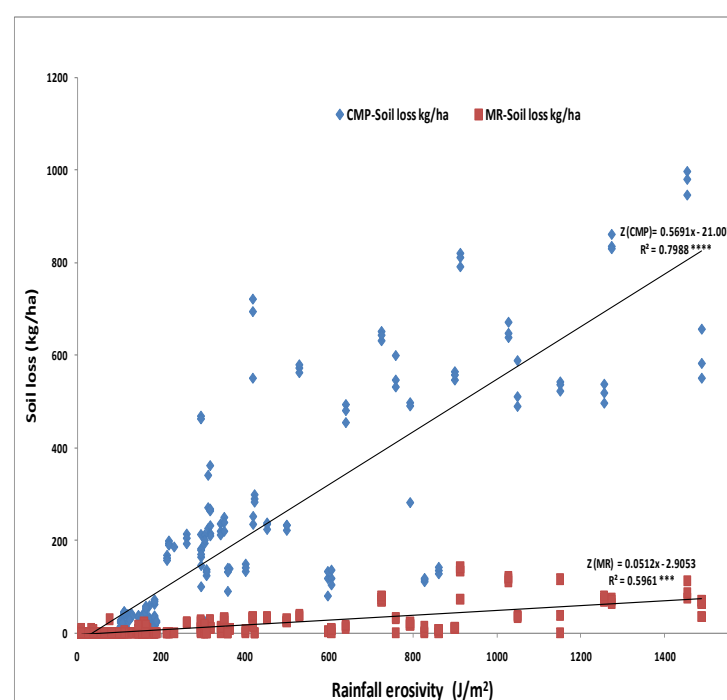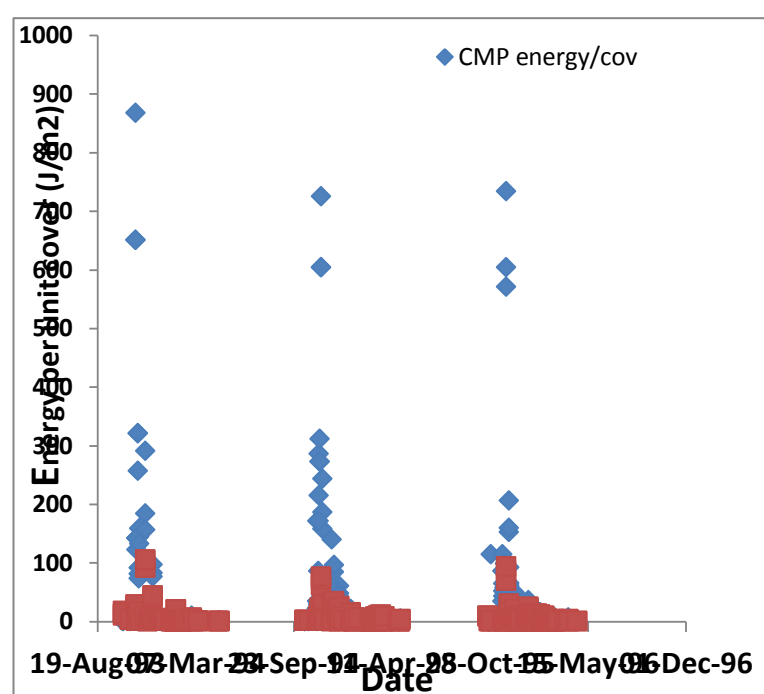
Figure 2. Comparison of CMP and MR over 3 cropping seasons in terms of (a) Rainfall energy per unit cover and (b) Soil loss against Rainfall Erosivity at Hatcliffe, Harare, Zimbabwe.

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Simulating maize (Zea Mays L.) responses to fertilizer under Conservation Agriculture practices in two distinct pedo-climatic zones of Zimbabwe

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Keywords: APSIM, parameterization, modelling simulation, modelling evaluation, nutrient use efficiency

Introduction

In sub-Saharan Africa (SSA), substantial increases in agricultural production are required to feed a rapidly expanding population. However, highly fluctuating rainfall, progressive degradation of soil quality, mainly caused by overexploitation, lack of external inputs and inadequate soil management practices have seriously affected agricultural productivity. To tackle such a challenge a number of international and local development organisations (FAO, NGOs etc.) suggest the implementation of Conservation Agriculture (CA) (FAO 2008). Simulations models have proved to be useful to capture the interactions between climatic conditions, soil types, nutrient dynamics and farming practices, all of which determine the efficiency of use of nutrients applied to cropping systems. However, the interaction of fertiliser use and soil water dynamics that take place under CA have been less studied through simulation modelling. Therefore, this paper describes the parameterization of the model APSIM (Agriculture Production System sIMulator) ver. 5.3 to test its ability to simulate such interactions as observed in field experiments carried out in two sites in Zimbabwe. Impacts of eight inorganic fertilizer levels and CA practices on maize performances in terms of fertiliser use efficiency were studied.

Materials and Methods

During 2007-08 season, a field experiment was carried out at the Domboshawa Training Centre (D.T.C.) and on the communal land nearby Majonjo village (M.V.) approximately 30 km NE and 70 km E of Harare, Zimbabwe. The D.T.C. site is on a loamy sand soil characterized by the presence in the 0-0.20 m layer of 1.04% of soil organic matter (SOM), 0.07% of total N and 10.77 g/ha of available P. This site had been under fallow for six years. The M.V. site is on a red clay soil and the SOM, the total N and the available P in the 0-20 m layer were respectively 2.33%, 0.16% and 4.98 g/ha. The tillage treatments were ox-ploughing on a bare soil and mulch ripping in D.T.C., while in M.V. they were hand hoe tillage and hand hoe planting basins with mulch retention. The treatments were laid out in a completely randomized design with 4 replicates at each site. Each replication was divided in 16 plots where CA (treatment A) and CT (treatment B) have been applied respectively 8 times. Each treatment received 8 different inorganic fertilizer levels (level $1= 0N – 0P_2O_5$; $2= 20N – 10P_2O_5$; $3= 20N – 40P_2O_5$; $4= 40N – 20P_2O_5$; $5= 40N – 40P_2O_5$; $6= 60N – 30P_2O_5$; $7= 60N – 40P_2O_5$; $8= 80N – 40P_2O_5$ expressed in kg/ha). Nitrogen fertilizer was spot-applied in 3 split applications. Nitrogen use efficiency (NUE), related to grain and biomass, was evaluated as the ratio of gained yields and the amount of N applied in fertilization level 3, 5, 6, 7 and 8. Analysis of variance (ANOVA) was used to test the effect of the two different treatments and eight fertilizer levels on maize performances. APSIM is a modular modelling framework that has been developed by the Agriculture Production System Research Unit in Australia (Keating et al., 2003). Whenever possible, the modules were parameterized with measured data as for the daily meteorological data, the management decisions like the plant population, the schedule of all field operations , the depth of tillage, the type and the amount of residues present on the ground at the sowing time, the amount of inorganic fertilizer applied, some phenological data about the maize variety ZS261including date of emergency, tasselling and silking and the chemical and physical soil properties for the 0-0.20 m layer. The parameters which describe soil water relationships were derived from standard equation starting from the soil texture. Other parameters, such as the amount of soil Organic Carbon (OC), mineral N, the two fractions (FBIOM and FINERT) which characterize in the model the SOM in terms of lability and the capacity of soil P sorption, were determined from standard values for the studied environment found in the literature (Chikowo et al., 2008; Nyamangara, 2001; Vogel, 1994; Zingore, 2006). The remaining parameters were calibrated using stepwise calibration starting from our knowledge and trial observations. Firstly, the model was parameterized against treatment A combined with fertilizer level 1, then application of other fertilizer levels was simulated and finally some parameters were modified to simulate the application of CA treatments, e.g. those describing the depth of tillage which was set as 0 cm under CA instead of 20 cm as for CT; the amount of residues at seeding time which was set as 4 t/ha instead of 500 kg/ha; the C/N and C/P ratios which were much higher under CA treatment than under CT due to the poor quality of maize residues in comparison with common weeds; the root exploration factor which was reduced from 0.8 for CT to 0.5 for CA due to clear difficulties for maize to establish extended roots under CA treatments in D.T.C.. It was not needed to change any parameters to describe soil water relationship because the model automatically modifies them in base of the quantity of residues applied on the soil surface. The evaluation of the model output in terms of maize dry grain yield and above ground biomass was done by comparing model simulated results and measured data from field experiments by using with seven model performance indicators and graphical representations.

Results and Discussion

In the D.T.C. site there were high statistically significant differences in both dry grain and above ground biomass yields between the two treatments and among the eight fertilizer levels ($P < 0.05$) (Table 1). Fertilizer level 1 yielded an average of 1.88 t/ha of grain and 1.76 t/ha of biomass while fertilizer level 8 yielded an average of 5.34 t/ha and 4.78 t/ha. In the M.V. site there were high statistically significant differences in grain and biomass production among the eight fertilizer levels while there were no significant differences in both variables between the two treatments. Fertilizer level 1 yielded an average of 1.56 t/ha of grain and 2.05 t/ha of biomass while fertilizer level 8 yielded an average of 2.95 t/ha and 5.02 t/ha. The comparison between observed and simulated grain and biomass yield is presented in Figure 1. APSIM 5.3 performance can be considered satisfactory because most of the simulation results are within the standard deviation of the observed values and most of the statistical indices were within the acceptable range (Table 1). Therefore, we can assert that in D.T.C. the maize performances for all fertilizer levels applied under CA treatments were significantly lower than in the CT plots mainly because maize suffered for soil compaction and water logging conditions as it was shown in the model's report file. Indeed, the application of CA combined with the registered environmental conditions determined a reduction in root growth and root absorption and therefore lower NUE for all fertilizer levels analysed both in terms of grain and biomass (Figure 2). Concerning maize performances in M.V. site the model explained the observed larger production of grain achieved under CA treatment combined with high rates of inorganic fertilizer than in CT plots. In such plots there was a slower release of nutrients and water turned into a longer availability of them and therefore into a larger

NUE. The model was not able to simulate the observed larger production of grain under CA treatment and fertilizer level 1 than under CT. Indeed, we observed that in general the simulations related to the CA practices are less precise. This was probably due to the lack in version 5.3 of APSIM of an option to specify the tillage method adopted, with the only exception of the parameters of tillage depth and residue management. The exercise showed in this paper is not sufficient to establish if in the two experimental sites CA treatments are more suitable than those of CT because it is based only on one year of field experiment, but we can conclude that modelling was a useful tool to add value to field experiment and to make it more meaningful.
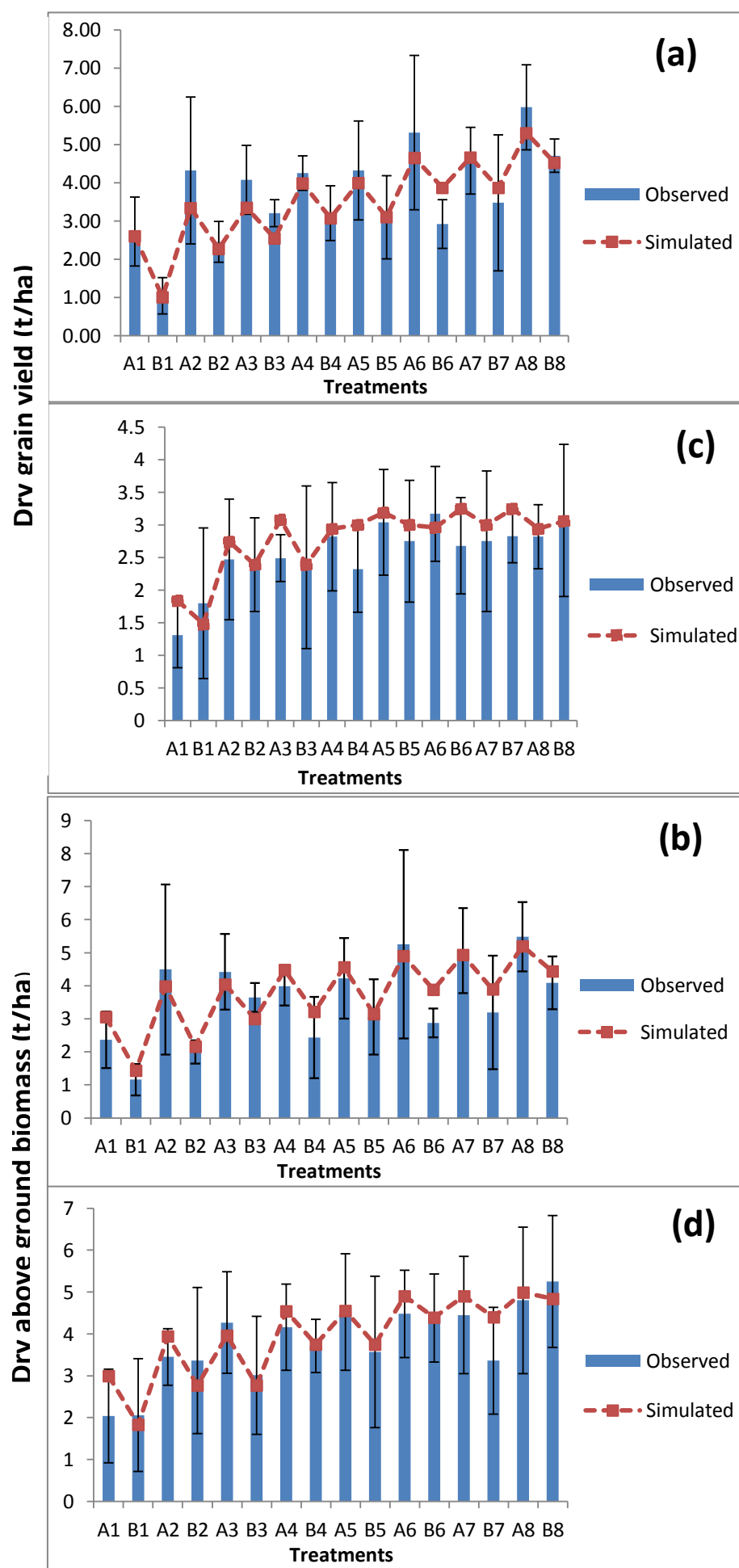
Figure 1. Comparison of observed and APSIM simulated maize grain (diagrams a and c) and above ground biomass (diagrams b and d) yields as affected by combined application of conventional tillage without residue retention (treatment A), conservation tillage with mulch retention (treatment B) combined with 8 inorganic fertilizer levels at D.T.C. (diagrams a and b) and at M.V. (diagrams c and d) sites. Error bars denote standard deviation of observed means, n=4.
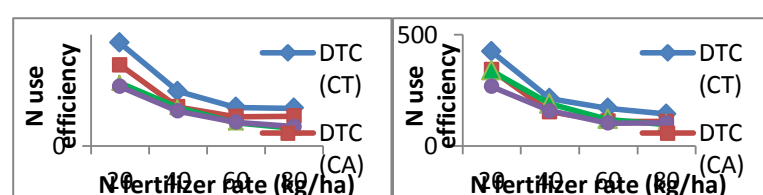
Figure 2. Nitrogen use efficiency (NUE), based on total grain (a) and biomass yields (b) and on fertilizer level 3, 5, 6, 7 and 8, gained at DTC and MV under CA and CT.

Table 1. Comparison of observed and APSIM simulated maize grain and above ground biomass yields as affected by combined application of conventional and conservation treatments with 8 fertilizer levels at D.T.C. and at M.V sites.

Model performance indicator	Grain Yield				Above ground Biomass			
	CA M.V.	CT M.V.	CA** D.T.C.	CT** D.T.C.	CA M.V.	CT M.V.	CA ** D.T.C.	CT ** D.T.C.
Observed data (t/ha)	2.52	2.61	3.01	4.44	3.52	4.02	2.81	3.52
Average error of bias (AE) (t/ha)	0.20	0.24	0.02	-0.46	-0.03	0.32	0.34	-0.02
Root mean square error (RMSE) (t/ha)	0.38	0.34	0.44	0.57	0.44	0.48	0.59	0.43
Coefficient of variation (CV) (%)	14.91	12.90	14.73	12.76	12.98	11.81	20.87	9.67
Modelling efficiency (EF)	-0.05	0.61	0.79	0.59	0.72	0.68	0.55	0.78
Coefficient of residual mass (CRM)	-0.08	-0.09	-0.01	0.10	0.01	-0.08	-0.12	0.00
Coefficient of determination (R^2)	0.73	0.84	0.82	0.86	0.77	0.85	0.74	0.82
t-test	0.44	0.35	0.96	0.33	0.96	0.43	0.49	0.92

**It shows high statistically significant differences

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Energy scenario and water productivity of maize based cropping system under Conservation Agriculture practices in South Asia

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Keywords: conservation agriculture, cropping system, maize, net energy, sustainability, water productivity

Introduction

Maize is one of the most important cereal crops in South Asia having wider adaptability to soil and diverse agro-climatic conditions. There has been a major shift in traditional monoculture of different crops towards cropping sequences due to the growing threat of food insecurity brought upon by natural resource degradation, declining water tables and projected climate change effects across the globe. In view of changing resource base and declining water table under the current farming scenario, concerted efforts are thus needed to maximize food production per unit of water, minimize land and environmental degradation and to attain socio-economic development through reorientation of agricultural research viz. adoption of system based research and deployment of new soil, water and crop management technologies viz. conservation tillage practices. Mechanization has provided various machines and options under different maize based cropping systems to tackle the various challenges under various agro-climatic conditions. During early seventies the energy crisis forced researchers/scientists to conserve energy in all sectors including agriculture and look for alternate option/source of energy. Presently the use of energy in agriculture is up to about 8% (Tandon and Singh, 2009).The energy used in various field operations *viz* tillage, irrigation, harvesting, and threshing and energy flow in crop production systems provides a good indicator about the effectiveness of various technological aspects of crop production systems in agriculture. Increasing demand on energy from agricultural sources has resulted in large-scale deforestation, soil erosion and loss of fertility on one hand and manifold increase in the requirement of commercial energy in the farm sector on the other side. For long term sustainability of production systems with higher efficiency in energy and water use the efforts have to be double pronged, firstly efficient use of energy and water by efficient technologies, and secondly harnessing benefits of less energy intensive production technologies/practices. Hence, in this study the efforts were made to determine energy and water used under various tillage and crop establishment practices and to conserve/reduce energy and water use on the farm by using conservation agriculture for various maize based cropping systems.

Materials and Methods

The present experiment consisting of three tillage management practices (zero till, permanent beds and conventional tillage) and four maize based cropping systems (maize-wheat-mungbean, maize-mustard-mungbean, maize-chickpea-*Sesbania* and maize-maize-*Sesbania*) was conducted at the research farm of the Directorate of Maize Research, New Delhi, which is situated at 28°58'N latitude and 77°10'E longitude with an elevation of about 228.6 m above mean sea level and having semi-arid and sub-tropical type of climate. The experiment was conducted at the same site during both the years without altering the layout plan and randomization of the treatments and was carried out in split plot design and replicated thrice. The initial composite soil sample of the experimental site was analysed and it was found to be sandy loam in texture and poor in organic carbon, low in available N and medium in available P and K having soil a pH value of 7.9. The field capacity and permanent wilting point of the experimental site were 19.12 and 6.52% on dry weight basis, respectively.

The total water requirement was calculated by adding total rainfall to total irrigation water applied under different tillage practices in various cropping systems which was estimated by using a Parshall Flume. Water productivity is the ratio of system productivity to the total water used under various treatments. The energy productivity and net energy were calculated by using the following formulae as suggested by Singh et al. (1997).

Net energy (MJ ha^{-1}) = Energy output (MJ ha^{-1}) – Energy input (MJ ha^{-1})

Energy productivity (kg MJ^{-1}) = Output (grain + by-product) (kg ha^{-1})/Energy input (MJ ha^{-1})

Results and Discussion

The inputs, such as fuel, electricity, machinery, seed, fertilizer and chemical take significant share of the energy supplies to the crop production system in modern agriculture due to intensive cropping. The water requirement and productivity of the water varied with resource conservation technologies under different maize based cropping systems (Table 1). The least water requirement along with maximum water productivity was found under permanent beds planting which was significantly different than zero and conventional till practices during both the years of study. Maize-chickpea-*Sesbania* cropping sequence was found to be the least water requiring sequence and also resulted in maximum water productivity during both the years of experimentation. Energy consumption per unit area in agriculture is directly related with the technological development for various cropping systems. Total energy output, energy productivity and net energy of different maize based cropping system were significantly influenced due to different tillage and crop establishment practices. The energy output, energy productivity and net energy was maximum under permanent beds planting over zero and conventional till (Table 2). Maize-chickpea-*Sesbania* cropping sequence resulted in maximum energy output, energy productivity and net energy over all other three cropping systems during first year while during second year energy outputs and net energy were maximum in maize-wheat-mungbean cropping sequence and energy productivity was maximum in maize-maize-mungbean. This was due to the differential yield response of the crops over the years. The system productivity and energy inputs in various maize based cropping systems under different tillage and crop establishment methods were found to be positively correlated with a value of R^2=0.486 (Figure 1). Singh et al. (1999) also reported that energy input and yield have positive correlation under different agro-climatic zones of Punjab.

The present study conducted for two years under various conservation agriculture technologies with different maize based cropping systems shows that permanent beds resulted in maximum water and energy productivity. Maize-chickpea-*Sesbania* cropping sequence resulted in maximum water and energy productivity but during second year energy productivity was maximum in maize-maize-mungbean.
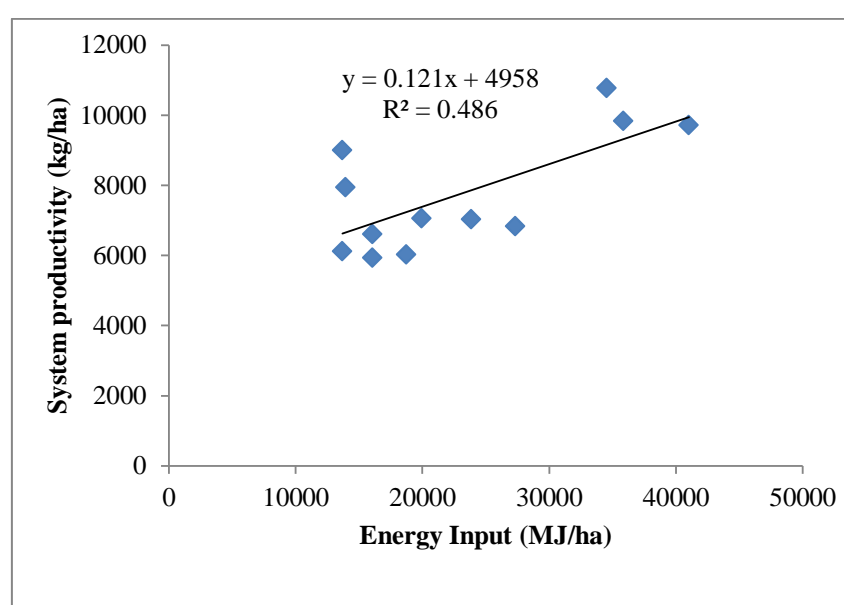
Figure 1. Correlation between system productivity and energy input in maize based cropping system under various tillage practices

Table 1. Water productivity of different maize base cropping systems under different tillage practices

Treatments	Water requirement (m^3)		Water Productivity (kg/m^{3}water)	
	2008-09	2009-10	2008-09	2009-10
Tillage practices				
Zero till (ZT)	6100 [b]	5950 [b]	1.38 [b]	1.31 [b]
Permanent Bed (PB)	5100 [c]	5100 [c]	1.78 [a]	1.63 [a]
Conventional Till (CT)	6800 [a]	6800 [a]	1.17 [c]	1.11 [c]
Cropping system				
Maize-Wheat-Mungbean (MWM)	7200 [a]	7000 [a]	1.27 [c]	1.47 [b]
Maize-Chickpea-*Sesbania* (MCS)	4200 [d]	4200 [c]	1.75 [a]	1.68 [a]
Maize-Mustard-Mungbean (MMM)	5600 [c]	5600 [b]	1.58 [b]	1.09 [d]
Maize-Maize-*Sesbania* (MMS)	7000 [ab]	7000 [a]	1.18 [d]	1.15 [c]

Table 2. Energy scenario of different maize base cropping systems under different tillage practices

Treatments	2008-09			2009-10		
	Energy output (MJ/ha)	Energy Productivity	Net Energy (MJ/ha)	Energy output (MJ/ha)	Energy Productivity	Net Energy (MJ/ha)
Tillage practices						
ZT	137198 [b]	4.27 [b]	105018 [b]	108004 [a]	4.56 [b]	84043 [a]
PB	149963 [a]	4.78 [a]	118609 [a]	100242 [b]	5.07 [a]	79778 [b]
CT	134307 [c]	3.88 [c]	99645 [c]	87797 [c]	3.67 [c]	63553 [c]
Cropping system						
MWM	149680 [b]	4.06 [c]	112544 [b]	151079 [a]	4.10 [d]	113943 [a]
MCS	156164 [a]	4.64 [a]	122527 [a]	100976 [b]	4.27 [bc]	77268 [b]
MMM	140467 [c]	4.61 [ab]	109835 [c]	78804 [c]	4.94 [a]	62648 [c]
MMS	115645 [d]	3.92 [d]	86122 [d]	63864 [d]	4.42 [b]	49307 [d]

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Soil organic carbon and nitrogen sequestration by long-term of Conservation Agriculture in a Mollisol of Mexico

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Keywords: no, minimum and conventional tillage systems; soil properties.

Introduction

Conservation agriculture can mitigate global warming (Lal, 2010) by organic carbon and nitrogen sequestration in the soil, moderating greenhouse gas emission, such as CO_2 and N_2O. The objective of this work was to evaluate the effect of three tillage systems on soil organic carbon (SOC) and soil total nitrogen (STN) sequestration and properties associated in a MOLLISOL in the Central Valley of Mexico. The effects of tillage systems on SOC and STN had been known, however in México, there is limited information about the long-term ($\geq$10 years) effects of soil conservation tillage systems.

We hypothesized that, after ten years of treatment, no tillage (NT) and minimum tillage systems (MT) would increase organic carbon and nitrogen content at the soil surface compared with the effects of conventional tillage system (CT), influencing carbon/nitrogen ratio. Additionally, this would reflect in higher SOC and STN under NT, and MT than CT. Reduction of losses by erosion, moderation of temperature and humidity regimes, and addition biomass through retention of residues from previous crops in rotation can increase storage of COS and STN under conservation agriculture, especially in the surface layer (Sainju et al., 2008). The long-term implementation of conservation agriculture systems which involve reduction of tillage and leaving residues of previous crops on the soil will tend to retain organic carbon and nitrogen, and improve other chemical characteristics of the soil, which may improve the long term productivity and profitability of food production.

Materials and Methods

A long-term field experiment was conducted in a Mollisol (*Soil Taxonomy*) from 1999 to 2008 at Agricultural Experimental Station of Chapingo University, in Central Valley of Mexico (19° 29'N, 98° 53'W, 2240m altitude). Treatments consisted of three tillage practices no till (NT), minimum till (MT), and conventional till (CT) in a rotation cropping system of *P. vulgaris* or *Z. mays* in spring and summer cycle and *T. aestivum or A. sativa* in autumn and winter cycle. Treatments were arranged in a Latin-square designs with three replications. The individual plot size was 46m x 46m, and the treatments were continued in the same plot every year to determine their long-term influence on SOC, STN and associated variables. Data were collected in the 2008 in the spring/ summer corn crop. The CT included moldboard plowing to 30cm depth after crop harvest and disking and levelling with a field cultivator. The MT included chisel plowing to 30cm before planting. The NT included planting in undisturbed soil. Both MT and NT were planting when at least 30% of the surface was covered with residues from the previous crop. Corn was planted using the no-till seeder in all treatments.

In September 2008, undisturbed soil core samples were collected with a hand probe (5.7cm inside diameter x 3.0cm high) from five random places in a central square of 20mx20m. Soil samples were collected at 0-3cm, 15-18cm, and 30-33cm of soil depth. These were air-dried, and sieved to 2mm for determining soil organic carbon (SOC), soil total nitrogen (STN) and associated variables. Bulk density (Mg m^{-3}) was determined by dividing the mass of the soil sample by volume of the probe, discounting weight and volume of roots, rocks, and residues. Total organic C and N concentration (%) in the soil was determined by the dry combustion method using a C and N analyser (Perkin Elmer 2400 Series II). The SOC (Mg C ha^{-1}) and STN (Mg N ha^{-1}) contents were calculated by multiplying their concentrations (%) by bulk density for each treatment and depth, for 0-11cm, 11-22cm, and 22-33cm soil layers. The carbon/nitrogen (C/N) was determined by ratio of C concentration (%) and N concentration (%). Data for organic C and N concentration, SOC, STN, bulk density, and C/N ratio among soil depths were analysed using GLM procedure of SAS. Tukey procedure was used for comparing the mean of treatments, and statistical significance was evaluated at P$\leq$0.05.

Results and Discussion

Soil bulk density was not significantly influenced (P$\leq$0. 05) by soil tillage treatments at 0-3cm, and 15-18cm soil depth (Figure 1). However, bulk density was significantly greater in CT at 30-33cm soil depth than NT, and MT, probably due to a plow pan resulting from more tillage operations in CT.

SOC was significantly influenced (P$\leq$0. 05) by soil tillage treatments in the soil layers evaluated (Figure 1), emphasising significantly greater value of SOC in NT than MT, and CT at 0-11 cm soil layer, but the opposite occurred at the 22-33cm soil layer. At 11-22cm layer SOC was not influenced by treatments. This suggests that residues produce increased SOC concentration at the surface soil, like poultry litter applied in long-term NT intensive cropping system in an Ultisol in northern Al, USA (Sainju et al., 2008). The larger SOC concentration observed in the 30-33cm soil layer under CT, compared with MT and NT, was probably an effect of the correspondingly higher bulk density, as well as the mix of profile soil that occurred under CT. Estimated C sequestration rates of NT were 4 Mg C ha^{-1} year^{-1} greater than CT, assuming that C sequestration is linear from 1999 to 2008. C sequestration under MT compared with CT was 2 Mg C ha^{-1} year^{-1} greater

Similarly, SOC, STN concentration varied significantly with treatments at the surface soil layer (Figure 1). This indicates that retained residues of previous crops on the soil under conservation tillage systems increases N cycling and increases soil N content. The difference between the levels of STN under NT and MT compared with CT, allowed us to calculate changes in STN levels in the 0-11 cm of the soil layer as influenced by soil conservation tillage systems after 10 years, and the ranged between 0.72 and 1.44 Mg N ha^{-1}. Assuming that N sequestration was linear over the 10 years evaluated, the estimated N sequestration rate by conservation tillage systems was between 72 and 144 Kg N ha^{-1} year^{-1}.

The C/N ratio of the soil also was influenced by soil tillage treatments at the surface soil layer after ten years (Figure 1). This suggests that both soil organic C and N probably change at different rates in the temperate climate of central valley of México, regardless of management practices.
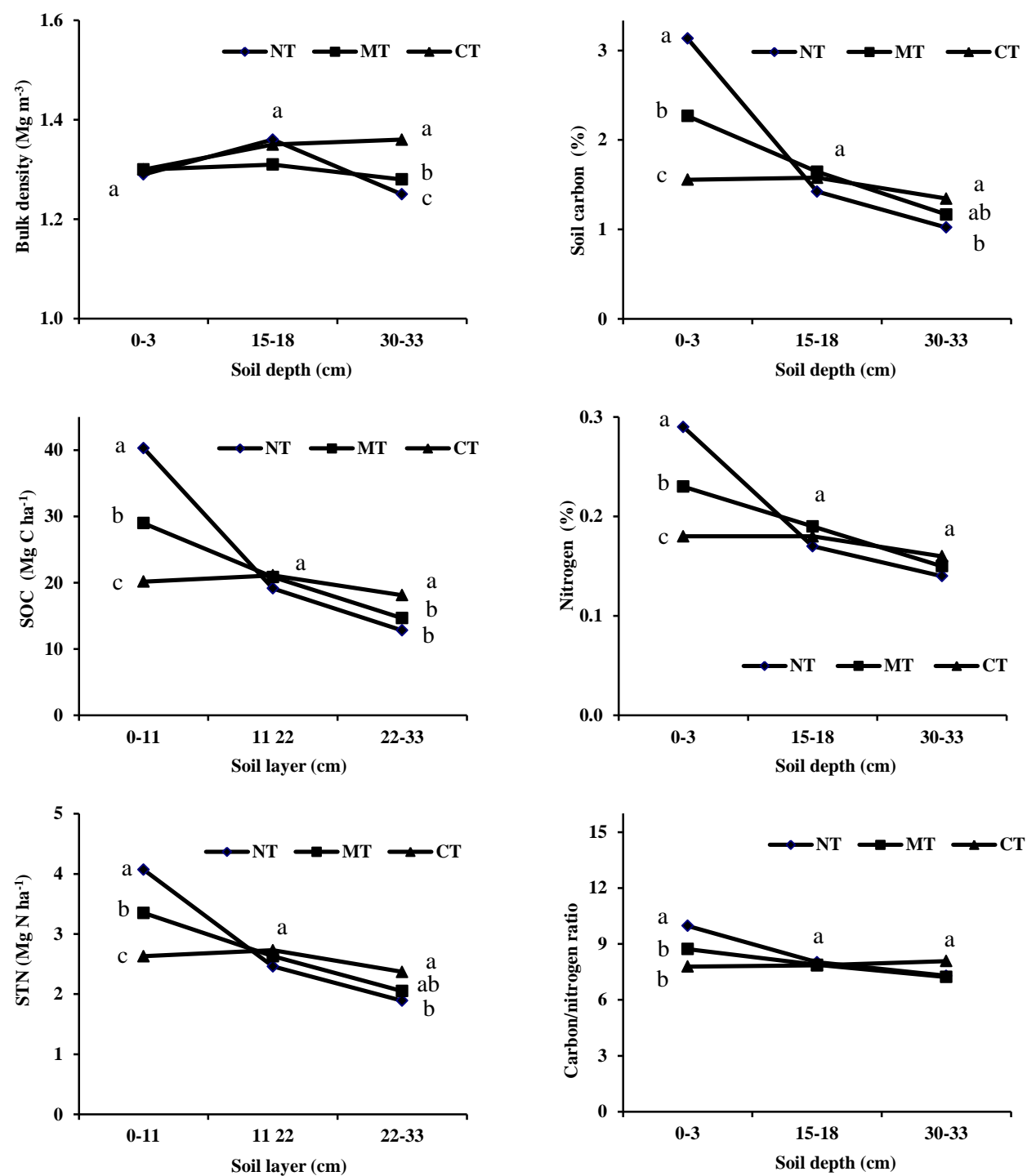
Figure 1. Soil organic carbon (SOC) and soil total nitrogen (STN) sequestration and soil associated properties under three tillage systems (NT=no tillage, MT= minimum tillage, and CT= conventional tillage) by long-term of conservation agriculture in a Mollisol of México.

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White grubs, Scarabaeidae larvae (Insecta, Coleoptera) control by plants in Conservation Agriculture: effects on macrofauna diversity

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Keywords: rice-based cropping system, direct seeding, cover crop, Madagascar

Introduction

Adoption of conservation tillage has reduced soil erosion in many parts of the world. Conservation management practices improve soil quality through the significant amounts of organic residues left on the soil surface, and cover crops also provide many benefits. These supply residues derived from dead plant parts and organic substances released from their living roots, and may foster soil organisms' abundance and diversity. They may also enhance ecosystem functions such as nutrient cycling (Rabary et al., 2008), soil structure and C sequestration, and pest and disease control (Ratnadass et al., 2006). In some regions of Madagascar, white grubs were found to be more abundant under direct seeding mulch based cropping systems (Ratnadass et al., 2006). White grubs are C-shaped larvae of a large group of beetles (Coleoptera:Scarabaeidae). Several species in this group cause significant damage to cereal crops by feeding on plant roots. The entomopathogenic bacterium *Metarhizium anisopliae* has been proven effective in controlling white grubs in some cases (Razafindrakoto et al., 2010), However, Randriamanantsoa et al. (2010) showed that there are many species of white grubs in Madagascar and most of them are endemic. Furthermore, some species are not pests but show "soil engineering" behaviour. This wide array of white grub species makes their biological control difficult. The fundamental dilemma in pest control with insecticide application is about significant detrimental effects on non-target species in the food web, which may deplete soil diversity and increase the possibility for subsequent pest outbreaks. This paper reports the impact a number of cover crops known for their pest-suppressing on white grub control within upland rice cropping systems. We presumed that these plants toxicity would alter the composition of soil macrofauna, but not negatively affect biodiversity overall, due to the positive effects of cover crops compared to those of the conventional tillage system.

Materials and Methods

A field experiment was conducted in 2009-10 in the Highlands of Madagascar, in the district of Andranomanelatra (S 19°46'45", E 47°06'25"), Antsirabe region. The area has a cold tropical upland climate with 10 – 20 days of frost annually and a mean temperature of 16.9°C. The site is at 1600 m above sea level with an annual average rainfall of 1450 mm. The soil is an andic distrustept, pH (H$_2$O) 5.4. The experiment was set up in a randomized complete block (RCB) design with 48 plots in 8 treatments over 6 blocks. Plot size was 14 m x 9 m. The treatments within rice-based cropping systems were no-tillage (NT) with cover crops compared to sole rice under NT without cover crop and rice under conventional tillage (CT). The cover crops used for white grub control were: hairy vetch (*Vicia villosa*), fodder radish (*Raphanus sativus*), *Brachiaria ruziziensis* x *B. brizantha* (var. mulato), *Crotalaria grahamiana*, *Cleome hirta*, *Tagetes minuta* and *Cosmos caudatus*. The 8 treatments were: i) Rice-Brachiaria; ii) Rice-Cleome-Tagetes-Cosmos; iii) Rice- Crotalaria; iv) Rice-Vetch; v) Rice-Radish; vi) Rice-Bean NT; vii) Rice-Bean CT; viii) sole Rice. In 2010, soil macrofauna abundance and diversity were assessed within each plot. One soil monolith, 25 cm x 25 cm x 30 cm, was extracted per plot, separated into litter and three layers: 0-10 cm, 10-20 cm, and 20-30 cm in depth according to the TSBF method. Monoliths were hand-sorted to collect invertebrates larger than 2 mm. Soil macrofauna were identified, counted and weighed. ANOVA were performed, using SAS (proc glm), on data transformed for non-parametric tests based on ranks according to Conover (1999). LSD test at *P* < 0.05 was performed to assess the differences among the means of abundance and biomass of macrofauna groups of six replicates.

Results and Discussions

In 2010, 2,155 individuals were collected from all the plots, counted and classified into 20 Orders and 48 Families. Classification were done up to species when possible but many species were not identified. The highest taxa numbers were found under *Raphanus sativus* and *Vicia villosa* (respectively 31 and 30 Families), with the lowest under CT and sole rice (19 and 20 Families). The NT system increased taxa number by 12% based on the rice + beans NT and rice + beans CT comparison. The NT increased taxa number by 16% under Brachiaria and Crotalaria cover crops. It increased up to 25% under radish. In decreasing order of abundance, the major taxa present in soil monoliths were Hymenoptera (ants) 32%, Haplotaxida (earthworm, mainly *Pontoscolex corethrurus*) 23% and Coleoptera 21%. All the other taxa accounted for less than 3% each, giving 24% in total. As for the feeding strategy (Table 1), there were no significant differences of macrofauna abundance in each group except for detritiphagous. Sole rice had the lowest number of detritiphagous although this was under NT system. Even so, it had no significant difference from the rice-bean NT. Sole rice NT also had poor macrofauna diversity. Our results confirm the importance of cover crops, especially under NT. They improve soil microclimatic conditions such as temperature, moisture and physical habitat. Moreover, the soil enrichment by organic matter from these plants favoured detritiphagous activity. Concerning macrofauna biomass, there were significant differences between cropping systems only for phytophagous and the non-identified group. The lowest phytophagous biomass means were found under rice-bean CT and rice-radish NT. White grubs formed 7.7% of the macrofauna density and the non-pest species were dominant (Table 2). White grub pests were absent from only three cropping systems (rice-bean CT, sole rice and rice-radish), while they were found in highest numbers under Brachiaria and Vetch. The significant soil pest attack observed in the sole rice field suggests damage by adults (data not shown) or other pest species. There is therefore a need to identify all white grub species, of which many are endemic. We also found *Polycleis africanus* (Curculionidae) was an important pest in some systems. Radish seems promising for white grub pest control. In addition, it did not reduce macrofauna diversity and abundance. Vetch was also favourable for macrofauna abundance but it did not express white grub pest control potential. Our results emphasise the importance of studying a wide range of plants as cover crops or residue mulch for soil pest control and the need to explore more plant species, because some have specific pest-suppressive effects.

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Rice straw mulching and nitrogen management to improve productivity of no-till wheat following rice in Bangladesh

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Introduction

No-till wheat cultivation utilizes residual soil moisture and reduces the time interval between rice harvest to wheat seeding under the intensive cereal cropping systems in Bangladesh. Generally, weed intensity is higher under no-tillage (Gill and Arshad, 1995; Fisher et al., 2002) that could be controlled by crop residue mulching (Erenstein 2002). Root development and proliferation depend on soil moisture and grain yield of wheat under mulches is higher due to longer rooting and higher moisture content in the upper soil layers (Bonfil et al. 1999). Under no-tillage, most of the applied fertilizers remain on the soil surface that directly expose them to air and sunlight, causing greater loss of N fertilizer. Straw retention as mulch reduces N loss especially by reducing volatilization (Bhagat and Verma 1991). The beneficial effect of crop residue mulch is well established and with the introduction of combine harvesters, cereals straw remains in the field either as mulch or it is incorporated into the soil in developed countries. But in Bangladesh, the use of crop residue in soil conservation is very limited. Farmers use the rice straw as feed for livestock, fuel and also in thatching their huts. The dual use of rice straw, as mulch for a short period and later withdrawing it for fuel may make it possible to resolve such competing needs for crop residue. Information relating to mulch management and N requirement in wheat under no-till conditions of paddy soil is scarce. Therefore, the objectives of this study were to determine the N requirement and to investigate whether rice straw mulch has the potential of increasing yield of no-till wheat by controlling weed growth, conserving soil moisture and increasing nitrogen use efficiency.

Materials and Methods\

The experiment was conducted at Wheat Research Centre, Dinajpur, Bangladesh for two consecutive years. Experimental field characterized as non-calcareous acidic alluvial soil with low organic matter content under the Old Himalayan Piedmont Plains of Bangladesh. There were twelve factorial combinations of three mulch treatments (No mulching-M_0, Rice straw mulching @ 4.0 t ha^{-1} that withdrawn at 20 days after sowing-M_1, and mulching @ 4.0 t ha^{-1} and retained on the soil-M_2) and four nitrogen levels (0, 80, 120 and 160 kg ha^{-1} from urea). The treatments were assigned in RCBD with 3 replications 5m×3m size plots. Spring type wheat (CV Prodip) seed were broadcasted uniformly on the no-till and moist (33 to 31% by wt.) soil surface of a post harvested paddy field on 20th and 25th November for the years 2007-08 and 2008-09 respectively. Half of the urea was uniformly applied in the field before sowing wheat. The rest of the N fertilizer was applied in two equal splits as top dressing at crown root initiation (CRI) stage on 21 days after sowing (DAS) and at 1st node stage on 35 DAS. Rice straw was spread manually over the soil surface to cover about 80% of the ground area just after sowing wheat seed. The crop was irrigated uniformly to bring the soil moisture near to field capacity at 21, 41, 60 and 80 DAS for both the years. Soil samples from the upper 15 cm depth for each plot were collected in 5 days interval to determine soil moisture. Weeds grown in wheat fields were sampled randomly using 0.5×0.5 m squares with four replications for each plot at 20, 35 and 45 DAS to determined dry biomass. The crop was harvested at maturity and grain yield and biomass were converted to t ha^{-1} at 11% moisture content. N content in grain and straw was analysed following standard method to estimate N uptake and ANR (%).

Results and Discussion

Soil moisture contents at different stages were similar for different N level but varied due to mulch levels. Surface (0-15 cm) soil moisture decreased faster in the plots with no straw mulch (M_0) and moisture contents under M_1 and M_2 were higher than M_0 in different stages for both the years (Figure 1a and c). Higher soil moisture content in M_1 and M_2 at initial stages favoured germination and stand establishment of wheat as compared to M_0. Due to irrigation at 21 DAS, soil moisture in all plots was raised to near field capacity at 25 DAS and then gradually decreased with time, but the rate of decrease varied among the plots. Even after withdrawal of straw mulch at 20 DAS for the M_1 treatment, the moisture content in the plots under M_1 remained at a level that was comparable to M_2 but higher than M_0. Primarily, mulching has role as a barrier against soil water evaporation thus surface soil moisture conserved by crop residue mulch.

The weed emergence and their growth in non-mulched plots were very high in both years. Rice straw mulching had a significant effect at controlling weed growth (Figure 2a and c). The dry mass of weeds under M_1 and M_2 was similar up to 35 DAS, and at 45 DAS it was higher in M_1 as compared to M_2; however, at this stage weeds could not compete with the wheat crop as reflected by similar yields of wheat under M_1 and M_2 (Table 1). This result suggested that mulching at early growth stage could be effective in no-till wheat production. Mulches may control weed growth typically by shading and or through allelopathic effects (Bilalis et al. 2003). The dry matter of weeds at different periods increased linearly with N levels from 0 to 160 kg ha^{-1} (Figure 2b and d).

The effect of straw mulch, N level, and their combination on grain yield and N uptake (grain + straw) of no-till wheat was significant for both the years (Table 1). Under a non-mulched condition N uptake was the least in N_0 level and was gradually increased with N levels. In contrast, under M_1 or M_2, N uptake was significantly increased till N level of 120 kg ha^{-1}. ANR (%) varied due to interactions, and it was the least at N level of 160 kg ha^{-1} with no mulching and it was the maximum at N level of 80 kg ha^{-1} coupled with mulch level of M_2 (Table 1). However, the means of ANR (%) under M_1 and M_2 were similar and much higher than M_0.

At any N level, both mulching treatments of M_1 and M_2 produced higher yield compared M_0. Under no mulching, grain yield increased linearly with increasing N rate, while under M_1 and M_2, yield was statistically similar for N rate of 120 and 160 kg ha^{-1} which indicates that rice straw mulching could save nitrogen @ 40 kg ha^{-1} in no-till wheat cultivation. The results demonstrated that controlling the limiting factors straw mulching can enhance the crop growth and development, and results in higher grain yield. Mulching also enhanced better rooting and increased the ANR% in relation to higher N uptake, which may lead to a higher grain yield of wheat. Bonfil et al. (1999) and Fisher et al. (2002) also reported the positive effect of straw mulching on no-till wheat.
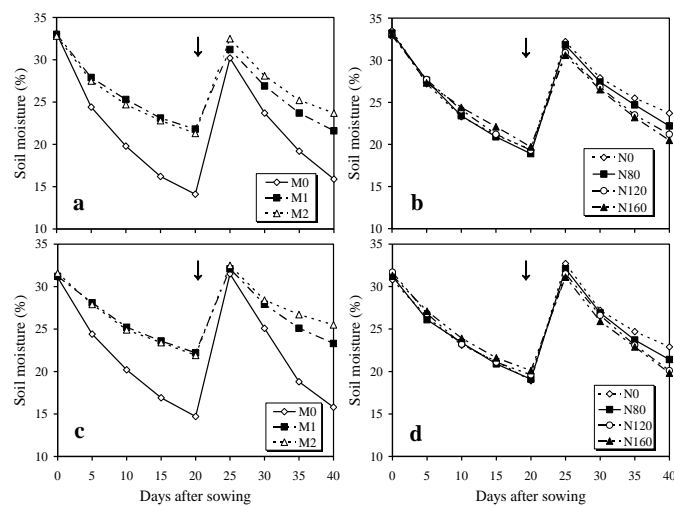
Fig. 1 Soil moisture dynamics in surface layer (0-15 cm) as affected by mulching and N levels in 2007-08 (a and b) and 2008-09 (c and d) seasons. Arrows indicate irrigation.
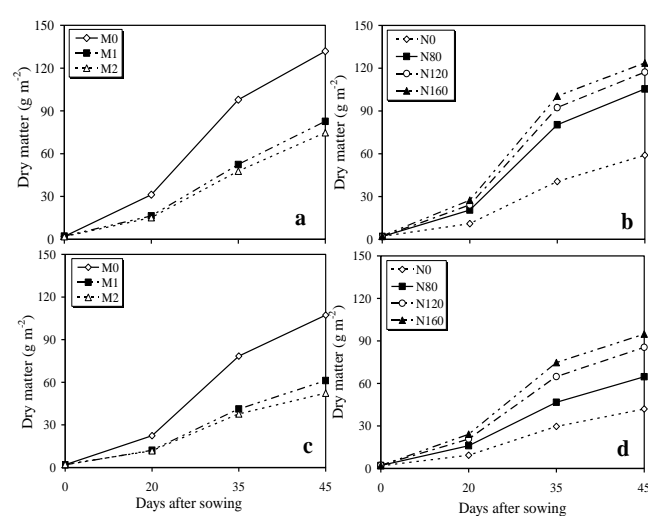
Fig. 2 Weed growth (Dry matter in g m-2) over time as affected by mulching and N level in 2007-08 (a and b) and 2008-09 (c and d) seasons.

Table 1: N uptake, apparent N recovery (ANR %) and grain yield of no-till wheat as affected by interactions of mulching and N levels

Treatments		2007-08			2008-09		
Mulch	N rate	N uptake	ANR	Grain yield	N uptake	ANR	Grain yield
level	(kg ha^{-1})	Kg ha^{-1}	(%)	t ha^{-1}	Kg ha^{-1}	(%)	t ha^{-1}
M$_0$	0	19.7		0.58	14.7		0.31
	80	58.9	49	1.93	51.6	46.1	1.52
	120	74.1	45.3	2.36	66.8	43.4	1.96
	160	86.4	41.7	3.06	80.1	40.8	2.54
M$_1$	0	24.1		0.77	21.9		0.67
	80	81.3	71.6	2.83	74.3	65.5	2.17
	120	101.4	64.5	3.71	96.8	62.4	3.74
	160	110.6	54.2	3.81	102.4	50.3	3.62
M$_2$	0	24.6		0.79	23		0.69
	80	83.6	73.7	2.92	76.9	67.4	2.21
	120	106.2	68.1	3.93	100.5	64.6	3.92
	160	112.9	55.2	3.98	107.4	52.8	3.73
LSD $_{0.05}$		10.2		0.36	9.8		0.34
CV (%)		9.5		10.2	10.4		11.2

M$_0$-No mulch, M$_1$-Rice straw mulch of 4.0 t ha^{-1} that was withdrawn at 20 days after wheat sowing and M$_2$- Rice straw mulch of 4.0 t ha^{-1} that retained on the soil surface.

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InfoRCT: productivity, income and environment simulation tool for Conservation Agriculture based rice-wheat rotation

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Key words: crop modeling, conservation agriculture, biocide residue, green house gas emission

Introduction

The rice-wheat cropping system (RWCS) is a major agricultural production system, which is source of livelihoods for hundreds of millions of rural poor of South Asia (Saharawat et al 2010, Jat et al 2011). Indiscriminate use of the natural resource base and changing climate in recent past have led to the negative yield trend and plateauing of rice–wheat system productivity (Pathak et al., 2003). The growing labor, energy and water shortages are likely to adversely affect the productivity of the RWCS (Gathala et al 2011). Conservation agriculture (CA) - based technologies improve production and income, and address the emerging problems (Gupta and Seth 2007, Jat et al. 2009, Saharawat et al. 2009). Long term field trials reveal that studying the efficiencies of management practices are not only time consuming and costly, but also some of the parameters (nitrogen flux, biocide residue and green house gases) are difficult to measure. Hence, modeling can be used for quantitative evaluation of efficiency of CA based management practices. Crop models can assist in the impact assessment and future extrapolation potential of improved CA technologies. The InfoRCT (**Info**rmation on Use of **R**esource **C**onservation **T**echnologies) is a Microsoft Excel-based spreadsheet model that can be adopted for quantitative evaluation of the RCTs in terms of productivity, resource use efficiency, cost effectiveness and environmental impact i.e., N loss, GHG emission and biocide residue in soil. Using InfoRCT this paper uses results from farmer managed participatory CA trials to evaluate and validate the effects of various CA based RCTs on productivity, resource (water, labour and energy) use efficiency, cost effectiveness and environmental impact i.e., N loss, GHG emission and biocide residue in soil in RWCS of the Indo-Gangetic Plain (IGP).

Materials and Methods

On-farm evaluation of RCTs was carried out on fields of 76 randomly selected RW growing farmers in North-western IGP. Initially a baseline survey from different villages was conducted to understand farmer input use in conventional farmer practice (FP, T1). The CA based RCTs introduced in the region are T2) Unpuddled-transplanted rice (UP-TPR) followed by no-till drill seeded wheat (ZTW), T3) Transplanted rice on raised beds (BP-TPR) followed by no-till drill seeded wheat on same beds (ZTW), T4) No-till transplanted rice (ZT-TPR) followed by no-till drill-seeded wheat (ZTW), T5) No-till dry-direct-drill-seeded rice (ZT-DSR) followed by no-till drill seeded wheat (ZTW). Details of each farm operation were recorded and analyzed for all input use and agronomic practices at each farmer's field. The cost of cultivation was calculated by taking into account cost of all inputs, their application and other management practices. InfoRCT integrates bio-physical, agronomic and socio-economic data to establish input-output relationships in RWCS under different tillage and crop establishment methods. FP data was used as the model input data to calculate the required amounts of fertilizer, irrigation water, biocides, human and machine labor, seeds as well as N budget, biocide residue, and GHG emissions. The climatic data were recorded from the nearest possible weather station. Using the primary data, InfoRCT model was validated for the fertilizer requirement; irrigation water requirement, N losses, GHG emission and biocide residue index under different CA based RCTs adopted by the farmers using the target-oriented-approach.

Results and Discussion

Experimental
On average highest rice yields (6.6 and 6.8 Mg ha^{-1} in yr 1 and 2) were obtained in unpuddled transplanting (T2) followed by zero-till transplanting (T4) and FP (T1). In DSR (T5) yields were 3 to 5% lesser than ZT-TPR (T4), UP-TPR (T2) and FP (T1) (Figure 1). In contrast to rice, wheat yield was 3and 4% higher on raised beds (T3) in yr1 and yr 2 followed by no-till wheat (Figure 1). This is in conformity with the findings of Gathala et al. (2011), Saharawat et al. (2010, 2009), and Jat et al. (2009). Rice-wheat system yields were similar in puddled transplanted (T1), unpuddled transplanted (T2), no-till transplanted (T4) and direct drill seeded (T5) treatments, but on raised beds (T3) yield was 5% lower than in T1 (Figure 1). In double no-till system 61% of the farmers had a system yield gain of 1.5 Mg ha^{-1} and 0.5 Mg ha^{-1} over T1 respectively.
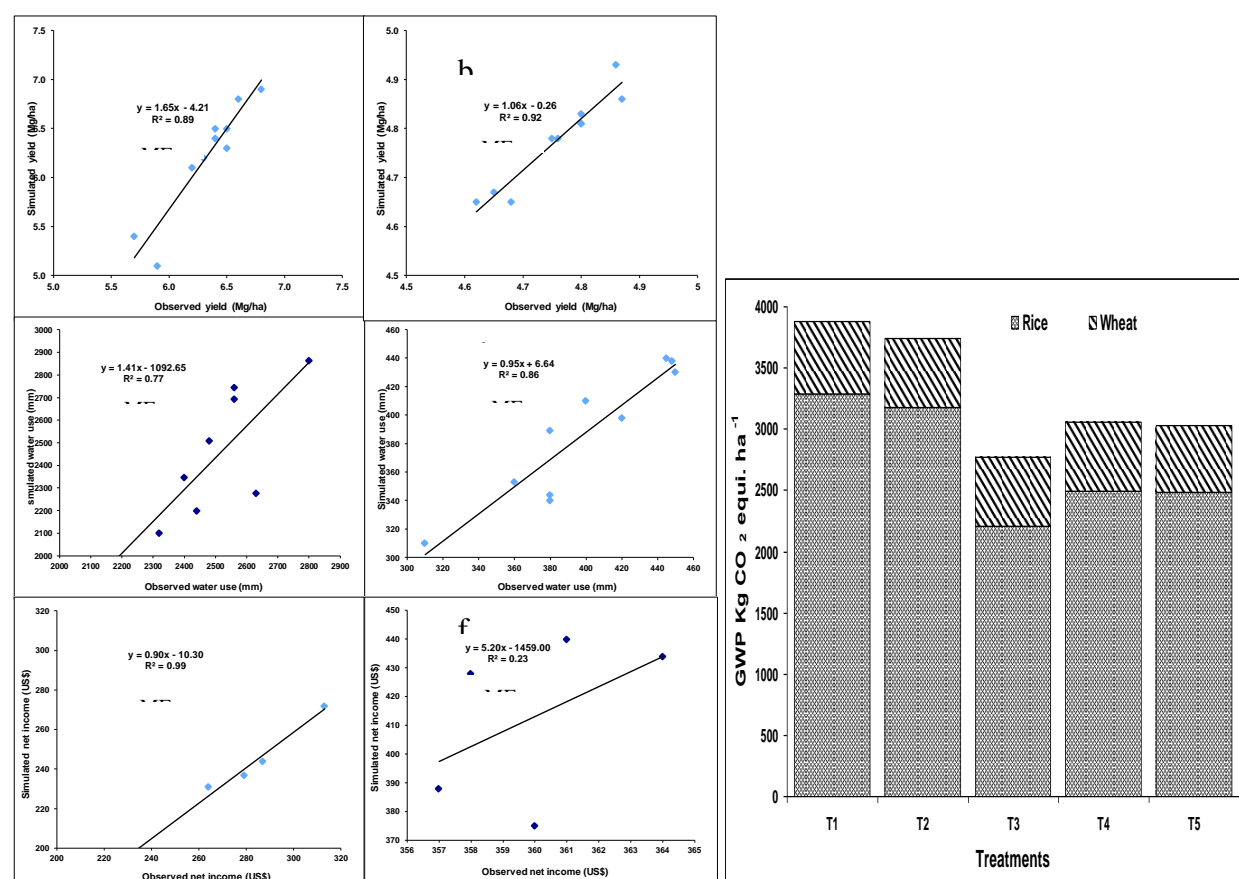
Figure 1 (left). Simulated and observed grain yields, water use and net income by rice (a,c,e) and wheat (b,d,f) respectively in various tillage and crop establishment practices

Figure 2 (right). Simulated global warming in various tillage and crop establishment practices of rice and wheat

InfoRCT validation

A fairly good correlation was obtained in observed and InfoRCT simulated yield of rice (ME = 0.78) and wheat (ME = 0.86) (Figure 1a, b). In rice simulated yields were generally higher than observed yields except in raised bed transplanting (T3), where yields were predicted 13 to 18% lower. Moreover the simulated grain yields in all treatments and in both rice (89**) and wheat (92**) were significantly correlated (Figure 5a, b). The observed and simulated irrigation water application had a good correlation in rice (ME = 0.45) (Figure 5c) except that the simulated values for water use in rice on raised beds (T3) were significantly low as compared to the observed values. Simulated irrigation water use in rice was fairly correlated (77**) in all treatments. Fairly good correlation (ME = 0.81) was observed in irrigation water use in wheat in all the treatments. The irrigation water application in wheat (86**) was significantly correlated (Figure 5d). InfoRCT simulated net income showed a fairly good correlation with the observed net income in rice (ME = 0.87) and (99**) (Figure 5e) in all the treatments. Poor correlation existed in observed and simulated net income in wheat crop (ME = 0.38) and (23**) (Figure 5f) due to differences in irrigation water, tillage operations and grain yield of farmers.

InfoRCT simulation

Simulated CH_4 emission in rice ranged from 25 to 59 kg ha^{-1}, and the FP (T1) had the highest emission followed by unpuddled transplanting (T2). Emission of N_2O from soil in rice as well as in wheat varied between 0.10 and 0.12 kg N_2O-N ha^{-1}. Farm machinery including pump used for irrigation emitted 389 to 507 kg CO_2-C ha^{-1} in rice and 58 to 81 kg CO_2-C ha^{-1} in wheat. Contribution of soil to CO_2 emission was taken as zero as organic C remained more or less static for the last 4-5 yrs in the study field. Different RCTs in RWCS had pronounced effects on the global warming potential (GWP), which varied between 2799 kg CO_2 equivalent ha^{-1} in raised-bed system (T3) and 3286 CO_2 equivalent ha^{-1} in FP (T1). Compared to the FP (T1) all the technologies reduced the GWP by 3 to 28% (Figure 2).

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Conservation Agriculture potential effects on soil erosion for rainfed crops in the Lake Alaotra region in Madagascar

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Keywords: RUSLE, Erodibility, C factor, small scale farming, Ferralsols

Introduction

Africa is facing an increasing population and food demand that has already led to large scale land use changes, increasing pressure on land and water resources (Drechsel et al., 2001). Soil degradation in tropical agro-ecosystems is strongly linked with water erosion of productive top soils. Such a process is particularly important for land dedicated to agriculture compared to natural ecosystems. It rapidly becomes an obstacle for achieving an increased food production in a more sustainable way in order to attend the growing population demand (Lal, 2007).

The three principles of Conservation Agriculture (CA) of no tillage, permanent soil cover and crop rotation (FAO 2008) are often seen as a promising solution for mitigating soil erosion processes and enhancing sustainable resources management (Lal, 1985). Reducing soil tillage intensity often results in a higher stability of soil aggregates, and protecting soil surface reduces water rainfall energy to detach and transport sediments (Scopel et al., 2005). The third principle has more indirect impacts on soil erosion. The protection they ensure the soil directly by their presence and by the total biomass produced as a mulch will differ as a function of the crops grown and their succession in time.

In the case of the Lake Alaotra Region in Madagascar, the fertile lowlands are now fully occupied by irrigated rice cropping and farmers are using more and more the hillsides called 'tanety' for producing staple crops such as maize, rice, legumes grains or cassava (Domas et al., 2010). Nevertheless these new rainfed fields are infertile loamy yellow and red ferralsols which are very susceptible to erosion. Diversified CA systems have thus been actively promoted in this region combining several crops and cover crops in rotation and/or intercropped.

The aim of this study was to quantify potential effects of CA systems in reducing soil erosion using the RUSLE model to explore different crops/cover crop combinations.

Materials and Methods

This study was conducted in the 'tanety' fields of the Lake Alaotra region with altitude ranging from 750 to 1450 m. We used as an example the classical ferralsol from Tafa experimental site (LAT: 17°32'5" and LONG: 48°32'17"). Local climatic conditions are tropical sub-humid with a tremendous variability in annual total rainfall (450-1600 mm) and rainfall distribution. The average yearly temperature is around 21°C.

We compared four different cropping systems:
1. Traditional. A two year rotation where upland rice is grown one year and maize the other. The crop residues are often removed after harvest. After some years the field is left as fallow.
2. CA Stylo 1. A three to four year CA rotation on the basis of the *Stylosanthes guianensis* (stylo). Stylo is introduced in the first year in association with e.g. groundnut. In the second year the Stylo grows alone to a height of about 1.5 meter. Upland rice is grown in the third year in the stylo mulch. Maize is grown in the fourth year as the stylo mulch disappears and new stylo starts to grow again. Data is obtained from test fields.
3. CA Stylo 2. In theory the same as 2 but closer to farmers' fields conditions with less weeding frequency and lower sowing density.
4. CA Dolichos. A two year CA rotation with a basis of *Dolichos Lablab* (dolichos). Dolichos is sown with maize the first year. In the second year upland rice is planted in the mulch of Maize+Dolichos.

To estimate soil losses we used the Revised Universal Soil Loss Equation (RUSLE) which has been applied in and modified for many regions in the world (Renard et al., 1997). RUSLE calculates a yearly average of soil loss at field level by multiplying five factors as in equation 1.

$$A = R \times K \times LS \times C \times P \qquad \text{eq. 1}$$

In our case, based on 46 years of daily effective rainfall measurements, a yearly average erosivity factor (*R)* could be calculated as 8487 MJ·mm·ha^{-1} h^{-1}. The average of five estimation methods was used to estimate the yearly soil erodibility factor (*K*) as 0.038 ton·h·MJ^{-1}mm^{-1}. Average slope length and steepness scenario was determined, yielding a (*LS*) factor of 1.5. After consulting local experts overall supporting practices (P) values were fixed as 0.4 for the Traditional cropping system and as 0.1 for the CA cropping systems. The major part of this study has been to evaluate the cover-management (C) factor for the different cropping systems and calculate consequences for soil erosion. The C-factor was divided into a crop component C$_{crop}$ and a mulch component C$_{mulch}$ for every month, calculated for each of them as $C_{c_i} = (1 - F_{C_i})$ where F$_{ci}$ is the fraction of ground cover. The C factor for each month has been calculated multiplying both crop and mulch C-factors.

Results and Discussion

The crop management factor C was divided into a crop component and a mulch component. This approach reveals in a transparent manner the respective contribution of crop and mulch cover in reducing soil loss. Results reported in (Figure 1) indicated that Stylo 1 is most effectively reducing soil loss through both crop and mulch. The difference between Stylo 1, situation at test fields, and Stylo 2, situation on farmers' fields, lies in a slower growth of the cover crop rather than the mulch cover. The impact of the Dolichos cropping system can be attributed to the mulch, because there is little difference with Traditional if only the crop cover is considered. Mulch of rice and maize is not adding much to erosion prevention. Dolichos mulch has 'bad timing' with respect to erosive rains compared to stylo mulch. Average

outcomes for crop management factor C is 0.04, 0.14, 0.13 and 0.56 respectively for the four cropping systems: Stylo 1, Stylo 2, Dolichos and Traditional, where the soil is often poorly covered.
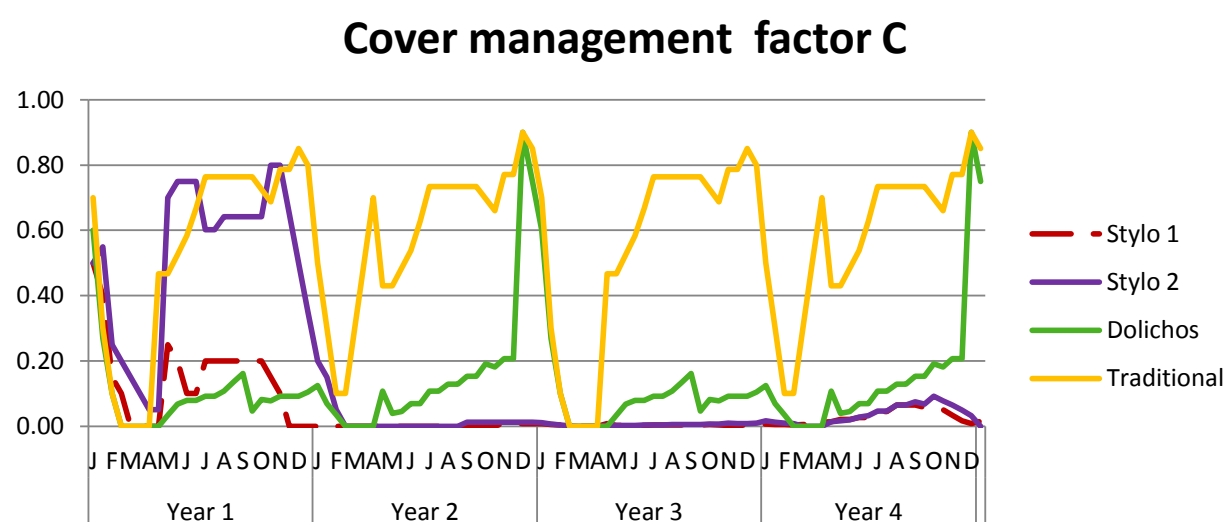
Figure 1. Variability of the C-factor throughout the years of rotation, for four cropping systems

For the traditional cropping system an actual soil loss of 86.6 ton·ha^{-1}yr^{-1}was found (Table 1). Compared to the calculated potential soil loss of 484 ton·ha^{-1}yr^{-1} for the same *LS* scenario, this is quite a substantial gain. Nevertheless the impact of CA on actual soil loss is even more important as relatively to Traditional, measured in ton·ha^{-1}yr^{-1}, it represents an additional reduction to 2.0 (2.3%) for Stylo 1, to 5.5 (6.9%) for Stylo 2 and to 9 (10.3%) for Dolichos.

Table 1. Actual calculated soil loss (ton·ha^{-1} yr^{-1}) from monthly crop cover factor (*C*) for the respective years of the rotation for four cropping systems

Cropping system	Year	Soil loss from monthly cover management *C* (ton·ha^{-1}yr^{-1})
Stylo 1	1	7.2
	2	0.1
	3	0.2
	4	0.5
	Av.	2.0
Stylo 2	1	18.4
	2	2.5
	3	0.3
	4	0.8
	Av.	5.5
Dolichos	1	7.3
	2	10.6
	Av.	9.0
Traditional	1	79
	2	94.1
	Av.	86.6

Such a reduction of erosion processes will positively impact on the long term soil organic matter and soil C stocks (Scopel et al., 2005), and will allow maintainance of crop productivity longer without resorting to expensive external inputs. This capacity to reduce soil degradation processes might be a key issue to convince small-scale farmers of CA advantages and overcome the difficulties for CA adoption in Africa as reported by Giller et al. (2009).

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Machinery development for crop residue management under direct drilling

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Keywords: Direct Drilling Machinery, Crop Residue management, Straw mulch

Introduction

Rice-wheat (RW) is the most popular cropping system followed on around 13.5 million ha area in South Asia extending across the Indo-Gangetic alluvial plain. In north-western (NW) India combine harvesting of rice and wheat is now a common practice leaving large amount of crop residues in the fields. Rice straw has found no local economic uses and remains unutilized. Rice straw incorporation is practiced by less than 1 % farmers as it is energy- and time-intensive and delays wheat sowing. Developing a cost effective technique for better utilization of this vast resource was an important challenge for the farm engineers. Minimum and zero-till technologies for wheat are beneficial in terms of economics, irrigation water saving and timeliness of sowing in comparison with conventional tillage (Malik et al. 2004; Singh et al. 2008). However, there were problems with direct drilling of wheat into combine-harvested rice fields: straw accumulation in the seed drill furrow openers, poor traction of the seed metering drive wheel due to the presence of loose straw and the uneven seed depth due to frequent lifting of the implement under heavy trash conditions. In practice, in order to seed wheat on time, the majority of the rice straw is burnt in-situ by the farmers in Punjab and Haryana States of India as it is a rapid and cheap option. Scientists were looking at alternative uses for rice stubble or new practices that are 'economically viable and acceptable' to the farming community. Punjab Agricultural University, Ludhiana in collaboration with CSIRO Land and Water, Griffith, and machinery manufacturer has developed a new machine called the 'Happy Seeder' under the ACIAR funded project. The Happy Seeder (HS) cuts and manages the standing stubble and loose straw in front of the furrow openers, retaining it as surface mulch and sows wheat in a single operational pass of the field. Operational costs for sowing wheat are 50-60% lower with HS than with conventional sowing. A new light-weight machine named the "Turbo Happy Seeder" is now commercially available and four manufacturers are already building this machine (Figure 1). The objective of this paper is to present recent developments in the HS machine in terms of increasing its working efficiency under heavy loads of residues for sowing wheat and other crops for sustainable crop production in the Indo-Gangetic plains of NW India.

Figure 1. Side View of Turbo Happy Seeder with Technical details and machine in operation

Materials and Methods

Machinery Development

The first prototype of the HS was a trailing machine developed in 2002 that consisted of two separate units, a straw management unit and a sowing unit. In the second version Combo Happy Seeder these two separate units were combined into a single unit which was mounted on three-point linkage for better manoeuvrability. The new version of the 9 row Turbo Happy Seeder with 20-22 cm row spacing with gamma type straw management rotor flails was developed with the continuous efforts and feedback from farmer participatory research and evaluation. The "Turbo Happy Seeder" is a zero till drill which is capable of seeding a following crop into 7-9 t/ha straw without straw removal/burning in a single pass and it can easily be operated with 38 hp double clutch tractor. However, evenly spread loose straw is a precondition for the smooth operation of all second generation drills including the HS. Although, straw spreaders are available on combine harvesters in developed countries, in South Asia most of the combine harvesters are without these attachments. The manual spreading of loose straw takes 8-13 man-h/ha and it is very difficult to spread the entangled dry loose straw due to its light weight. Keeping this in mind, efforts were also made to develop a straw management system (SMS) as an attachment to the existing conventional combine harvester for managing and spreading the loose straw evenly in the harvested area. This will not only facilitate the smooth operation of second generation drills in combine harvested fields but also will help in conserving moisture in the field after harvesting.

Results and Discussion

Punjab Agricultural University (PAU), Ludhiana, along with other partners like the Cereal System Initiative for South Asia project (CSISA) and the Department of Agriculture, Punjab (DoAP), has carried out field demonstrations of 9-row Happy Seeders in different districts from 2007-08 to 2009-10. A total of 154 demonstration sites were established by the DoAP, PAU and CSISA hub. The data were recorded for HS fields in comparison to the adjoining conventionally tilled fields, both managed by the farmer. The average wheat yield over 154 locations in the Punjab State was 4.56 and 4.42 t/ha for HS and conventional wheat plots, respectively (Table 1). The weighted average wheat yield for HS sown plots was 3.24 % more than the conventionally sown wheat. The paired t test was applied on the data of mean yields obtained from HS and CT (Table 1) and the calculated value of t =2.993 is more than the critical value t_{16} (0.05) = 1.745 indicating that HS yields are significantly higher at 5% level of significance. Additional advantages like less weed growth, water savings, improved soil health and environment qualities were also noted under the use of HS technology. The lower yields of wheat under HS compared with CT at some locations were mainly due to late sowing of wheat because of unavailability of HS at the optimum time.

Table 1. Wheat yields (t/ha) for Happy Seeder (HS) and conventional (CT) sown plots for years 2007-08 to 2009-10 in various districts of Punjab, India.

Location (no. of sites)	Grain Yield (t/ha)			
Year	Mean +SD			
2007-08	CT	HS	(HS-CT)	HS/CT x 100
Amritsar (31)	4.67 +0.28	4.85 +0.35	0.18	3.9
Fatehgarh Sahib (8)	4.40 +0.18	4.43 +0.30	0.03	0.7
Sangrur (3)	4.68 +0.27	4.73 +0.31	0.05	1.1
Ludhiana (4)	4.26 +0.64	4.36 +0.45	0.10	2.3
2008-09				
Fatehgarh Sahib (14)	4.34+0.62	4.54+0.59	0.20	4.61
2009-2010				
Sangrur (8)	4.51±0.31	4.87± 0.40	0.36	8.0
Barnala (3)	4.83±0.29	4.71±0.36	-0.12	-2.5
Fatehagarh (4)	4.47±0.66	4.91±0.80	0.44	9.6
Ludhiana (23)	4.37±0.29	4.48±0.46	0.11	2.7
Kapurthala (3)	4.17±2.04	4.17±1.04	0.00	0.0
Jalandhar (16)	4.38±0.48	4.48±0.78	0.10	1.7
Ferozepur (4)	3.66±0.19	3.73±0.26	0.07	1.8
Nawanshahr (6)	5.17±0.42	5.13±0.43	-0.04	-0.6
Mansa (1)	3.75±0.00	4.00±0.00	0.25	6.7
Tarantaran (3)	4.00±0.00	3.92±0.19	-0.08	-2.1
Gurdaspur (1)	4.25±0.00	4.25±0.00	0.00	0.0
Amritsar (22)	4.15±0.47	4.35±0.55	0.20	4.7
Overall (154)	**4.42**	**4.56***	**0.14**	**3.24**
CT : Conventional Tillage, HS : Happy Seeder* significantly higher than CT at *p=0.05*				

Adoption of Happy Seeder technology in Punjab

With the active participation of DoAP and various cooperative societies in the state, the total area of HS sown wheat has increased to 752 ha in 2009-10 compared to 280 ha in 2008-09 - an increase of 150%. It is estimated that 250 Happy Seeders are available in the Punjab State, with about 2000 ha of irrigated wheat sown in paddy residues during 2010-11 (a three-fold increase since 2009-10). Twenty-one progressive farmers of Punjab State purchased Happy Seeders for the 2010-11 wheat season, sowing 355 ha of wheat.. Under a Punjab Government initiative to reduce rice straw burning, the Punjab State Farmers Commission has distributed 160 HS machines among Primary Agriculture Cooperative Societies (PACS) in the state during 2010. To speed up the adoption rate of HS technology, the Government of Punjab is going to provide a 60% subsidy to farmers for buying the HS (total cost US $ 2560 approx.) in the coming year 2011-12 compared to 30% for the ZT drill costing about US $ 800. The adoption of HS technology is also slowly picking up in other states like Haryana and Western UP.

Use of Happy Seeder for sowing of alternate crops

Short duration variety of mungbean (SML 668 cv.) can be directly sown into wheat residue after combine harvesting of wheat. Adaptive trials on mungbean showed that the average yield was 3% higher with the HS sown crop compared to conventional tillage system. This practice saves tillage costs, and reduces soil temperature and evaporation losses. Based on results of these adaptive trials PAU has recommended direct sowing of mungbean into the crop residue using HS. Maize fodder can also be successfully sown in the combine harvested wheat fields in the month of April after wheat harvest. One progressive farmer in Amritsar district sowed maize (variety J1006) as fodder on an area of 5 ha during 2009-10 which yielded more than 80 t/ha (fresh weight) giving additional income of about US $ 1240. Efforts have also been made by the CSISA project to direct seed rice into wheat residue with the HS.

Summary

Crop residue burning is a serious environmental issue. The HS to date is a promising technology offering an effective solution to manage crop residues under a zero tillage system and promote conservation agricultural practices in intensive cropping systems. It is a good example of a productive collaboration between PAU, ACIAR and the private sector. The area sown under HS technology is slowly increasing with the joint efforts of PAU Ludhiana, CSISA project and DoAP but still very committed extension efforts are required for its widespread adoption. On account of its high cost and limited use, a 60 % subsidy may also be continued in future so that the large areas can be covered for addressing the problem of straw burning: instead of penalising farmers who burn crop residues it would be better to provide an incentive of US $ 30 per ha to farmers for not burning crop residue for an initial period of five years, but this is yet to be considered by the Government.

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Effect of establishment method and tillage of rice and wheat in the rice-wheat system of the Indo Gangetic Plains (IGP) of India

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Introduction

The demand for food grains in India by 2020 will be 268.8 Mt, and the combined share of rice (41.1%) and wheat (33.9%) will be 79.6%. Together these two crops share about 87.5% of the irrigated area of the country and thus make a very dominant rice wheat cropping system (RWCS) in IGP. RWCS has evolved rapidly since the 1960s as a result of the introduction of modern high yielding varieties and improved access to irrigation, fertilizer and pesticides. The majority of the rice is transplanted but, as in many parts of Asia where there are water and labour shortages, there is increased interest in direct seeding. It is a fact that intensive cultivation, extensive irrigation infrastructure, mechanization, easy access to production inputs and better marketing increased the production growth rate of rice and wheat grain, but with adverse effects on natural resources. Therefore, methods for reducing the adverse effects are needed. Direct dry seeding of rice, instead of transplanting into puddled soil, offers the potential for water savings, reduced labour demand at peak times, and improved soil structure. Direct sowing in rice and zero tillage in both rice and wheat reduces production inputs, and with potential benefits for soil structure. Weeds however are a major challenge to direct seeding. A long term experiment thus was conducted to evaluate rice, wheat and total cropping system performance as affected by rice establishment method and tillage for both crops.

Materials and Methods

The trial was conducted on a silty clay loam soil at Pantnagar from 2001-2009 with double split plot design with five rice establishment methods, two wheat establishment methods in sub plots and three weed management practices in the sub sub plots. The five rice establishment methods were: conventional transplanting (TPR), wet seeding (sprouted seed sown on puddled soil through drum seeder, WSR), direct dry seeding after conventional dry tillage (DSR), direct dry seeding after a flush irrigation to germinate weeds before the final tillage (DSFR), and zero tillage direct dry seeding after a flush irrigation to germinate weeds and application of glyphosate (ZTR). The two wheat establishment methods were conventional tillage (CT) and zero tillage (ZT). Weeds in the rice were controlled using herbicides followed by two hand weedings at 30 and 60 DAS/DAT. Butachlor (1.5 kg ha^{-1}as PE applied to TPR at 2 DAT, Anilophos 0.4 kg ha^{-1}at 7 DAS to WSR, and Pendimethalin (1.0 kg ha^{-1} was applied 0-1 DAS to all the dry seeded treatments, every year. In wheat weeds were controlled by application of 1.0 kg ha^{-1} Isoproturon at 35 followed by hand weeding as needed. Data were analyzed using analysis of variance (ANOVA) technique appropriate to split split plot design (Panse and Sukhatme, 1978). Regression equations were developed and coefficient of determination was also calculated. The overall significance of treatments was tested by 'F' test. Rice equivalent yield (REY) was calculated by using following formula.

REY=Yw/Pr*Pw+Yr, where, Yw=Yield of wheat, Yr=Yield of rice, Pw=Price of wheat (Rs11.20 kg^{-1}), Pr = Price of rice (Rs 09.50 kg^{-1})

Results and Discussion

Rice yield
Result of statistical analysis (F-test) showed that interaction between years and rice establishment methods was significant with respect to rice. Other interactions were non significant. Across nine years there was decline in rice yield in all the rice establishment methods. Rice yield were most stable in the DSFR (Regression line in Figure 1 and equation in Table 2) method of rice establishment followed by TPR and DSR. Variability of rice yields grown dry-seeded during five year period was lower than transplanted rice during the same period (Lantican et al, 1999). There is more yield decline in DSR method because weed management is a concern here but if weeds are managed well then rice yields can be more stable then transplanting. Coefficient of determination (R^2) is high in ZTR and WSR but on the other hand slope is also more towards yield decline which suggest that under these rice establishment methods, yield decline can be predicted more precisely over the years.

Wheat yield
Wheat yields were affected significantly by years and rice establishment techniques as well as by years and wheat establishment methods. Regression analysis (Table 2) shows that unlike rice grain yield wheat yield predicted to increase in response to different rice establishment methods over a period of nine years. Regression analyses indicate that over the years there was more increment in wheat yields when it was followed by DSR than TPR. Findings were similar to those reported by (Pandey et al 2002). Zero tilled plots yielded better than conventional tilled plots. However in those years where there was reduction in wheat grain yield reduction was more pronounced in zero tilled plots.

Rice equivalent yield
Rice equivalent yield was higher in TPR-CT and WSR-CT compared to TPR-ZT and WSR-ZT. However DSR-ZT had more rice equivalent yield than DSR-CT. Above results could be attributed to better rice productivity in the puddled soils compared to unpuddled soils. Better performance of DSR-ZT than DSR-CT could be due to better wheat yield in zero tilled plots. The best wheat yield was obtained when soil was deep-tilled and unpuddled for rice and not tilled for wheat (Pandey *et el* 2002)

Impact on resource conservation and economics

Dry seeding (DSR) had higher net returns than both TPR mainly due to higher cost involved in puddling/transplanting. Zero till planting of wheat reduced production cost further due to less tractor time (Table 2). As regards system DSR-ZT system recorded highest gross and net income and lowest cost of production. The tractor time under ZTW was just 10.5% that of CTW which reduced fuel consumption and ultimately the cost of production.
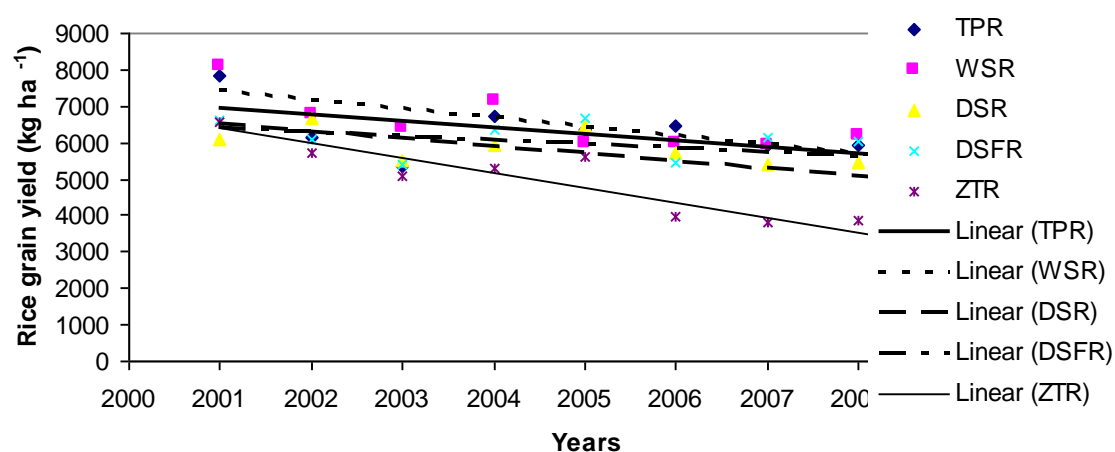
Figure 1 Regression trendlines between years and different rice establishment methods with respect to rice grain yield
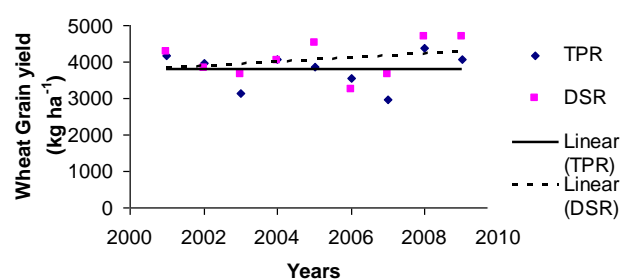
Figure 2: Regression trendlines of TPR and DSR on wheat grain yield across nine years
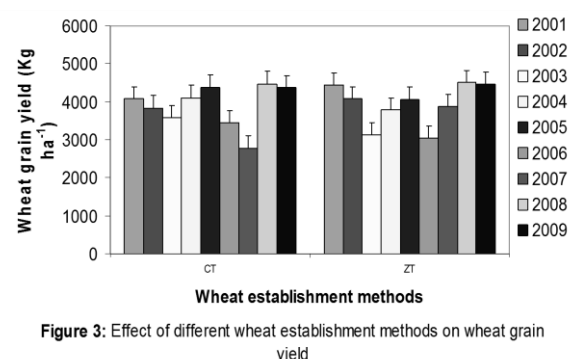
Figure 3: Effect of different wheat establishment methods on wheat grain yield

Table 1: Regression equation and coefficient of determination (CoD) between years and rice establishment methods in terms of rice and wheat grain yield

	Rice grain yield		Wheat grain yield	
	Regression Equation	CoD	Regression Equation	CoD
TPR	y = -179.48x + 366065	0.3657	y = -1.6167x + 7033.1	0.0008
WSR	y = -246.98x + 501627	0.6893	y = 54.3x - 104968	0.0626
DSR	y = -203.4x + 413511	0.5438	y = 56.333x - 108885	0.0908
DSFR	y = -115.77x + 238070	0.2606	y = -58.821x + 121714	0.099
ZTR	y = -406.63x + 820063	0.8751	y = 35.183x - 66558	0.0319

Table 2: Economics of RWCS (Rs ha^{-1}), rice equivalent yield (kg ha^{-1}) and tractor time (hr) under different establishment methods of rice and wheat in rice-wheat system

	Total cost		Gross return		Net return		Rice equivalent Yield		Tractor time	
	CT	ZT	CT	ZT	ZT	CT	CT	ZT	CT	ZT
TPR	35574	33146	76752	35574	33146	76752	10538	10014	7.1	67.8
DSR	31752	30464	72009	31752	30464	72009	9798	10151		

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Evaluation of mulch for irrigated zero till wheat in north-west India

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Keywords: APSIM, simulation, water productivity, soil evaporation

Introduction

Retention of crop residues on the soil surface conserves water by suppressing soil evaporation (Es) (Balwinder-Singh et al., 2011a). As Es can constitute as significant proportion (30-60%) of total wheat crop water use (ET) (Cooper et al., 1983), suppression of Es may preserve water for subsequent use as transpiration (T), or it may reduce the need for irrigation in irrigated crops. The effect of mulching on irrigation requirement has received little attention, especially in the intensive rice-wheat systems of north-west India. An important challenge is to understand the impacts of mulch over the likely range of seasonal conditions, and to extrapolate the findings of site specific field experiments to other site and climatic conditions. Crop models provide this capability. Therefore, field experiments and model simulations were undertaken to quantify the interactions between mulch and irrigation management for zero till wheat in the rice-wheat cropping system of Punjab, India.

Methods

A replicated field experiment was conducted over two wheat seasons (2006-07 and 2007-08) on the experimental farm of Punjab Agricultural University (PAU), India. There were two mulching treatments: rice straw mulch (mulched, 8-9 t straw ha^{-1}) or bare soil (non-mulched), and six irrigation treatments: I_1 - irrigation when soil matric potential (SMP) decreased to -40 kPa at 15-20 cm soil depth for the first irrigation, and at 40 cm for subsequent irrigations; I_2 (control – recommended practice) - irrigation at crown root initiation (CRI) and thereafter when the ratio of the amount of irrigation water (IW) applied at the previous irrigation to cumulative pan evaporation (CPE) minus rain decreased to 0.9, i.e. IW/(CPE-rain) = 0.9; I_3 - same as I_2 minus the irrigation at CRI; I_4 – one irrigation at CRI then irrigation when IW/(CPE-rain) = 0.6; I_5 - one irrigation only, at CRI; I_6 - as for I_2 minus the last irrigation. At each irrigation, 75 mm water was applied. Details of the site, management and monitoring are provided in Balwinder-Singh et al. (2011a).

The results of the field experiment were used to calibrate the APSIM-Wheat model (Balwinder-Singh et al., 2011b), which was then used to study the effects of mulch and irrigation on yield, components of the water balance and water productivity. In all scenarios, wheat (var. PBW 343) was sown with a plant density of 150 m^{-2}, row spacing 20 cm, sowing depth 5 cm and nutrients non-limiting. In the mulched treatments, rice straw was applied at 8 t ha^{-1} on the day of sowing (10 November), while the non-mulched treatments had a bare soil surface. The simulations were performed using 36 years (1970-2006) of weather data from the meteorological station at PAU, on sandy loam and clay loam soils. Seven irrigation treatments scheduled according to soil water deficit (SWD) and rainfed wheat were compared. Irrigations were applied when SWD reached 10%, 20%, 30%, 40%, 50%, 60% and 70% of plant available water capacity of the 0-60 cm soil layer. The amount of irrigation water applied was 120% of SWD to represent the inherent inefficiency of flood irrigation.

Results and Discussion

In 2006-07 there was well-distributed rainfall (total 159 mm), and the control irrigation treatment required only one post-sowing irrigation. As a result, only treatments I_1 and I_2 were implemented. In the second year, there was very little rain until shortly before maturity (seasonal total 88 mm), the control treatment received 3 post-sowing irrigations, and all 6 irrigation treatments were implemented with differing number (1-3) and/or amount (75-225 mm). In both years, mulch delayed the time of irrigation and reduced the total number of irrigations by one, with SMP-based scheduling (Balwinder-Singh et al., 2011a). In the simulations, mulching also reduced the amount of irrigation required, more so with frequent irrigation scheduling, and more so in drier years (Figure 1a). However, mulch reduced the average number of irrigations by less than 1 for all irrigation schedules except the most frequent (10 and 20% SWD).With practical flood irrigation thresholds of around 40-50% SWD, mulch reduced the number of irrigations by one in almost 50% of years, a reduction in irrigation input of 50 mm on the sandy loam and 60 mm on the clay loam. Both the field and modelling studies showed that the reduction in irrigation with mulch was due to lower soil evaporation (Es). For example, with scheduling at 40% SWD, mulch reduced average Es by 24 and 29 mm on the sandy loam and clay loam (Figure 1b), respectively, with similar reductions of 35 and 40 mm in the field experiments in the control treatment on the clay loam soil (Balwinder-Singh et al., 2011c). In the model simulations, mulch suppressed ET by 5-7%, by a larger absolute amount (up to 50 mm) in the more frequently irrigated treatments, and by more on the clay loam than on the sandy loam. This is in contrast with the field studies of Balwinder-Singh et al. (2011a) who found no effect of mulch on ET, as the reduction in Es was offset by increased T.

In the field experiments, there was a consistent trend each year for higher yield with mulch in all irrigation treatments except those with the lowest yields (severest water deficit stress, I_4 and I_5) (Fig 2a,b). However, the interaction between irrigation and mulching treatments on grain yield was only significant at p<0.10 each year. The effect of mulch was significant at p<0.05 in 2006-07, and at p<0.10 in 2007-08. In contrast, the simulations showed negligible effect of mulch on grain yield for SWD from 10-60%, and with a maximum yield increase with mulch of about 10% under rainfed conditions (Figure 1c). In the field experiments, irrigation water productivity (WP$_I$) was significantly higher with mulch than without mulch with SMP-based irrigation scheduling, but there was no effect of mulching on WP$_I$ for any of the 5 irrigation treatments with scheduling based on CPE. The model simulations also showed a consistent trend for higher WP$_I$ with mulch, more so on the clay loam soil, with an increase of about 10% across all schedules (Figure 1d). However, in contrast to the field experiments, the model simulations showed that WP$_I$ increased with decreasing irrigation frequency. Mulching significantly increased grain water productivity with respect to ET (WP$_{ET}$) with SMP-based scheduling in 2006-07, but there was no effect of mulch (or irrigation treatment) on WP$_{ET}$ in 2007-08. The model simulations showed a consistent trend for slightly higher WP$_{ET}$ with mulch (by about 7%) across all irrigation treatments and both soil types.
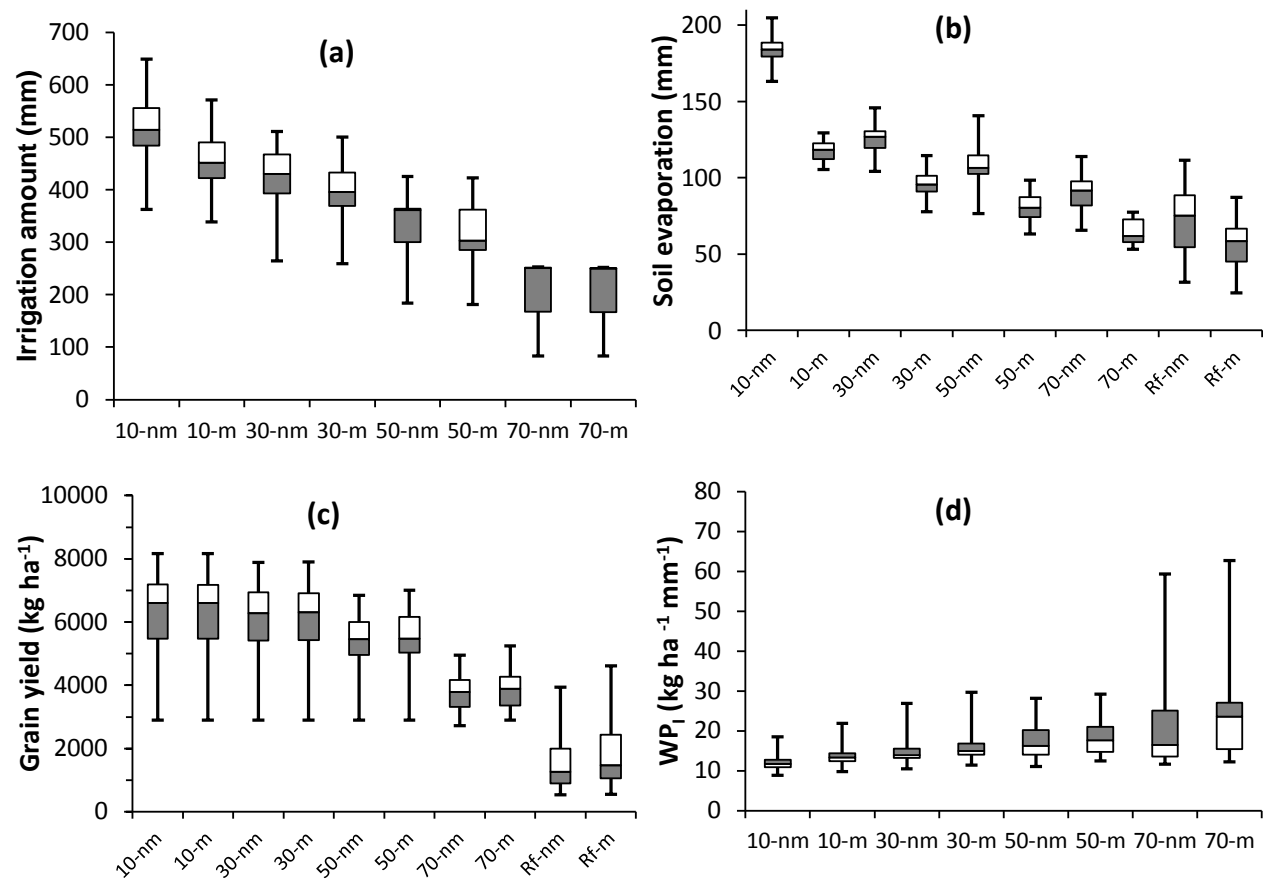
Figure 1 Simulated effects of irrigation schedule and mulch on (a) irrigation amount, (b) soil evaporation , (c) grain yield, (d) water productivity on the sandy loam soil. Error bars represents range, ( ) represents 75th percentile, ( ) represents 25th percentile. 10=10% SWD etc., Rf=rainfed, nm= non-mulch, m=mulch
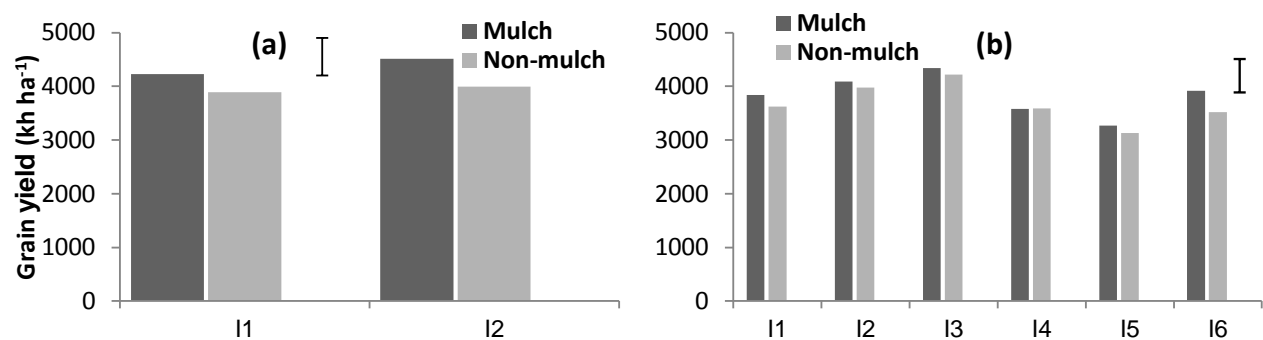
Figure2 Effect of mulch and irrigation schedule on grain yield in the field experiments in (a) 2006-07 and (b) 2007-08. Error bars represents LSD (0.05) for the interaction of mulch x irrigation.

Conclusions

The results show the benefit of scheduling irrigations based on soil water status if the benefits of mulch in reducing irrigation input and increasing WP_I are to be realised. The model simulations suggest that mulch can reduce the number of irrigations by one, or about 50 mm, in about 50% of years for wheat sown into rice residues in central Punjab, India, while maintaining grain yield. However, the effect of mulch on ET is less clear, with the field experiments indicating no effect, while the modelling studies suggest a reduction of about 10% for irrigations scheduled at around 40-50% SWD. Clearly this is an area for further investigation.

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Enhancing nitrogen use efficiency in wheat sown into rice residue and effect of straw management on soil health in rice-wheat system in North West India

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Introduction

Rice-wheat (RW) systems occupy 13.5 million hectares of cultivated land in South Asia and are critical for food security and livelihoods. High yields of the irrigated RW system result in the production of huge quantities of crop residues. While wheat straw is collected and often fed to animals, rice straw is considered poor feed for animals due to its high silica content. Burning of rice straw is common in the highly productive north-western parts of India and has increased environment pollution and results in large nutrient losses (Yadvinder-Singh et al., 2005). Presently, total rice straw utilization in Punjab (India) for different purposes constitutes less than 2% of the 22 million tons produced annually (Yadvinder-Singh et al., 2010). Substantial loss of plant nutrients (especially N and S) and organic carbon also occurs during burning of crop residues. Incorporating rice residue before wheat planting is challenging for farmers because of the short interval between rice harvest and wheat planting and additional costs (US$ 55/ha) involved for incorporation. The insitu incorporation of crop residues with high C–to–N ratio into soil typically results in microbial N immobilization and a temporary decrease in plant-available N (Yadvinder-Singh et al., 2005). A 7- year study by Yadvinder-Singh et al. (2004) demonstrated that rice and wheat productivity were not adversely affected when rice residue was incorporated for at least 10 days and preferably 20 days prior to establishment of the succeeding crop. A breakthrough was recently achieved in the development of a new generation of seeders called Happy Seeders (HS) capable of direct drilling wheat into heavy rice residue loads without prior burning (Sidhu et al., 2007). The use of crop residues as a mulching material under optimal conditions has been found beneficial as it reduces maximum soil temperature and conserves water (Yadvinder-Singh et al., 2010). Nitrogen management for wheat sown into rice residue and following rice may differ from that where residue has either been removed or burned in-situ. Recycling of crop residue is likely to have favourable effect on soil heath (Yadvinder-Singh et al., 2005). Field experiments were conducted to study the kinetics of decomposition and the subsequent release of N from rice residue and N management in wheat sown into rice residue. Reducing fertilizer N contact with the straw by drilling the fertilizer below the soil surface and/or delayed top dressings of fertilizer may reduce N losses and increase N use efficiency in wheat. The effect of rice straw retention on soil fertility and yield of following rice was also studied.

Material and Methods

The kinetics of decomposition and the subsequent release of N from rice residue was studied using a litterbag decomposition technique in two soil types under field conditions. Sealed nylon bags were placed horizontally on the soil surface in the field after sowing of wheat. One litterbag from each replicate was randomly removed at monthly intervals continuing through harvest of the wheat. The loss in mass of the rice straw sample placed in the nylon bag is considered as the amount that had decomposed during that period. Residue decomposition data were fitted to a first-order exponential single-pool decay model.

Twenty-one on-farm experiments were also conducted at different locations to study the response of wheat sown into rice residues to different rates of fertilizer N application. Fertilizer N was applied in two equal split doses (one-half broadcast before sowing and the remainder top-dressed before first post-sowing irrigation).

A replicated field experiment was conducted on a sandy loam soil to study the time and method of fertilizer N application on nitrogen use efficiency in wheat during 2007-10.

The effect of different tillage/seeding implements (conventional tillage after straw burning, zero till after straw burning, 'Happy Seeder surface residue retention, and roto seeder after straw burning) on soil strength was studied in farmers' fields, using an automatic recording cone penetrometer. The roto seeder is a rotavator with a seed cum fertilizer box fixed on the top and used for sowing wheat in a single operation in the rice straw burned fields. The effect of rice straw retention on soil fertility was also studied.

Results and Discussion

Buried rice residue had lost about 80% of its initial mass at the end of decomposition cycle (140 days), leading to a decomposition rate (k) of 0.21-0.24 day_{-1} that was about three times as fast as that in the surface-placed residue (0.078 day_{-1}). About 50-55% of the rice residue placed at the soil surface was not decomposed at the time of wheat harvest. Total N release from buried residue by maximum tillering stage was about 6 kg N ha_{-1} (15% of initial) in the sandy loam and 12 kg N ha_{-1} (27% of initial) in the silt loam. The amount of N release from the buried residue on the sandy loam increased to 12 kg ha_{-1} by the booting stage and to 26-28 kg ha_{-1} by maturity. Since N application after maximum tillering will have only a small effect on grain yield of wheat, the additional amount of N released after booting may not affect grain yield. In contrast, there was no release of N (N was immobilized) from the residues on the soil surface throughout the study period, with no N benefit to the growing wheat crop.

Data from on-farm experiments at three locations showed that wheat sown into rice residue responded to the application of N up to 120 kg N ha_{-1} - similar to that recommended for conventionally sown wheat. On the basis of these findings, there appears to be no need to apply higher doses of N to wheat sown into rice residues retained on the soil surface than that recommended for conventionally tilled wheat.

Data from a three-year study showed that the recommended practice (120 kg N/ha with half at sowing and half before the first post-sowing irrigation (T2) increased the wheat yield by 61-95% over the control without N fertilizer (Table 1). Applying DAP at sowing and applying the remaining N as urea (96 kg ha_{-1}) in two equal doses before the first and second irrigations (T6) significantly increased the grain yield and N use efficiency compared to T2 during 2007-08 and 2008-09 (Table 1). However, in the 2009-10 season, wheat yield was similar in both treatments. The increase in organic carbon content with surface residue retention was greater on the sandy loam with lower initial organic carbon content than on that previously observed on a silt loam (Yadvinder-Singh et al., 2009). The amount of C sequestration in the

soil from the straw mulch after 2.5 years was about 25% on both the soil types. The amount of C sequestration from the straw incorporation under conventional tillage was only about 17%. Maintaining rice straw for two years increased the availability of P and K in the soil compared to straw removal. Crop residues are very rich in K with a large fraction in water soluble form and add a large amount of K to the soil. The release of K from rice straw is fast and about 70% of total straw-K is released within 10 days after surface placement/incorporation. Recycling of rice residue continuously for two years increased the grain yield of the following rice crop by 11.7% on the sandy loam and by 8.2% on the silt loam soil. The increase in grain yield of rice after wheat was possibly due to improvement in soil N supply with the recycling of rice straw. Soil strength increased with the longer use of roto seeder but the values were quite low in the HS and conventional till fields. The mean soil strength (kPa) in the roto seeder fields compared with 'Happy Seeder' increased by 41.1, 67.4 and 88.3% at 20 cm soil depth after 1, 2 and 3 years of its use, respectively.

Table 1. Effect of method & time of N application (120 kg N ha-1) on grain yield and N use efficiency of wheat sown with HS during 2007-10

Treatment	Grain yield(t ha$_{-1}$)			Recovery efficiency of N %		
N applied (kg ha$_{-1}$) at sowing- 1$_{st}$ irrig.-2nd Irrig.	2007/8	2008/9	2009/10	2007/8	2008/9	2009/10
T1 -No N control	2.03	2.38	3.06	-	-	-
T2 - 25*D +35#B- 60-0	3.96	4.37	4.92	58.3	35.5	41.3
T3- 25D+35B-30-30	3.82	4.24	4.82	54.2	36.4	41.7
T4- 25D+65B-0-30	4.10	3.82	4.60	59.2	29.2	37.3
T5- 25D+95B-0-0	4.07	3.48	4.50	60.0	22.6	34.6
T6- 25D-48-48	4.76	4.75	4.87	78.3	48.3	43.4
T7- 25D+35¶PSI-60-0	4.17	4.07	4.87	62.5	41.2	39.8
T8- 25D+35PSI-30-30	4.26	4.23	4.59	67.5	41.8	38.8
T9- 25D+65PSI-0-30	3.97	4.39	4.66	59.2	40.8	36.0
T10- 25D+95PSI-0-0	3.77	4.61	4.81	50.0	47.5	38.7
LSD (0.05)	0.38	0.56	0.60	6.10	3.9	4.3

*D- drill, #B- broadcast at sowing, ¶PSI, before pre-sowing irrigation

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Economics alternatives of owning the Happy Seeder for managing stubble and direct drilling wheat in Rice-Wheat System

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Key words: Burning stubble, custom hiring, subsidy, total costs

Introduction

In rice-wheat (R-W) systems of Punjab, India about 90% of the 17 Mt rice stubble is burnt each year, due mainly to the lack of suitable machinery to direct drill wheat into combine harvested rice residues, To address the problem of direct drilling into rice residues, researchers from Australia and India have developed the 'Happy Seeder' (HS), a tractor powered machine, that enables stubble mulching, seed and fertiliser drilling operations in a single pass (Sidhu et al. 2007).

In Punjab, R-W farmers have made huge investments in tractors and machinery to help meet the timeliness needs of different field operations vital for successful production of two crops a year. Due to the limited use of machinery on typically sized (4-5 ha) rice-wheat holdings, there are high costs of farmer owned equipment. There is a general lack of information available on the total costs of owning tractors and machinery by R-W farmers. Additionally, more than 35% of marginal and small rice-wheat farms are serviced by about 20% of farmers who own HS and work as part time machinery contractors (Jagdeep Singh, a machinery contractor, personal communication). There are questions on the true cost of contracting and whether contract rates are sufficient to recover the total machinery cost.

Adoption of the HS also involves significant initial capital investment and maintenance costs for the limited use of direct drilling wheat after rice in winter season. Also the Punjab Government is trying to promote the HS by providing large subsidies to individual farmers, machinery contractors and agricultural cooperatives without knowing the total costs to farmers using their own machinery both with and without subsidy, the true costs of contracting out farm machinery, or whether the current contract rates are sufficient to recover the true annual costs of the HS.

Therefore, the present study aims to assess the total cost of the HS to a farmer, part-time contractor and to a commercial contractor both with and without subsidy; compare the total costs with the current custom hiring rate for the HS to estimate what percentage the actual rates of using the HS are higher or lower than the market custom rates; and estimate the total cost involved in different ways of accessing the HS.

Methodology

The analysis, undertaken from the financial perspective, has estimated the total costs of ownership for 3 situations: (1) owning a HS and tractor used on a RW farm, (2) contracting-out the HS by part-time contractors and (3) commercial contractors, both with and without government subsidy on a HS.

The analysis considers the fixed and variable costs of ownership, taking into account the costs associated with the HS, tractor, shelter, labour, motor vehicle and phone.

Data and assumptions used in the analysis
The study has estimated the costs of the following alternatives of obtaining the HS.
1. Farmer using own HS: The total costs of using own HS and tractor were calculated for a typical 4.4ha rice-wheat farm with 4.1ha of net area under RW (Milham et. al. 2011), both without and with a 25%, 50%, or 100% government subsidy on a new HS. It is assumed the tractor is used for 200 hours for different field operations, whereas the Happy Seeder is used for 15 hours for direct drilling of wheat on 4.1 ha of rice stubble in the winter season.

2. Part-time contractor: A part-time contractor, after direct drilling wheat on his own farm, direct drills wheat on 8 ha of other farms, charging a contract hiring rate of $56 per ha for the HS and tractor. It is assumed, part time contractor gets 25% subsidy on a new HS. He uses his tractor for 500hrs, 200 hrs on his own farm and 300 hours for contract work during both summer and winter.

3. Commercial contractor: It is assumed that a commercial machinery contractor also gets 25% subsidy on the HS and would be able to direct drill 60 ha of wheat (within a narrow sowing window of 4 week). A commercial contractor uses his tractor for 1000 hrs per annum for different field operations during both summer and winter season.

- The cost of a new tractor is $US 8900, Happy Seeder $US2660; Machinery shed $US780, scooter $US890, mobile phone $US225 and annual wages of a full time worker $US1100 (including value of in-kind costs). A 10% per annum rate of interest on capital invested, and a 10 years of economic life of both tractor and the HS.

- The HS, using 35hp tractor, takes 3.75hours to direct drill one ha of wheat and can direct drill 2 ha of wheat per day. Total area under R-W system In Punjab, India, is 2.7 M ha

Some of the other data and assumptions used in the analysis are given in Table 1

Table1: Data and assumptions used in the analysis

	Happy Seeder			Tractor		
	Farmer	Part-time contractor	Commercial contractor	Farmer	Part-time contractor	Commercial contractor
Salvage value (%)	20	10	2	25	20	15
Annual Repairs	2%	5%	5%	5%	10%	10%
Annual use (hrs)	15	45	225	200	500	1000

The study has used different rates of depreciation, repair and salvage value after 10 years due to different levels of annual use of machinery by farmers, part time as full time contractors (Table 2).

Results and Discussion

Table 2 reveals that with a 25% subsidy on a new HS, the per ha total cost of using own HS is significantly higher than the current contract rate of $56/ha for hiring a HS. Even with a 100% subsidy on the HS, using his own HS is more expensive compared to per ha cost of hiring the HS. Similarly, the study have found that even with a 25% percent subsidy, the current contract hiring rate is 30% less than the per ha true cost of the HS and a tractor to a part-time contractor, but the HS even without any subsidy would enable a commercial contractor to not only recover the total cost of the HS and tractor, help him earn some a small profit from contracting the HS.

The study has estimated that even paying an increased contract rate $78/ha (40% more than the current contract hiring rate of the HS), the cost of hiring a HS would be significantly less (60% less) than the per ha total cost of using own tractor and HS. But this would help the part-time contractor to recover per ha total cost of the HS and tractor used for contract hiring, and would enable a commercial contractor to earn around 30% net return.

The study has estimated that different adoption models would result in significantly different numbers of HS required in Punjab, by using the HS through commercial contractors would require 45,000 HS units (with a total cost of 120 million US$) compared to 225,000 HS units, if using through part-time contractors and more than 675,000 HS units (costing 1,800 million US$), if farmers were to own their HS machine to direct drill wheat in 2.7 million ha currently under RW system.

Table 2: Annual costs of alternative approaches of owning the HS

	Own HS on a typical Rice wheat farm			Machinery contractors			
				Part time		Full time	
Level of subsidy (%)	0	25	100	0	25	0	25
Cost of Happy Seeder							
Total ownership cost (US$/ ha)	95	70	4	33	25	7	5
Total variable cost(US$/ ha)	20	20	20	11	11	2	2
Total cost (US$/ ha)	114	89	23	44	36	9	7
Cost of Tractor							
Total ownership cost (US$/ ha)	25	25	25	10	10	5	5
Total variable cost (US$/ ha)	28	28	28	27	27	25	25
Total cost (US$/ ha)	53	53	53	37	37	31	31
Other ownership costs (US$/ ha)	6	6	6	3	3	2	2
Cost of HS, Tractor and other costs							
Total ownership costs (US$/ ha)	126	101	35	47	38	14	13
Total variable costs (US$/ ha)	48	48	48	38	38	28	28
Total cost (US$/ ha)	174	149	83	85	76	42	40
Current contract rate (US$/ ha)	56	56	56	56	56	56	56

Increased daily hours (12 up from 8) of operation would increase the area of HS use per year. This would reduce per unit ownership and total cost of the HS to a commercial contractor to $38 and would enable him to earn over 30% profit margin over the current market contract hiring rates. This would reduce the total number of machines to 30,000 units with a total cost of 80 million US$ and a government subsidy of only 20 million US$, required to direct drilling and managing stubbles in the entire RW area in Punjab.

To encourage farmers to access the HS through use of contractors, the policy makers will have to make sure that the commercial contractors get enough work to successfully run their business without compromising the timeliness of sowing of wheat especially on small and marginal farmers This will help the RW industry and the state government save millions of dollars in adopting and promoting conservation agriculture and saving environment.

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Effect of narrow opener geometry on lateral surface soil movement and implications for no-till seeding

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Keywords: No till, Soil movement, Rake angle, Narrow opener, Herbicide incorporation, Bent leg opener

Introduction

Australian no-till farming often uses narrow point openers to open the soil and place seed and fertilizer in the soil. They are generally used in conjunction with spraying pre-emergence herbicides for weed control and are followed by press wheels to pack soil over the seeds. These openers can create excessive soil disturbance and soil throw, with the effect of increasing the depth of soil cover on adjacent furrows (Desbiolles and Saunders, 2006), increasing stimulation of weed seed germination (Chauhan et al., 2006) and enhancing seedbed soil moisture loss (Chaudhuri, 2001). In Australian farming systems, pre-emergence herbicides are often mechanically incorporated by the sowing operation, and excessive lateral soil throw at seeding can result in herbicide contaminated soil reaching adjacent seed rows (Derpsch, 2007, Desbiolles and Saunders, 2006). The factors previously identified in the literature affecting soil movement include: soil condition such as texture, moisture and structure (Sharifat, 1999), tool settings such as speed and depth (Sharifat, 1999; Godwin, 2007) and opener geometry (Sharifat, 1999; Godwin, 2007; Chaudhuri, 2001). This paper reports on the soil movement created by a range of narrow points with various rake angles (angle contained between the active face of the opener and the direction of travel) and the use of a commercial bent leg style opener. The work used small aggregate size cubes in a grid pattern over the depth profile and across the path of the opener, acting as tracers to indicate 3D soil movement. This report outlines the results of surface tracer displacements only, as an estimate of the likely movement of pre-emergence herbicide sprayed on the soil surface by the mechanical incorporation process. This movement can affect both the efficacy of weed control and the potential risk of crop damage.

Materials and Methods

Experiments were undertaken in remolded soil bin conditions using the seed placement test rig at the University of South Australia (UniSA). Four flat narrow point openers of 16 mm width with rake angles of 35°, 53°, 72° and 90°, respectively and a bent leg opener with a 10 mm wide foot were tested using a forward speed of 8.2 km/h and work depth of 120 mm. A randomized complete block design with four replications was used to evaluate the effect of rake angle on the soil movement. A subsequent comparative test was undertaken by a range of narrow points with various rake angles. The 3 m long soil bin comprised a reconstituted sandy-loam soil with a 10.6% soil moisture content (w/w, dry basis) and 1.37 g/cm^3 soil bulk density (dry basis). Soil movement was measured by placing PVC cubic tracers (1 cm x 1cm x 1cm) in a reference grid within the soil profile prior to tillage and measuring their final position after tillage using a 3 dimensional digitizing frame. The 13 surface tracers were positioned with one on the center of opener travel path and the others symmetrically set at 10, 20, 30, 60, 90 and 120 mm from the centre. These surface tracers were placed at half their height (5 mm) into the soil. The furrow loosening result was assessed over a 0.5 m length of furrow using a scanning laser soil profile meter and included the surface profile of the loosened soil and the furrow soil failure boundaries measured after excavation of the loosened soil.

Results and Discussion

Figures 1 to 4 show 'whole-of-trial' tracer data for the 4 rake angle openers, including 4 replications with left and right pseudo-replications obtained by symmetry, while the furrow profiles shown are the average furrow cross-sections (note: the variability in the lateral soil throw over the 0.5 m long sample is not displayed by the average profile but is reflected in the position of individual tracers). The results showed that each of the various rake angle tools cleared all of the surface tracers from above the centre of the furrow below which the seeds would commonly be expected to be placed (seed zone). The tool with the low rake angle of 35° had the narrowest band of cleared tracers and this would indicate that pre-emergent spray placed on the surface would be moved a smaller distance from the furrow centre (±45 mm) giving the narrowest zone through which weeds may be able to emerge. The tools set at the other rake angles achieved a wider band of cleared tracers and this would likely result in more weed competition near the seed row. The tool with the 53° rake angle gave the widest band of soil with no tracers (±90 mm). Typical row spacing (L_c) in Southern Australian no-till farming systems ranges from 225 to 300 mm while small proportions of farmers may operate at other row spacing, as narrow as 180 mm and as wide as 380 mm. All tools threw a considerable volume of soil beyond the furrow boundaries. Their furrow backfill factor, defined as the proportion of furrow size filled with loose soil, was 93%, 92.1%, 97.4% and 98.1% at the 35°, 53°, 72° and 90° rake angles, respectively. A significant quantity of loose soil reached over the width of 180 mm, but by 250 mm the soil volume reduced considerably, as shown by both the height (depth) of the loosened soil and the large majority of tracers contained within. This indicates that, at narrower no-till row spacing, these tools will move significant topsoil contaminated with pre-emergent herbicide onto the adjacent furrow, with the potential for causing crop damage depending on herbicide solubility and absorption pathways. The soil-bin tests were conducted at 8.2 km/h and at 120mm depth, and the extent of lateral soil throw and interaction with adjacent furrows would increase at higher speeds but reduce at shallower depth (Desbiolles and Saunders, 2006). In contrast, as shown in Fig 5 the bent leg style opener shows that the majority of loosened soil can be retained within its respective furrow, this is explained by the offset and bevel edge shank at the soil surface not contributing to lateral soil throw. As a result, the furrow backfill factor was comparatively assessed at 100%. In operation, the bent leg opener would not throw soil into adjacent furrows and affect the depth of soil cover over their seed zone nor change their profile of incorporated pre-emergent herbicide. The bent leg profile used in the experiment showed a 65 mm wide band of soil near the shank which did not include any tracers, in line with the action of the bevelled edge shank, and which could be suitable for a seed row location. Further work is studying the effect of bent leg opener geometry on various aspects of soil movement. The work is aiming to shed light on the opportunities for opener design and operational setting to assist with fine tuning the effectiveness of an increasingly mainstream weed management practice in Australia.
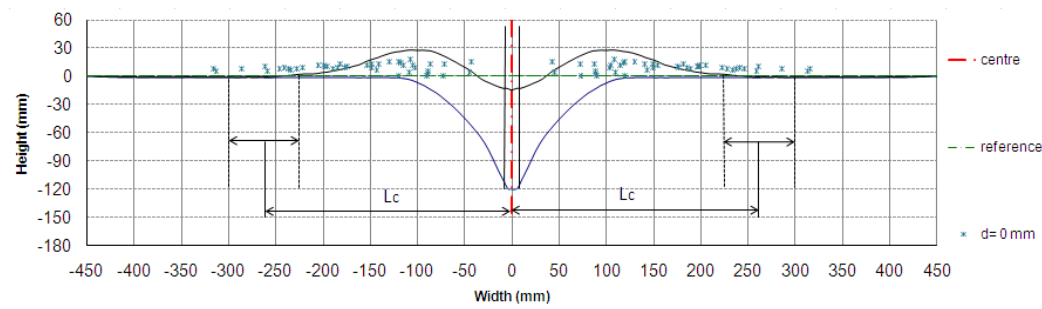
Fig. 1: Cross section of soil profiles and tracer locations- n= 4 (α= 35°, v= 8.2 km/h and d= 120 mm)
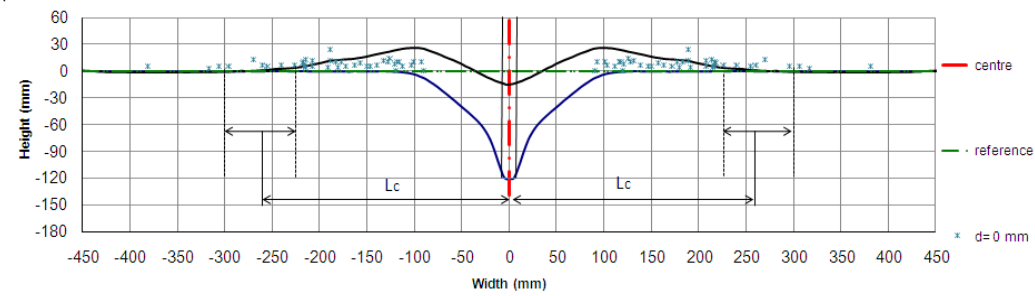
Fig. 2:Cross section of soil profiles and tracer locations- n= 4 (α= 53°, v= 8.2 km/h and d= 120 mm)
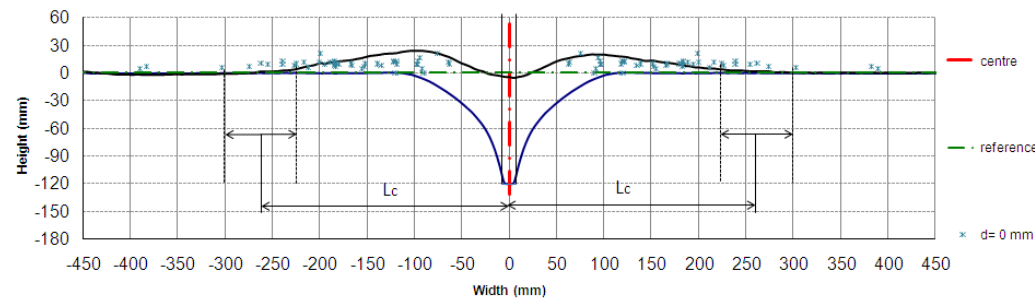
Fig. 3: Cross section of soil profiles and tracer locations- n= 4 (α= 72°, v= 8.2 km/h and d= 120 mm)
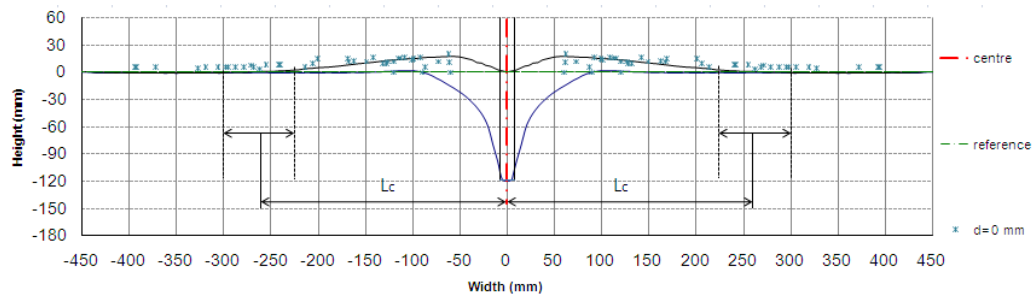
Fig. 4: Cross section of soil profiles and tracer locations- n= 4 (α= 90°, v= 8.2 km/h and d= 120 mm)
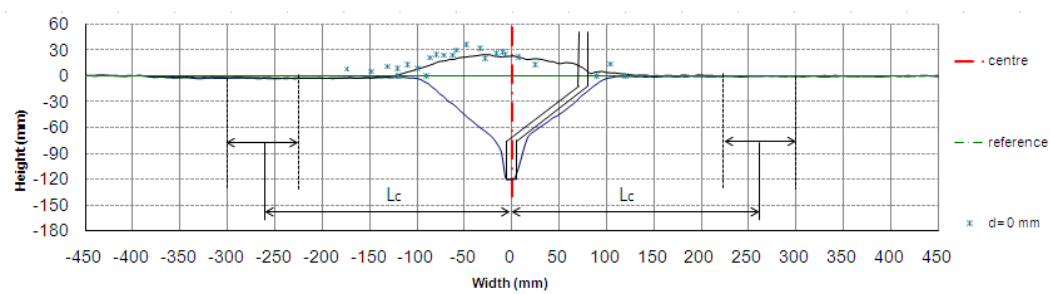
Fig. 5: Cross section of soil profiles and tracer locations with commercial bent leg opener-n= 2
(v= 8.2 km/h and d= 120 mm)

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Conservation Agriculture (CA) in southern Africa: longer term trends in soil quality and crop productivity

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Keywords: infiltration, soil moisture, climate change, soil degradation

Introduction

Increased soil degradation coupled with unpredictable future weather scenarios in southern Africa increase the need for agriculture systems that maintain or improve soil fertility and are more resilient to external climatic stress. Conservation agriculture (CA) is proposed to be a suitable cropping system for such environments. CA is based on minimum soil disturbance, crop residue retention and crop rotations and has been widely promoted since the late 1990s by numerous NGOs and governmental organizations in southern Africa. The benefits of CA have been widely published based on results from the Americas and Australia (Wall, 2007; Kassam et al., 2009). However little research has been conducted in Africa to establish the longer term effects of CA on soil quality, water dynamics and crop productivity (Thierfelder and Wall, 2009), which has provoked some critics in the last few years about the applicability of CA for small-scale farmers in southern Africa (Giller et al., 2009). Research on CA is necessary to give scientific support to large-scale donor investments and to advance overall knowledge and understanding of this promising cropping system. This paper summarizes results of four long-term research (LT) trials established in several agro-ecological environments of southern Africa to test the effects of conventional and CA cropping systems on soil quality and crop performance indicators.

Materials and Methods

Trials were established at four locations in southern Africa: Henderson Research Station (HRS) in Zimbabwe established in 2004 on a sandy soil (884 mm mean annual rainfall), at the Monze Farmer Training Centre (MFTC) in Zambia established in 2005 on a loamy clay soil (748 mm mean annual rainfall), at Sussundenga Research Station (SRS) in Mozambique established in 2006 on a sandy loam (1155 mm mean annual rainfall) and at Chitedze Research Station (CRS) in Malawi established in 2007 on a loamy clay soil (920 mm mean annual rainfall). All the long-term (LT) trials have different CA treatments with minimum soil disturbance and crop residue retention and a conventionally treated control plot. The conventional control plots are either ploughed or hoe-cultivated and crop residues removed. All trials are planted with both sole maize crops and maize in rotation with other crops (i.e. maize rotated with cotton, sunflower, sunnhemp or cowpeas). Several soil quality indicators were evaluated on these LT trials: infiltration (measured by a mini-rainfall simulator), soil moisture (capacitance probes), aggregate stability (wet sieving), soil organic matter. Yields of grain, seed cotton and total biomass were measured on the different treatments at each trial site.

Results and Discussion

Results from all LT trials show clear advantages of CA over conventionally ploughed or hoe-cultivated treatments. Final infiltration rate was generally higher on CA as compared to conventional control plots (47% higher at HRS, 206% higher at MFTC, and 88% higher at both SRS and CRS in 2010) (Table 1). Results were however not significant at SRS due to in-field variability. Higher infiltration rates led to higher available soil moisture throughout the year, especially during drought periods - an important aspect in the context of mitigating negative effects of climate change expressed by unreliable and unevenly distributed rainfall (Thierfelder and Wall, 2010b). At MFTC and HRS, the "oldest" LT trials in this study, higher available soil moisture was measured on CA plots as compared to the control plots in most of the years. In 2010, soil moisture in the CA treatments exceeded that in the conventional control on average by 35% at HRS and a modest 4% at MFTC.

Table 1: Effect of different cropping systems on infiltration rate (mm) and available soil moisture (mm) at four trial sites in 2010

	HRS		MFTC		SRS	CRS
	Final Infiltration	Available soil moisture	Final Infiltration	Available soil moisture	Final Infiltration	Final Infiltration
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Conventional control, maize	40.7 b	88.7 b	15.4 b	154.6 b	20.8 a	33.1 b
CA, maize	60.0 a	119.7 a	47.7 a	161.4 a	35.7 a	56.6 a
CA, maize rotation			46.6 a	161.1 a	42.6 a	68.3 a

*means within the same column followed by the same letter are not significantly different 5% probability level, LSD-Test

Continuous application of crop residues as mulch increased soil organic carbon (SOC) at MFTC with highest rates on fields with a maize-cotton rotation (Table 2). At the same time, the conventionally ploughed control plot suffered decreases in SOC and also had lower aggregate stability.

CA treatments generally yielded more than conventionally ploughed treatments but significantly higher maize yields were only recorded in the relatively older LT trials at HRS and MFTC (Table 3). In 2010, CA maize treatments in rotation with sunnhemp exceeded the conventional control by 72% at HRS and the CA sole maize treatment by 32 %. At MFTC the CA maize treatment in rotation with cotton exceeded the control plot by 55% and the CA sole maize treatment by 29%. Yield results at SRS and CRS were more variable and there were no significant differences in yield between CA treatments and the conventionally ploughed control in most of the years. Results suggest that improvements in soil quality develop slowly but lead to increased crop productivity after some time. From past research we know that higher yields from crops under rotation might be due to reduced pest and disease incidence but may also be attributed to better soil structure and more efficient nutrient cycling through deep rooting crops (i.e. cotton) (Thierfelder and Wall, 2010a). An improved soil structure will also result in increased water infiltration and available soil moisture, which will help reduce the negative effects of seasonal dry-spells. The biggest advantage from CA systems can therefore be expected if all principles of CA are applied leading to improved soil hydraulic properties and higher crop yields in the longer term.

Table 2: Change in total carbon (%) and aggregate stability (%) measured at different times in one conventionally tilled and three conservation agriculture treatments. Monze FTC, Zambia.

Treatments and sites	Total Carbon (%)		Change	Total Carbon (%)		Change	Aggregate stability (%)
	2005 0-10cm	2008 0-10cm	%	2005 0-30cm	2008 0-30cm	%	2009 0-10cm
Conventional control, maize	0.67	0.56 b	-16.4	0.58	0.54 c	-7.3	23.7 b
CA, maize	0.72	0.76 a	+5.6	0.69	0.75 a	+9.4	45.2 a
CA, cotton-maize	0.64	0.68 ab	+6.3	0.61	0.61 bc	+0.6	45.1 a
CA, cotton-sunnhemp-maize	0.68	0.77 ab	+13.2	0.63	0.68 ab	+8.3	41.5 a
LSD		0.19			0.12		14.2
Probability level (PF)	NS	1%		NS	1%		5%

*means within the same column followed by the same letter are not significantly different at given probability level, LSD-Test (Thierfelder and Wall, 2010)

Table 3: Longer term effects of conservation agriculture and conventional tilled treatments on maize grain yield (kg ha^{-1})

Sites and Treatments	Cropping season					
	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Henderson RS						
Conventional control, maize	2542 a	3254 a	4358 a	1193 a	1789 b	1373 c
CA, maize	2370 a	2456 a	5234 a	1150 a	2787 a	1818 b
CA, maize/sunnhemp rotation				1364 a	2913 a	2371 a
Monze FTC						
Conventional control, maize		3620 b	4878 b	4084 b	3303 b	3011 c
CA, maize		4894 a	5141 b	4559 b	3905 ab	3874 b
CA, maize/cotton rot			6221 a	5985 a	4541 a	4690 a
Sussundenga RS						
Conventional control, maize			1522 a	778 b	3634 a	1292 a
CA, maize			1478 a	924 ab	3810 a	1083 a
CA, maize/sunflower rot				1226 a	4132 a	1344 a
Chitedze RS						
Conventional control, maize				4832 a	4866 b	4964 a
CA, maize				5259 a	5005 ab	4780 a
CA, maize/cowpea rot				5545 a	5743 a	5766 a

Notes: Control means the conventional control in this area which is mouldboard ploughed at HRS, MFTC, and SRS and a hoe-cultivated ridge-and-furrow system at CRS with residue removal; CA means the crop is seeded following the principles of conservation agriculture with residue retention The CA plots were direct seeded with an animal traction direct seeder at MFTC and SRS, with animal traction direct seeder and jabplanter at HRS and with a dibble stick at CRS Means followed by the same letter in column are not significantly different

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Controlled traffic/ permanent bed farming reduces GHG emissions

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Keywords: controlled traffic, resilience, soil emissions.

Introduction

Tillage might be unnecessary for crop production, but no practical mechanised system can avoid field traffic, usually by wheels, often when subsurface soil is moist. Soil damage is rarely obvious in CA, because soil compaction is universal when we "random wheel" about 50% of crop area in each crop cycle in mechanised systems, and natural amelioration takes several years.

Research comparisons between wheeled and long-term non-wheeled soil have consistently demonstrated major wheel impacts on run-off and infiltration, plant available water capacity, soil biota, planting energy requirements and crop performance. Some evidence from Australia and China is summarised in table 1, and is consistent with wheel compaction results from elsewhere, including some with small-scale equipment, when the control was long-term non-wheeled soil.

In practical terms, wheel damage can be minimised only by the use of controlled traffic or permanent bed farming (CTF), where all load-bearing wheels are restricted to permanent traffic lanes oriented for drainage. Precise crop management in soft soil from hard compacted traffic lanes also provides a range of 'system' benefits, improved timeliness and cropping opportunities being the most obvious (McPhee et.al 1995). Productivity and sustainability benefits of CTF have been confirmed by surveys of CTF farmers in Australia which have demonstrated increasing yields and cropping frequency, with less time, fuel, fertiliser and agricultural chemicals (e.g.Bowman 2009).

CTF will reduce environmental impact by reducing energy requirements, runoff and soil loss, and the emission impact of partial CTF in organic vegetables in the Netherlands has been demonstrated by Vermeulen and Mosquera (2009). The likely magnitude of this effect in Australian broadacre production was explored by Tullberg (2010), and this paper reports a pilot trial of CTF emissions.

Materials and Methods

The work was carried out on the eastern Darling Downs in an area that had been in permanent CTF no-till for 3 years, in a heavy black vertosol with ~2% slope (located at 151°44'49"E 27°44'55"S). Emission monitoring chambers were installed shortly after wheat was seeded at 35 cm row-spacing on 16th June 2010. A narrow-tine-and-disc opener combination no-till seeder (Excel Ag. "Stubble Warrior") simultaneously injected 80 kg/ha N (anhydrous ammonia) in the interrow.

Tyres (0.45 m section width) of the tractor used for seeding (Deere 8400, 3 m track width, mass approx. 10 Mg) were normally restricted to permanent traffic lanes by precise 2cm GPS "autosteer" (Leica). For this experiment the tractor was driven twice on the permanent beds, prior to seeding, offset first by 0.75 and secondly by 1.0 m from the permanent lanes, to create a 0.8 m zone of once-wheeled soil, representing random traffic (non-CTF) cropping. Two rows were planted in this zone.

Static chambers (0.254m ID, 0.35 m height) were installed in the interrow of this "random traffic" wheeled zone; in the non-wheeled "permanent bed" interrow; and in the non-seeded-or-fertilised permanent "traffic lane". These were driven to a depth of about 10 cm, in lines roughly on the contour, at right angles to the row direction. Four sets of chambers were spaced ~ 10 m apart.

Chambers were sealed only during emission monitoring, when 20 ml samples were collected from headspaces after 20, 40 and 60 minutes, for methane and nitrous oxide analysis with a Shimadzu GC-2014 Gas Chromatograph. Flux rates were calculated from the linear increase in gas concentration (Butterbach-Bahl et al., 2011). Soil temperature and moisture content at 10 cm depth were sampled with a TDR, and soil samples taken for of nitrogen analysis at the start and conclusion of this trial.

Emissions were monitored four times in the first 24 days to establish background emission levels. Rainfall was small (21mm total) during this time so 50 mm water was added to each chamber on day 26, after which several minor rain events were recorded. Final monitoring occurred on day 42.

Results and Discussion

Nitrous oxide and methane emission rates are illustrated in Figure 1, together with rainfall events. N_2O emission from all treatments were similar for 20 days after planting, with only non-significant increases from wheeled treatments effects after 20mm rain on day 17. No further rain was forecast so 50mm irrigation was applied to each chamber on day 28. This immediately stimulated an order of magnitude increase in N_2O emissions from random and traffic lane treatments, but little change from the permanent bed. This effect was maintained by further rainfall on days 36(6 mm) and 43(18 mm). Surface water persisted for > 24h after rainfall events in the wheeled treatments..

Mean N_2O emissions from random wheeling were non-significantly greater than those from permanent traffic lanes, but both were significantly greater ($P<0.05$) than emissions from the permanent bed treatments on 3 occasions. Differences in methane flux were significant on only one occasion when it was being absorbed by the permanent bed but emitted by wheeled treatments. These outcomes are broadly consistent with those of Vermeulen(2009) and Ruser et al(1998) with larger emission differences coincided with greater soil moisture levels in the wheeled treatments.

Total emissions over the full 42 days post-seeding were calculated by summing [mean emissions (start and end each period) x duration]. The accumulated values were converted to CO_2-e, using GWP of N_2O =310, CH_3 =23, indicating emissions of 57.8, 325.0 and 370.0 kg/ha CO_2-e from permanent bed, permanent traffic lane and "random" wheeled soil respectively. This would indicate 42-day post-seeding CO_2-e emissions from this CTF grain production system of 90kg/ha (39kg from 12% traffic lane, 51 kg from 88% permanent bed). This is about 40% of the emissions of 214 kg (185 from 50% random traffic and 28kg non-wheeled) likely from non-CTF management. Better spatial/temporal fertiliser placement should further reduce traffic lane nitrate and emissions.
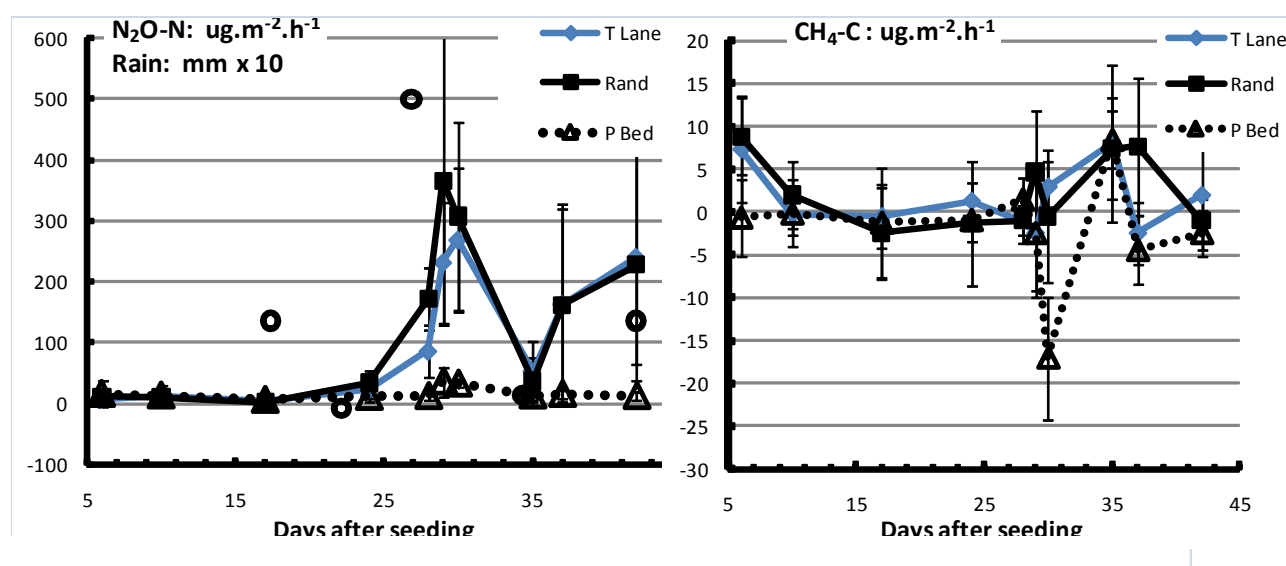
Figure 1. Wheel effects on post-seeding emissions of N_2O and CH_3. Rain (mm x 10) indicated by ⊙

Table 1. Some broad comparisons between wheeled and non-wheeled soil

Parameter		Units	Australian Vertosol		China, Loess	
			Wheeled	Non-wheeled	Wheeled	Non-wheeled
Wheel Load		t/axle	4-5		1-2	
Rainfall (5year mean)		mm/yr	907 (incl. irrigation)		558	
Runoff (5year mean)		mm/yr	193	112[L]	32	18[W]
Grain yield(5year mean)		t/	3.70	4.05[T]	3.05	3.25[W]
Infiltration (80mm/h ~ 1h)		mm/h	27	97[L]	12	41[W]
Available water	Top	mm	29	47[M]	27	30[W]
Bulk density	300mm		1.36	1.28[M]	1.51	1.59[W]
Fuel use, seeding		l/ha	5.6	3.0[T]	/	/

[L] Li et (2007); [W] Wang et al(2009): [T] Tullberg et al(2007); [M] McHugh et al(2009)

Conclusions

These pilot trial results indicate that post-seeding emissions from CTF are about 40% of those from non-CTF no-till crop production. Nitrous oxide is a major component of emissions from cropping, so this will be a useful mitigation opportunity if confirmed in further work. CTF also provides substantial reductions in fuel and other inputs. Improved rainfall infiltration, storage and cropping opportunities under CTF will also enhance resilience to climate change.

Multiple environmental and economic problems are caused by our failure to recognise the system impact of wheels in mechanised farming. CTF systems are conceptually simple, but practical and economic implementation is complex, and defeats many intending adopters. CTF is used by ~ 15% of Australia's leading farmers, but this would be much greater if machinery, technology and farming system standards were developed. This will happen much faster once CTF permanent bed technologies are recognised as an essential "4th pillar" of CA, along with no-till, cover and rotation, and seen as standard practice by the agricultural research and extension community.

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Conservation Agriculture in Haryana, India: past experiences and future plans

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Introduction

Haryana is an agriculturally important state of India and is the second largest contributor of food-grains (17.6% during 2009-10) with merely 1.4% (4.4 M ha) of the geographical area of the country. Agriculture is the mainstay and backbone of its economy and more than 65% of the population is directly or indirectly dependent on agriculture and related activities. Haryana has accorded high priority to the agricultural sector since it came into existence and has created strong infrastructure facilities, including a network of rural roads, electrification, canal system and market facilities to provide the needed impetus to agriculture development in the state. This infrastructure, coupled with agriculture research and an excellent extension system at ground level, has resulted in tangible results. As a result, food-grain production has increased from 2.6 MT at the advent of the green revolution era (1966-67) to 16.6 MT during 2010-11 - a six-fold increase. There have been major gains in wheat (11-fold) and rice (16-fold) production, making the rice-wheat rotation a major production system. However, monotonous (monocrop) systems, over-exploitation of natural resources, poor quality of ground water and increasing costs of production, coupled with changing climates, pose serious threats to the sustainability of the major production systems (rice-wheat, cotton-wheat, pearlmillet-wheat/mustard, wheat-sugarcane) of the state. Despite this, the state has earned the *"Krishi Karman Award"* for best performance in wheat production (11.6 mt) and productivity (4624 kg ha^{-1}) in the country during 2010-11. This has happened due to adoption of high yielding genotypes with very high seed replacement rate and zero tillage: Haryana is on the forefront in adoption of zero tillage wheat (~ 0.5 M ha). But most wheat is cultivated in rotation with rice, which is planted after conventional tillage and puddling which is not only detrimental to soil health and soil quality, but also is threatened by labour and water shortages, all resulting in decreased farm profitability. The same is true with the other major production systems. Therefore, the Government of Haryana has identified conservation agriculture (CA) as one of the most important strategies to deal with these issues. This paper synthesizes of the strategy of the Government of Haryana to address the issues of sustainability of agricultural production systems through policy reforms and related prioritization of investments in agriculture.

Materials and Methods

The majority (~ 67%) of farmers of Haryana are small and marginal having land holding less than 2 hectares. The natural resources, particularly soil health and ground water, are severely threatened. To sustain agriculture on a long term basis without jeopardizing either the country's food security or the farmers' economic growth, it has become necessary to develop conservation agriculture. During the past decade, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU) of the Government of Haryana, in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT), has done a commendable job in developing and promoting CA as a management strategy for addressing the issues of resource fatigue and farm profitability. This has been appreciated and recognized well by the regional and global community. Recently, the Government of Haryana through its 'Farmers Commission' has re-emphasized CA as one of the most important strategies for addressing the second generation problems and future challenges in agriculture. Therefore the Government of Haryana, through the Farmers' Commission, has recognized CIMMYT, an institution known as a protagonist of the Green Revolution in the developing world, as one of the most important sources for providing improved germplasm and CA technologies in the state. Accordingly, the State Government has established a CA working group to develop an 'Action Plan for CA' so as to make Haryana the most feed secure state in the country. Keeping in view the past experiences on CA, the Government of Haryana in consultation with the Farmers' Commission has prioritized its investments in agriculture focussed on CA.

Results and Discussion

The Honourable Chief Minister of Haryana has declared 2011 as "Water Conservation Year" which attests to the emphasis that the Government places on natural resources. To sustain agriculture, the Government of Haryana has prioritized the use of the funds from several important schemes of the Government of India on CA viz., National Food Security Mission (NFSM) - US$ 7.5 million; Rashtriya Krishi Vikas Yojana (RKVY) - US$ 40 million; National Horticulture Mission - US$ 22.6 million; Accelerated Fodder Development Programme - US$ 3.5 million; and other minor related schemes. In the current year CA has been prioritised and a large portion of the funds of these schemes redirected to support CA activities and investments. The major focus of these schemes is on:

- Soil health improvement through soil health cards issued by the state soil testing laboratories;
- Promotion of water saving technologies viz laser leveling, direct seeded rice, residue management, zero tillage and micro irrigation systems;
- Farm mechanization focused on CA machinery;
- Crop diversification through incorporating a legume into the rice-wheat system and other crops into the sugarcane systems using CA technologies. A new scheme has been introduced to promote cluster-bean (*Cyamopsis tetragonaloba*) and maize. Summer moong (*Vigna radiata*) has been promoted as an "opportunity crop" in between wheat and rice, which has had unprecedented growth and expanded to more than 40,000 hectares in one season alone. Horticultural and vegetable crops have been promoted to diversify the cropping system and improve the nutritional status of the people.
- Relay planting of wheat into standing cotton in the cotton-wheat system.

The future plans of the Government of Haryana for promoting CA as a vehicle of change in agricultural production and sustainability (HFC, 2011) is outlined below:
- The Department of Agriculture will mount a baseline survey of tube well water quality for irrigation, incorporated into a GIS framework, to delineate problematic areas and link this with soil health cards.
- Problem soils (saline, alkaline, water-logged) will be mapped and linked to soil fertility and cropping system maps for updating soil health cards.
- Laser level at least 3.0 m ha of irrigated and dry lands through promoting custom services.
- At least 50 % of the cultivated area (~ 1.5 m ha) will be brought under CA based crop management practices.
- Direct seeded rice (DSR) on 50% of the basmati rice area and all of the rice-potato/vegetable systems.

- No-till mechanical transplanting on 10 % of the rice area.
- Zero-till surface with residue retention on 50% of the wheat area using the Turbo Happy Seeder through the creation of CA machinery banks, supported by '*Single Window Services'*.
- Promotion of dual purpose wheat for green fodder in October planted wheat (one cut for fodder then leave for grain production).
- Partial diversification of rice-wheat system to maize-wheat system with CA.
- In sugarcane systems, 80% sugarcane area will be brought under inter-cropping using raised bed planting technology.
- Fifty percent (50%) cotton area will be brought under relay and inter-cropping systems to improve productivity of cotton-wheat systems. Transplanting of cotton (~10% area) will be promoted in the tail-ends of canals with saline aquifers. For this, high clearance tractors and small seeders will be introduced.
- The subsidies of tillage machinery will be reprioritised to promote CA machinery and especially versatile equipment for CA systems: multi-crop, multi-purpose CA machinery.
- A CA network involving the KVKs (Krishi Vigyan Kendra - Farm Science Centers) and the Department of Agriculture will be created.
- CA will be considered to be introduced in course curriculum in the university to develop a new generation of scientists with an understanding of and expertise in CA.
- CA will be further promoted through system based technical advisories to farmers using modern Information and Communication Technologies (ICTs). In this respect, the available database will be linked with the Agriplex system developed by CIMMYT and cell phone based service provision will be established and strengthened to enable real time information access by farmers.
- A network of public-private sector partnerships will be established and promoted for CA.
- The Department of Agriculture will encourage and support the formation of farmer cooperatives based on CA and will facilitate and subsidise the purchase of CA equipment.

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Controlled Traffic Farming – more productivity, sustainability and resilience

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Keywords:farming systems, triple bottom line benefits, spatial technologies

This paper describes the development of Controlled Traffic Farming (CTF) as a farming system, its triple bottom line (economic, environmental and social) benefits and potential improvements using spatial information technologies.

Research in the 1990s (Tullberg et al (2007), Yule et al (2000)) showed that controlled traffic (permanent wheel tracks and fully matched implements) managed soil compaction; improved soil physical and biological health (infiltration increased by 19% and earthworm numbers by 10 times); increased machinery efficiency, effectiveness and adaptability (Figure 1); reduced crop variability; and increased crop growth and yield, typicallyby 15-20%. This research also found that controlled traffic supported no-till farming by increasing field access and timeliness, and preventing overlaps and misses. The accurate guidance necessary for CTF also assists with rapid inter-row planting into standing residue, increasing flexibility of rotation. Finally, the research showed that with designed farm and field layouts, controlled traffic and no-till delivered soil erosion control (reduced by up to 90%) and waterlogging management (Yule and Cannon, 2002). These layouts aim to remove surface water quickly and safely to disposal structures.When combined, these practicesdelivered much higher triple bottom line benefits (Table 1).

Table 1. System benefits from adoption of CTF. 16 farmers cropping 4,250ha on the eastern Darling Downs, Queensland were studied (Bowman, 2008).

Indicator	Conventional	CTF	Benefit
Soil Loss (Tons)	273,000	78,000	-90%
Fuel Use (litres)	338,000	130,000	-60%
Nitrogen Loss (kg)	119	9	-90%
Carbon dioxide Loss (tons)	1,199	373	-70%
Labour (hours)	4,590	1,744	-60%
Annual Income ($)	1,652,500	2,586,230	+44%
Gross Margin ($)	547,279	918,366	+68%

Our on-farm RandD found that these three practices - controlled traffic, no-till and accurate guidance systems - could be efficiently combined into farming systems for broadacre grain and fibre cropping. This defines controlled traffic farming (CTF).

Guidance to drive straight and to return to the same wheel track position was a constraint until real time kinematic (RTK) geographic positioning systems(GPS) solutions were available.At about 10% of tractor price, this has allowed precise controlled traffic (+/- 2cm), and precise row and inter-row operations, simply by staying on the permanent wheel tracks. Growers could managecrops at the individual row scale, even with large machinery (Millner, 2009). In addition, RTK GPS provides accurate elevations (+/- 5cm) and growers can obtain topography data for high quality contour maps and layout design.

RTK guidance made CTF available to all grain growers but the lack of measurement tools at the scale of single rows and wheeltracks constrained adoption. We identified solutions from the spatial information technologies.

The wheeltracks provide a spatial footprint for remote sensing. At high resolution, it is possible to relate observed variability to farm management. For example, 1m pixel satellite imagery has identified and quantified waterlogging;poor fertiliser spreading; effects of previous harvest traffic; insect and disease attacks; fertiliser, variety and erosion responses; and inefficiencies due to trees, rocks and poor layout. Typically, more than 50% of the crop variability observed in imagery is caused by the grower. When these causes are addressed, fields with considerable soil differences, produce even crop growth (Yule, 2010).

With the spatial CTF footprint, satellite or aerial imagery provides digital, spatial records of the crop growth across the farm. Imagery provides high resolution data to help interpret yield monitor data. These measurements are automated, remote and do not interfere with farm operations.

CTF and these spatial measurements provide growers with a platform for continuous improvement. They also allow on-farm RandD because strip trials of any input can be installed automatically, recorded and subsequently measured with imagery and yield monitoring (Yule, 2006).Current research people can use their skills to design, analyse and interpret these trials and every farmer can do them, for their farm and farming system.

Measurement of whole system performance and improvement is difficult. Rainfall is an important variable but water use efficiency is a complicated calculation. We experimented with a simple approach of relating cumulative yield to cumulative rainfall for each field. We call this System Rain Use Efficiency (SRUE). We analysed data from multiple fields on 6 farms across Australia. The plot for individual fields was surprisingly linear but the SRUE differences between farms were very large. For example, the SRUE for 3 farms in central Queensland was 6.5, 5.2 and 2.8 kg/ha/mmover 8 years (Figure 2a). In other words, the grain produced from 3,000mm of rainfall varied from 8 to 21 tonnes. The method also identified the effect of a management change to permanent raised beds in Victoria. Production increased from 4.4 to 11.6 kg/ha/mm with this change in farming system (Figure 2b), (Yule, 2010).

Figure 1. Efficient wheat harvesting with CTF
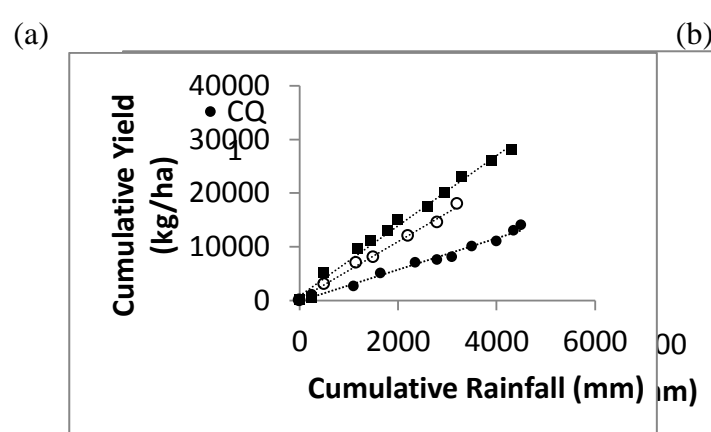
Figure 2. System Rain Use Efficiency for (a) a single field on three different farms in Central Queensland, and (b) a single field that was changed to raised beds after 4 years in South-west Victoria.(Vertical axis in both cases is cumulative wheat-equivalent grain yield).

Conclusion

CTF is a farming system including controlled traffic, no-till, designed field layouts and other improved practices. CTF manages soil and landscape degradation, improves machine and operation efficiencies, improves access, timeliness, production and profits, and reduces labour, fuel use, GHG emissions and environmental impacts (Table 1). CTF supports spatial technologies of guidance, remote sensing and yield monitoring. High resolution imagery, topography and yield monitoring provide new spatial tools to measure and record field and farm performance, and SRUE measures farming system responses for every paddock. CTF has been adopted by about 15% of Australian grain growers but adoption requires appropriate technical advice and support. CTF reduces in-field variability and should be adopted before practices such as variable rate are tested.

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Sustainable intensification of maize-bean production among smallholder farmers in western Kenya

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Introduction

Maize and beans are important food crops in western Kenya, mostly grown by resource-poor farmers in complex and risky farming systems. Trends in population growth in Kenya indicate that the demand for maize and beans is projected to continue increasing ca. 3–4% annually, supporting a case of the sustainable intensification of maize and bean production. Conservation agriculture (CA) has been proposed as a set of principles that could help reverse widespread soil degradation in the region and help farmers stabilise yields by mitigating the effects climate variability. Though numerous questions remain on how CA practices might fit in a complex mix grain – grazing farming systems, where limited land, cash and labour impose severe constraints on farmers' options. In this manuscript we present the initial results from a participatory research program aimed to develop and test resilient smallholder maize-bean farming technologies based on the principles of CA that are likely to sustainably increase, stabilize and diversify the livelihoods of small holder farmers from western Kenya. Here we report results of the first year of on-farm trials and the capacity of APSIM (Keating et al., 2003) to model the performance of intercropped maize and bean yields under conventional and CA practices.

Materials and Methods

On-farm trials

A number of on-farm trials were established in Siaya County, western Kenya (0º 0.4' N; 34º 16' E, 1297m a.s.l.). The soils are well-drained, moderately deep Ferrasols, and the long term average annual rainfall is 1200 mm. The area is characterized by small households (i.e. 1-2.5 ha per household), and a low input low-output farming system. Maize yields fluctuate around 1 t ha^{-1}, and the main limitation is low nitrogen availability due to high soil degradation. Trials were planted on 7 farms (replicates) located at less than 2 km from each other, during the long rains season of 2010. Treatments included common beans intercropped with maize under the following treatments:

T1   Conventional tillage, hand weeded, and residues removed;
T2   Minimum tillage, herbicides applied, and residues retained;
T3   Minimum tillage, herbicides applied, beans inoculated, and residues retained;
T4   Minimum tillage, herbicides applied, desmodium-beans-maize intercropped, and residues retained.

All treatments received a uniform application of 60kg P and 80kg N/ha only on the maize crop. Soil samples (0-15, 15-30, 30-60cm) were taken at the beginning and end of the season, and soil water content, bulk densities, pH, soil nutrients (N, P, and K) and Organic carbon were determined. Plant cuts were taken at flowering and at physiological maturity. The participating farmers collected local rainfall records during the whole extent of the trials. Bean and maize crops were harvested between 18-19th June 2010, and 19-23rd July 2010, respectively. Over 25 farmers evaluated the treatments at early, mid and late crop growth stages for vigour, uniformity, weed control and yield. Biomass and yield data was analysed by ANOVA using GenStat-Discovery Edition 3, and means were separated by LSD$_{0.05}$.

APSIM modelling

The performance of the APSIM model (Keating et al., 2003) was validated against the observed results from treatments T1 and T2. Then the validated model was used to evaluate potential improvements in the intercrop system using 30 years of climatology obtained from a nearby weather station. APSIM simulations included no-till (T1) and conventional tillage (T2) maize - bean intercrops. The tested improvements in the intercrop system included (i) an intercrop, maize + bean intercrop followed by bean relay crop; (ii) maize + bean intercrop followed by a maize crop; and (iii) a maize and pigeonpea intercrop.

Results and Discussion

No significant differences, on any of the measured variables, were observed during this first year of trials between conventional and conservation tillage. Bean yields were significantly higher in treatment 3 i.e. minimum tillage, herbicides applied, beans inoculated, and residues retained, indicating that nitrogen was still limiting crop growth and production. The bean crop did not receive nitrogen fertilisation. No differences were observed on maize yield, water use or total water use efficiency (Table 1). Water use was unrelated to maize yields, but significantly ($p < 0.05$) related to beans yield (Figure 1a). However, for the subset of sites where data on both yields and water use were available for both beans and maize in the intercrop, the total grain yield production i.e. maize yield plus bean yields was highly ($p<0.01$) related to water use (Figure 1b). For this subset of sites, the relationship between the total grain yield i.e. maize plus beans, and water use i.e. water use efficiency, ranged between 13.1 and 14 kg/mm/ha (Figure 1b). At the end of the season (i.e. maize harvest) the amount of residual (total) water in the soil was still 233mm (i.e.in the 0-60cm top soil), indicating that an additional crop could have been planted after the harvest of the bean crop in early July.

Table 1. Yields and water use by bean and maize yield during long rains season (2010) at Siaya, western Kenya.

Treatment	Bean yield (kg/ha)	Maize grain yield (kg/ha)	Water use♣ (mm)	Average total water use efficiency♠ (kg/mm/ha)
1	355b	4075	521	8.5
2	626b	4650	487	10.8
3	927a	4416	562	9.5
4	707ab	4483	526	9.8
LSD (5%)	231.5	NS		

♣ Average water used from planting to harvest calculated as: soil water at planting, plus in-crop rainfall, minus soil water at harvest.
♠ Ratio between the sum of the average bean and maize grain yields, and average water use.

Table 2. Potential productivity (±SE) of alternative maize/legume options vis-à-vis maize bean rotation at Siaya, western Kenya, simulated using APSIM from 1979-2010.

Cropping system	Long term average yields (kg/ha)			Total yield (kg/ha)
	Maize	Companion crop	Relay crop	
Maize/bean	2534±281.4	1209± 23.5		3743
Maize/bean-bean	2550±283.9	1219± 24.9	641 ± 26.9	4410
Maize/bean-maize	2547±285.3	1245± 26.8	6180 ±215.0	9972
Maize/pigeonpea	6741±255.0	687±8.9		7428

We used the APSIM model to test whether another bean or maize crop could be relay planted into the maize i.e. after the harvest of the intercropped bean, or whether a longer season pigeonpea crop would be a better option in the intercrop (Table 2). Simulated results indicated that if a maize/bean intercrop is followed by a relay maize crop, total food production could be more than doubled. However, this system may require a considerable amount of nitrogen fertilizer, which may not be available to the farmers. Alternatively, a second bean crop, requiring little additional nutrients input, could be relay cropped into the maize. The maize-pigeonpea intercrop is another option where maize yields could be maximised by the reduced early competition from the pigeonpea crop. In the context of the existing maize-bean rotation system, the observed yields of both crops were variable and generally less than the potential yield simulated by the APSIM model indicating an apparent yield gap which could be related to unknown constraints operating in farmers' fields (Figure 2). Understanding these constraints could lead to improvement in yield of both crops in this rotation system.
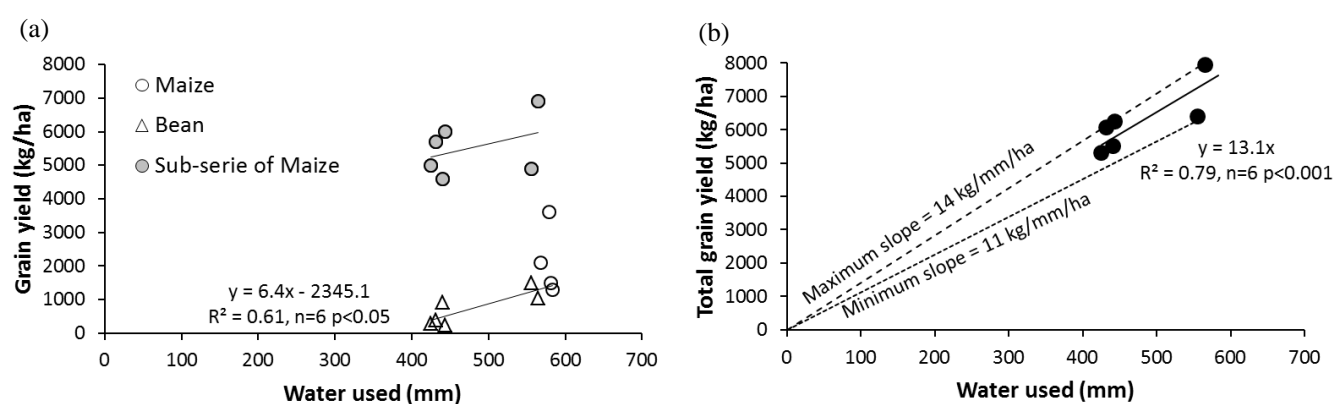
Figure 1. Relationship between the grain yields of maize and bean and water use (a); and (b) relationship between total yield and water use for the sites where yield and water use data was available for both crops i.e. triangles and grey circles for bean and maize, respectively.
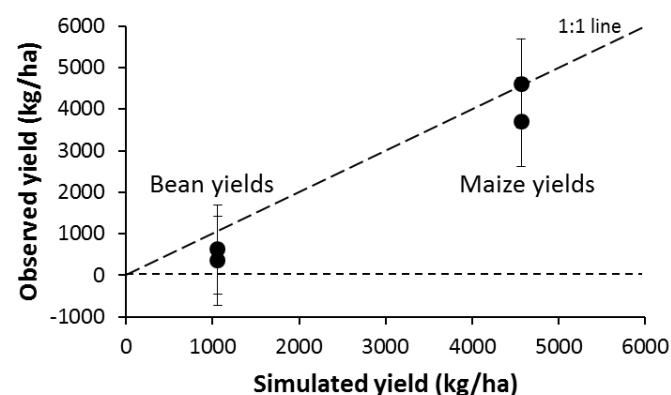
Figure 2. Simulated and observed bean and maize yields. Vertical lines are standard errors.

Here we conclude that there might be interesting opportunities for intensifying maize-legume farming systems in western Kenya that make better use of the long rains. These opportunities include relay cropping maize or legume crops after the harvest of the legume in traditional intercropping farming systems depending on the availability of soil water at sowing. These results also demonstrate the importance of proper monitoring i.e. full soil profile, for available soil water before, during and after the cropping season, to identify opportunities to increase the soil water productivity.

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Designing modular frameworks for crop modelling: implementation and guidelines for use

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Introduction

Adoption of advanced software engineering techniques in crop modelling in the past decade has led to the construction of modular frameworks, consisting of libraries of models from which selections can be made. Advantages of a modular structure include the possibilities for: (i) interchange of code among models, (ii) testing of alternative hypotheses, (iii) use of simple or comprehensive modules as required for a particular application, and (iv) sharingof expertise. Although these advantages are undeniable (Acock and Reynolds, 1989), and have occasionally been illustrated, some within the APSIM (Agricultural Production Systems sIMulator, Keating et al., 2003) framework (e.g. McMaster and Hargreaves, 2009), little research has explicitly addressed the process of module comparisons or model adaptation within such frameworks. Modular frameworks provide technical possibilities to link modules, even if these links are meaningless in term of crop physiology or interaction between plant and soil. Therefore there is a need to support selection of modules in a consistent way between the agronomic domain and the software domain (Roux et al., 2010). The selection of the modules must be governed by the objectives of a specific simulation exercise. Thus, in addition to the implementation part of the framework (e.g. software engineering), there is a need to further focus on the model building process, and more specifically on the decision-making process of selecting one module rather than another (modelling part of the framework) and incorporating that module into the model structure (i.e. module assembly). This selection process is based on explicit criteria or approaches to guide model development. The aim of this article is to discuss the choices made in the development of modular frameworks in crop modelling at the implementation and modelling levels, and to discuss how such frameworks can contribute to the advancement of modular crop modelling, but also address its limitations.

Materials and Methods

CROSPAL (CROp Simulator: Picking and Assembling Libraries, Adam et al., 2010), APES (Agricultural Production and Externalities Simulator, Donatelli et al., 2010) and APSIM (Keating et al., 2003) are a few examples of modular frameworks, illustrating how modularity has been applied so far in crop modelling. Reflections on differences and similarities of the software design adopted to build these modular frameworks helped in identifying what is essential to create the libraries, without creating "Yet Another Modelling Framework" (Van Evert et al., 2005) and which are the consequences of their differences.

The assembly of the appropriate modules is based on criteria or systematic methodology for module selection. We suggest the use of three main methodologies to define and facilitate the assembly of modules: (i) uncertainty matrix, (ii) model comparison, and (iii) expert knowledge elicitation. The uncertainty matrix distinguishes different types and sources of uncertainties in order to facilitate uncertainty classification. We apply this methodology to select a soil nitrogen module (mineralisation explicitly described or not) to simulate crop growth in response to nitrogen management and emphasize the importance of accurate simulation of nitrogen uptake. Model comparison enables the investigation of the effect of the level of detail incorporated in process-based crop growth models on simulated potential yields under a wide range of climatic conditions (Adam et al., 2011). Finally, expert knowledge elicitation is used to define a new crop model for grain legume (pea, *Pisum sativum L.*) from an existing cereal (durum wheat, *Triticum durum L.*) model.

Results and Discussion

The software design of all three frameworks studied (Table 1) allows modularity and flexibility in adapting the model structure. The choice for one specific design mostly depends on the expertise of the future user of the modular framework. Use of an XML file (Table 1) to configure a model (i.e. define its structure), as possible in APSIM, provides total flexibility to the user to select any module, no matter whether the different modules "fit" together conceptually. Technically, everything is possible once individual modules have been properly implemented and modifications in the configuration of the structure of the model escape any consistency check in the agronomic domain. In APES, the use of the composite strategy provides less freedom to the user, as the developer defines this composition within the component (IStrategy) on the basis of his or her own opinion on the anticipated future modelling exercise and/or application. However, the selection of a specific model structure still remains the responsibility of the user through the use of model options. In CROSPAL, the choice for the use of the abstract factory (a way to encapsulate a group of individual factories that have a common theme, Table 1) relies on the logic used to assemble the crop model. The way module are selected and assembled is the consequence of the vision of the developer in the agronomic domain (e.g on crop functioning) and should correspond to the different criteria included in the graphical user interface, criteria defined with the help of uncertainties studies.

Table 1. Comparison of the different software designs adopted in different crop modelling frameworks (including definitions of technical terms)

Level of granularity	CROSPAL	APES	APSIM
Modules *Basic crop processes*	Strategy	Strategy	Dynamic link libraries (dlls)
Component *Crop*	Abstract factory and criteria with a GUI	Composite strategy (IStrategy: interface)	Generic model structure/ XML configuration
Crop models *Soil-crop* (i.e. crop simulator)	Definition of new concrete factories	Components linked via wrapper (using the ModCom framework)	GCROP linked to the APSIM engine

Factory, in object-oriented computer programming, a factory is an object for creating other objects. It is an abstraction of a constructor, and can be used to implement various allocation schemes. **GCROP**, the generic crop model template of APSIM; **GUI**, graphical user interface; **ModCOM**, a software framework to assemble simulation models (Hillyer et al., 200); **Strategy design pattern**, define a family of algorithms, encapsulate each one, and make them interchangeable; **Wrappe**r, classes enabling combination of other classes that could not be combined, because of incompatible interfaces; **XML**, Extensible Markup Language

Use of uncertainty matrix, model comparison and expert knowledge elicitation stressed the importance of the documentation of the modelling process. These uncertainty assessments should be seen as the basis of the logic that enables one to go from the objective of the simulation to the "appropriate" crop model (Figure 1). The definition of this logic is based on a stylised decision-making process rather than based on pragmatic decisions (e.g. data availability, expertise...).The use of the uncertainty matrix emphasized the importance of explicitly defining the unknown. The use of model comparison enables one to tackle the issue of the required level of detail and highlights the risks of over-simplification of processes when data are scarce (Adam et al. 2011). And finally, the integration of expert knowledge in the development of the framework emphasizes the importance of explicitly describing the underlying assumptions through the use of conceptual modelling and the future potential of visual tools such as declarative modelling. Using these three methodologies, we derived an explicit description of the conceptual model, including (i) the domain of application, (ii) the type of model required, (iii) the relations and assumptions underlying the choices, and (iv) the verification of the conceptual model.
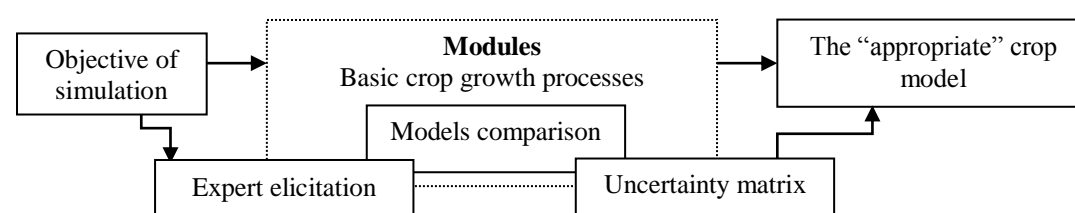
Figure 1. Approaches used to guide the selection of the model that represents the system under study.

While technical advances have stimulated substantial progress in the crop modelling field, especially in providing modular frameworks that allow easy coupling of different models at a higher scale for use in integrated assessment studies (Van Ittersum et al., 2008) or for further understanding of crop physiology (Hammer et al., 2002), conceptualisation of the systems remains an essential step. Consequently, the crop modeller should act as an interface between the developers and the end users: he or she must understand a minimum of all disciplines involved in the process of model development (Roux et al., 2010), integrating knowledge from the users (i.e. agronomists) and the developers (software engineers) to bridge the gap.

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Cultivation of African walnut *Tetracarpidium conophorum* Mull. (Arg) on agricultural plantation: An approach to Conservation Agriculture in Nigeria

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Introduction

Pluckennetia conophora Mull. (Arg), [formerly known as *Tetracarpidium conophorum* (Müll. Arg.) Hutch. and Dalziel] is from the family Euphorbiaceae and commonly called the African walnut (GRIN, 2010). African walnut is a perennial climber found in the moist forest zones of sub-Sahara Africa (Oke, 1995). It is cultivated principally for the nuts that are cooked and consumed as snacks, along with boiled corn (Oke, 1995; Victor, 2003; Edem *et al.*, 2009). Oke and Fafunso (1995) reported on the high nutrient potentials of the nut. Adebona *et al.* (1988) developed a biscuit-like snack food from the nut, throwing some light on the functional significance of the oilseed.

The plant of *P. conophora* is planted under an indigenous tree that can provide strong support for the heavy weight of the climber when fully established on the crown of the tree. The climber of *P. conophora* takes over the crown of the tree which is used as support when fully established and thereby competes for sunlight and also affects fruiting of the host tree. Therefore, trees that do not produce high economic fruits are mostly used to serve as support for the climber. Gathering and processing of the fruits is at the household level, this creates social interaction between the young and the old within the communities. In most cases, the fruit are allowed to drop after maturity and gathered by both the children and women, but sometimes by the farmers themselves. The gathered fruit are allowed to rot, after which the seeds are removed and washed. In cases where the farmer was in need of money and cannot wait for the fruit to rot, a knife and cutlass are used to open the fruits and the nuts are removed.

The loss of biological diversity from clearing of forests for plantation establishment has been emphasized. Cultivating forest products on agricultural plantations is one way to restore and conserve threatened forest resources. This study, therefore, assessed the socio-economic contributions of African walnut to local farmers and other stakeholders that could be harnessed to facilitate conservation agriculture through multiple land use systems.

Materials and Methods

Multi-stage random sampling techniques were used to select two communities each from three Local Government Areas in Ekiti, Ogun, Ondo, Osun and Oyo states of Nigeria. Primary data were collected from producers and marketers through two sets of structured questionnaires, oral interviews and focus group discussions. Three-hundred copies of the questionnaire were administered to producers to collect information on the production and socio-economic contributions of the walnut. Another set of 300 questionnaires were administered to the marketers to assess the major source of the walnut, marketing chain and marketing challenges.

Results and Discussion

Data collected from interviews and questionnaires indicated that the climber of *T. conophorum* is cultivated on plantation of cocoa, kola, oil palm, and orange by 81.7% of the farmers. Small scale farmers at the local level constituted the highest producers of the walnut. The male gender dominated the production sector of African walnut and the reason is that, in South-West Nigeria, the male has the right to own land on which the product is mainly planted. Land is normally handed over to the male as family inheritance, and plantations of cocoa (among which the product is mostly produced) and other cash crop plantations are owned mostly by males. On the contrary, processing of farm produce was seen as a female job, therefore processing of the African walnut fruits to obtain the nuts was mostly done by the women, although commonly with the assistance of children.

The walnut has not been fully developed for industrial utilisation; consumption is therefore as snacks. Neither the producers nor the marketers engaged in credit sale of the product. The marketable quantities are bought in cash by the intermediaries. The family member(s) of the producer, mostly the wife, do the selling at home (in case the village merchants come to buy) or take to the market for sale. The village merchant moves from village to village and market to market to buy the available raw nuts. The bulk of the walnuts produced are consumed in the city, therefore, the village merchants transport the product to the wholesalers in the cities and towns for onward distribution to the retailers. At times, the wholesalers and retailers that reside close to the local markets also make their purchases in such markets. Many of the marketers preferred selling the product after it has been cooked and at retail price. Processing of the nuts before sale adds value and generates greater profits compared to any other method of selling along the marketing chain. It was a common phenomenon to see both youth and adults on the street hawking the nuts displayed on trays or holding packed nuts in transparent nylon bagos along major roads for passengers in vehicles or passers-by to buy. High profits are obtained from the sale of the product if sold at retail price rather than at wholesale price.

Apart from consuming as snacks, some studies on the plant have revealed there is good nutritive value in the nuts (Oke and Fafunso, 1995; Adebona *et. al.*, 1988; Akpuaka and Nwankwo, 2000). The nuts have been shown to cure male infertility problems and the leaves are used for the treatment of dysentery (Ajaiyeoba and Fadare, 2006). The oil from the nut has been used in formulation of wood varnish, stand oil, vulcanized oil for rubber and leather substitutes. Despite these indepth studies on the nutritive value and medicinal potentials of African walnut, the product is yet to be fully developed for industrial utilisation in south-west Nigeria. Small scale farmers at the local level constituted the highest producers of the walnut. These have been hampering its full scale production and exploration of its inherent potentials.

A higher selling price is obtained by both the producers and the marketers when there is less quantity of the product in the market, but in situations where there is over suply, coupled with the problem of lack of appropriate storage facility, the product is sold at reduced prices. Lack of storage facilities is therefore a challenge to marketing of the walnut. After it has been cooked, the product must be consumed within 1-2 days or else it will develop a foul odour not pleasant for sale or consumption.

The most prominent problem encountered by the producers of African walnut was inadequate transportation as a result of deplorable rural road networks. Many of the products become spoiled due to transportation problems resulting from inaccessibility to the fields. In places where the vehicles can get to the production sites, high transport fares to convey the product from the farm to the market discourage the producers and this poses a great challenge to the opportunity for a good price to the grower. In summary, high transportation cost leads to spoilage of the product on the farm; producers selling to the middlemen at a give-away prices; and increases in the final market price.

The socio-economic contributions of African walnut to farmer and other stakeholders have been seen as an opportunity to conserve indigenoue trees under which it is grown. This is seen as a multiple land-use system and an approach to conservation agricuture in Nigeria and applicable elsewhere.

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Assessing rural resources and rural livelihood development strategies combining socioeconomic and spatial methodologies

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Introduction

In many mountainous regions of Asia, poor socioeconomic conditions and natural resources degradation follow a certain spatial gradients such as from an urban centre to remote areas, from valley bottom to mountain top, from irrigated lowland to mountain rain fed; leading to further resource degradation and socioeconomic differentiation. This suggests the co-existence and a relationship between resource availability, use and livelihood for the farming families. It also indicates that the unsustainable uses of land and water resources in any spatial location might be because of various factors such as economic, ecological, socioeconomic and or institutional. So in order to find the best option of achieving sustainable management of natural resources and socioeconomic development, it is necessary to find out the association of socioeconomic and biophysical condition in the different spatial gradients of an area. Then the location-based problem solving strategies can be tested in producing best possible recommendations for the future. Farming practices adopted by the farmers in the hills of Nepal differ owing to spatial differentiation leading to differential resource availability, infrastructure development, and external intervention. This paper presents the spatial differences in farming practices and their impact on rural livelihood from an urban centre to rural areas along the altitudinal gradients in a small watershed in Nepal. It also assesses the impact of different possible future development strategies on the spatial distribution of the farmer's livelihood.

Materials and Methods

This study employed a combination of socioeconomic and spatial methodology to assess different land, water resources and rural development strategies. Biophysical analyses were carried out using remote sensing (RS) and geographic information system (GIS) technology. Socioeconomic conditions were assessed based on in-depth household interviews. Both analyses were linked and the relationships between socioeconomic conditions and resources degradation were assessed. Farming practices and rural livelihood were assessed through a farming systems approach and spatial differentiation was assessed by means of GIS. Socioeconomic data were collected through household survey from spatially randomly selected farm households and linked to GIS using households' geographical positions to establish a link between socioeconomic and biophysical environment.

Spatial regression model was established to explain the spatial distribution of farm income from the explanatory biophysical variables land quality indexes and cost distances. Land quality indexes for the agricultural land were estimated based on the slope, whether the agricultural land is irrigated or not. Cost distances from the different parts of the watershed to the nearest market centre were measured using a GIS based cost weighted distance model. Correlations between variables were observed by exporting the grid cell information to a spread sheet and then to the SPSS software package. Cost distances and land quality indexes were found significantly highly correlated with farm incomes. Estimated income and impact maps for different land quality improvement and cost distance reductions scenarios were constructed by exporting the regression result into the GIS.

The GIS based multiple regression model used for income estimations was also used to estimate potential future income generation in different scenarios of farm management. For this purpose, the land quality index of the grid cells and cost distance from each of the grid cells to the nearest market centre were modified (Bahadur KC, 2005). Since the index represents the differences in the quality of the land, different land qualities can be simulated with the model by changing the weighting factors of the individual classes as required for the setting up of scenarios. Modifications of the weights of individual grid cell of different themes allow the simulation of future land quality indexes of the respective grid cell. The final land quality index for each grid cell is calculated by multiplication of weight given to each individual grid theme. A higher land quality index signifies better land quality. In the multiple linear regression models, this was used together with the cost distance to explain the farm income.

Results and Discussion

Land use land cover change assessment during 1976-2003 shows that agricultural land use increased by 35% , due to conversion from forest land. Agricultural expansion was most conspicuous at higher elevations. About 36%, 18% and 6% of forest lands were converted into agricultural activities from higher, middle and lower elevation respectively (Bahadur KC, 2009). Spatial differentiations were found in the adoption of farming practices. Results of spatial distribution of living standard parameters including farm family income and food availability showed a decreasing trend as the elevation increased. In remote rural villages where lands do not have irrigation facility and livestock keeping is common, maize-dominated subsistence farming is also present. Farmers in the lower hill villages practice intensive inorganic farming, especially rice and vegetables. These differences in farming practices are mainly due to the spatial location of the settlement, land quality, infrastructure and resource availability, and external intervention. As one moves from higher to lower altitudinal gradient and from remote to urban centres, these factors start becoming favourable. Yields of food crops are higher in lower altitudes than higher altitudes. Income differentiation shows a higher farm and family income in the most favourable zones nearby market centres and at lower altitudes. Off-farm income, which contributes much to family income, is appreciably higher in lower hills as compared to higher hills where agriculture is the mainstay of livelihood. Opportunities for quality education, health, and housing are improved as one moves from remote to urban areas, while provision of quality drinking water is better in rural villages. In order to deliver the benefit to the distant inhabitants, there is the need to develop infrastructure and strategies of increasing land productivity. Relations of land use dynamics to other factors shows that deforestation around high-income areas and near road and market centre were less compared to low income areas and far from the road and market centre. The spatial trajectories were then contrasted, with particular attention to the socioeconomic condition and institutional arrangements governing access to land resources. While overall land change patterns in the region are largely explained by elevation and socioeconomic condition adjacent to the forest land, more specific, sub regional, trajectories reflect the signatures of institutions governing access to land.

The features of this GIS based multiple linear regression model indicated a good explanatory value of the relationship between spatial distribution of farm income and land quality indexes and cost distances with a coefficient of determination (R^2) of 0.73 and sufficiently high levels of significance for the whole function (F-test) as well as its components (t-tests), which exceeded a probability level of 99% in all cases. The model aims at regionalizing the current income situation and uses statistical dependencies for the simulation of the effects of future strategies. The integration of socioeconomic and biophysical attributes with infrastructure, institutional and policy changes is relevant for formulation and assessment of cause and effect patterns. Spatial differences in socioeconomic variables are mainly related to road, market and other infrastructure which are crucial for livelihood development. Households with poor access to these infrastructures have low farm and family income and poor livelihood and the opposite is true in accessible areas. The results of GIS based cost distance modelling shows substantially higher time to reach to the market from rural areas. The findings also pinpoint that most of the socioeconomic parameters are governed by spatial position of the household and therefore any intervention to improve the livelihood through agriculture development should take this spatial variation into account.

Future strategies of reducing cost distance through road improvement and improving the quality of land through soil and water management activities shows increasing trend of farm income and decreasing the spatial differentiation of incomes among the farmers living in the different zones of the watershed (Figure 1). If the tested strategies will be implemented an improvement of living conditions and reduction in resources degradation could be achieved. The combination of socioeconomics and spatial concept and methods is an appropriate methodological option for formulating and testing long-term problem solving strategies towards better planning for improving living standard of rural farming people and sustainable management of natural resources. This concept can be relevant for strategy testing in similar regions in mountainous zones.
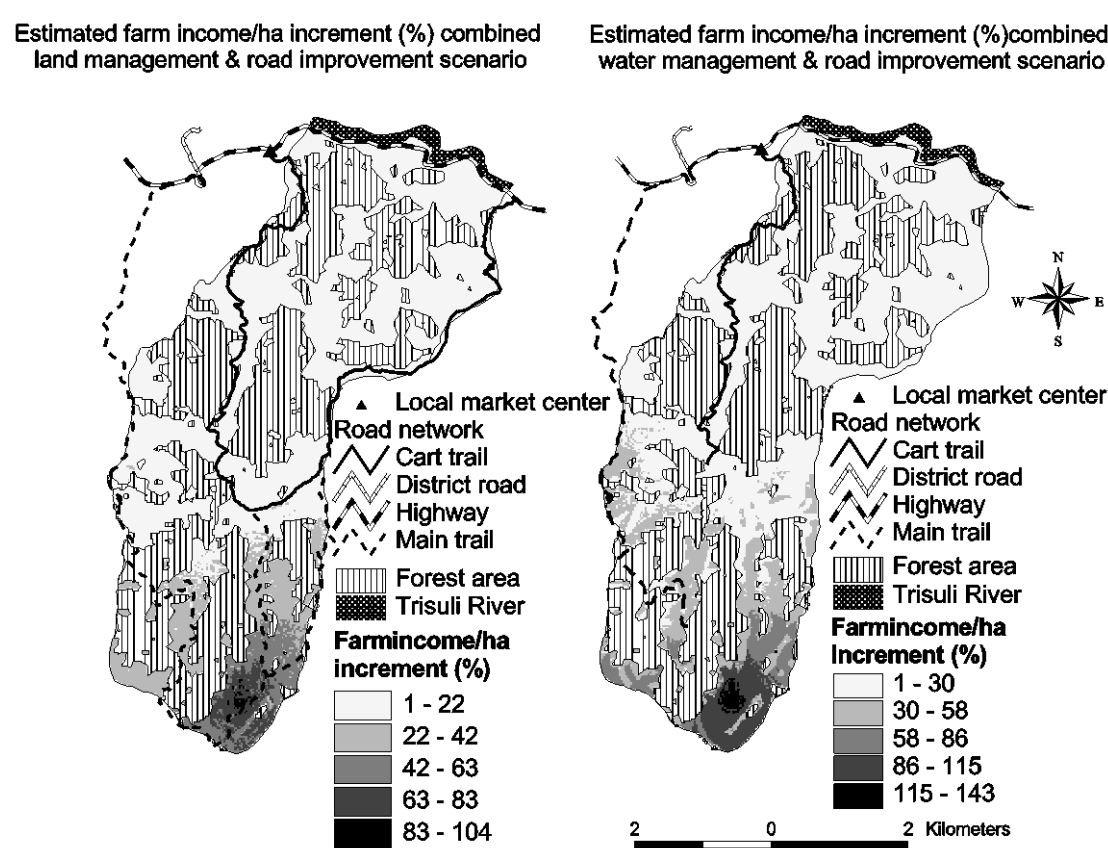
Figure 1: Assessment of the combined strategies: Impact of combined land and road improvement on income (left) Impact of combined road and water improvement on income (right)

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Mixed crop-livestock businesses reduce price- and climate-induced variability in farm returns: a model-derived case study

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Keywords: whole farm, systems modelling, APSIM, GRAZPLAN, economics

Introduction

Mixed crop-livestock systems have dominated Australia's broad-acre farming zone for over 50 years, yet there is unease that these systems are in decline and the resilience and sustainability benefits they provide may be diminished. Hence, there is a need to re-examine what mixed farming has to offer. Farmers operate mixed farming systems for many reasons and it is difficult to disentangle the various benefits they provide. These can range from the ability to manage spatial variability in land capability across the farm, to benefits from production synergies such as legume-based pastures fixing nitrogen for subsequent crops. Farm-level production and economic data do not enable value to be attributed to the various elements of these systems. Modelling provides a useful mechanism by which these elements can be examined in isolation and the scale and nature of the benefit/cost to the farming system quantified.

In this paper we examine the economic risk mitigation effect of maintaining a mix of segregated enterprises in a farm business. We use simulation modelling of crop and livestock systems in combination with retrospective economic analysis to estimate year-to-year variability in whole-farm profit. We also examine the effect of climate-induced production variability and price variability in isolation and when both are combined. Our results show that farm businesses that operate a mixture of crop and livestock enterprises, even if these are totally separated in time and space, have less variable farm returns compared to a specialised business focussing on only one enterprise.

Materials and Methods

The Agricultural Production Systems Simulator (APSIM; Keating et al., 2003) and GRAZPLAN (Donnelly et al., 1997) simulation models were used to simulate a crop rotation and self-replacing Merino sheep enterprise grazing annual grasses and subterranean clover pasture at Temora, NSW (34°25'S, 147°31'E, average annual rainfall 521 mm) from 1980 to 2010. All soils were assumed to be identical (a brown chromosol with plant-available water holding capacity of 125 mm to 1.2 m depth). Crop and livestock management practices in the simulations were generally similar to those used by Lilley et al. (2009), except that the crop and livestock enterprises were completely separated (including no grazing of stubbles). The cropping enterprise simulated was a wheat-canola-wheat-barley-wheat rotation, with equal areas of land allocated to each phase of the rotation every year. Simulations assumed fixed amounts of fertilizer N were applied to the crops via split applications at sowing and floral initiation of 20+20 kg N/ha for cereals, and 25+35 kg/ha for canola. In the livestock enterprise, ewes were grazed at a stocking rate of 5 ewes per pasture hectare and mated beginning on 1 February each year. A proportion of the flock was mated to Merino rams to produce replacement stock, and the remainder to Border Leicester rams. Lambs were sold during December and January once they reached 45 kg live weight. Wheat grain was fed to all stock when pasture availability and/or quality were insufficient to maintain stock body condition above threshold levels.

Indices of prices received by farmers for wheat, barley, canola, wool, lamb and mutton and prices paid for labour, fuel, chemicals and vaccines, and feedstuffs between 1981-82 and 2009-10 were deflated to 2009-10 price levels using the Australian Consumer Price Index (Australian Bureau of Agricultural and Resource Economics, 2011). 2010 price values were then scaled by the deflated indices to produce time courses of real farm prices and costs back to 1981. Commodity prices for 2010 were wheat $185/t, canola $400/t, barley $160/t, all wool (incl. fleece, bellies and skirtings) $6.37/kg greasy wool for ewes and $3.37/kg greasy wool for lambs, and slaughter lambs $3.20/kg live weight and sale ewes $2.60/kg live weight. 2010 costs for each enterprise were taken from gross margin tables for south-western NSW published by the NSW Department of Primary Industries; costs not corresponding to labour, fuel, chemicals and vaccines, or feedstuffs were left constant.

Gross margins per hectare for each enterprise and year were calculated from the simulated annual crop yields, livestock and wool sales, and the computed real prices and costs for that year. Average crop yields and livestock production were utilised to explore the effect of price variability in isolation and likewise, average commodity prices and costs were held constant to explore the effect of climate-induced production variability in isolation. Whole-farm annual gross margin returns for various proportions of each enterprise on the farm were then calculated by a simple weighted average, in line with the assumption of complete separation of enterprises.

Results and Discussion

We found no correlation between annual GM from crop and livestock enterprises when both variability in climate and price were considered ($r^2 = 0.003$), and when price effects only were considered ($r^2 = 0.02$) (Figure 1a and 1c). As might be expected there was a closer correlation ($r^2 = 0.12$) between annual GM driven by production outputs alone (Figure 1b), since climate conditions are likely to impact on both livestock and crop production similarly.

Because crop and livestock returns are not correlated, mixtures of these two enterprises buffer variability in whole-farm income. The coefficient of variation (i.e. standard deviation divided by mean) of farm gross margin was lowest at cropping proportions between 30-50% (Figure 1d). Intriguingly, this proportion is the same as the average cropping proportion found on farms across the mixed farming zone of Australia (ABARE 2011). Farm businesses containing only one enterprise had much higher variability in annual gross margin (Figure 1d). The cropping enterprise had a much higher estimated average GM ($245/ha) than the livestock enterprise ($176/ha) under the location, uniform soil and price levels used to simulate production in this study. A mixed enterprise was mid-way between the two. Hence, a trade-off between maximising farm returns and minimising variability in returns was clear.

Neither climate-induced production nor price variability considered independently was as large as when the two were combined. On farms dominated by one enterprise, production variability induced larger fluctuations in farm GM than price variability. Cropping-dominated enterprises experience greater variability in annual GM due to price fluctuations than livestock-dominated enterprises (Figure 1c and 1d).
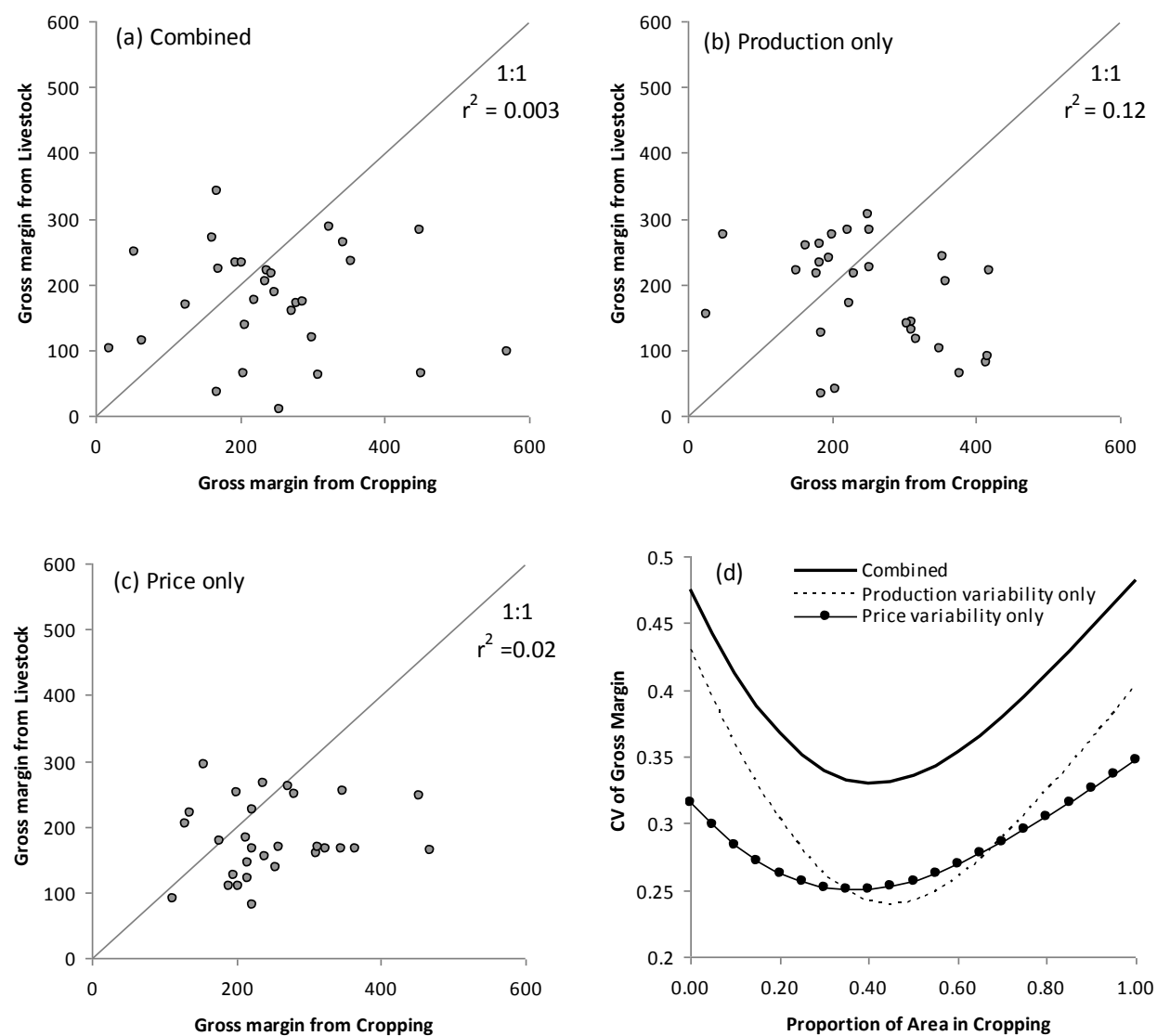
Figure 1. Model-derived variability in annual gross margin (GM) returns from livestock and cropping enterprises over 29 years at Temora, New South Wales are not correlated when both climate-induced production variability and price variability are considered (a) or examined independently (b and c). Hence, businesses operating a mixture of cropping and livestock enterprises have a lower coefficient of variation (CV, standard deviation divided by mean) in whole-farm gross margin (d) even when the enterprises are completely separated in space and time.

Overall, without considering many potential benefits that mixed farming can offer, such as reducing input costs, and more suitable allocation of land to enterprises, this analysis suggests that reducing fluctuations in returns is a compelling motivation for maintaining a mixture of enterprises. While this example is clearly limited in its climatic breadth, we expect that similar results would be obtained in other dryland farming regions where climate variability is high and where little market protection is provided.

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Future vegetable farming in Papua New Guinea – responding to resource constraints and population in a developing country: a case study

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Keywords: climate, soil resources, socio-economic

Introduction

The population of Papua New Guinea (PNG) is growing at approximately 2.1% per year (CIA 2009) increasing the demand for food. Internal migration to peri-urban areas, in particular, the national capital of Port Moresby (PoM), and increased demand from an expanding middle class and expatriate mining and gas industry professionals are compounding food demands. Highland regions e.g. Eastern Highlands Province (EHP) grow a range of temperate (or western) vegetables, but distance from PoM, and poor transport infrastructure and services constrain consistency of supply and quality. Seasonally dry coastal lowlands and cooler highlands (Sogeri Plateau, Goilala District), in Central Province (CP) nearer PoM could increase production and improve supply. In 2008, about 50,000 tonnes of PoM's 141,000 tonne/yr fresh produce came from peri-urban gardens (FPDA 2008) on on rocky, erodible, drought prone and difficult to irrigate sites (Bleeker 1975). Thus, sustainable production is unlikely. Vegetables, e.g. root and leafy crops, broccoli and zucchini are also produced in alluvial flood plains and on the Sogeri Plateau. Retail prices are unstable, and marketing is mostly through informal markets and direct supply to end users or supermarkets. Supply has not met PoM demand (FPDA 2008), so this study was initiated to identify constraints to and opportunities for expanding production to improve vegetable supplies to PoM markets.

Materials and Methods

Field visits to farms and research institutes, interviews of individual or groups of farmers, agricultural RDandE officers, commercial providers in EHP and CP, and market operators and retailers in PoM were undertaken during May and July 2009. The purpose was to determine farm characteristics and practices, land management and recent developments in vegetable production in EHP, and to identify opportunities for improvement in production and delivery to consumers in PoM. Data were analysed using rapid value chain analysis (Collins and Dunne 2008). Climatic limitations were assessed as in Hackett (1988) for PoM and Goroka (35 and 9 years of data), and from qualitative survey and literature sources. Land resources were assessed by soil profile assessment at key sites and GIS mapping (Doyle, et al. 2010).

Results and Discussion

Biophysical considerations in designing future farming systems

Climatic characteristics and limitations, principally temperature and water supply (Table 1) vary with altitude and topography. Rainfall also increases to the east in CP lowlands improving land use potential, though irrigation and enhanced drainage will be necessary during the dry and wet seasons respectively. High temperature is a major constraint to temperate vegetable production, though spring onions, white radish, bulb onions and shallot are grown near PoM. Soils and landscape are highly variable, and only those currently used or most suitable, and their physical and chemical limitations are included (Table 2). Potential for production in acidic and phosphorus fixing but otherwise physically fertile Red Ferrosols on flatter sites of the highly dissected Sogeri Plateau is moderate to high, but in the Goilala district, soils are poorer and have lower production potential (Hanson, et al., 2001). Alluvial soils in the lowlands have good structure and moderate natural fertility, but both would be expected to both physically and chemically decline once cultivated.

Table 1. Climatic characteristics and main climatic constraints in Central and Eastern Highlands Provinces

Location and altitude	Rainfall (mm)	Wet season	Mean max temp (^{o}C)	Mean min temp (^{o}C)	Main climatic constraints
Port Moresby 44m (Weather station)	899	Dec-Apr (61%)	31.4-32.5	22.4-23.7	High temperature (for C3 plants)* Inundation (Dec-April) Water stress* (May-Nov)
Goroka (EHP) 1587m (Weather station)	1722	Sept-May	25.5-27.5	14.9-16.2	Mild water stress* (June-Aug)
Goilala District (CP) ~1000m (at Tapini AP)	2200 - 3200	~Sept - May	Highly variable, related to altitude		Water stress* (~June-Aug) Low temperature, occasional frost Cloud cover
Sogeri Plateau 500-1000m	2200 - 3500	Few data, expect temperatures to be between Port Moresby and Goroka temperatures, with only minor climatic limitations			

Sources: Hanson et al (2001), PNG National Weather Service (2009), Goilala District (2011)

* Assessed as in Hackett (1988)

Table2. Soil characteristics and constraints in Eastern Highlands and Central Provinces

District	Principal soils	Physical limitations	Fertility limitations
EHP	Andisol	Slope, erosion risk	Acid infertility, P fixation, low K and B, high C:N ratio, some areas low Zn, Mo, Cu, Mn
CP Lowlands	Alluvial	Inundation Impeded drainage	Fertility decline leading to multiple deficiencies Organic matter loss, structural decline
	Skeletal soils	Slope, erosion risk, low water holding capacity	Multiple deficiencies
Goilala	Ferrosols, Andisols	Slope, erosion risk	Multiple deficiencies, P-fixation
Sogeri	Ferrosols	Slope, erosion risk	Acid infertility, multiple deficiencies, P-fixation

Sources: Birch et al 2009, Hanson et al 2001, Radcliffe and Kanua 1998

Socio-economic considerations in designing future farming systems

Shifting cultivation, where an area is cultivated for several years and then allowed to revert to natural vegetation for an extended period to restore soil fertility, is widely practised. However, as the population and food demands increase, the now shorter and shorter rotations increase the risk of land degradation through erosion and nutrient depletion. Individual farmers or groups of farmers (e.g. cooperatives in the Goroka district (EHP) and Rigo and Goilala (CP)) select crops to maximise returns and meet socio-cultural norms. Limited availability and expense of inputs such as suitable cultivars, fertilisers, agricultural chemicals and portable irrigation infrastructure can compromise production. Transport and marketing infrastructure and market performance (Bonney, et al., these proceedings) combined with size and scale of enterprises, seasonality of production, insecurity of land tenure and land management all limit capacity to improve overall system performance.

What of the future farming systems?

Future farming systems in PNG will be substantially determined by topographic, climatic and soil features and socio-cultural conditions. Land management is likely to range from low-input practices ranging from long bush fallows and burning, to high input techniques such as legume rotations, composting, mounding, drainage, soil retention barriers, mechanised tillage and irrigation. Land tenure, predominantly 'customary' with no individual ownership, may impede development of larger enterprises requiring substantial infrastructure. Aggregation of production from small holdings, group purchase of equipment and inputs, and cooperative arrangements among kinship groups will achieve some benefits of economies of scale through larger scale production and improved marketing. This is already occurring e.g. in EHP (Birch, et al 2009). Challenges in agronomic practices will be enhanced retention of organic matter (Sparrow et al 2011), optimisation of use of local resources and strategic use of purchased inputs which are likely to remain expensive and not readily available. Nitrogen fertilisers and N from legumes are already being used in higher input production systems, but are not to any extent in the still dominant subsistence farming with shifting cultivation. Adequacy of future production will depend on utilising a range of agro-ecological environments appropriate cultivars of vegetable crops and planned production schedules to ensure continuity of supply and income through the year.

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Using value chain systems modelling to develop more sustainable cool temperate vegetable marketing systems in a transitional economy: a case study in PNG

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Introduction

Agriculture is important to Papua New Guinea (PNG) accounting for 21 per cent of GDP and 17 per cent of total exports (Coppel, 2004). Production is predominantly carried out by smallholders working 'customary land' using subsistence agriculture methods. Family subsistence needs are still largely met by the household's production on its own land and so they are not compelled to rely on regular sales to obtain daily necessities (Benediktsson, 1998, Worinu, 2007). Supply chains generally operate with spot market forms of governance (Gereffi and Frederick, 2009) characterised by short term, opportunistic, sometimes exploitative and even violent behaviours. Thus, there are few incentives for smallholders to improve consistency of supply or the quality of their vegetables to markets outside their local area. This perpetuates poverty and disempowerment of smallholders (Vermeulen and Cotula, 2010) and, if they aspire to change their situation, the cost of accessing education and health services drives significant internal migration to major urban centres (Bourke and Harwood, 2009). In particular, this has caused social and environmental problems in the peri-urban areas around the capital, Port Moresby. The PNG Fresh Produce Development Agency (FPDA) conducted the only major study of fresh vegetable supply to Port Moresby and estimated that there is a shortfall in vegetable production that could be as high as 80,000 tonnes per annum (Liripu, 2008). The recent resources boom has exacerbated this shortfall and imports increasingly substitute for local production reducing the benefit of the boom to PNG. Central Province has the physical and climatic potential to meet much of Port Moresby's demand for food however, finding sustainable models of agrifood production compatible with the complex socio-economic and infra-structural constraints on commercial-scale production will be necessary if this is to occur.

Materials and Methods

Marketing supply chains are frequently regarded as 'systems' (Bäckstrand, 2007) whilst Knoppen and Christiaanse (2007) argue that multidisciplinary approaches are necessary to provide improved explanations for the dynamic, complex interactions involved in the appropriation, coordination and adaptation processes in supply chain operation. This has prompted many international development agencies to use systems approaches such as Participatory Action Research (PAR) (Reason and Bradbury, 2001) to overcome the 'wicked problems' of agrifood production in transitional economies. Hence, this project adopted a multidisciplinary approach to the development of efficient and effective value chains in Central Province, PNG based on sustainable, low input horticultural production and value chain management principles to meet the growing demand for fresh vegetables in Port Moresby. The research methods were based on a participatory action learning cycle 'with' rather than 'on' the participant smallholders (Heron and Reason, 2001). An initial 'scoping study' used Rapid Value Chain Analysis to identify the focal vegetables, participating communities and the priority constraints on production and marketing. Then, following Bonney et al (2007) data were collected on the material flows, communication flows and relationships from observation ('walking the chain' to map the material flows) , semi-structured and group interviews using convergent/divergent interview techniques with a wide range of chain participants. As it was not possible for consumer value attributes of the focal vegetables to be investigated directly with consumers, retail and institutional buyers were interviewed. Data were analysed using qualitative content and thematic analysis, aided by the computer application NVivo (Version 8) to identify the themes. This formed the basis for the development of current and future state models and identification of the potential 'chain improvements' which were validated with chain participants.

Results and Discussion

The biophysical constraints to developing the vegetable production system have been dealt with by Birch et al (2011), in these proceedings, however, it is sufficient to note that they are important contributors to the highly variable quality, quantity and consistency of vegetable produce being 'pushed' into the marketing system. Therefore, this paper will focus on addressing the marketing system constraints identified in the current state model.

The types of markets
The main market outlets for fresh produce are the informal roadside and local markets (Type 1), distant informal markets in major urban centres (Type 2), community entrepreneurs who act as 'aggregators" (Type 3), commercial wholesalers (Type 4), the formal markets (Type 5) such as those run by local government and direct to the institutional markets such as hospitals, hotels and mines (Type 6) (Birch et al., 2009).

Poor infrastructure for marketing
The road, telecommunications and finance systems in regional PNG present major constraints on the vegetable marketing system. The country does not have a national, inter-connected road system and non-arterial roads are very poorly maintained due to the terrain and climate. Whilst cell phone telecommunications are improving rapidly, the lack of internet services outside the major urban centres and patchy cell phone reception mean that only the most basic marketing information is possible, even if it were available. Finally, the banking system does not operate outside of the major towns and, with the prevailing lack of law and order, the use of cash is not advisable.

Lack of economies of scale and coordination in marketing
Smallholders generally transport several fifty kilogram bags of vegetables to markets on public motor vehicles and then hawk their produce around the various outlets until a satisfactory price is obtained. Prices received are highly variable partly due to the variability of supply and demand but also as a result of the mixed passenger freight transport causing some post-harvest deterioration in already highly variable quality of produce. In addition, costs are higher than a specialised freight service, considerable time is wasted and frequent harassment and intimidation is experienced.

Poor chain relationships

In the current system, the relationships involved are transactional, short-term with price-based incentives and no trust, commitment or coordination of supply. All parties regularly engage in opportunistic, exploitative behaviour that invites reciprocal behaviour thus reinforcing the behaviour. In particular, women are subjected to frequent harassment and the outcome is that smallholders often sell their produce to the first buyer to avoid further conflict.

A preferred production and marketing model

The preferred, future state model is based on an improved low input, more environmentally sustainable production system producing a more consistent flow of higher quality vegetables into Port Moresby (Birch et al (2011) these proceedings). The model being implemented is based on contract between a Type 4 or 6 market outlet and a smallholder cooperative which allows smallholder farmers to drop in and out of production as motivation or social obligations dictate whilst still maintaining the overall contracted output. Vegetables will be brought from remote farms and villages in the area to designated pickup points where a small, all-terrain vehicle with refrigerated box will regularly collect produce. The transaction will be on the basis of weight and grading. The produce will be pre-graded by the cooperative using a simple visual grading system, weighed and the grading checked and receipted into the freight contractor's vehicle. The produce will then be transported out to a major arterial road and loaded onto a larger refrigerated vehicle for transport to a single contracting market outlet. This specialist freight service will be efficient and maintain the cool chain and, where possible, 'front-load' trade goods for the villagers thus avoiding the need for them to frequently travel to Port Moresby. The use of a trading account will enable the trade goods to be paid for by the proceeds of vegetable sales thus avoiding the need for cash payments. In some instances, cooperatives may establish their own 'trading stores' or identify a member of their cooperative willing to start one as their own business. This approach will be particularly helpful in remote, isolated areas where travel to the capital is difficult and infrequent.

This model is dependent on all the chain participants acting in a trustworthy manner with an intent to develop long term partnerships and collaboratively innovate or 'co-innovate' to solve the chain's problems in efficiently and effectively addressing consumer and customer needs in the chain. This will require understanding the informational and skill needs of the participants and the delivery of targeted, just-in-time training. A particular focus will be the training needed to improve the productivity of women in vegetable marketing and encouraging young people to see a future in rural-based vegetable production businesses.

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Capacity for broadacre mixed farmers to adapt to climate change in Queensland

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Introduction

The ability of farmers to effectively adapt to climate change depends not only on the degree of exposure to climatic change but more importantly the amount of knowledge, support and opportunities available to them in order to respond to that change. Adaptation options operate at the farm scale in addition to industry level approaches (Rodriguez et al. 2011). Changes to enterprise mix (e.g. proportion of crops to pastures) are an example of one farm-level adaptation option. Frameworks to assess the adaptive capacity of farmers have been developed to provide information on the potential of farm enterprises to adjust their whole farming enterprise under future climate scenarios across regions and industries. The rural livelihoods framework (Ellis 2000) provides one method of assessing major influences on farmers' vulnerability based on the assessment of five capitals: human, social, natural, physical, and financial capitals. This holistic approach is well suited to allow farmers to identify and prioritise adaptation options and barriers for any given change scenario (Brown et al. 2010). While climate change adaptation options for mixed farmers are well documented (Howden et al. 2010 and Stokes et al. 2010), the willingness and ability of farmers to adopt these options of farmers varies regionally.

Research to understand and measure the adaptive capacity of Australian farmers has been undertaken as part of a national study to deliver projections of the impacts of climate change on the productivity of crops and pastures across Australia. The objective of this research is to identify indicators that describe constraining and enabling factors affecting farmers' capacity to adapt under projected climate change and combine this information with biophysical impact data to determine the vulnerability of Australian farming systems to climate change. A total of 12 adaptive capacity workshops were held across the country from July 2010 to July 2011. Farmers were asked to identify and self-assess their adaptive capacity. The results from these farmer self-assessments will be compared to indices developed from ABS and ABARE data at a national level. This paper focuses on the results from two workshops from mixed-farming regions in south-east Queensland i.e. Goondiwindi and Roma, Queensland Australia.

Methods

At all 12 locations participants were chosen by local co-ordinators to reflect the range of farming enterprises within the region. Each workshop ran for 3-4 hours, with 5-16 participants in attendance. Most attendees had a farming background, though rural financial planners, agribusiness and regional Natural Resource Management (NRM) extension staff also participated. The local catchment co-ordinator selected participants (five in Goondiwindi, and nine in Roma). These two regions are characterised by medium to large broad acre mixed grain and grazing farms operating in one of the most variable climatic regions in Australia, and where farming is considered to be under threat from expanding coal and coal-seam gas mining developments.

A brief introduction was given on projected climate impacts for the region to set the context for the workshop. Participants were then given an overview of the workshop process including definitions of the five capitals. They were then invited to identify key indicators for each of Human, Social, Natural, Physical and Financial capitals that enabled or constrained their ability to manage their mixed farming enterprises under climate change for their local area. Participants rated each indicator on a scale of 0 to 5 according to the degree to which the indicator was likely to be supporting climate change adaptation in the future (Brown et al. 2010). If indicators were severely constraining (<2) then participants were asked to think of actions that would help to address these.

Results and Discussion

Overall, the endowment of capitals for mixed farmers around Goondiwindi was variable, with relatively high levels of Natural and Physical capitals, moderate levels of Social capital and low levels of Human and Financial capitals (Figure 1). By comparison, the endowment of capitals for mixed farmers around Roma was low to moderate, with a relatively high level of social capital. Human, Natural and Financial capitals were moderate, neither enabling nor constraining adaptation to climate change. Physical capital was low, potentially constraining adaptation in the future. Significant commonality existed between the two regions in terms of the identification of common Natural, Physical and Financial issues that would either enable or constrain future adaptation (Table 1)

Scores for indicators were based on existing opportunities within regions. Common human and social capital themes included the age of farmers, off-farm labour availability, the skill base of farmers including formal and informal education, access to extension staff, and activity in community groups such as sporting clubs and Landcare. A vibrant, attractive regional centre was seen to be central to the long-term viability of the region providing health and education services and opportunities for off-farm income.

- Human capital was perceived to be particularly constraining in both regions: age and access to labour were a concern in Goondiwindi while access to extension was constraining in Roma. These indicators were seen to limit farmers' abilities to adopt and or trial new management options.
- Natural capital scored relatively highly and included indicators that valued natural resources, particularly land capability and water access. Landscape amenity was important for both regions as participants were aware of the need to have an attractive physical environment, including access to goods and services, to attract and retain people within the region.
- The availability and condition of infrastructure including communications, roads and rail, and processing and storage facilities were common indicators between the regions. External pressures in the form of land values and commodity prices/input costs were highlighted as being important indicators of financial capital.

Capital	Indicator	Goondiwindi	Roma
Human	Mentoring for extension staff		0
	Age	1	3
	Access to labour	1	
	Access to management advice		1
	Attitude		2
	Family priorities/stage of life	2	
	Formal education		3
	Employment opportunities		3.5
	Confidence in farming	3.5	
Social	Access to health services		1
	Corporate farms	1.5	
	Extension and support services	2	
	Transient workforce	2	
	Isolation	2.5	
	Family structure/stage of life	2.5	
	Club/association membership		2.5
	Changes to community structure		3.5
	Regional climate forecasting		4
	Landcare		4
Natural	Weed and pest control		1.5
	State of natural resources	2.5	
	Land capability	3	2.5
	Water availability and quality	3	2.5
	Landscape amenity	3.5	3
	Ecosystem services	4	
Physical	Waste management	0.5	
	Marketing/processing/storage infrastructure	2	1
	Energy infrastructure		2
	Demonstration sites		2.5
	Road/rail infrastructure	2.5	1
	Communication infrastructure	3	2
	Genetic resources	4	
	Service infrastructure in rural centres	4	
	Water infrastructure	4	2
Financial	Value of product	0.5	
	Willingness to invest in farm	0.5	
	Input costs	1	
	Return on investment	1	
	Land prices/value	1	1
	Cash reserves		1.5
	Financial instruments		1.5
	Managing risk	2	
	Equipment and technology costs	2	
	Cost of livestock feeding during drought	3	
	Diversify income sources		3.5
	Off-farm income	3.5	4.5
	Demand for land		4

Table 1. List of indicators that mixed farmers used to self-assess their capacity to adapt to climate change from Goondiwindi and Roma, Queensland. Each indicator was scored from 0-5, with 0 being constraining and 5 being enabling adaptation for climate change.
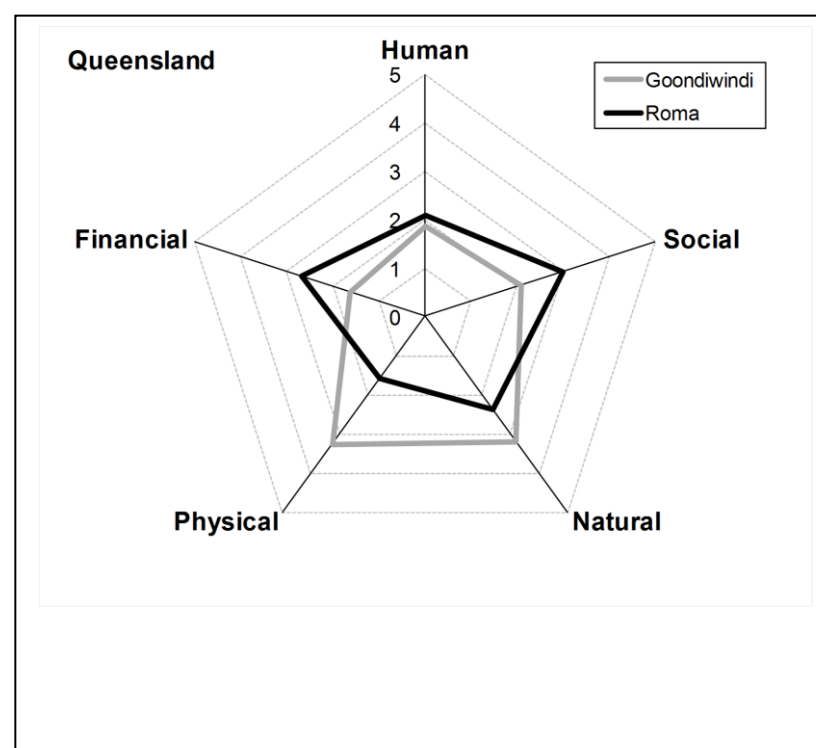
- The development of mining activities around Roma provided many opportunities in the form of off-farm income and access to regional services but also affected access to farm specific services, particularly relating to ready access to mechanics and skilled labour. In Goondiwindi farming is still the primary occupation but use of off-farm income was estimated to contribute to household incomes for more than 60% of farms in the region.

Priority actions to alleviate constraining indicators in both regions included: attracting people to and retaining people within the region; training and mentoring extension staff; provision of finance and business training to young farmers to allow them to establish in the region, and train and retain skilled labour. Increasing farm business management skills was seen as a priority for all farmers, including diversifying income streams both on and off farm. Addressing value chains was seen as a way to increase the value of produce, while upkeep of road/rail/storage and processing facilities is necessary to access markets. The need to attract health specialists to rural areas and to increase the use of technology, particularly video conferencing was seen to increase the quality of life, and time available in the community for those who were travelling extended distances to seek medical assistance.

Biophysical modelling of changes to enterprise mix under climate change will inform farmers of the potential to alter the proportion and varieties of crops and pastures grown on farm (Rodriguez et al. 2011). However, farmers will be reluctant or unable to take up future opportunities if regional centres are in decline, if processing facilities are not accessible and if up-skilling of farmers and support staff, including extension personnel, is not undertaken.

Responses at the workshops were framed by the experiences of recent floods, affecting the condition of road networks, drought, affecting on-farm viability and reliance on off-farm income, and the price received for produce compared to the cost of inputs. The rural livelihoods approach complements the biophysical modelling undertaken in each region and has highlighted potential gaps in policy that may combine to constrain the production of food and fibre under climate change.

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Performance of an efficient dairy farm system using combined environmental impact mitigation strategies in a variable climate

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Introduction

New Zealand dairy farms are coming under increasing pressure to reduce nitrate leaching and greenhouse gas (GHG) emissions. Farm systems will need to be implemented that achieve these goals whilst maintaining or increasing operating profit per hectare in order to remain competitive. A combination of technologies and system changes are needed to achieve the best overall economic and environmental outcomes. Beukes et al. (2011) showed that increasing milk production whilst simultaneously reducing GHG emissions was best achieved by implementing a combination of 5 on-farm mitigations. These included 1) lower cow replacement rates, 2) increased genetic merit cows, 3) use of a stand-off pad, 4) using low protein feeds, and 5) using less nitrogen (N) fertiliser and applying a nitrification inhibitor. Most of these strategies can also contribute to less urinary N deposition on pasture, which is the greatest contributor to nitrate leaching into groundwater. However, in New Zealand's pasture-based dairying systems, climate has a major effect on milk production and the environmental impacts of dairying. We modelled an average dairy farm in the Waikato region of New Zealand and analysed the impacts of implementing the strategies of Beukes et al. (2011) on pasture and milk production, profitability, GHG emissions and nitrate leaching under 3 climate scenarios.

Materials and Methods

The farm system designs and impacts of individual mitigation strategies are detailed in Beukes et al. (2011). We used the baseline farm and a modification of system ES2 (efficient farm) in the Waikato region. Briefly, the baseline farm describes an average pasture-based farm with less than 10% of feed imported, stocked at 3.0 cows/ha, with an annual cow replacement rate of 23% and average cow genetic merit (BW 60). Nitrogen fertiliser was applied at 180 kg N/ha/year to 80% of the farm area, effluent from the farm dairy was applied to the remaining 20% of the farm. A support block (1/5th the size of the milking platform) was included in each system, for grazing young cattle and making pasture silage. Replacement animals were sent to the support area after weaning and returned to the milking platform as rising 2-year old cows before calving.

The efficient system was changed from the baseline farm as follows: 1) Replacement rates decreased to 17%, with better reproductive performance (11 cf. 13% empty rate); 2) cow genetic merit increased (BW 120), producing heavier cows (483 cf. 469 kg) and allowing for a lower stocking rate (2.6 cows/ha) and longer lactation (274 cf. 223 mean days in milk); 3) cows stood off pasture on a stand-off pad for 12 hours per day in late lactation (March/April), supplemented with up to 2 kg/cow/day pasture silage on pasture, with effluent from the dairy and loafing pad spread over 24% of the farm; 4) maize grain bought in and fed ($\leq$ 4 kg DM/cow/day) in mid- to late lactation during pasture deficits; 5) decreased N fertiliser use (50 kg N/ha/year on all pasture excluding the effluent area) and nitrification inhibitor application (according to manufacturers' recommendations) to pasture on the milking platform in autumn and winter.

These systems were modelled using a whole farm model (WFM; Beukes et al. 2008) to generate pasture and milk production (reported in milksolids (MS); fat + protein), operating profit, methane emissions and urinary N excretion onto pasture. Pasture growth was generated in WFM using climate data from the Ruakura Meteorological Station for the years 2003/04, 2004/05 and 2007/08 (June to June), with total annual rainfall of 1197 mm (wet), 1056 mm (average) and 945 (dry) mm, respectively. Operating profit was calculated using economic inputs from the 2008/09 DairyNZ Economic Survey and a milk price of $6.10/kg MS. Total greenhouse gas emissions (methane plus nitrous oxide) were estimated with Overseer® (Wheeler et al. 2008) using production and management from WFM and annual rainfall data. Urinary N excretion and management from the WFM and daily climate data were used in the APSIM modelling framework (Keating et al. 2003), to generate N leaching, with urine simulated in patches (Vogeler et al. 2010). APSIM simulations were run separately for the dairy milking platform, support grazing and effluent areas, and then consolidated to calculate N leached for the entire farm system.

Results and Discussion

Climate has a large impact on pasture production, and hence milk production and dairy farm profitability in New Zealand. Annual pasture production varied by 5 t DM/ha (Table 1) between the wet and dry year for these baseline and efficient systems. Milk production was consistently greater for the efficient system than the baseline farm (Table 1), with the increase in MS/ha ranging from 8% in the wet, to 17% in the dry year. The ability to feed grain during feed deficits resulted in less annual variation in milk production for the efficient system.

The technologies implemented on the efficient farm changed farm expenses and income, with the profitability of the efficient farm (Table 1) 18 to 80% greater than that of the baseline farm. We used one costing model across all years to show the effects of climate variability on profitability. However, the variability between years in on-farm expenses and milk price should be considered when assessing these systems, as should impacts on labour requirements.

Methane is the primary contributor of GHG from New Zealand agriculture and is driven largely by animal numbers and feed intake. Hence, within each system, as milk production increased, so did methane emissions (Table 1). However, average emissions were considerably lower for the efficient system despite having higher milk production than the baseline farm. Total GHG emissions (Table 1) from the efficient farm system were 23 to 27 % lower than that from the baseline farm, consistently meeting the national target of a 20% reduction.

The efficient farm system reduced nitrate leaching by 30 to 50%. There was a 2 to 3-fold difference in leaching between years within systems. Urinary N deposition was highest in 2003/04, but total N leached from these patches was the lowest (Table 1). Leaching results from interactions between urinary N deposition, pasture N uptake and soil drainage. For these simulations, leaching (Table 1) was highest

for urine deposited in 2007/08, despite this year having the lowest annual rainfall and urinary N deposition. This may be because of the high winter rainfall and low annual pasture production, and the effects of climatic conditions in the year after urine was deposited.

This work has shown the potential for greatly reducing the environmental impact of dairy farming in New Zealand whilst increasing milk production and profit by combining a range of technologies and farm system changes. These goals were consistently achieved over a range of climatic conditions, but the degree of improvement varied with climate (Table 1). For our efficient system, the greatest impact on profit was in years of low pasture growth, and the greatest impact on nitrate leaching was in years of high pasture growth. Climate effects on GHG emissions were less pronounced. It is recognised that New Zealand dairy farms are currently managed under a diverse range of systems and climates. Therefore, the feasibility of a range of combined strategies should be tested on farm under varying conditions.

Table 1. Production, profitability, nitrogen (N) leaching and greenhouse gas (GHG) emissions from a baseline (Base) and efficient (Effic.) Waikato dairy farm modelled over 3 contrasting climatic years. Pasture and milk production are from the milking platform only. GHG emissions include the milking, support and maize growing areas. Leaching includes milking and support areas, and maize growing area where specified.

	2003/04 (wet)		2004/05 (average)		2007/08 (dry)	
	Base	Effic.	Base	Effic.	Base	Effic.
PASTURE PRODUCTION						
t DM/ha/year	17.5	16.7	15.1	14.3	12.1	11.8
GRAIN FED						
kg DM/cow/year	0	45	0	213	0	386
MILK PRODUCTION						
kg MS/cow/year	386	470	368	460	342	452
kg MS/ha/year	1095	1185	1044	1160	971	1140
N LEACHING						
kg N/ha/year (+ maize area)	38	19	56	28	79	60
kg N/ha/year	38	19	56	30	79	55
kg N/kg MS	0.03	0.02	0.05	0.03	0.08	0.05
METHANE EMISSIONS						
kg CO_2 e/ha/year	7,101	6,037	6,769	5,604	6,381	5,198
GHG EMISSIONS						
kg CO_2 e/ha/year	11,364	8,784	11,172	8,542	11,051	8,117
kg CO_2 equiv./kg MS	12.4	9.0	12.8	9.3	13.7	9.3
OPERATING PROFIT						
$/ha/year	3510	4129	2441	3216	1148	2072

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Economics of growing mungbean after rice in the rainfed lowlands of Cambodia

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Introduction

About 84% of the rice area in Cambodia is classed as rainfed lowlands, supporting a single rice crop annually (Ouk et al. 2001). A wet-dry climate (with erratic rainfall in the wet season), low soil fertility, and insect pests limit rice production to subsistence levels, with a high risk of falling below subsistence in unfavourable seasons. Some farmers have incorporated a second rice crop in the early wet season, which can increase farm incomes by 25-40%, given access to water for supplementary irrigation (Chea et al. 2004). To further increase production in these conditions, an ACIAR project has introduced several non-rice crops following the main rice harvest, using different methods of supplementary irrigation – manual (with a bucket), pumping, and gravity-fed (from a dam). Mungbean was considered to have potential for efficient water use and high returns. This paper reports an economic analysis of mungbean cultivation based on field experiments.

Materials and Methods

The analysis was based on data from two experiments in 2009-10 and 2010-11 where mungbean response to type and level of irrigation was tested on paddy fields with typically sandy soils of low fertility at CARDI near Phnom Penh ($11^o28'$ N; 104° 48' E; 17m ASL) (Eastick et al. 2010). Mungbean was cultivated under flatbed conditions from January to April, following a single wet season rice crop. Residual soil moisture was available for establishment, but supplementary irrigation was required. The main economic measure used was the net cash return per unit of family labour (NCRL). Rainfed paddy fields have little alternative use in the dry season and labour is also under-employed. The mungbean crop requires an outlay of cash for inputs and the expenditure of family labour. The farmer would not be concerned with the return to land but would be hoping for a positive NCRL that is higher than any alternative activity. The NCRL was calculated by subtracting cash expenses from gross income and dividing by the number of days of family labour. Gross income was calculated by multiplying measured yield by the current farm-gate price. Cash expenses were based on current prices for seed, fertilizers, and fuel. Family labour was estimated for land preparation, planting, fertilising, applying cow manure, weeding, harvesting, and irrigating. Labour estimates were based on group interviews with farmers at field days, not the labour used in the experiment. NCRL was estimated for two irrigation levels and the three irrigation methods. The experiments used a wide range of irrigation levels and identified between 0.9 and 1.3 ML/ha as agronomically viable, corresponding to yields of 477 kg/ha and 689 kg/ha, respectively. These two levels were used in the analysis. For manual irrigation, the main input was labour, measured as days/ha. In the experiments, labourers were paid a daily wage to water the crop with a 12 L bucket. One labourer carried up to 96 buckets per 5-h day (1,152 L or 0.11 mm). For farm conditions, a 24 L container was assumed and a 7-h day, making 192 buckets (4,608 L or 0.46 mm) per day. For the pumping method, the main cost was the outlay for fuel. Pump capacity was estimated to be 1.5 h/L of fuel. For gravity-fed irrigation, labour was required to control the inflow of water.

Results

Table 1 shows the cash expenses and labour inputs assumed in the economic analysis. These are expressed on a per-ha basis though in practice labour and water constraints limit cultivation to around 0.2 ha. The cash expenses for seed and fertiliser were based on experimental rates and market prices (though fertiliser prices have fluctuated widely). Fuel was costed at USD 1.00/L. Pumping needed 50 and 72 h for the two irrigation levels, costing around USD 33 and 48 in fuel. The labour inputs varied with irrigation method and level. The labour input for land preparation only includes human labour; the opportunity cost of using family-owned draught animals is difficult to estimate but can be assumed to be negligible in the dry season. Likewise, the opportunity cost of cow manure was assumed to be negligible as it is not commonly traded, so only the labour required to cart the manure from the farm-yard to the field was included. Three rounds of hand-weeding were undertaken. With manual irrigation, the lower level of irrigation required around 37,500 buckets or 195 days/ha and the higher level required 54,200 buckets or 282 days/ha. The labour for controlling gravity-fed irrigation varied with the level of irrigation. The labour for harvesting varied from 30 days/ha for the low-irrigation/low-yield scenario to 43 days/ha for the high-irrigation/high-yield scenario, based on 16 kg harvested per day. Table 2 shows the computation of NCRL. Given a farm-gate price of USD 1.50/kg of grain, gross income varied from USD 716/ha to USD 1,034/ha for the two irrigation levels. Subtracting cash expenses, net cash returns/ha were highest for manual irrigation at the higher irrigation level (USD 854/ha). However, the labour requirement was very high for this method, so when net returns/ha were divided by labour input/ha, the net returns per day (NCRL) favoured the pumping and gravity systems, which returned between USD 3.70/day and USD 5.40/day for the two irrigation levels, more than twice the NCRL for manual irrigation and well above the rural wage of USD 2.00/day.

Discussion

Mungbean production appears a profitable use of family-owned resources of land and labour that are otherwise underutilised during the dry season. This depends on access to supplementary irrigation at between 0.9 and 1.3 ML/ha and a cost-effective method of irrigation. Hand watering is not attractive but pump and gravity irrigation are promising. Rural electrification would substantially reduce the costs of pumping. The upper yield obtained in the experiments is higher than the yield of around 610 kg/ha obtained in upland areas in the wet season, which is widely recognised as the most favourable environment for legume crops (Chea et al, 2009). This could be due to the rates of fertiliser used in the experiments as well as higher insolation in the dry season. Actual yields on lowland farms in the dry season are lower than the experimental yields; access to working capital for fertiliser could be the limiting factor. However, the market price for mungbean grown after rice in the lowlands reflects that this is the off-season for upland production. Hence the price is relatively favourable and appears to be trending upwards. At USD 2/kg the NCRL at the high level of irrigation would increase to USD 2.8/day for manual irrigation and USD 7-8/day for the other two methods. Labour input per ha is high, but with only a portion of the rice-field cultivated, the total labour requirement would be feasible, while the addition to family income would be attractive. As farm activities are limited in the dry season, this provides an opportunity to utilise family labour on-farm rather than migrate in search of employment.

Table 1 Gross income, expenses and labour inputs for mungbean cultivation in rainfed lowland paddy field

Item	Unit	Quantity	Unit price (USD)	Total (USD/ha)
Output/income				
- 1.3 ML	kg/ha	689	1.50	1,034
- 0.9 ML	kg/ha	477	1.50	706
Cash expenditure				
Seed	kg/ha	20	1.50	30
DAP	kg/ha	195	0.54	105
KCl	kg/ha	50	0.88	44
Fuel for pumping (P):				
- 1.3 ML	litre/ha	48	1.0	48
- 0.9 ML	litre/ha	33	1.0	33
Family labour				
Ploughing (2 times)	labour-day/ha	12	2.0	24
Harrowing	labour-day/ha	2	2.0	4
Planting	labour-day/ha	42	2.0	84
Manuring	labour-day/ha	5	2.0	10
Weeding	labour-day/ha	45	2.0	90
Manual irrigation (M):				
- 1.3 ML	labour-day/ha	282	2.0	564
- 0.9 ML	labour-day/ha	195	2.0	390
Gravity irrigation (G):				
- 1.3 ML	labour-day/ha	7	2.0	14
- 0.9 ML	labour-day/ha	4	2.0	8
Harvesting:				
- 1.3 ML	labour-day/ha	43	2.0	86
- 0.9 ML	labour-day/ha	30	2.0	60

Table 2: Returns to mungbean production by irrigation level and method

Irrigation level (ML/ha)	Gross income (USD/ha)	Cash costs (USD/ha)		Net cash returns (USD/ha)		Labour input (days/ha)			Net cash return to labour (NCRL) (USD/day)		
		M/G	P	M/G	P	M	P	G	M	P	G
1.3	1,034	179	227	854	806	431	149	159	2.0	5.4	5.4
0.9	716	179	213	536	503	331	136	141	1.6	3.7	3.8

M = manual irrigation; P = pump irrigation; G = gravity-fed irrigation.
Article I.

Conclusion

There is reasonable economic potential for mungbean cultivation following rice in the rainfed lowlands of Cambodia, giving a positive return to otherwise underemployed family resources of land and labour. Supplementary irrigation of around 1 ML/ha is needed to ensure yields of about 0.5-0.7 t/ha. Manual irrigation gives low returns to labour but pumping or gravity methods give a reasonable return, more than double the rural wage. Returns may improve with increasing demand for mungbean, improved access to fertiliser and credit, and reduced costs of pumping due to electrification.

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Modelling adaptation options for a Western Queensland mixed grain and graze farm – evaluating enterprise options under climate change

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Keywords: whole farm systems modelling, APSIM, climate change

Introduction

Managing climate variability is intrinsic to farming in Australia and effective management of variability will be fundamental to managing climate change (Howden 2003). Australian farmers are constantly adapting to climate variations and change in both tactical and strategic ways e.g. earlier planting in central Queensland with reduced frost risk (Meinke et al. 2004) and the shift from sheep to cattle grazing in south Queensland in the late 1800's (McKeon et al. 1993).

Farms around Roma in Western Queensland are at the margins of suitability for cropping and usually allocate more favourable soils to grain cropping with the remainder of the farm occupied by native or improved grass pastures. Forage crops are also grown. Thus, there are several scenarios that are relevant to farmers in this region that can be addressed by simulation: i) what is a profitable allocation of the farm area to crop and pasture? ii) what is the value of integrating an annual legume? iii) how do the various options perform under climate change? In this study, a case-study farm was modelled using APSFarm (Rodriguez et al. 2011), profit and risk outcomes were quantified and advantageous options indentified.

Materials and Methods

The case study farm was 4000ha in size situated north-east of Roma, Queensland (-26.57°S, 148.79°E). Approximately 40% (1100ha) of the farm was utilised for grain cropping. The farm carries between 1100 to 1500 cattle. The crop rotation was four wheat crops followed by a chickpea crop. Wheat was 'sown' 9 May to 1 June and chickpea, 1 May to 7 June. Annually, 400ha of forage oats and 100ha of forage sorghum were grown. Buffel (*Cenchrus ciliaris*) was the grass pasture.

The livestock enterprise is a cattle 'backgrounding' activity where payment is received on a weight gain basis. Steers of approximately 250kg weight are purchased, fattened then sold when they reach 450kg. The farmer received $0.85/kg net of costs. The cattle are initially placed onto the buffel pasture, and then moved to the forages when sufficient biomass is available, in the order of: oats, lablab, forage sorghum. Stocking rates and liveweight gains for each pasture were coded into the APSFarm program using data from Day et al. 1997. In drought, simulation rules remove cattle from the pasture paddocks if the biomass reaches a critical lower limit. If no other pasture is available the cattle are sold.

Four changes to the enterprise structure were tested under current climate and projected climate A1FI, MIROC-H at 2030 and 2050 (http://www.ccsr.u-tokyo.ac.jp/kyosei/hasumi/MIROC/tech-repo.pdf). i) 500ha extra cropping obtained from a reduction in the area of buffel grass, forage oats and forage sorghum. Machinery size was increased incurring extra costs but increased work rates, ii) 500 ha extra pasture area and forage areas obtained from the cropping area. Livestock numbers were increased on a pro-rata basis to maintain the given stocking rate, iii) replacing 20% of the grain cropping paddocks with the annual summer forage Lablab (*lablab purpureus*) with a pro-rata increase in livestock numbers. Additional analyses were conducted to investigate the effect of increased stocking rate in scenario iii) and iv) the effect of one high emission climate change scenario.

Results and Discussion

The results indicate that cropping was still fundamentally the most profitable farming enterprise in this region (Figure 1a). Increasing cropping area by 500 ha increased mean annual farm profit by 33% compared to the baseline scenario whilst increasing the pasture/forage area reduced mean annual farm profit by 19%. However, the variability of returns for the increased-pasture area scenario was very much less than that of the increased cropping area scenario.

Effect of integrating lablab and higher stocking rate

Integrating summer legume, with the low stocking rate, produced a similar median farm profit to the baseline farm. Nitrogen fertiliser costs were reduced by 25% and no extra expenditure on machinery above the baseline level would be required. However, the variability in returns was greater than the other scenarios and the variability very much higher than that of the extra-pasture scenario rate. The risk of negative returns was the highest (5.0%) of all scenarios.

Doubling the stocking rate on the forages (including integrated Lablab) from 0.9 to 1.8 beasts per ha increased mean annual farm profit of the integrated Lablab scenario by 33% compared to the baseline scenario. This was the same increase as for the 500ha extra cropping and would be done without the need for extra machinery, labour or fertiliser. The pasture utilisation percentage of the pastures was increased from 10% to a much more satisfactory 37%.

Effect of potential climate change

The baseline (current farm enterprise mix) performed relatively well under climate change with 5% and 10% reductions in mean farm profit at 2030 and 2050 respectively (Figure 1b). At 2030 there was only a small advantage indicated by the extra crop and extra pasture scenarios, both with 4% reduction in profit. The integrated Lablab had an 8% reduction in profit. At 2050, there was no advantage in enterprise change as reductions in profit were 14%, 11% and 17% for the extra crop, extra pasture and integrated Lablab scenarios respectively. The high performance of this case study farm has been re-iterated in a separate study (Rodriguez et al. 2011) which showed the current management performing at the frontier of the Pareto options of variable inputs under current climate and with climate change.

This study used a real farm in western Queensland and included an accurate replication of the soil, climate, machinery, labour and financial factors. The farmer was satisfied that APSIM model is producing grain and livestock yields appropriate to his experience. Hence these scenarios can be used as an indicator of the direction of farm profits that cannot readily be trialled on-farm. The value of increased pasture and forage as well as integrating a legume, and hence reduced reliance on nitrogen fertiliser, was dependent on a higher stocking rate and

greater pasture utilisation. The trade-off is greater variability of returns and higher risk of negative returns. The current farm enterprises mix was shown to perform well under (one) scenario of climate change but further options need to be quantified.

a)
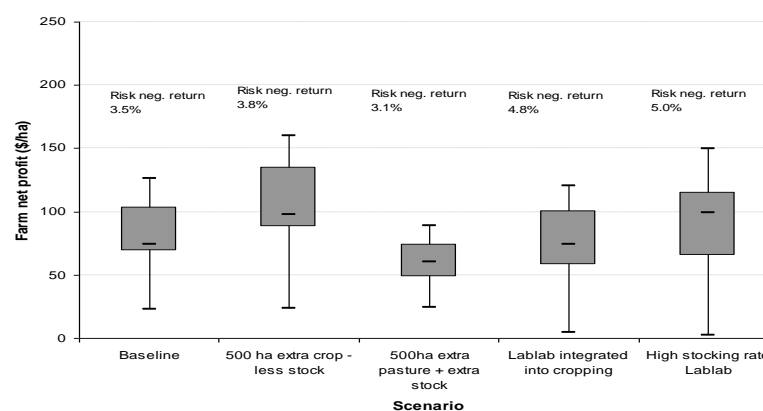
b)
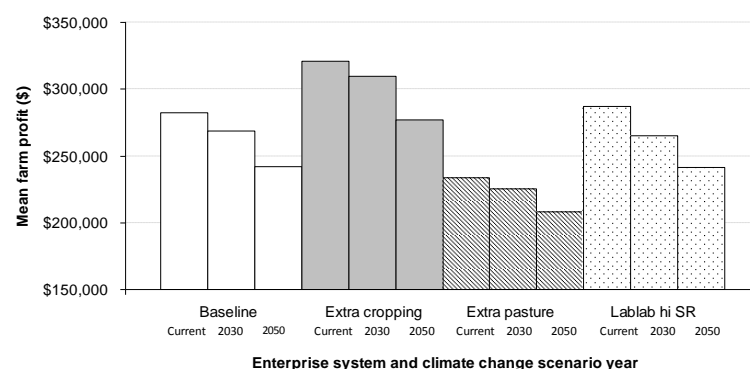
Figure 1. a) Distribution of net profit for significant enterprise changes for a mixed grain and graze farm at Roma in western Queensland with wheat price = $220/t and beef price = $0.85/kg and b) effect of climate change on enterprise mean profits

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Feed gaps and the effect of cereal grazing in a dryland farming system of the South Australian Mallee – a crop-livestock model application

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Keywords: whole farm systems modelling, AusFarm, dual-purpose wheat

Introduction

The Mallee agro-ecological zone in south-eastern Australia is characterized by a Mediterranean-type climate with low annual rainfall (average 250-350 mm/year) and dune-swale landscapes with high soil variability. The dominant dryland farming system combines wheat and barley in rotations with volunteer medic-based pastures that are primarily grazed by sheep. Producers' aversion to risks associated with climate induced variability of pasture production results in low overall stocking rates and consequently low pasture utilization rates (Robertson and Wimalasuriya, 2004). Besides the main feed sources of pasture and cereal stubble, feed supplementation is common (Robertson, 2006), limiting farm profitability. Recently, the grazing of dual-purpose cereals to fill the early winter "feed gap" has attracted interest in the drier regions of southern Australia (Moore, 2009), but information on how this would affect the feed budget is limited.

In farming systems faced with severe climate and soil constraints and major temporal and spatial variability, simulation models are a useful research and development tool to identify gaps in resource use efficiency and assess the potential of interventions to improve productivity. This study used the AusFarm whole farm system model to simulate crop, pasture and animal production for a typical farm at the lower range of the rainfall gradient in the South Australian Mallee. The aim of the research was to characterize feed intake and feed gaps throughout the year, and to assess the opportunity for the grazing of dual-purpose wheat to provide an alternative feed source.

Materials and Methods

A typical mixed farm located at Waikerie in the Mallee (average annual rainfall 252 mm) was characterized in terms of its soil types, land use and the crop, pasture and livestock management rules that govern decision-making. This characterization was conducted through interviews with an expert panel (farmers, advisors, researchers) from the region. A multi-paddock simulation model corresponding to this farming system was then configured using the AusFarm modelling tool. AusFarm was used because it permitted the APSIM soil water, soil nutrient and crop dynamics models to be coupled to the GRAZPLAN pasture and livestock dynamics models, and because AusFarm contains a scripting language that can express the whole farm management rules obtained in the characterization interviews. For further information on the biophysical simulation models and the AusFarm software, see Moore (2009). The resulting simulation model was run with long term (50 years) climatic input data. The simulation outputs were cross-checked against literature values, and provided to the regional group for discussion. An iterative process of adapting the model assumptions ensued until the simulation outputs represented reality in a satisfactory way.

Feed gaps were assessed by comparing pasture growth and availability with feed demand, by identifying periods during which animals lose weight and by determining the amount and timing of supplementary feeding. The intake of different feed types was compared for the baseline scenario of the typical farm and a scenario in which grazing wheat was introduced on 10% of the farm area. Dual-purpose wheat crops were dry-sown on April 1 each year (approximately 6 weeks before the average cereal sowing date) and were grazed only if standing biomass exceeded 500 kg/ha prior to Zadoks growth stage 30. Grazing of wheat continued for a maximum of three weeks. A conventional wheat variety (cv Mace) was compared to a dual-purpose variety (cv Wedgetail).

Results and Discussion

The typical farm had an area of 2000 ha, equally distributed between light-textured dune soils and heavier swale soils with moderate subsoil constraints. A wheat-barley-annual pasture rotation was used on both soil types. Six equally-sized paddocks of each soil type where simulated, with rotation sequences offset so that two thirds of the farm was under cereal and one third was under pasture at all times. A self-replacing Merino ewe flock was run at a stocking rate of 0.8 ewes per farm ha. Ewes were mated mid November each year. Supplements, consisting of 30% hay and 70% cereal grain, were given to maintain the ewes' body condition at acceptable levels throughout the year.

Growth rates of the medic-based pastures peaked in August and the availability of good quality pasture was low from November through to May-June. It is a common practice in the Mallee to graze sheep on cereal stubbles during summer and autumn to bridge the gap in pasture availability (Robertson, 2006; Figure 1). Although the stubble and spilt grain provide a valuable feed source for a few weeks, animals lost weight in summer and autumn. This cycle of weight loss and gain implies an important loss in productivity due to energy conversion inefficiencies in these processes. Lambing took place at the end of April, so that energy demands were high during autumn and early winter when feed availability was usually low; this feed gap resulted in supplement intake peaking from April through to the beginning of July (Figure 1). Farmers usually keep stocking rates low as a risk coping strategy, resulting in low pasture utilization rates. This was reflected in the model results with pasture utilization only 30% on average. However, the merits of this risk coping strategy were confirmed: although varying the stocking rate from a hypothetical 0.4 to 1.6 ewes per farm ha increased the pasture utilization rate, it also markedly increased the reliance on feed supplements (Figure 2). The average farm gross margin (taking into account annual income and variable costs associated with crops and livestock) improved slightly from $A302k to 339k, but the year-to-year variation, and thus the risk, also increased with higher stocking rates (Figure 2).
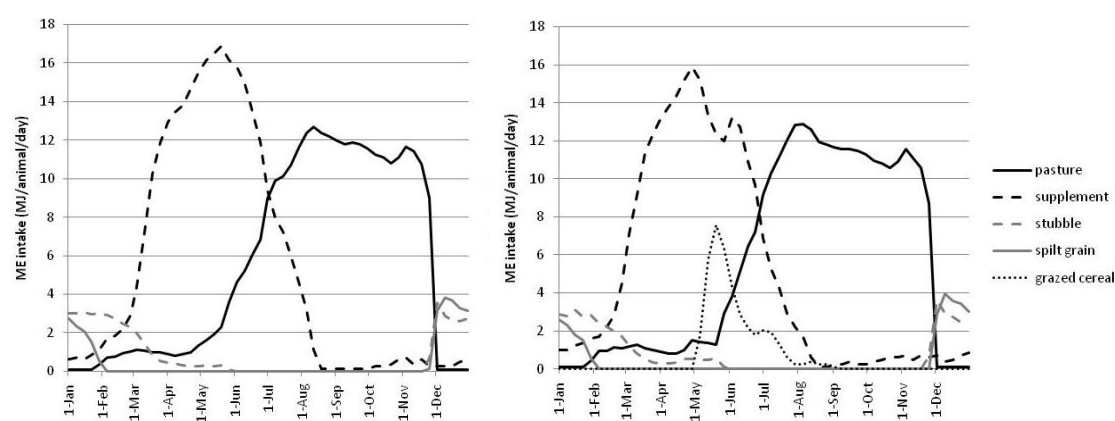
Figure 1: Da ily intake of metabolizable energy (ME) (MJ/animal/day) from different feed sources for the baseline scenario (left) and for the scenario with grazing dual-purpose wheat on 10% of the farm (right) (long term average for the period 1950-1999)
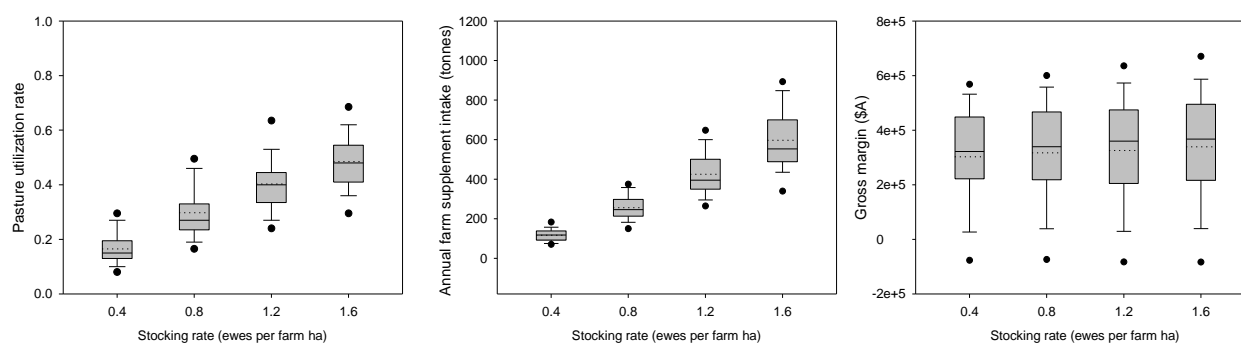
Figure 2: Box plots showing pasture utilization rate, annual farm supplement intake and overall farm gross margin for 4 stocking rates for a typical farm in Waikerie over 50 years of weather data.

The winter wheat cultivar Wedgetail created a grazing opportunity in 88% of the years with an average grazing duration of 27 days. When used as a dual-purpose crop, the spring wheat cultivar Mace allowed for grazing in 60% of the years with an average 7 days of grazing. This difference is related to the longer vegetative growth stage in winter wheat varieties, which together with the high nutritional quality of the biomass (Moore, 2009), results in a feed opportunity in early winter. Indeed, the grazing period usually occurred from the beginning of May to mid June (Figure 1), which coincided with the lambing period. With 10% of the farm under the Wedgetail wheat cultivar, ewes used an average 32 kg of wheat shoot dry matter per animal per year, totalling 51 tonnes on a farm basis. This resulted in a statistically significant ($P < 0.01$; Mann-Whitney U statistic) decrease in the annual intake of supplements from 257 tonnes in the baseline scenario to an average of 222 tonnes. The positive effect on pasture biomass availability from deferred grazing described by Mokany et al. (2008) was not observed in this study, probably due to the low stocking rate. Grain yield penalties for the grazed Wedgetail cultivar compared to the baseline practice amounted to 476 and 246 kg/ha on the dune and the swale soil, respectively. These penalties were explained by the grazing effect and the dry-sowing rule for dual-purpose wheat. The effect was evaluated in economic terms by assuming a cereal grain price of $A250/tonne and accounting for the forage grazing value by multiplying the forage energy intake by the average price paid per metabolizable energy (ME) unit in supplements (roughly $A0.015 per MJ ME). Compared to the baseline scenario, a financial loss of $A46/ha and a gain of $A14/ha were calculated for the dune and the swale soils, respectively. This difference in soil types suggests that spatial management of soil variability plays an important role in Mallee farming systems.

While grazing cereals can profitably close part of the early winter feed gap, supplement demand remains high in the autumn period, presenting an opportunity for other potential feed sources.

This study provides an example of how simulation models can be used to assess the potential effect of interventions and aid the design of more sustainable and robust farming systems.

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Co-innovation of family farm systems in Uruguay: the role of farm modelling

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Introduction

Faced with continued decreases of product prices on the internal market and increasing costs of inputs and energy over the past 20 years, vegetable family farms in Uruguay have been intensifying and specialising their production systems, putting more pressure on already deteriorated soils and on limited farm resources. To identify options for sustainable development of vegetable family farms, we developed a whole-farm optimization model (Farm IMAGES) and carried out a model-aided explorative study in earlier work. The study showed that decreasing the area of vegetable crops by introducing long crop rotations with pastures, introducing green manures and animal manure applications during the inter-crop periods, and integrating beef-cattle production into the farm system would be a better strategy than prevailing farmers' practice of increasing the area of vegetables and specialising on only a few crops (Dogliotti et al., 2005).

During 2004, the results of this study were presented to farmers, to the board of the main farmers' union and to leaders of the national research institute, which resulted in funding to put the main ideas into practice through an 'action-research' project. The project (2005-2010) started with six pilot farms and was extended in 2007 by adding ten more farms with European Commission funding (EULACIAS). It engaged farmers and researchers in a co-innovation process that significantly improved the farm systems of the participant farms (Dogliotti et al., 2010). During the same period the Farm IMAGES model was improved and input-output relations were adapted to changes in the socio-economic environment and data from the pilot farms.

In this paper we present the impact of the co-innovation process on the sustainability of the pilot farms and we compare these results with the potential trade-offs between family income and soil conservation explored with Farm IMAGES for two of the pilot farms. The study shows how whole-farm modelling can contribute to the learning process of stakeholders and to farm systems innovation.

Materials and Methods

The co-innovation projects included 16 farms selected to represent a large range of variation in resource endowment, soil quality and physical distance to the market. Farmers' willingness to discuss strategic choices, and their involvement in local farmer groups were also important selection criteria. Selected farms had vegetable production as main source of income and were located from 15 to 70 km from the main vegetable market in Montevideo. The farm area varied from 4.4 to 59 ha and the irrigated area varied from 0 to 60% of the area of vegetable crops. The set of farms included highly mechanized farms and farms with animal traction. On some farms animal production was a very important source of income while others were specialized in vegetable production. Most farmers' formal education level was primary school. The systems approach involved diagnosis of farm system sustainability, re-design, implementation and evaluation, often in several iterations if time permitted. The pilot farms were characterized during a diagnosis phase. With the farmers we identified the critical points for sustainability and drew up a problem tree of each farm. The re-design procedure comprised improvements in erosion control support practices and spatial layout of fields; designing a feasible cropping plan according to resource availability and agronomic rules, including crop rotations, inter-crop activities to improve soil quality and strategic weed control measures. The plans were discussed with the farmers and modified until an agreement was reached. Implementation and evaluation started in 2005-06 for the first group of six pilot farms and 2007-08 for the other ten farms.

We improved Farm IMAGES' ability to evaluate animal production activities in mixed farming systems and used it to explore trade-offs between family income and soil conservation for two of the pilot farms. Resource endowment was 3.1 and 14.5 ha of usable area, 4060 and 5160 h of labour, and 0.35 and 0.8 ha of irrigated area for Farm 1 and Farm 2, respectively. Mechanization level and soil type were similar on both farms.

Results and Discussion

From the beginning of the implementation and evaluation period till year 2009-2010, productivity on the pilot farms increased and soil quality improved. We estimated a 51% increase in family income averaged over the 16 farms, 24% increase in the ratio between family income and average income of the population, 53% increase in labour productivity and 39% reduction in the difference between attainable and actual yield of main vegetable crops. The ratio between irrigated area and vegetable area increased by 16%. The Ginni index of the distribution of farm area among crops decreased by 12%. The ratio between soil organic carbon (SOC) content in the top 20 cm and the difference between the SOC content in reference sites and the 'stable' fraction of the SOC increased by 23%.

As a result of the model-aided co-innovation process, the erosion in both farms was reduced by 54%, but still exceeds the tolerance limit of 5 Mg ha^{-1} yr^{-1} for this soil type (Figure 1). Family income was increased by 78 and 166% in Farm 1 and 2, respectively. However, income in Farm 2 was still under the average family income of rural population estimated in $u 243,168 yr^{-1} (INE, 2010). Explorations with Farm IMAGES showed that erosion could be further reduced by 31 and 36% and at the same time income could be increased by 7 and 147% in Farm 1 and 2, respectively (Figure 1). Analysis of trade-offs between soil erosion and family income showed that for each Mg of reduction in soil erosion, income would be reduced by 31,696 and 5,263 $u yr^{-1} (Figure 2). It would be possible to reach the soil erosion tolerance level and a family income double the average in Farm 2. However, the soil erosion tolerance level could not be reached in Farm 1 with the production activities and technologies taken into account in the calculations. In Farm 2, the reduction in vegetable area associated with the redesign was compensated by increasing the area of pastures and forage crops, and extend animal production, which mitigated the reduction in income. The small size of Farm 1 did not allow such resilient response.
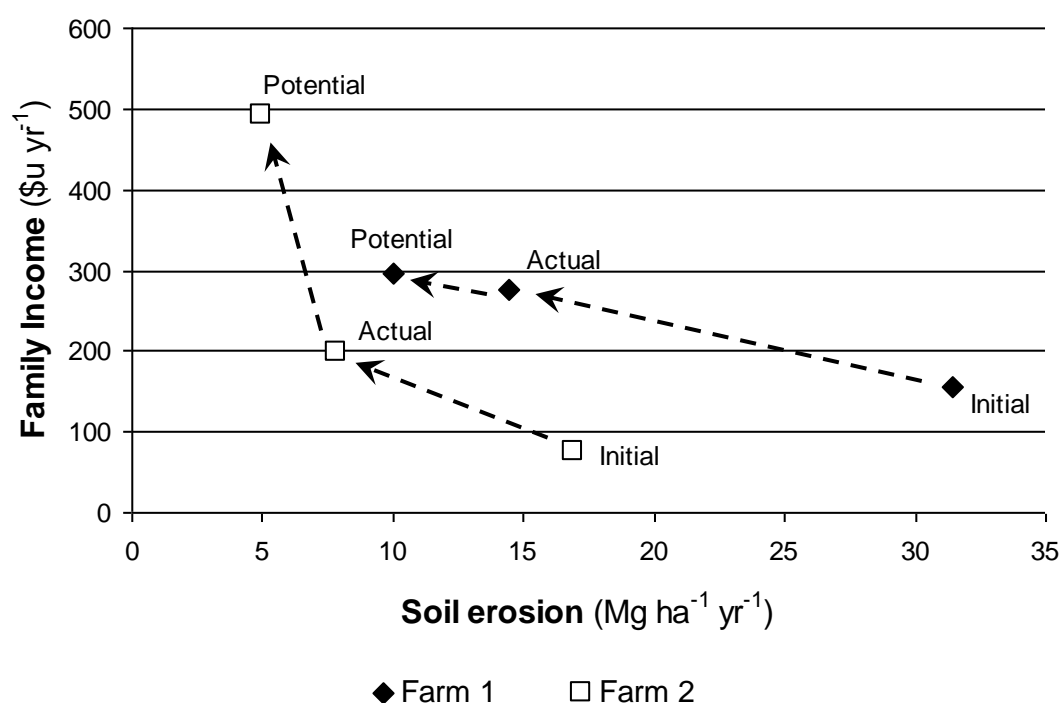
Figure 1. Soil erosion and family income for pilot farms 1 and 2. Initial refers to the situation before implementation of plans, Actual to the results of 2009-2010, and Potential to the lowest attainable erosion level without reducing Actual family income based on explorations with Farm IMAGES.
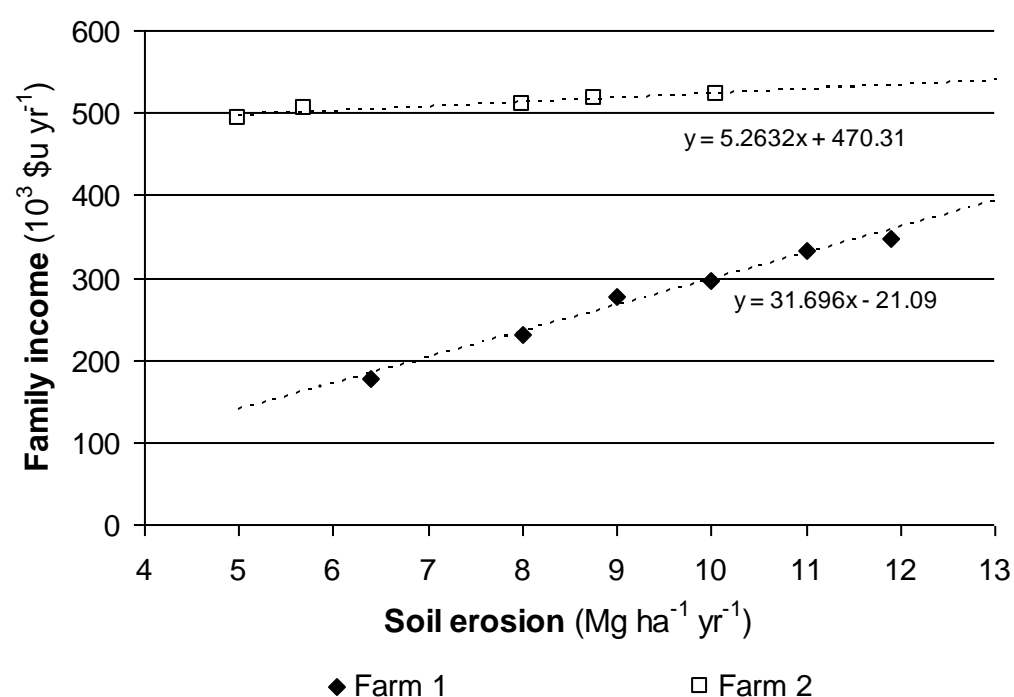
Figure 2. Trade-off between soil conservation and family income for pilot farms 1 and 2 explored with Farm IMAGES.

Results of the co-innovation process and from Farm IMAGES explorations were presented to stakeholders during 2010. The benefit of model-aid planning used in a participatory (co-innovation) process was demonstrated. As a result, we are currently involved in two new farm systems innovation projects started in 2011, one funded by the Municipality of Montevideo and the Comisión Andina de Fomento including 60 farmers and three technical advisers, and the other funded by the Ministry of Agriculture and the farmers' union (CNFR) to train the extension agents of the North East of Canelones Cooperative.

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To mix or not to mix: evidences for the unexpected high productivity of new complex agrivoltaic and agroforestry systems

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Keywords: mixed systems, joint production, Land Equivalent Ratio

Introduction

Concerns about the long-term sustainability of intensive monoculture systems have raised interest in more complex systems that mix crops with other productive components. We explore better strategies to simultaneously convert solar radiation into food, wood and energy. Is it best to use the current dominant land use scheme where crops, forests and photo-voltaic plants are separated in different land units? Or could we imagine new systems that will mix the components intimately at the plot scale? We test the hypothesis that such complex systems may be more eco-efficient. New agrivoltaic (AV) systems combine arable crops with photo-voltaic panels (Dupraz et al., 2011) to produce both food and energy (Figure 1). Improved agroforestry (AF) systems in temperate areas show promise (Eichhorn et al., 2006) and start to be widely adopted in Europe (Liagre and Colomb, 2010). Such mixed systems may increase profitability and combine a high productivity with environmental services such as carbon-neutral energy production (Palma et al., 2007; Wise and Cacho, 2005). Preliminary results also indicate that such systems may be more resilient to climate change than monocultures (Talbot et al., 2009). These complex systems can have higher overall productivity than monocultures due to better resource use efficiencies (e.g. higher land equivalent rations). They also overcome the competition for land between energy and food production.

Figure 10 : A prototype of an agri-voltaic system combining solar panels and field crops. A 4 m clearance allows easy mechanization of the system with conventional machinery. Location : Montpellier, France

Materials and Methods

AF and AV mixed systems have been evaluated by both field monitoring of prototypes and by simulation with numerical models. For 15 years, we monitored a new design of an agroforestry system mixing poplars and cereals, from tree plantation to tree harvest, allowing us to measure the actual productivity of such a system. We also monitored during 1 year a prototype of a new agrivoltaic system, resulting in the first estimate ever of the productivity of such systems (Dupraz et al., 2011). For longer term studies, numerical models were used to provide estimates of the long-term productivity.

The Land Equivalent Ratio (LER) concept was originally proposed to measure the efficacy of intercropping (Mead and Willey, 1980). We suggest extending this concept to any mixture of production components, such as in AF and AV systems. The LER is calculated as the sum of the relative yields of the components, each relative yield being defined as the ratio of the production in mixture to the production in monosystems. Any LER value above 1 indicates a benefit. LERs of annual crop mixtures are easy to measure, as each growing season provides an estimate. LERs of perennial AF or AV systems are trickier to measure or predict (Dupraz, 1998). The long-term growth of the tree component must be measured, and the productivity of the intercrops must be monitored for a long time, until crop production is eventually no longer profitable. LER measurements require sole production control plots that are often missing or biased in experimental designs. This explains why almost no measured LERs of AF were ever published so far (Malézieux et al., 2008). The LER of an AV system was calculated as the sum of the relative yield of the crop (shaded crops in the AV system versus monoculture) and the relative production of electricity (agrivoltaic plant versus standard photovoltaic plant).

An integrated AF model was used to predict the long-term productivity of AF systems (Talbot et al., 2010). This model was first calibrated with tree-only and crop-only plots, then validated on the tree-crop system. The model allows decomposing the production predictions into various multiplicative effects (Talbot et al., 2011). Modelling the crop development in an AV system was achieved by coupling a radiative model to a crop model (Marrou et al., 2010). The radiative model is based on a ray tracing algorithm and calculates the amount of radiation (direct + diffuse) reaching the soil under the solar panels, with a daily time step and a 10 cm space step. The STICS crop model (Brisson et al., 2003) was used to simulate the development of the crop under partial shade at the different locations under the PV panels. All calculations for both AF and AV systems used the soil and climate conditions of the Restinclières farm, located at 15 km North of Montpellier, France (43,42°N – 3,51°E).

Results and Discussion

Measured LERs for AV and AF systems were surprisingly high : 1.2 to 1.5 in AF and 1.3 to 1.6 in AV (Table 1). It should be emphasised that a 1.4 LER means that a 100 ha AV or AF farm produces as much as a 140 ha conventional farm where the productions are separated. The use of the simulation models allowed to explore various designs of AF and AV systems, and suggested some crucial features to maximise the productivity of the system. North-South tree lines, 50 to 100 trees.ha^{-1} densities, a dynamic pruning scheme of the trees and the use of winter crops are recommended for AF systems. According to the model, three factors appeared to be essential for obtaining

efficient AF systems : phenology lags between tree and crop components, plasticity of the root systems of the tree in response to the competition by the crop and the availability of a deep resource of water that is within reach of the rooting system of the trees.

Table 1 : LERs of two different* agrivoltaic systems as predicted by modelling

	Solar panel	Crop♣	Crop♣	LER based on Yield	LER based on Dry Matter
	Relative Yield	Relative Yield	Relative Dry matter		
Monosystem	1	1	1	-	-
FD Agrivoltaic System	1	0.73	0.64	1.73	1.64
HD Agrivoltaic System	0.52	0.83	0.80	1.35	1.32

* FD is a system with solar panels at Full Density, similar to a standard photovoltaic plant. HD is a system with a half density of solar panels (one row every two rows is suppressed), to provide more radiation to the crop.
♣ The simulated crop is a winter durum wheat.

For AV systems, the shade is permanent throughout the year, but the shading patterns vary with seasons. More research is needed to determine the optimum panel density for various crops. Preliminary results on salad, pea and wheat crops indicate that winter crops may not benefit from the new environment, while summer crops may take advantage of the protection against excess heat or evaporative demand. Both AF and AV systems appear to be very efficient in resource use. The levels of complexity involved in the two systems are different : in AF systems, the trees are a living component : their phenology produces a dynamic shade pattern during the year, they are never in a stationary state from year to year, they keep a memory of the past years and finally they have roots that compete with the crops. In AV systems, the fixed solar panels produce the same shading pattern every year and do not compete for below-ground resources. However both systems share some common mechanisms: reduction of the available radiation, protection of the crops against excess heat, heterogenous availability of rain water into the soil. However, the same indicator (LER) proved very useful, and a common methodology for analysing the model outputs was used. This methodology is appropriate for any system with short time steps interactions between the productive components, which is a key feature of mix systems including crops.

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Intercropping maize and mungbean to intensify summer cropping systems in Queensland, Australia

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Keywords: *Vigna radiate*, *Zea mays*

Introduction

Most rainfall occurs during summer in dry land cropping regions of Queensland, Australia and current climate change predictions indicate that the region is likely to become hotter with an even more summer dominant rainfall pattern (IPCC, 2007). This has important implications for agriculture (Rodriguez et al 2011) and presents both challenges and opportunities for crop production. We see an opportunity to increase productivity and farmers' income by intensifying production during the higher rainfall summer months. Previous investigations indicate that land productivity could be increased with intercrops (Watiki et al 1993) and relay crops (Caviglia et al 2004) by increasing resource capture and resource use efficiency (*i.e.* rainfall, solar radiation and nutrients). Maize-mungbean intercropping systems are established elsewhere (Sangakkara 1994) and both species are adapted to dry land cropping in Queensland, Australia. Here we present the initial results from a field study where we evaluated the potential for the intensification of summer cropping using intercrops of maize and mungbean in Queensland, Australia.

Material and Methods

Maize (*Zea mays* L.) hybrid 34N43 and mungbean (*Vigna radiate* L.) cv. Emerald were sown on the 1st February 2011 at Gatton, Queensland, Australia (27°32′S, 152°19′E). The soil is a deep alluvial, weakly cracking vertisol (USDA taxonomy: Typic Chromustert). Treatments included sole maize at 2, 4 and 8 plants/m^2, sole mungbean at 20 plants per m^2, and mungbean/maize replacement intercrop (*i.e.* 2 x 2 row) with maize populations of 1, 2 and 4 plants/m^2, and a mungbean population of 10 plants/m^2 (the same intra-row densities as the sole crop treatments). All 7 treatments were sown in 12 by 8 m plots in a randomised complete block design with 4 replicates. The site was fertilised with urea at 110 kg/ha plus Starter Z$^®$ 50 kg/ha and then tilled prior to planting (total N = 55.6 kg/ha and Zn = 1.25 kg/ha). Additional zinc foliar sprays were applied as mild nutrient deficiency symptoms presented on maize at the 8 leaf stage (total application 0.2 kg/ha). The mungbean was inoculated with Nodulaid^{TM} Group I (Becker Underwood). At planting the soil was at field capacity (*c.a.* 290 mm), and in crop rainfall was 303.2 mm. Weeds and insects were controlled as necessary. A 4.5 m^2 area from monoculture treatments and 9 m^2 area from intercropped treatments were hand harvested at black layer formation in maize, and black pods up to 90% of mungbean plant height. All mungbean plants and a subsample of 5 maize plants were collected from the harvest area to calculate above ground biomass. Land equivalent ratio (LER) were calculated by adding the partial LER for each species. Partial LER = intercrop yield/sole crop yield, for crops at the same in-row plant spacing (*e.g.* maize yield at 4 plants/m^2 intercropped divided by 8 plants/m^2 sole cropped). Data were analysed as a blocked one-way ANOVA with GenStat 11th Edn (VSN International, Hemel Hempstead, UK). Where appropriate, means were separated by least significant difference (l.s.d.) at the $p = 0.05$ level.

Results and Discussion

The yield of monoculture maize increased 1.4 fold as plant population increased from 2 to 4 plants/m^2, but no further yield increases were observed when maize population increased to 8 plants/m^2 (Table 1). The yield of maize intercropped with mungbean similarly increased 1.5 and 1.4 fold as maize population increased from 1 to 2 and 2 to 4 plants/m^2, respectively. It appears that sole maize yield reached a plateau between 4 and 8 plants/m^2, though in the intercrop, it is not clear if maximum yields were achieved at the highest density of 4 plants/m^2.

Table 1. The effect of maize (Mz) and mungbean (Mb) plant populations (pl/m^2) grown in monoculture (sole) or intercrops (IC) on yields and land equivalent ratio (LER).

Treatment	Yield (t/ha)			Yield (g/plant)		Partial LER*		Total
	Mz	Mb	Total	Mz	Mb	Mz	Mb	LER*
Mb 20 pl/m^2 Sole		2.40a	2.40e		12ab			
Mz 8 pl/m^2 Sole	7.35a		7.35a	96e				
Mz 4 pl/m^2 Sole	6.85a		6.85a	164c				
Mz 2 pl/m^2 Sole	4.80b		4.80c	212b				
Mz 4 and Mb 10 pl/m^2 IC	5.14b	0.73d	5.87b	133d	8c	0.70a	0.30c	1.00a
Mz 2 and Mb 10 pl/m^2 IC	3.92c	0.89c	4.81c	203b	10bc	0.58b	0.37b	0.95a
Mz 1 and Mb 10 pl/m^2 IC	2.62d	1.07b	3.68d	231a	13a	0.55b	0.45a	0.99a
l.s.d. ($P = 0.05$)	0.63	0.59	0.59	25	3	0.04	0.02	

n = 4.

* LER calculations were based on yield/ha

Each species occupied half of the plot in intercropped treatments with half the plant population of monoculture treatments at the same in-row plant spacing (*i.e.* 8 plants/m^2 sole *vs.* 4 plants/m^2 intercropped). Therefore, if intercropping has no effect on yield, then we would expect partial LER values of 0.50. The partial LER calculated herein indicates that the intercropped maize produced higher yields on the same land area as sole crops (*i.e.* partial LER > 0.5; Table 1). For example, intercropped maize yield declined by only 30 to 45% compared to monoculture maize sown at the same in row spacing despite the 50% reduction in plant population and area sown. As the maize population increased the partial LER also increased indicating that maize was more susceptible to intraspecific competition than interspecific competition, especially at higher population densities. The primary source of competition was likely to be light capture, as the other major growth factors *i.e.* water and nitrogen, were at adequate levels throughout the experimental period. The high maize partial LER could be explained by increased light capture by border rows of the structurally dominant maize species in replacement intercropping systems (Zhang et al 2007).

Even though partial LER indicates that intercropped maize was a more efficient land user, monoculture maize consistently out yielded intercropped maize at the same population densities (*e.g.* 4 plants/m^2 sole vs. intercropped; Table 1). This may be due to closer in row plant spacing between maize plants in the intercropped *i.e.* higher intraspecific competition, than in the sole system at the same population density.

Mungbean yield decreased by 56 to 70% in the intercrop compared to sole crop. This was partly due to the decreased mungbean population, *i.e.* from 20 to 10 plants/m^2 in the replacement intercropping system, as yields per plant only declined significantly ($p \leq 0.05$) when intercropped with maize at more than 2 plants/m^2 (37% yield reduction per plant; Table 1). Mungbean partial LER declined with increasing maize populations confirming that mungbean is susceptible to competition from maize in this intercropping system. Light competition is also suspected of being the primary limiting factor responsible for these reduced mungbean yields, as shading directly above the mungbean canopy (*c.a.* 0.60 m) at midday was 4, 11 and 12%, as maize population increased to 1, 2, and 4 plants/m^2, respectively. Shading above the mungbean canopy is likely to increase either side of midday due to the north-south row orientation. Islam et al (1993) found that mungbean yield was reduced with 45%, but not 15% shading.

The total LER was approximately 1 for all treatments indicating that similar yields could be achieved on an equivalent area by planting each species in monoculture. Therefore, there was no benefit of intercropping over monoculture as tested here *i.e.* a 2 by 2 replacement intercrop. However, we hypothesise that increasing plant populations in intercrop or relay cropping systems (Watiki et al 1993) and appropriate matching of the crop phenologies, could produce more productive systems than sole cropping. This may include, a longer season mungbean cultivar sown at populations optimal for sole crops, and shorter season maize sown at a population density that minimises negative shading effects on mungbean. Alternative species may also help achieve the suggested benefits of intercrop and relay cropping systems.

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Modelling sowing time response of canola in the northern wheatbelt of Western Australia

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Keywords: Canola, tactical management, crop modelling, APSIM

Introduction

Canola has become an increasingly important component of Western Australian Mediterranean farming systems in the past decade, with 1.031 million tonnes produced from 981,000 ha in 2010 (ABS 2011). It has a reputation among growers of being sensitive to drought and high temperature during grain filling, and of requiring early sowing for best results. Annual crops in Western Australia's wheatbelt grow predominantly on rainfall received during the growing season (Anderson and Garlinge 2000) and usually the sowing time depends on the first rains of the season (termed the break of the season). The break can occur at any time from mid April until the end of June in Western Australia and is the cause of considerable anxiety among farmers when it has not occurred by mid to late May. Deciding when it is too late to sow canola is therefore an important decision growers must make. Unfortunately canola sowing time response varies between locations, and between seasons and soil types at a location. In addition, dwindling resources for research means that there is not a substantial body of time of sowing trial data to inform this decision at most locations.

Farré et al. (2007) modelled the sowing time response of canola at three locations in Western Australia using APSIM (Keating et al. 2003, Farré et al. 2002). They concluded that canola was most risky in low rainfall environments, and that it could be profitably planted later in high and medium rainfall than in a low rainfall environment. However, all their analyses were based on crops grown with luxury levels of N, and none of their locations were in the northern wheatbelt. Here we present model runs for a high and low rainfall location in the northern wheatbelt at a range of N application levels that were designed to help farmers making canola sowing time decisions.

Materials and Methods

Simulations were run in APSIM 6.1 for Buntine (average annual rainfall = 338 mm) and Mingenew (average annual rainfall = 402 mm) in Western Australia's northern wheatbelt. Local soils on which canola is grown were chosen from the APSOIL database (duplex sandy gravels Irwin no 416 for Mingenew and Buntine no 418 for Buntine). The crop was a mid-season triazine tolerant canola sown at 40 plants/m² on 20 April and thereafter at approximately 10 day intervals until June 20 at Buntine and 10 July at Mingenew. These dates span the normal sowing time of annual crops at these locations. Simulations were run over the period for which reliable meteorological data (extracted from the SILO database) was available; 1901 to 2009 for Mingenew and 1930 to 2009 at Buntine. Plant available soil water (PAW) was reset to nil on 1 January, and soil mineral N to 50 kg/ha NO_3-N and 25 kg/ha NH_4-N on 20 April each year. Mineral N was concentrated in the top 50 cm of the soil profile. 50 kg/ha NH_4-N was applied at sowing, in line with farmer practice, and 0, 30, 60, 90, 120, or 210 kg/ha urea-N was applied at the 5 leaf stage.

In a second set of runs for Mingenew only canola was sown on the same dates as in the first set but only when PAW in the top 20 cm of the soil profile reached 80% of capacity less than 10 days prior to sowing. All other details were the same.

Results and Discussion

In general grain yield declined with later sowing, but how much depended on N application, especially at Mingenew. With no N applied after sowing there was almost no difference in yield between 20 April and 30 May at Mingenew, and only a modest decline of 17 kg/ha/day thereafter. At Buntine yield declined in the no N simulations from 30 April onwards at about 16 kg/ha/day. At high rates of applied N yield declined from the earliest sowing date at 21.6 and 18.8 kg/ha/day respectively at Mingenew and Buntine. This compares with simulated rates of decline with delayed sowing ranging from about 10 to 20 kg/ha/day found by Farré et al. (2007) for canola further south in Western Australia, and is less than values often quoted for other crops in Western Australia (eg French and D'Antuono 2003 for lupins and Anderson and Garlinge (2000) for wheat).

We hesitated to use these results with farmers in 2010 because the yields from June sowings at Mingenew were higher than previous field trial and farmer experience led us to expect. We explored two possible explanations for this. The first relates to the effects of climate change since 1975, and the fact that our experience with canola in the northern wheatbelt has nearly all been in the past 20 years. Figure 2A shows that the median yield with 120 kg/ha N in the period 1901 to 1975 was from 236 to 519 kg/ha higher than in the period 1976 to 2009 when sown on the same date. The second possibility we explored questions how relevant serial sowing time simulations like these are to the problem farmers face. This is because farmers are interested in the performance of late sown crops in season when there has been no early break, yet many of the late sown simulations in this data set are from seasons with early breaks. On average we expect seasons with early breaks to have more rainfall than those with late breaks, and therefore higher yield potential. To address this question we ran a set of simulations where crops were sown late only when there had been no earlier sowing opportunity. Figure 2B shows that this resulted in higher median yields before 10 May due to exclusion of very poor seasons, and lower yields afterwards, but the difference was in the range of only 100 to 200 kg/ha until after 20 June, and these latter medians were calculated from very few numbers. These data gave a rate of yield decline of 33.7 kg/ha/day for non-N limited canola, 50% higher than the rate observed when canola was sown at every date in all years.

(a)　　　　　　　　　　　　(b)
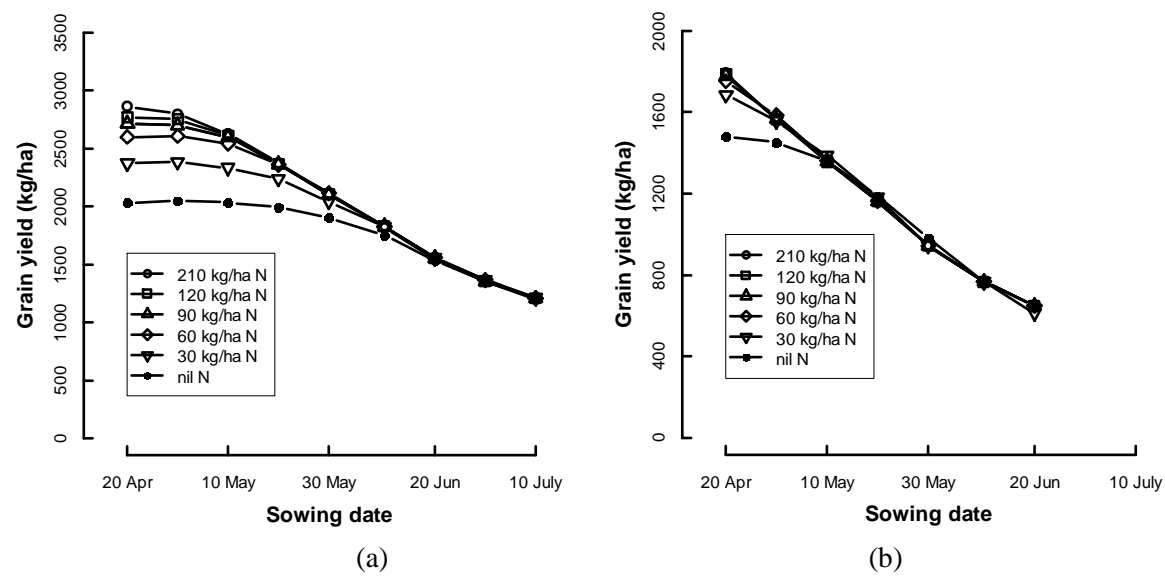
Figure 1. Simulated sowing time response for canola at Mingenew (A) and Buntine (B) in Western Australia with different amounts of urea-N applied at the 5 leaf stage. Figures show median grain yields over the simulated period.

(a)　　　　　　　　　　　　(b)
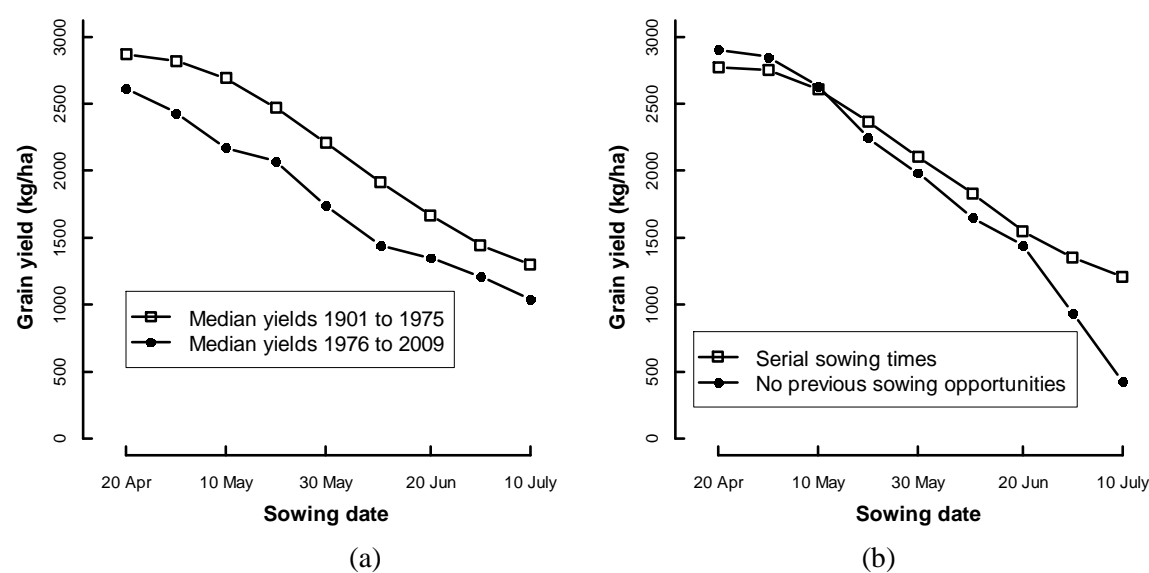
Figure 2. Simulated sowing time response for canola at Mingenew with 120 kg/ha urea-N applied at the 5 leaf stage, comparing response in the periods 1901 to 1975 and 1976 to 2009 (A) and comparing the response when sown at each date in all years with that when sown only when a previous sowing opportunity had not occurred (B).

These results show that simulation modelling can be useful in understanding how canola responds to agronomic management in a much larger range of environments than could ever be achieved in field trials. This work emphasises that N application is important in realising the high yield potential early sowing offers, and that optimum N rates decline as the season progresses. It also emphasises that canola can be sown later in high rainfall than in low rainfall environments in the northern wheatbelt as well as further south as found by Farré et al. (2007). The difference in pre- and post- 1975 results also indicates how climate change has already impacted on Western Australian agriculture, and suggests that careful thought should be given to choosing met data for long term simulation studies such as this. This type of simulation can easily be done for a range of locations to assist farmer decision making, and presenting outputs in a probabilistic format will allow individual growers to assess them in the light of their own circumstances and risk profile. Probability exceedence plots derived from these data will be updated periodically within the key decision making period for sowing and additional relevant information extended via a weekly email service in 2011.

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Opportunity to increase phosphorus efficiency through co-application of organic amendments with mono-ammonium phosphate (MAP)

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Keywords: Compost; Barley (*Hordeum vulgare*); partial substitution; fertiliser efficiency

Introduction

As the world's population continues to increase towards the predicted 2050 figure of 9 billion (Fischer et al., 2002) so too does the demand for food. Until the early 1950s, world agricultural production kept pace with population mainly through the expansion of cultivated area and increasing crop yields (i.e. production per unit area) (Gilland, 1993). This was achieved through breeding improvements, expanding and improving irrigation systems, and protecting crops from disease, insects, and competition from weeds, as well as applying increasing quantities of chemical fertilisers (Gilland, 1993). However, the sustainability of the required agricultural production is in question if the raw inputs of many fertilisers, such as those supplying phosphorus (P), are finite, and if fertiliser costs continue to increase such that production profitability is lost (Cordell et al., 2009). Therefore, alternative, or simply more efficient, sources of nutrition are required. The efficacy of single and combined applications of compost and synthetic fertiliser were compared in a glasshouse trial to determine the potential for reduction in synthetic fertiliser usage through partial substitution with compost. A microbial inoculant alone and in combination with compost or synthetic fertiliser was also included in the comparison undertaken. This project tests the hypothesis that conventional synthetic, and organic, fertilisers could be used together to maintain or increase yield, whilst reducing demands on conventional, mined, synthetic P supplies through greater fertiliser efficiency.

Materials and Methods

Barley (*Hordeum vulgare* L. cv. Hindmarsh) was grown in a glasshouse trial set up in 12.7 x 12.7 cm plastic pots using soil collected to a depth of 5 cm from a site at Charles Sturt University, Wagga Wagga, Australia (S 35° 3' 56.556" E 147° 19' 27.696"), as in Gale et al. (2011). Initial nutrient analysis is shown in Table 1. The trial consisted of 11 treatments comprising single additions or combinations of compost, mono-ammonium phosphate and a microbial inoculant (Table 2). Treatments were replicated four times. Fertiliser applications of 20 kg P/ha (equivalent to 91 kg MAP/ha) are generally accepted as the required P application rate for grain production on similar acidic soils (Schefe et al, 2008) and was used as the baseline application rate for P fertiliser. Compost and MAP were applied singularly and in combination with each other so that rates of 20 kg P/ha, measured as Colwell (1963) available P, were applied to each pot. Applying compost at a rate to give 20 kg P/ha resulted in a compost application equivalent to 33.4 t/ha.

Compost for this trial was produced in windrows similar to Kuhlman and Cormac-Walshe (2000) from material sourced by the Charles Sturt University green waste management program with feedstocks including wood shavings used in horse stables, grape marc, and food scraps from campus kitchens. The chemical constituents of this compost are also outlined in Table 1. The synthetic fertiliser used in the trial was commercial Mono-Ammonium Phosphate (MAP) that contained 21.9% available P, as measured by the Colwell P (1963) method. 'Microsoil', a patented liquid microbial fertiliser and inoculant said to enhance the efficacy of solid and liquid chemical fertilisers, was prepared for application and applied by following the manufacturer's instructions (Microsoil, 2011). Two applications of inoculum were made to pots at equivalent field rates, at sowing and after 4 weeks of the glasshouse trial, alone or with MAP or compost applied at rates equivalent to 10 kg P/ha.

After eight weeks growth both the above and below ground plant material was collected, weighed and analysed for P content as in Gale et al. (2011). The amount of P which was present in each pot at the beginning of the trial (Initial P) was determined based on the sum of the measured soil P prior to the experiment and the calculated additions (Table 2). The cumulative P which was taken up into the leaves and roots of the barley is also presented. All statistical analysis was conducted using GenStat Version 5. Analysis of variance (ANOVA) was used to calculate least significant differences (LSD) to determine significant differences between means.

Results and Discussion

Uptake of P was greatest when compost constituted more than half of the 20 kg P/ha (Table 2). Uptake efficiency (P Uptake / Initial P) was also greatest with 50% of the P applied as compost. Lower P uptake in the treatments containing greater than 50% MAP may be explained by more P-binding. P-binding occurs when available P forms complexes with Fe and Al under acidic conditions (Evans and Condon, 2009; Schefe, et al., 2008) created by nitrification around the MAP granule. The compost treatments had a pH around 7.6 (CaCl$_2$) and were therefore less likely to have had this type of binding occur. An alternative explanation is that some of the pool of total P in compost was mobilised to create a larger pool of available P as the trial continued. This may then have resulted in an increase in P taken up. A key implication of increased uptake efficiency, when more than 50% compost is applied, is that total application of organic and/or synthetic fertiliser required per crop will be less because the crop takes up a higher proportion of what is applied.

There were no significant differences in dry matter yield (DMY) between treatments meaning that the greater P uptake of the treatments with more than 50% compost resulted in significantly lower utilisation efficiency (DMY / P Uptake) for these treatments. Alternatively, significantly lower P uptake, without any significant difference in DMY, from the MAP only treatment resulted in the greatest utilisation efficiency. That is, for the same amount of DMY, less P was taken up into the plant. As with its effects on uptake efficiency, P-binding is likely to be part of the reason for this result. Given that P uptake was significantly higher with the addition of compost is it proposed that utilisation efficiency is significantly lower (Table 2) due to other nutritional limitations on the plant. These nutritional limitations may include nitrogen (N) because the amount of N in the compost application was smaller than that in the MAP application. In the compost alone treatment (equivalent rate of 33.4 t/ha of compost) an equivalent of 7.95 kg of mineral N per hectare was applied. By contrast, MAP at a rate of 91 kg/ha applied 9.10 kg ammonium N, representing an increase of 14% of applied mineral N. However, this result shows that in relative terms there are large reserves of P in the plant which can be mobilised at grain formation in the compost treated pots.

Table 1 Chemical properties of soil and compost used in glasshouse pot trial.

Parameter	Soil	Compost	Nutrient application (kg/ha)	
			Compost	MAP
Ammonium Nitrogen (mg/Kg)	4	40	1.34	9.10
Nitrate Nitrogen (mg/Kg)	3	198	6.61	
Sulphur (mg/Kg)	2.88	327	10.92	1.37
Potassium Colwell (mg/Kg)	315	13250	411	
Phosphorus Colwell (mg/Kg)	11	597	19.94	19.11
Phosphorus Retention Index	31.6	< 0.00		
Phosphorus Buffering Index	62.2	213		
Total Phosphorus (mg/Kg)	277	4952	165	
Organic Carbon (%)	3.44	8.88		
Conductivity (dS/m)	0.052	3.66		
pH (CaCl$_2$) (1:5)	4.70	7.60		
pH (H$_2$O) (1:5)	5.70	8.40		

Table 2 Total Dry Matter Yield of above and below ground plant material; Initial P = soil P + P applied as fertiliser prior to sowing; P uptake = Total P in above and below ground plant material; Uptake efficiency = P uptake/Initial P; Utilisation efficiency = DMY/P uptake. Data designated with different letters within each column are significant different at P<0.01.

	DMY	Initial P	P uptake	Uptake efficiency	Utilisation efficiency
	g/pot	mg P/pot		mg P uptake/ mg initial P	g DMY/ P uptake
20kg P/ha as MAP	8.8	51.5	9.4a	0.18a	0.94c
1:3 application of compost and MAP	9.3	51.5	11.2ab	0.22ab	0.86bc
1:1 application of compost and MAP	9.9	51.5	12.3bc	0.24b	0.80ab
3:1 application of compost and MAP	9.8	51.5	13.7c	0.27b	0.72a
20kg P/ha as compost	9.9	51.5	12.9bc	0.25b	0.78ab
Control	6.1	19.3	6.1	0.31	0.91
Microsoil straight	5.6	21.3	6.3	0.30	0.89
10kg P/ha as MAP	6.9	35.4	7.9	0.22	0.87
Microsoil + 10kg P/ha MAP	6.4	37.4	6.7	0.18	0.96
10kg P/ha as compost	8.5	35.4	10.2	0.29	0.83
Microsoil + 10kg P/ha Compost	8.6	37.4	10.9	0.30	0.80
LSD	**1.8**	**-**	**2.5**	**0.06**	**0.14**

The capacity to examine long term use was beyond the scope of this project, however, through long term trials it would be possible to determine the reduced application requirement of synthetic P fertiliser over time through the use of compost. A detailed evaluation of a local community's propensity to adopt compost would be an important area for further investigation because the soil chemistry associated with the efficient management of nutrients is only one part of the process of adoption of nutrient efficient farming practices.

The paired comparison of treatments with, and without, Microsoil in Table 2 show that when used under optimal glasshouse conditions Microsoil did not affect results. This is not very promising as even positive results in the greenhouse studies using inoculums rarely translate to positive field outcomes (Evans and Condon 2009). Therefore the use of microbial inoculants, like Microsoil, in combination with MAP or compost may not enhance P efficacy in order to grow more food. In contrast, results showed that co-application of compost and MAP did increase efficacy which could lead to greater crop yields, or the same amount of food with less inputs.

Acknowledgements

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Western Australian farm businesses build resilience

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Keywords: farm business management, resilience, adaptation, climate change

Introduction

Climate variability and change pose important challenges for grain growers and mixed farmers in Western Australia (WA). Rainfall has declined significantly in the WA wheatbelt since the mid 1970's at the same time as temperatures have increased, especially in winter and autumn. The frequently disappointing seasons in the last two decades – often featuring late breaks of season and frustrating finishes to the season - constitute emerging evidence of a further step-down in rainfall.

The concept of resilience of farmers has been addressed more from the perspective of psychology (e.g., Hegney et al., 2007) and sociology (King et al., 2009) than from business management. Although there are contributions from general business management literature (see for example, Margolis and Stoltz, 2010, Coutu, 2002 and Johnson-Lenz 2009), the perspective of farm business management has been limited, but Milestad (2003) and Gray (2010) are exceptions.

Changes to the climate challenge farm businesses to adapt in a profitable and sustainable way. Those that adapt well to seasonal variability are likely to be on an optimal path of adaptation to climate change.

Many farm businesses in Western Australia are meeting the challenge: they are adapting, trialling and adopting a range of alternative strategies. These are supported in a continuing way by the agencies, funding bodies, farm groups, consultants and advisors contributing to the body of information available to the businesses. In the search for better adaptability to change, the decision-maker's emphasis upon productivity has to be modified, at the margin, with first, the objective of profitability and second, the need to have the capacity to respond to, or recover from, foreseeable but unpredictable events – resilience – and of course, third, sustainability.

Methods

This paper reports a series of case studies, through which the author gleaned the strategic approaches to change employed by four farm businesses. These approaches are described in Table 1. Each of the businesses demonstrates the complexity and diversity of its legitimate responses to the highly variable and changing environments in which they do business. One important dimension of such change concerns climatic variability. Each in their own way could be said to be doing the *right things well and in a timely fashion*.

Table 1. Farm level strategies in response to changes in business environments.

Environmental dimension:	Climate variability	Soil health (acidity, sodicity)	Social changes	Output and input price fluctuations (e.g., changing grain :wool or meat :wool price ratios)
Farm cases				
Grain/sheep (high rainfall)	Hair-trigger stocking rate – agistment or sale	Lime application	Farm family coherent and cohesive; building network through presenting at farmer groups	Build meat sheep ewe flock balanced with merino
Grain/sheep (medium rainfall)	Use of lick-feeders and grain to replace energy input from pasture	Defining areas to exclude from grazing	Leverage trusted sheep stud status to introduce new breed of wool sheep (Afrinos)	Build meat sheep (Afrino) flock producing both high quality wool and quality carcases
Beef cattle stud (high rainfall)	Perennial pasture component	Mineral fertiliser, gypsum and lime applications	Neighbourhood cooperation and sharing of equipment and manpower	Reduce inputs in periods of output prices, promote performance tested bulls
Grain/sheep (medium rainfall)	Summer-growing pasture (lucerne); shorter season cereal varieties	Deep-rooted pasture (lucerne)	Multi-enterprise (contracting, leasing, farming); defining business boundaries outside the property boundary	Emphasise most profitable enterprise whilst retaining capacities for others

Results and Discussion

An examination of these resilient farm businesses showed they tend to share common attributes. The case studies suggested the following six characteristics (following Johnson-Lenz 2009):

1. They *Constantly Scan their Environment*. They scan their business environment for relevant changes or trends or emerging opportunities and threats. This includes business issues (prices, costs, demand shifts, supply chain issues); natural environmental issues (weather and climate, biodiversity, invasive species, soil health, salinity); social issues (community attitudes towards animal welfare, organic or "green" products, desire for local products); and regulatory issues (effects of international regulatory changes). Resilient farmers are aware of changes in, and the variability of, their local climate.

2. They *Prepare* for *Potential Disruptions*. That is, they make *contingency plans* to cope with realistic, if unlikely, scenarios. Late season breaks challenge the growth potential of annual pastures, and hence the carrying capacity of grazing enterprises. A contingency plan would envisage selling or agisting stock upon certain trigger-level shortfalls of rain by certain predefined dates being reached. A sowing schedule for cropping would be in the form of a contingency plan. Then, for instance, if the season break has not yet occurred

by a certain date, suitable paddocks, with low burdens of weed seeds, would be dry-seeded. Other paddocks would drop out from the schedule. Further contingency plans are made for severe drought and its implications.

3. They *Build Flexibility* into the farm business. When a disruption occurs, a non-standard approach can be readily used. Flexibility can be acquired at some cost, often relatively low, by deliberately building redundancy into the system. An example is to have the capacity to make last-minute switches in seed type: for example, changing the length of season variety in response to the timing of the break. This would require the seed to have been purchased and stored in good time. As a result, in the farmer's environment, a higher proportion of the crop sown in a late break is of a variety more likely to mature before possible heat and water-stress events during seed-fill during late spring. If an early break occurs, the yield potential would be higher than with an unchanged variety.

4. They have *Excellent Networks of Personal Communication*. They have lots of rich, mutually-supportive and trustful relationships with fellow farmers, suppliers, service providers and their family and employees. These networks have rich information flows. Social capital is high. People in the networks with needed expertise and information about adapting to climate change are highly regarded. As a result, when an opportunity arises to adopt a new practice the farmer has ready access to information for an informed decision.

5. They *Experiment and Innovate*. They do small-scale experiments all the time: to see if it works, or would be a better method. These then help in adapting to change in the future. For example, they do experiments with new varieties of drought tolerant cereals or, to take opportunistic advantage of potentially increasing summer rains, with summer-growing crops. Then when larger scale changes are called for, they have information and experience concerning the options available. As a result, when the trade-off between market premium and yield shifts to favour low protein wheat (or high), they know which variety will work in their setting.

6. They *All Know* and *Share Goals* and *Values*. The farm family together with their employees take the time to build mutual understanding about the explicit goals and values used in the farming business. Employees and junior family members add to creativity and flexibility in dealing with a crisis, because they are engaged and motivated.

The case studies suggest that farm businesses which exhibit these six characteristics tend to be resilient and adaptable and hence they survive when challenged. It is important for farmers to continue to run a profitable and sustainable farming business whilst they explore a range of practical strategies by which they can adapt. The case studies also suggest that in order to achieve the required ability to respond - the required resilience - investments are required, to:

- Build infrastructure (e.g., grain and seed grain storage, water catchments and new storage capacity);
- Undertake planning (e.g., agistment alternatives and when to use them);
- Provide excess resources (e.g., reserve feed, water and grain); and
- Develop social capital (e.g., a mutually-supportive network including fellow farmers).

Furthermore, the farm business which is consistently more profitable than its peers will tend to be better able to weather the bad years - to be more resilient.

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Striga asiatica : a driving-force for dissemination of conservation agriculture systems based on *Stylosanthes guianensis* in Madagascar

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Keywords: Conservation agriculture, DMC, *Striga asiatica* control, *Stylosanthes guianensis*, small scale farming, food security, resiliency, robust cropping systems, Madagascar

Introduction

Striga is estimated to infest up to 50 million hectares of crop lands and to adversely affect 300 million people in sub-Saharan Africa. Areas of otherwise productive agriculture have been abandoned because of this scourge. *Striga* is a growing pandemic, undermining the struggle to attain food security of the continent (Ejeta, 2007). Hearne (2009) reviewed a wide range of control options for Striga *hermonthica* and *Striga asiatica*, the most noxious species to cereals. She explained the elusive wide-scale effective control of *Striga* by variable reliability of technology, poor access and cost of control technology, limited practicality of the methods, and poor information.

In the middle-West of Madagascar (elevation: 700 to 1100 m; rainfall: 1000 to1500 mm/year with a 6 months-long dry season), *S. asiatica* infestation in uplands often pushed farmers to abandon cultivation of cereals such as rice (*Oryza sativa*) or maize (*Zea mays*; Sorèze, 2010). It was urgent to propose practical cropping practices controlling *Striga* to allow farmers to produce their own staple food. The objectives of the study were to design, test and disseminate such cropping systems.

Materials and Methods

From 2002/03 cropping season, TAFA (a local NGO) and CIRAD set up experiments on a former farmer field abandoned because of high *S. asiatica* pressure. Various Direct seeding Mulch-based Cropping systems (DMC) were tested (2 to 4 replicates, 200 m² plots) and compared with the conventional practices with tillage. The DMC systems are part of the Conservation Agriculture practices, with introduction of multifunctional cover crops growing in association with the main crops or whenever climatic conditions are too risky for planting a commercial crop. This increases biomass production and the efficiency of the systems, which function as tropical forest ecosystems (Séguy et al, 2006; Kassam et al., 2009).

Most of the tested systems were based on a rice//maize rotation, as it is favoured by farmers.
Rice//Maize rotation with conventional tillage (CT) was compared with:
(i)   Rice + *Stylosanthes*//Maize + *Stylosanthes* (CA St), with *Stylosanthes guianensis* cv CIAT 184 used as dead mulching material for direct seeding
(ii)   Rice//Maize + *Brachiaria ruziziensis* + *Cajanus cajan* (CA Br C), used as dead mulch
(iii)   Rice//Maize + *Vigna unguiculata* (CA Cp), used as dead mulch
(iv)   Rice + *Arachis* sp.//Maize + *Arachis* sp. (CA Ar), with *Arachis pintoï* or *A. repens* kept alive, controlled with low rates of herbicide before direct seeding.
From 2004/05, extension programmes conducted by FAFIALA, ANAE and SD-Mad (local organisations, members of the Direct Seeding Group of Madagascar, GSDM) started the dissemination of the best cropping systems identified by TAFA/CIRAD.

In 2009/10, a specific study was conducted in TAFA experimental plots to measure *Striga* seeds remaining in the soil and the number of *Striga* plants that had germinated and parasited maize plants three months after sowing. Cylinders of soil (12 cm in diameter, 10 cm high) were sampled at 0-12 cm and 24-36 cm from maize rows at 0-10 cm and 10-20 cm soil horizons (2 samples in each of the two replicates for the CA/DMC systems, 2 samples in each of the 5 replicates for CT system) to measure the number of *Striga* plants parasitizing maize. The number of ungerminated *Striga* seeds was measured in 25 g of soil for each sample. Variance analysis was conducted after square root transformation of the measured data.

Results and Discussion

Among the various cropping systems designed for the conditions of the middle-West of Madagascar, several cropping systems actually control *S. asiatica*. Table 1 shows that the best control of *Striga* (number of *Striga* seeds remaining in the soil, and number of *Striga* plants parasitizing maize) is obtained with perennial *Arachis* (*A. pintoï* or *A. repens*) or *Stylosanthes guianensis*.

Systems based on *S. guianensis* always produce more rice than other systems (Figure 1). Over a six year period, these systems produced significantly more (Fisher pairwise comparison, least significant difference, p-value = 0.05) than all other compared systems (4.27 t/ha of rice on average for CA St; 1.81 t/ha for CT). The second best system associates maize with cowpea (3.16 t/ha of rice after such an association). Surprisingly, the system with perennial *Arachis*, which was the most efficient in controlling *Striga*, was the only system not significantly different from conventional tillage (AC Ar, 2.36 t/ha on average). This can be explained by competition for water between the main crop and the living cover crop when it is not properly controlled, especially during dry years (2004-05 and 2006-07). This system requires a specific know-how. It is rarely adopted by farmers.

Inversely, systems based on *S. guianensis* proved to be practical, robust and resilient systems, adapted to various farm conditions: from small-scale farming with very limited means to large commercial farms. They can be managed with very limited inputs (no herbicide, very low fertilisation, etc.) or at large scale (mechanical or chemical control of the cover crop), etc. The cropping intensity can be adapted to the

available space and technical know-how of the farmers, i.e., production of a cereal crop once every other year (the simplest to manage, with very low inputs), twice every three years or every year (the most complex to manage, requiring good mastery and inputs to compensate nutrients exported with the grains).

The high adaptability and practicality of these systems based on *S. guianensis* make them easily adopted by farmers. They represent 60 to 70 % of the CA/DMC systems extended in the middle-west of Madagascar, which disseminate rapidly (Figure 2). The possibility to re-introduce cereals in the systems thanks to *Striga* control has been identified as a major factor of CA/DMC adoption (Sorèze, 2010). Thus, with such systems, the main constraint to conventional agriculture in the area (*Striga*) becomes a major driving-force of dissemination of CA/DMC systems.

Table 1: *Arachis repens*, *Arachis pintoï* and *Stylosanthes guianensis* control *Striga*. First data indicates the average number of seeds or plants for the 0-20 cm soil horizon. Data in parentheses are the mean values of the transformed data (square root). Mean values in each column followed by the same letter(s) are not different in Fisher pairwise comparison (least significant difference, p-value = 0.05).

Cropping systems Maize +	Average number of *Striga* seeds (0-12 cm)	Average number of *Striga* seeds (24-36 cm)	Average number of parasite striga plants (0-12 and 24-36cm)
(CA) *Arachis repens*	0.5 (.000) a	0.0 (0.000) a	4.0 (1.414) ab
(CA) *Arachis pintoï*	1.0 (1.000) a	2.5 (1.118) ab	0.0 (0.000) a
(CA) *Stylosanthes*	1.5 (1.207) a	1.5 (1.207) ab	1.0 (0.707) a
(CA) *Brachiaria+Cajanus*	4.5 (1.914) ab	4.0 (1.984) bc	3.5 (1.725) bc
(CA) Cowpea	15.5 (3.845) c	1.5 (0.866) ab	3.0 (1.732) bc
(CT) Tillage	8.6 (2.792) bc	8.6 (2.939) c	8.4 (2.928) c
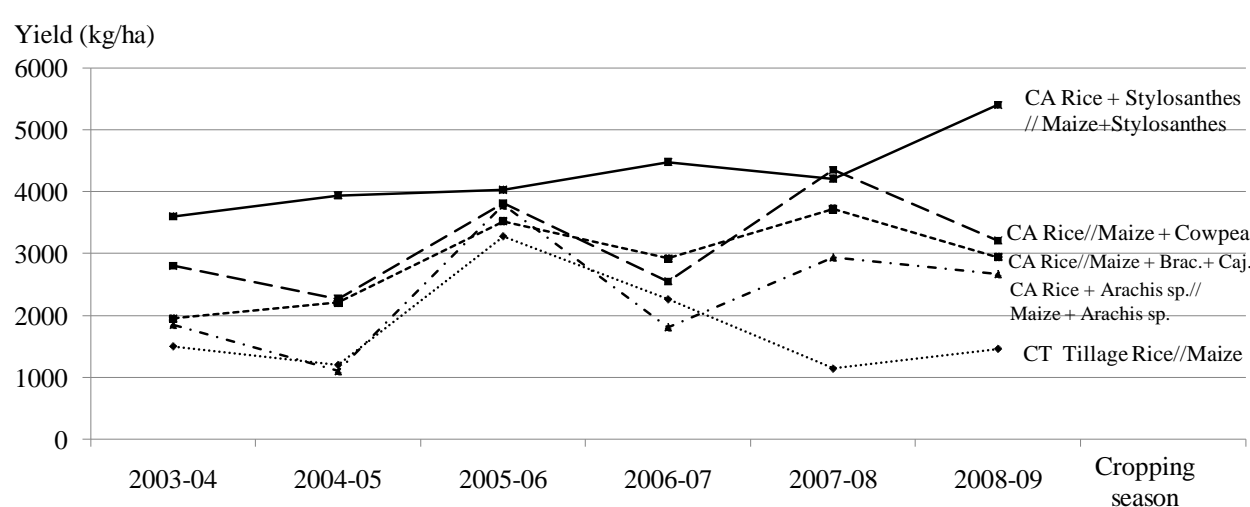
Figure 1: CA cropping systems based on *Stylosanthes guianensis* produce more and more regularly than any other system under high *Striga* pressure. Rice yield in kg/ha, for the recommended fertilization level (5t/ha manure + 50 N - 30 P – 40 P). "Rice//Maize" indicates a crop rotation with rice the first year, maize the following year. "+ " indicates an association crop + cover crop
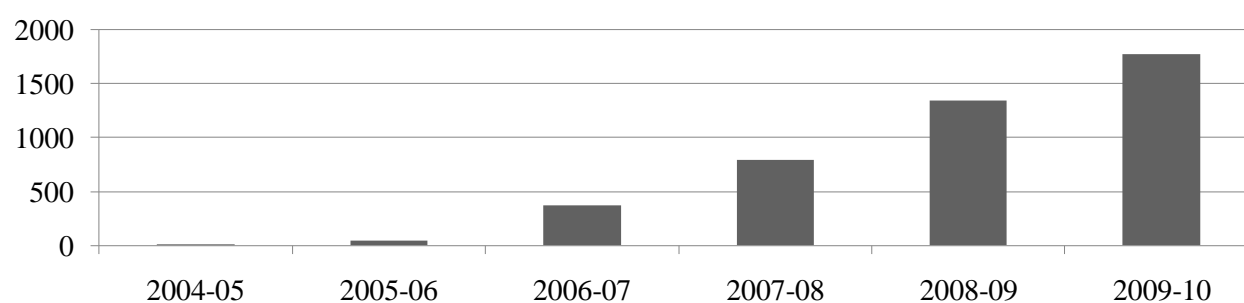
Figure 2: Extension of Direct seeded Mulch-based Cropping systems in the middle –West of Madagascar. Surface area in ha.

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Assessing the adaptation of arable farmers to climate change using DEA and bio-economic modelling

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Keywords: arable production, farm model, Data Envelopment Analysis, Netherlands

Introduction

Climate change (CC) affects agricultural production all over the world. Future farming systems are challenged to adapt to the changing socio-economic and bio-physical environment in order to remain competitive and to meet the increasing requirements for food and fibres. Identifying technological trends and exploring possible adaptation strategies is crucial for designing future farming systems and effective agricultural and environmental policies. Identification of current "best" farm practices and assessment of many alternative adaptation options is necessary for comprehensive explorations. The increased occurrence of extreme events, price volatility, variation among individual farms (in terms of available resources and objectives) and investment decisions should be also taken into account. The objective of this article is to assess the impact of CC on arable farming systems in Flevoland (the Netherlands) and to explore the adoption of different adaptation strategies. We applied Data Envelopment Analysis (DEA) that uses empirical data from individual farms to identify "best" current farm practices and derive relationships regarding current farm management. A Bio-economic farm model was used to simulate the behaviour of individual farmers and explore regional CC scenarios for 2050. Impacts of gradual CC change on crop yields but also the impacts of the increased occurrence of extreme events were taken into account. Adaptation options were identified in workshops while possible price changes were simulated.

Materials and Methods

The Farm System SIMulator (FSSIM) is a bio-economic farm model that simulates the farmer's behaviour within a scenario setting (Janssen et al., 2010). FSSIM consists of two main components: i) the agricultural management component (FSSIM-AM), where current and alternative production activities are quantified (with respect to inputs and outputs), and ii) the mathematical programming component (FSSIM-MP) that allocates optimally the available farm resources to the different activities by maximizing gross margin and by accounting implicitly through calibration for other objectives of the farmer. Given the optimum farm plans and the identified input-output relationships, a number of bio-physical and economic indicators are quantified. DEA was used to recover relationships between important inputs and outputs involved in arable farming in Flevoland. Inputs, outputs and farm resources of 85 representative, individual farms from the Farm Accounting Data Network were used. To assess current farm management, the 85 farms were ranked based on their capacity to convert inputs into outputs and the best farm practices were identified. To explore changes towards 2050, regional CC scenarios from the Royal Dutch Meteorological Institute (KNMI) were combined with socio-economic scenarios (Riedijk et al., 2007). A Bio-physical model (WOFOST) was applied to calculate the crop yields and their fertilizer inputs for the scenario of globalized economy with a simultaneous strong increase of temperature and atmospheric CO_2 concentration (A1-W) (Table 1) while a semi-quantitative and participatory approach (ACC) was used to quantify the impacts of extreme events (e.g. prolonged wet periods in spring, dry conditions in spring and summer) on crop yields and quality (Schaap et al., 2011). Relevant adaptation options for preventing yield losses due to increased occurrence of prolonged wet periods in spring and dry conditions in spring and summer were identified after interaction with stakeholders (Table 2). Given the current set of production options and the expected changes in the input-output relationships because of CC, the available agricultural activities of the future were generated. The partial equilibrium model CAPRI (Britz et al., 2007) was used to simulate prices for the future scenario, considering impacts of CC and technological developments on crop yields. FSSIM-MP was used to simulate each of the 85 individual arable farms and calculate farm performance in different model runs: 1) FSSIM was calibrated to current input-output levels (*Base*), 2) expected increase of yields in 2050 because of temperature rise, longer growing seasons and increased atmospheric CO_2 concentration, but also yield losses due to the increased occurrence of extreme events were taken into account (*Yield*), 3) relevant adaptation options presented in Table 2 and all their possible combinations, were evaluated (*Adapt*), 4) the impact of simulated prices for 2050 calculated by CAPRI were assessed (*Price*), 5) the consequences of increasing scale of production, through hiring land and labour, increasing capital inputs and extending livestock activities were evaluated (*Scale*). Specifications of model run 2 to 5 are additive (conditions of 2 are added to 3 etc.).

Results and Discussion

Results of DEA show that existing arable farming systems in Flevoland are very close to technical efficiency and only 5% of the existing farm practices can produce the same amount of outputs with fewer inputs. Moreover, simulations with FSSIM showed that almost 40% of the existing arable land in Flevoland is used in a way that profit is maximized. Yield changes due to temperature rise, and increased atmospheric CO_2 even with increased occurrence of extreme events (*Yield*) result in substantial increase in production of all main crops assuming an increase of fertilizer use (45%) (Figure 1). The increased occurrence of extreme events reduced yields, but these do not offset the projected increases due to gradual CC. Offering adaptation options in the *Adapt* scenario resulted in slightly higher gross margins (Figure 1a). The most preferable adaptation options are those of increasing sowing densities (43 % of the area), and soil organic matter content (19% of the area) because of the low investment requirements. GPS steering is selected for 8% of the land and by those farmers where capital is not the main limiting resource. The simulated price increase of main crop outputs is much lower than the price increase of inputs. As a result, in the *Price* model run the gross margin decreases substantially (Figure 1a). Total production of potatoes, onions and sugar beet decreases while the revenues from livestock activities and soft wheat production increases substantially. Input levels also decrease (Figure 1b). The percentage of land where GPS steering and automatic inflation is used increases (20 and 14%) because of lower capital requirements. Allowing for increasing scale of production by hiring more labour, renting more land and increasing capital inputs (*Scale*), improved the farm's gross margin. It can be concluded, that the A1-W scenario will result in reduction of farm income, decreased demand for labour and land, and diversification of production. CC will have a positive impact on crop yields in the Netherlands. However, the projected input/output price ratio has a larger impact. A combination of adaptation options like increasing sowing densities and soil organic matter content, and precision agriculture techniques were simulated to be adopted by farmers to avoid the impact of extreme events.

Table 1: Changes in crop yields and fertilizer use as calculated by WOFOST model for A1-W scenario (2050) versus current yields.

	Current Yield (tons/ha)	Yield change (%) Gradual CC	CC + extreme events	Fertilizer change (%)
Soft wheat	8	14	14	17
Potatoes	57	7	6	9
Sugar beet	74	30	30	37
Vegetables	66	20	8	25
Other arable crops		20	20	25

Table 2: The impacts of adaptation option on the inputs and outputs of an average year in 2050

	Additional input requirements				Beneficial effect on production				
	Capital (1000 €)	Mainten-ance (€)	Labour* (hrs/ha)	Energy (€/ha)	Potatoes (%)	Onions (%)	Sugar beet (%)	Wheat (%)	Other arable output (%)
More org. matter top soil	0		10	100	1.5%	1.5%	0.2%	0.2%	0.2%
GPS steering	20	300	10		5.2%				
Automatic inflation	20	300	8		3.3%				
Irrigation in Spring	25	400	40	100		6.5%			
Re-sowing	0.5		25	250		3.1%			
Higher sowing density	0.5					0.5%			
Irrigation in Summer	25		40	100		12.6%			

*Additional labour and energy requirements are calculated based on the farm specific areas of potatoes and onions.
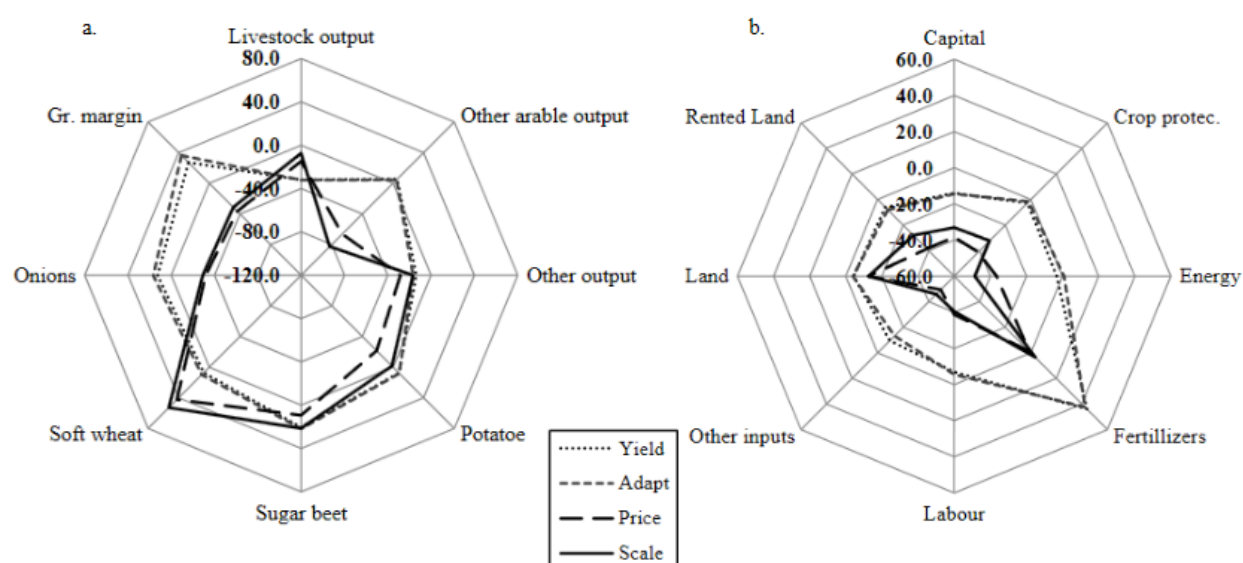
Figure 11. Average simulated levels (for 85 farms) of a) outputs and b) inputs in different model runs, expressed in percent change from Base model run.

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ADOPT: a tool for evaluating adoptability of agricultural innovations

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Keywords: Adoption, Diffusion, Prediction, Innovation, Technology

Introduction

A wealth of studies exist about the adoption of new practices and technologies in agriculture. But despite increasing demand from research, development and extension agencies for estimates of likely extent and rate of adoption there have been very limited attempts to distil this body of knowledge into a model to make quantitative predictions across a broad range of contexts. This paper reports on the development of ADOPT (Adoption and Diffusion Outcome Prediction Tool). The tool has been designed to: 1) predict an innovation's likely peak extent of adoption and likely time for reaching that peak; 2) encourage users to consider factors affecting adoption during project design; and 3) engage R, D and E managers and practitioners by making adoptability knowledge and considerations more transparent and understandable. The tool is structured around four aspects of adoption: 1) characteristics of the innovation, 2) characteristics of the population, 3) actual advantage of using the innovation, and 4) learning of the actual advantage of the innovation. The conceptual framework (see Figure 1) used for developing ADOPT is described followed by a summary of its application in project development.

Results and Discussion

Many large investments in R, D and E are made with good intentions but no strategy for understanding or predicting desired levels of adoption. Without this, R, D and E investment can result in poor investment returns and unsatisfactory or illusory on-ground benefits. There is demand from R, D and E funding agencies for ex-ante assessments of adoptability of technologies developed through proposed R, D and E investments. A tool based on established adoption and diffusion principles also offers a level of consistency when comparing forecasts of impacts across projects. In addition, a more complete understanding of the attributes of innovations and how they influence adoption and diffusion could allow the attributes of the innovation or the extension strategy to be modified so that levels of adoption and diffusion can be improved.

The Conceptual Framework

Pannell et al. (2006) published an exhaustive list of adoption influences, related not just to the innovation but also to the adopter or potential adopter, and provided a sound basis for the development of the conceptual framework which underpins the tool. The variables that were used were determined, in part, by the aims of the tool. These were that the tool should: not have high data demands, be simple enough to be readily used, encourage a process of learning, promote users' engagement with adoptability issues, encourage users to think more deeply about the definition and characterisation of both the innovation under consideration and the target population of potential adopters, and be based on principles well established in the literature. Variables were excluded from the framework if they lacked consistency, were likely to be too closely associated with variables already included in the model, were inconsistent in the direction of their relationship, had onerous data gathering requirements, or were not a strong influence on adoption. The conceptual framework hypothesises the interrelationships between the influences on adoption and diffusion that we have sought to develop for a targeted population and innovation.

The literature shows that influences on adoption can be conceptualised as related to either, 1) learning about relative advantage, or 2) the actual relative advantage. Similarly each influence can also be characterised as being related to the population or to the innovation. The conceptual framework at its simplest has four quadrants. The left-hand quadrants—*Population-specific influences on the ability to learn about the innovation* and the *Learnability characteristics of the innovation*—only influence the time taken to reach peak adoption; they do not influence the peak adoption level (Griliches 1957). The right-hand quadrants *Relative advantage for the population* and the *Relative advantage of the innovation* influence both the time taken to reach peak adoption and the peak adoption level. They influence the time taken to reach peak adoption in two ways (Griliches 1957) because *Relative Advantage* also affects the *Learning of Relative Advantage* node. This next section describes the variables used in the conceptual framework.

Learnability of the Population Quadrant

The top left quadrant is about considering the population-specific influences on the ability to learn about the innovation. Adoption involves a learning process where farmers gather information, reassess their beliefs about the innovation under consideration and review their decision whether to adopt or not. This quadrant is about learning of the benefits or the relative advantage provided by the innovation. The four variables contributing to this quadrant are: 1) *Group Involvement* which is aimed at uncovering whether the target population has group involvement relevant to the innovation, 2) *Advisory Support* which aims to uncover how much the target population uses advisors for advice relevant to the innovation, 3) *Relevant Existing Skills and Knowledge* which captures whether potential adopters will need to spend time developing new skills and knowledge before they can gain the expected advantage from the innovation, 4) *Awareness* which captures the target population's existing awareness of the innovation.

Learnability Characteristics of the Innovation Quadrant

This bottom left quadrant is about the innovation-specific influences on the ability to learn about the innovation. The three variables are: 1) *Trialability* which ascertains if small-scale trials are possible, 2) *Innovation Complexity* which identifies whether adopting the innovation requires complex changes to the farming system, 3) *Observability* which focuses on observation of the use of an innovation in a district.

Relative Advantage for the Population Quadrant

The top right quadrant is about establishing whether the advantage potentially gained from adopting the innovation is a sufficient motivation to shift the population towards adoption of the innovation. The six variables are: 1) *Enterprise Scale* which aims to define the number of farms among the target population that could benefit from adopting the innovation, 2) *Family succession/Management horizon* which aims to identify the planning horizon of farmers, 3) *Profit Orientation* which mediates the influence of other factors related to the expected profit to be gained from adopting the innovation, 4) *Environmental Orientation* which is intended to measure the proportion of

the population who are likely to pursue environmental payoffs as a primary goal of their management decisions, 5) *Risk Orientation* which seeks to incorporate the target population's level of risk aversion, 6) *Short-term constraints* which is aimed at determining the proportion of the target population that may be less willing to make an investment because of their short-term capital constraints.

Relative Advantage of the Innovation Quadrant

The bottom right quadrant deals with the advantages of the innovation. It is the part of *Relative Advantage* that is derived from the innovation's characteristics and not related to the population's perception of the innovation's characteristics. The eight variables are: 1) *Relative upfront cost of innovation* which aims to identify innovations requiring high upfront costs, 2) *Reversibility of innovation* which is designed to uncover whether it is possible to do something else at a later date, 3) *Profit Benefit* which is designed to gauge the profit to the overall farm business from the innovation, 4) *Time for Profit Benefit* which aims to capture the expected time delay before the profit benefits are achieved, 5) *Risk effect* which is aimed at identifying whether the innovation reduces the possibility of the farm business experiencing years of poor performance, 6) *Environmental Costs and Benefits* which aims to uncover the environmental costs and benefits of adopting the innovation, 7) *Time to Environmental Benefit* which aims to capture the expected time delay before the environmental benefits are achieved and mediates any environmental benefit identified by the previous variable, 8) *Ease and Convenience* which is aimed at identifying non-pecuniary costs and benefits.

The Tool

ADOPT aims to operationalise a conceptual framework based on well established adoption theory and literature (Lindner 1987; Feder and Umali 1993; Rogers 2003; Pannell, Marshall et al. 2006). The tool provides the interface for users to interact with the thinking and the concepts described in the framework. Users respond to questions for each of the twenty-one conceptual framework variables, which are then used in equations and functions that represent how we think the variables of the conceptual framework relate to each other, and the influence they have on adoption and diffusion. The outputs of the tool are years for *Time to Peak Adoption* and a percentage for the *Peak Adoption Level*. The expected diffusion of the innovation is displayed using an S-shaped cumulative adoption curve (see Griliches 1957; Marsh, Pannell et al. 2000). The tool is being tested for reliability and the results are also being validated with innovations that have known diffusion characteristics.
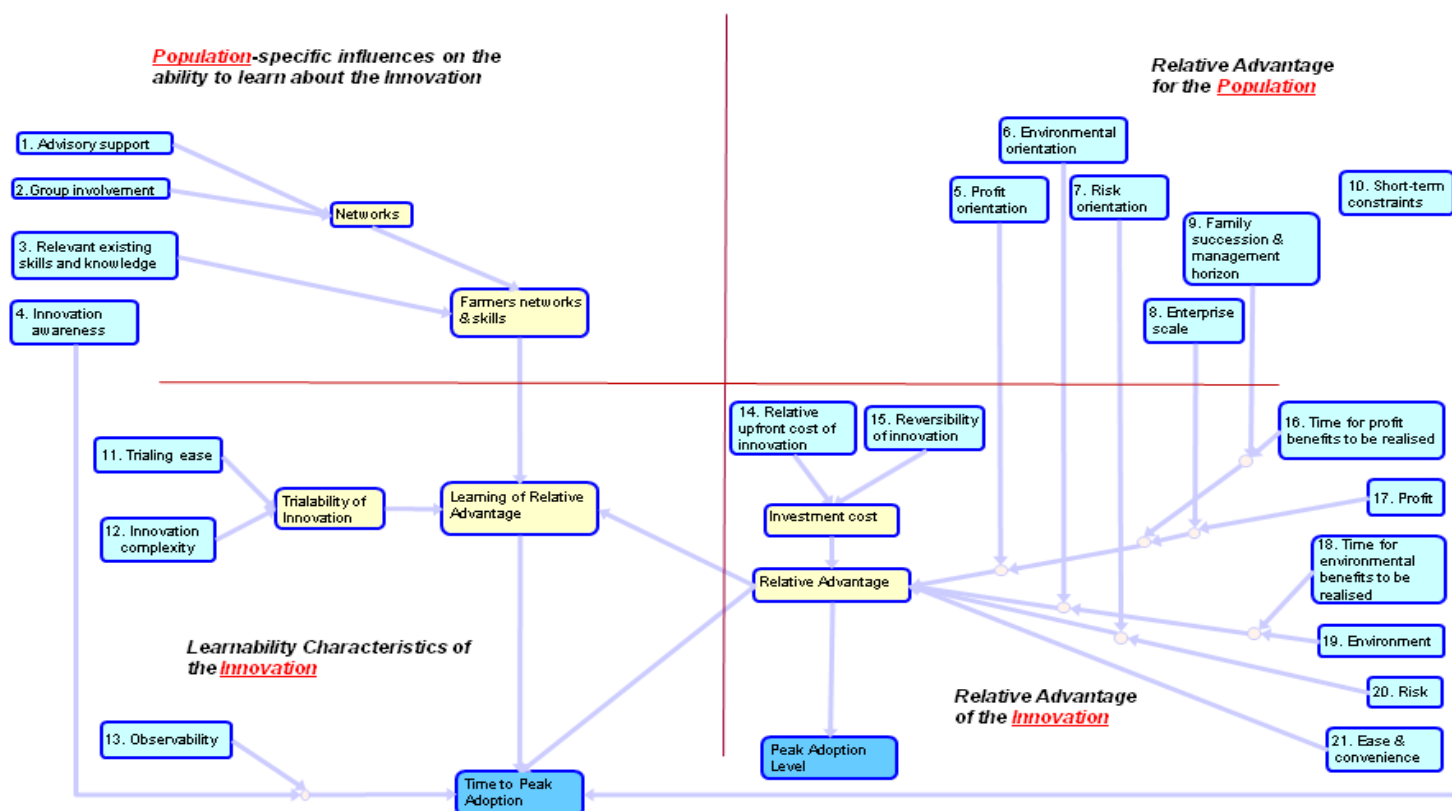
Figure 1: The Conceptual Framework

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Towards an efficient and useful crop disease model

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Keywords: systems modelling, crop sequences, break crops

Introduction

Biotic stresses in plants severely affect crop yields. In cereal cropping systems, common soil borne diseases such as Take all *Gaeumannomyces graminis tritici* and Rhizoctonia *Rhizoctonia solani (AG8)*, have historically been managed through crop rotation. The principle of crop rotation is simple, a non-host crop is grown to break the disease life cycle and ensure the subsequent cereal crop is grown in an agro-environment with a reduced likelihood of disease. In practice the management of crop disease through crop choice is more complex (Kirkegaard et al. 2008).

Kirkegaard et al 2008 points to the importance of multiple factors when attempting to quantify and understand the break crop effect. For a simple disease such as take-all this includes; the amount of inoculum present when a suitable host crop is planted; the presence or absence of a host for the disease during a non cereal phase; the climate that precipitates an increase in the disease and the climate that predisposes the cereal crop to a serious yield loss as a result of the disease. Incidence of other diseases like *Rhizoctonia solani* (AG8) is influenced by additional factors like the level of organic carbon and the presence or absence of suppressive organisms.

These factors mean that within any single experiment exploring the break crop effect on a subsequent cereal crop, there will be a litany of variables that could influence the outcome and many of these cannot be directly addressed within the confines of conventional experimental design. The break crop effect is complex and scientists have struggled to develop simple heuristics for farmers to follow regarding the decision about when to grow a break crop (Kirkegaard et al. 2008). I therefore explore the historical and future role of modeling diseases' incidence and severity in cereal crops.

The advent of crop simulation models

Most agronomy trials have similar limitations to crop sequencing trials, where they provide season and site specific insights into an agronomic process. In the last 30 years, crop simulation models and agricultural decision support systems have evolved to the point where they can add value and context to original trials. Crop simulation models historically have allowed researchers to explore the effects that crop choice has on factors such as nutrient cycling and soil water dynamics. Such models have been able to demonstrate the probability that growing lucerne prior to wheat would dry the soil to a level that affects the yield of the subsequent wheat crop (Dolling et al. 2005). These findings can be contextualized around nuances of soil type and annual amounts and distributions of rainfall and summarised into simple heuristics that farmers can use to make informed decisions about management. Cop simulation models can therefore be used to develop meaningful and useful management strategies for farmers that can then be adopted by industry. Given these evolutions in crop modeling, it is surprising that soil borne diseases have not been incorporated into modeling frameworks for cereals.

Empirical crop rotation models

Crop rotation models and crop sequencing models have been developed in agriculture. These have been developed at the farm scale (MIDAS) (Kingwell and Pannell 1987) and field scale to explore weed management (RIM) (Pannell et al. 2004). These examples are typical insofar as the break crop or rotation effects are expressed as a percentage improvement of cereal crop yield. This simple representation of the break crop effect means complex whole farm models can be optimized. They are mathematically tractable. These models do not capture the biophysical processes present and differ markedly from the approaches adopted in conventional crop simulation models. In effect, the biophysical processes of disease in these models are represented as a scalar that does not interact with other abiotic process.

A pathway to better rotation and disease models

There is an obvious departure in the modeling philosophies adopted by the crop simulation modelers and the empirical modelers of crop sequences at the farm scale. Crop simulation modellers have developed a complex model that captures thousands of interactions between biophysical variables. Conventional agronomic and crop physiology trials are used to inform each process in the model. These models do not optimize, the user simply compares the output from different sequence choices. In contrast, the simple frameworks used to evaluate crop sequencing decisions by the empirical modelers are mathematically elaborate, but require few parameters to run. These two philosophies provide an insight into why crop diseases and crop rotations have historically been modeled using empirical models rather than process based crop simulation models. Crop simulation models require relatively precise estimates of multiple state variables through time. In theory plant pathologists should be able to satisfy these requirements, but in reality they would struggle.

For example, diseases effects on crops are often described in terms of a damage score (e.g. Kirkegaard et al. 2000). They have not been described in terms of reductions in root growth and root exploration that would be required to parameterize a disease infected crop. Crop simulation models require a relatively precise estimate of the physiological changes a biotic stress invokes on the crop from a functional perspective. Oblique references to well accepted scoring mechanisms for disease severity are inadequate; they do not describe the change in crop function in sufficient detail. Crop simulation models operate on a daily time step and agronomic and pathological studies of crop diseases need to be conducted in a manner where the changes in the inoculum level of the pathogen can be differentiated with respect to time. For example, many studies note the importance that climate and season plays on the accrual of inoculum, and the response of the crop to the inoculum's level. Whilst rate processes are involved, relationships between inoculum levels at a given point in time cannot be related to incremental increases in thermal time or plant available water. In effect, the agronomic research into crop disease has not yielded information that can easily be incorporated into conventional crop simulation models. Recent changes in pathology, such as the advent of DNA screening of soils to replace soil bioassays (Ohel-Keller et al. 2008), mean that these problems could be overcome in the near future.

An interim solution?

While pathologists should aim to develop datasets that can be incorporated into crop models so biotic and abiotic stresses can be concurrently evaluated in a crop sequencing sense, systems models such as LUSO (Lawes and Renton 2010) can provide scientists with a sense of what may be possible. LUSO is a bioeconomic state and transition model where crop yield is influenced by the disease population and weed population. At this point in time it is static, but it can be modified using Markov Chains to explore stochastic processes. From a bioeconomic modeling perspective LUSO is complex. From a crop simulation modeler's perspective it is simple. It captures the two components of disease (incidence and severity) and can explore the influence of disease on a rotation sequence because disease populations (incidence) are modeled through time. The transition matrix for disease can be altered if insights about climate are brought into the model using Markov Chains. Initially these insights could be derived from historical experiments where the goal may be to parameterize a distribution of disease incidence, rather than try and parameterize absolute values for disease incidence. A similar approach could be taken when trying to model disease severity, as it affects the cereal crop.

As rotation experiments are conducted with detailed measurements of climate, water use, disease incidence and impacts on the crop, then these data could be synthesized and incorporated into existing crop simulation models. The model could then be used evaluate rotations that are biologically robust and economically efficient. This could lead to more resilient farming systems.

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Agroforestry adaptation and mitigation options for smallholder farmers vulnerable to climate change

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Keywords: agricultural management, carbon sequestration, crop sensitivity, production stability

Introduction

Smallholder systems in the tropics are expected to experience decreased precipitation and increased temperatures in future predicted climate scenarios, creating problems in production stability for many of the world's most economically unstable farmers. Research has shown that many crops are sensitive to changes in temperature and precipitation and have a narrow threshold for production success, such that threshold events that occur during key developmental stages of the crop can lead to production failure (Gregory and Ingram 2000). Agricultural vulnerabilities to climate change have been observed in a number of important crop species. Observations of rice production in the Philippines during an el Niño drought season showed decreases in seed weight and overall production (Lansigan et al. 2000), and studies of wheat have shown that heat pulses applied during anthesis reduced both grain number and weight (Wollenweber et al. 2003). Many agriculturally based economies have few other livelihood strategies (Altieri 1999), and small family farms have little financial? capital to invest in expensive adaptation strategies, thereby increasing the vulnerability of rural, agricultural communities to a changing environment (Tilman et al. 2002). Management options that reduce the risks of climate variability to production and increase resilience for small farmers should be actively documented and promoted. One such strategy is the implementation of agroforestry systems which can help systems adapt to greater climate variability as well as mitigate greenhouse gases through sequestration. By improving production and financial stability, agroforestry systems provide many benefits for smallholder farmers vulnerable to the effects of climate change and may prove to be especially important in rural, agriculturally based economies with few other livelihood options.

Materials and Methods

A survey of the agroforestry and climate change literature was conducted on the Web of Science from September to November 2010. Subsequent review of the collected articles (search key "agrofor* AND climate change" = 573 articles) revealed two main categories of how the implementation of agroforestry systems can benefit smallholder farmers facing climate change. The first category was examples of agroforestry implementation as a climate change adaptation tool to protect against changing temperature and precipitation regimes. The second category was of the potential greenhouse gas mitigation benefits that could be achieved with implementing agroforestry systems into present agricultural systems. Methods of agricultural adaptation to climate change were documented across scales of climate stress and scales of the farming operation.

Results and Discussion

Agroforestry systems are a key type of agriculture that allow for a high level of progressive adaptation from simply increasing structural and temporal diversity of the production system to selling ecosystem services for increased economic diversification. There are many types of agroforestry systems that are employed in a number of regions of the world and at different levels of complexity (Montagnini and Nair 2004). Silvoculture systems are agricultural systems where trees are planted within a pasture field to provide shade to pasture animals as well as provide food and fuel for the farmer. Another type of agroforestry within agriculture is the intercropping of trees within row-crops systems to provide windbreaks/shelterbelts for the crops and increase the soil stability of the region. Mixed-use forests are a type of agroforestry that allows for multiple crops to be produced in a small physical area, increasing the temporal and structural diversity of the ecosystem, and the net benefits or negatives are largely based on the design of the system. The range of agroforestry systems possible can potentially allow for many different types of adaptation to occur under a range of conditions (Schoeneberger 2009, Figure 1). However, levels of co-benefits depend on the amount of diversity integrated into the system, as more diversity within the agroforestry system will lead to greater co-benefits (Figure 2).

Types of Agroforestry	
Alley cropping	Rows of trees planted at wide spacings while growing annual crops in the alleyways
Windbreaks (Shelterbelts)	Linear plantings of trees and shrubs to form barriers to reduce windspeed
Silvopasture	Trees combined with pasture and livestock production
Forest Farming	Natural stands whose canopies have been manipulated in order to grow high value crops in the understory

Figure 1. Examples of different agroforestry systems – alley cropping, windbreaks, silvopastures, traditional forest farming

Figure 2. Photographic representation of the variety of diversification that may exist in one example crop –the coffee agroforestry system. The system ranges from traditional agroforestry with substantial structural diversity (left), to partially shaded systems in the commercial polyculture (middle two photos), to an intensively managed system with no shade (right).

As a method of adapting agriculture to climate change, agroforestry systems have been shown to increase on-farm production resilience to climate variability by buffering crops from the effects of temperature and precipitation variation as well as strong winds associated with storms. In coffee agroforestry systems, crops grown under heavy shade (60-80%) were kept 2-3°C cooler during the hottest times of the day than crops under light shading (10-30%) (Lin 2007) and lost 41% less water through soil evaporation and 32% less water through plant transpiration (Lin 2010). Windbreaks planted in citrus groves have been shown to reduce wind speeds by 80-95%, reducing wind damage up to two times the distance of windbreak height (Tamang et al. 2010). Agroforestry systems also tend to have increased crop diversity within the agroforestry systems such that a greater diversity in food, fuel, and fodder items is produced for the smallholder farmer (Méndez et al. 2010). There are other naturally occurring co-benefits that occur in agroforestry systems including enhanced nutrient cycling, integrated pest management, and increased resistance to diseases, which will additionally protect farm production (Beer 1998).

Creating agroforestry systems that reduce the outward flux of CO_2, N_2O, and CH_4 through better management will contribute significantly to reducing GHG emissions, and mitigation studies have identified agroforestry systems as a potential long term GHG sink (Verchot et al. 2006). The carbon sequestration potential of agroforestry systems is estimated to be between 12 and 228 Mg C ha^{-1} with a median value of 95 Mg C ha^{-1} (Albrecht and Kandji 2003). For smallholder agroforestry in the tropics, potential carbon sequestration rates range from 1.5-3.5 Mg C ha^{-1} yr^{-1} (Montagnini and Nair 2004). Selling carbon credits may provide another source of income for farmers, diversifying their agricultural portfolio further. Policy analysis has shown that at prices of $100 per MgC, carbon sequestration in agroforestry systems would have the potential to raise per capita incomes of farmers by up to 15% (Antle et al. 2007). For these reasons, agroforestry systems may prove to be very useful component of agricultural adaptation as both an economically feasible adaptation strategy for smallholder farmers vulnerable to climate change as well as a profitable greenhouse gas mitigation opportunity.

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Can corporate farms provide new pathways to improve the profitability and productivity of family farms?

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Keywords: innovation adoption, family farms, corporate, technical change.

Introduction

Family farms are the backbone of the broadacre agriculture sector in Australia. However, the profitability and technical efficiency gap between top performing farms and the average farm is expanding, largely due to management and capital constraints that are limiting adoption of existing technologies (ABARE, 2010; Hughes et al., 2011). These trends suggest that relative to the average family farm, "leading" broadacre farms are adopting, at a faster rate, new organizational and technical innovations to enhance productivity and profitability. The majority of leading farms are owned and operated by family entities; however, corporate farms and other agribusiness companies are increasingly appearing at the forefront of innovation adoption. The diversity of business models adopted by corporate entities introduces new technical, organizational and managerial innovations with the potential to increase the profitability and productivity of family farms – particularly if new innovations are blended with the inherent advantages of family farm enterprises. In this paper we define and characterise the existing range of corporate farm business models operating in the Australian broadacre sector. The key technical, organisational and managerial innovations adopted by corporate entities are identified, and examples of each model and its potential benefits are provided. A new hybrid family farm business model is analysed and the implications are discussed.

Materials and Methods

A desktop review and extensive interviews with various agribusiness leaders were undertaken to identify, define and characterise firms operating corporate farm businesses throughout Australia.

To evaluate the corporate business models, a conceptual framework based on Pannell et al. (2006) and Hughes et al. (2011) was developed linking critical capital (human, financial and natural) with technical change (innovation adoption), technical efficiency (innovation diffusion) and production frontier progression. To gain insights into how the corporate entities differ in innovation adoption relative to traditional family farms, structured interviews were conducted with a number of executives and farm management personnel from corporate farms representing the range of business models. Responses to the interview questions were summarised and the key innovations were distilled and highlighted.

Results and Discussion

Six unique corporate farm business models were identified in the broadacre sector of Australia (Table 1): 1) *localised hub*; 2) *multiple hub and spoke*; 3) *crop co-production*; 4) *land transformation*; 5) *contract farming* and 6) *management services*. The *localised hub* model optimises human, financial and natural capital at a local- or district-level by maximising utilisation rates of machinery, labour and infrastructure. The scale of operations and associated efficiencies also create opportunities for specialized and highly skilled labour. Such a hub is usually developed via the purchase of a number of existing contiguous or nearby properties, which are then managed as one unit or hub. The *multiple hub and spoke* model mimics the *localised hub* model at a local level, but it has greater human and financial capital requirements at an organizational level due to the scale of operations across multiple hubs, and the additional complexity generated by the replication of such hubs across diverse geographical locations, agricultural products and production systems. This model has more intensive critical capital requirements as a result of the broader scope of operations, but this diversity can also reduce the business's exposure to production and price risk. The critical capital requirements make it difficult to emulate by most individual family farms. Farm alliances or similar forms of collaboration between geographically diverse farmers could be an alternative.

Table 1. Business models and examples of corporate farm models operating in Australia

Model	Examples
Localised hub	• **Cubbie Group Ltd.** – 93,000 ha aggregation and the largest cotton producers in Australia.
Multiple hub and spoke	• **PrimeAg Pty. Ltd.** - Own over 31,000 ha of cropping land, 6,000 ha of grazing land and 67,000 ML of water across five hubs in the northern grain region.
Crop co-production	• **Australian Agricultural Contracting Ltd.** – In 2010, approximately 400,000 tonnes of wheat, barley and canola were contracted with 200 farmers across WA, SA, VIC and NSW.
Land transformation	• **Greenfield Pty. Ltd.** – Purchased and undertaken a pasture improvement programme across 25,000 ha of dryland farmland in NZ.
Contract farming	• **Corporate Farming Australia (Glencore Grains Australia)** – Lease and own dryland and irrigated crop land across Australia.
Management services	• **Growth Farms Australia** – Manage over 40 properties throughout VIC and NSW from beef and sheep to dryland and irrigated cropping enterprises.

The *crop co-production* model is different from the previous two models as contractual relationships are established with existing farmers allowing them to offset production risk via a payment transfer system. In essence, variable costs of production (e.g. fertilizer, seed and chemicals) are paid for by investors, with the farmer supplying labour, machinery and expertise to plant, manage and harvest the crop. Any profits resulting from the crop are then shared between the farmers and investors based on contract specifications. Such a model reduces downside risk but constrains upside returns (for farmers) and could be attractive to farmers with a high debt load or employed strategically on a short-term basis (e.g., by farmers wanting to trial a new innovation within a lower risk setting).

There are limited examples of corporate entities utilising a *land transformation* model. This model is highly situational and quite different in scope to the other models described. It is reliant on a risky but potentially high return scenario in which a largely untried and non-adopted technical innovation is applied to acquired farmland to dramatically enhance productivity and profitability. Such a model can only exist and be viable within a limited context, especially when there are widespread and significant barriers to adoption of a particular innovation within a region. The innovation is usually characterised by high skill, knowledge and analytical requirements, and high upfront

and reversibility costs. Such barriers can often be significant hurdles that can potentially be overcome by a corporate entity due to a superior combination of human, financial and natural capital.

The *contract farming* model is not new; however its use by large corporate entities in broadacre farming is a recent innovation. A number of sub-categories exist within this model type ranging from contract grazing services to contract cropping arrangements. These require varying levels of farmer capital and input into decision-making, depending on the agreed contractual arrangement. Such contractual arrangements have a range of benefits for the farm owner similar to the other models, including reducing production risk, specialization, allowing enterprise diversification with the outsourcing of non-core activities, and providing flexibility for stage of life decision-making considerations. Finally, the *management services* model is designed to assist farms requiring management support (e.g. absent landowners or farmers considering a transition to retirement) by providing specific management services via a profit-sharing arrangement.

Some attributes of various corporate farm models offer clear advantages over traditional family farm models. Yet, corporate entities also face unique challenges relative to traditional family farms. For example, the benefits derived from specialization and organizational efficiency are reduced if they can only be utilized seasonally or if unpredictable production shocks impact output; and if wage employees have skewed incentive signals which lead to inefficient work practices compared to family owner labour (Allen and Lueck, 1998). Further, the efficient allocation of capital and associated profit requirement of corporate entities can be both an opportunity and constraint that may adversely impact long-term investment in the sector due to competing and attractive investment options in other asset classes. The ability of traditional family farms to better manage and overcome these challenges explains why the broadacre sector is still predominantly a family affair. However, a hybrid approach that adapts some of the beneficial features of corporate farm models into a family farm-based business may allow such businesses to gain sufficient human, financial and natural capital to increase their rate of technical change and profitability within an increasingly capital-intensive and complex operating environment.

An example of a hybrid approach is a business model developed by Collaborative Farming Australia. This model involves two or more family farms forming a joint-venture arrangement that involves leasing their land to a new company that they jointly manage under a board of management. This model enhances the three critical forms of capital of the farm business, optimizes scale efficiencies and facilitates the process of labour specialization. However, the model also introduces new risks and challenges the existing notion of what it means to own and manage a family farm as decision-making and control are shared amongst joint venture partners. At present there is one case study of this hybrid approach in the northern Mallee region of South Australia. This hybrid approach has resulted in the use of no-tillage farming systems and other technology where adoption constraints had previously prevented their use. It has also led to increased labour specialization, the contracting of agronomic expertise, exclusive and efficient grain freight arrangements, and a range of other benefits related to economies of scale (M. Krause 2011, pers. comm., 6 April). These types of innovative corporate and hybrid arrangements and structures are increasingly emerging within broadacre agriculture in Australia and there is growing evidence of their potential impact on land management and technical change. Further research is being conducted to identify which models or components are most applicable and in what circumstances they offer the greatest potential for increased productivity and benefits to family farms.

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A more predictable approach to sequestration of organic carbon in soil

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Introduction

Stores of soil carbon have been declining globally with catastrophic consequences for sustainable systems of land use, especially in food production. Efforts to resolve the declining levels of soil organic carbon have focussed on various systems of conservation and "organic" amendments. These approaches have unpredictable outcomes (Goaverts et al. 2007), and the reasons for the lack of success are unknown. The notion that much stored organic carbon is protected within soil aggregates is now largely accepted (Kogel-Knabner et al. 2008). According to the hierarchical model, aggregates are formed from the combined action of organic materials, hyphae and fine roots of plants (Tisdall and Oades 1982). Accordingly, adding plants, increasing organic matter or activating fungal hyphae alone is unlikely to enhance soil aggregation and levels of organic carbon will remain unchanged. The stabilised organic materials largely appear to be humic substances, which are recalcitrant to enzymes because they are held in protected and anoxic locations. Thus addition of organic matter leads to increased oxidation and rates of breakdown in the amended soil because the carbon is not protected. Similarly, plant remains including roots are located in the oxic zones. The action of oxygen and lignin degrading enzymes remove these potentially recalcitrant materials from the soil (Rasse et al. 2006). The specific group(s) of fungi that aggregate soil is also unclear. While arbuscular mycorrhizal (AM) fungi are by far the most abundant group of fungi in soil, and their hyphal length correlates with aggregation of soil (Wilson 2009), AM fungi probably do not contribute to the pool of polyphenolic and polyaromatic carbon compounds that constitute the humic fraction. Thus other fungi may interact with AM fungi providing the organic carbon that is then bound by hyphae of AM fungi to form aggregates with cores containing recalcitrant organic carbon. The biochemistry of most fungi is poorly understood. The most abundant polyaromatic compound formed by fungi (and other microbes) that also results in humus (Koroleva et al 2007) in melanin. Thus melanitic fungi are likely to contribute to the pool of humus, though other materials may also be important. Finally, saprotrophic fungi commonly have very short periods of activity in soil. Fungi most likely to contribute carbon are thus likely to be linked to an ongoing source of energy, and this group includes root endophytes. The research summarised here experimentally tests whether aggregation is associated with the action of three components: organic matter, plants and fungi, and whether stores of organic carbon can be increased in soil by the contributions from arbuscular mycorrhizal and melanitic endophytic fungi.

Materials and Methods

AM fungi: Mine spoil (0% OC, pH 9) was amended with compost from zero to 18% by weight and placed in split plastic pipe 30 cm high. Tubes were planted with either no seedlings or seedlings of two shrubs and one grass either uninoculated or inoculated with eight AM fungi. Phosphorus was added to non-AM plant to control for the presence of mycorrhizas. All treatments were watered regularly and held in a controlled atmosphere growth room for six months. Soil aggregation (Mean Weight Diameter, MWD) was quantified and content of organic carbon (OC) in each fraction determined at harvest.

Melanitic endophytic fungi: Farm soil (6% OC, pH 6.2) was placed in rectangular pots with two compartments separated by a 53 μm grid that allowed penetration of hyphae but not roots. Seedlings of subterranean clover inoculated with one of 26 melanitic endophytic fungi were grown in the plant compartment for 14 weeks. Soil aggregation (MWD) was quantified and content of organic carbon in each fraction of the hyphal chamber determined at harvest.

Results and Discussion

AM fungi: MWD increased with increasing compost amendment of mine spoil and declined with depth. Presence of plants significantly reduced aggregation. Presence of AM fungi on the plants increased aggregation at low compost but not high compost (Table 1). The proportion of organic carbon in spoil was similar in composted and composted planted treatments. The presence of AM fungi on plants increased OC by approximately 5% in all composted treatments. AM fungi disproportionately increased the quantity of large aggregates. However, OC was stored in all size classes. Different plant species marginally influenced aggregation but not carbon sequestration (data not shown). In addition, presence of plants and AM fungi returned both pH and CEC of composted spoil to starting quantities.

Table 1. Mean Weight Diameter of compost amended mine spoil in which no plants, plant and plants with arbuscular mycorrhizal fungi were grown for 6 months.

Added compost	0	6%	12%	18%
Control	480 [a]	610 [a]	960 [b]	1060 [b]
Planted	490 [a]	610 [a]	730 [a]	760 [a]
Plant + AMF	470 [a]	730 [b]	970 [b]	870 [a]

Melanitic endophytic fungi: two out of 26 isolates marginally increased aggregation of a carbon rich soil. Approximately half significantly increased stores of OC, up to 23% in the case of isolate 367 (Table 2). Many of the fungi also increased the pH of the soil.

Table 2. MWD and OC% of soil in which selected melanitic endophytic fungi were grown for 14 weeks.

Fungus	MWD	%OC
Nil	990 [a]	6.4 [a]
Isolate 222	1030 [b]	7 [b]
Isolate 274	1020 [b]	7.5 [b]
Isolate 367	1010 [a]	7.9 [b]

Overall, AM fungi significantly increased aggregation only if adequate organic matter was present in the soil. In a field study (Wilson 2009), OC and age of field were correlated, and the contribution of AM fungi to OC assumed from data on GRSP. In this study, AM fungi increased organic carbon to a minor extent. Two melanitic endophytic fungi marginally increased aggregation yet some 10 isolates significantly increased stores of OC in an already carbon-rich soil. The data indicate the two groups of fungi have different and complementary roles in the development of soil aggregates and carbon pools.

This new model requires testing under a range of experimental and field conditions. If supported, the use of compost, and two different types of fungi open up completely new ways to ensure soils can be used more sustainably. The new model indicates approaches that will enable the restoration of degraded soils and methods to utilise waste materials in developing new plant growth substrates. In addition, the new model offers a clear explanation for the lack of predictability in previous attempts to restore soil by using compost, green manure crops or no-till agriculture. Profound changes in productivity are essential if the increasing world population is to be fed. Increased sequestration of organic carbon in soil will contribute to meeting this need.

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Identifying the fit for perennial forage options in a crop-livestock system: use of a whole-farm optimization model

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Keywords: whole-farm economics, MIDAS, forage shrubs, saltbush, perennials

Introduction

Considerable extension, research and incentives have been invested in developing the role of perennial forage shrub species for the low rainfall crop-livestock zone of southern Australia (de Koning and Milthorpe 2008). Their use is primarily to help fill the major autumn feed gap, resulting from the decline in feed value of post-harvest crop residue, and prior to the opening rains that initiate annual pasture growth. In addition, deep-rooted, perennial plants such as shrubs promote more efficient water use and year-round ground cover compared with annual crops and pastures (Norman et al. 2008; Harris 2010), as well as extra shade and shelter for livestock. The fact that most shrubs investigated are Australian native species, which are especially well adapted to the environmental challenges of this land, further contributes to improved environmental resilience by allowing the system to better cope with extremes such as drought (Revell et al. 2008).

In the low and highly variable rainfall (250 - 350mm) Mallee region of southern Australia livestock numbers have greatly declined, although the majority of farms still retain a sheep enterprise with 60-80% of the farm area typically dedicated to crops. The use of perennial shrubs in mixed cropping and livestock systems is seen as a way to diversify the system and make it more sustainable. Existing forage shrub plantings are predominantly commercially available types of Old Man Saltbush (*Atriplex nummularia*), but the proportion of farms that plant forage shrubs, and the extent of those plantings remains low (Llewellyn et al. 2010). This may be because currently available commercial forage shrubs tend to have low quality and production (Norman et al. 2008). Nevertheless, efforts to identify and develop new saltbush types and forage shrub options with improved production and feed quality characteristics is showing promise and may offer the opportunity for greater benefits than existing options (Emms et al. 2006).

Research is also being undertaken to develop a whole-farm bio-economic optimization model to represent the South Australian/Victorian Mallee farming system as part of the EverCrop® project. Based on Revell et al. (2008), the project aims to identify the key drivers of the profitability and placement of forage shrubs and other perennial options within a mixed Mallee farming system and the likely impact of new improvements to these options. This paper reports on how the whole-farm bio-economic model has been used to investigate the impact of different shrub production and nutritive levels on the relative profitability of shrubs in a Mallee farming system.

Materials and Methods

The Mallee MIDAS (Model of an Integrated Dryland Agricultural System) is a bio-economic optimization model (based on Morrison et al 1986 and Kingwell and Pannell 1987) that represents the 250 - 350mm rainfall zone of the South Australian and Victorian Mallee. MIDAS was chosen because its complex framework allows for the integration of biological, physical and financial information relevant to whole-farm economics. The model uses linear programming (LP) to select a farm strategy that maximizes equilibrium farm profit in the medium term. Its detailed representation of the farming system allows us to assess the economic trade-offs of including a new farming option in the system.

The Mallee MIDAS includes seven main land management units (LMU) for the typical 3,000 ha Mallee farm on the common dune-swale land system. These LMUs incorporate areas with poor crop production potential due to high stone content, infertile deep sands, and chemically-constrained heavier-textured soils where dry springs commonly lead to crop failure and a range of soils with higher production potential, including sandy loams as the most common soil. Crops grown in the region and represented in MIDAS include: wheat, barley, triticale, canola, and a range of legume crops, with fallow also an option. Merino and crossbred sheep are the dominant livestock, which can be sold or reared for wool and meat. The animals are grazed mainly on annual medic pasture, and forage shrubs have been added with a pasture understorey as part of the forage shrub block (Norman et al. 2008).

The model also includes in its structure: over 200 crop-pasture rotations and their inter-year biological effects (e.g. plant nutrition and disease effects); over 80 sheep classes with different management options per class; 10 pasture growing periods as well as major feeding periods within the year; a range of feeding options; several grain, stubble and wool quality classes; deferment of pasture grazing from one time period to the next, allowing for degeneration in terms of both quality and quantity of feed; soil nitrogen balance and fertilization options; chemical control of weeds, pests and diseases; groundwater recharge; loss of topsoil by erosion; machinery specifications; labour requirements; and farm finance. Model outputs include: crop-pasture rotations and enterprise areas for each LMU; sheep stocking rates and flock structure; supplementary feed requirements; fertilizer rates; volume of groundwater recharge and top soil loss by erosion; expected annual whole-farm profit; and shadow prices and costs (which indicate the relative value of alternative activities).

Results and Discussion

The Mallee MIDAS model is used to investigate the economic consequences of including a forage shrub-based system in a typical Mallee farm. Forage shrubs are generally being assessed for their ease and cost of establishment, growth performance, nutritive value for livestock, and overall effect on the profitability of the farming system. Previous studies on the fit of shrubs in dryland farming systems in Western Australia (e.g. Bennett et al. 2004; Bathgate et al. 2007; Monjardino et al. 2010) suggest that their profitability depends critically on the value of foregone production (opportunity cost), on the relative nutritive value of all the fodder available (i.e. pasture, stubbles, supplementary grain and hay, as well as shrubs), and to a lesser extent on production levels and the cost of shrub establishment. Mallee MIDAS results confirm these findings.

The Mallee MIDAS model is further used here to compare forage shrubs with production and nutritive value similar to existing stands (Llewellyn et al. 2010), with potential new/improved species and mixes displaying higher production and nutritive value. The results show that having higher performing shrubs on the farm has a significantly positive impact on farm profit, through increasing the profitability of areas with marginal soil. Overall, shrubs provide a valuable feed source during the time of the year when production and quality are low

(i.e. late summer/autumn). Thus shrubs enable livestock to be carried over the dry months for a lower cost compared with grain supplements. Consequently, farmers are able to either increase stocking of the farm or reduce supplementary feed costs, or both. This increased flexibility helps spread the risk in a particularly volatile environment.

In conclusion, the use of the Mallee MIDAS model has indicated the potential for profitable incorporation of forage shrubs in the system. However, at the base level of production and nutritive value, profitability was relatively low, consistent with the relatively low levels of adoption currently found. Improved performance of shrub-based forage blocks is shown to substantially increase profitability. This suggests that current work to develop improved shrub types has the potential to lead to greater incorporation of forage shrubs in mixed cropping and livestock systems. The likely fit for forage shrubs is on the poorest crop-yielding soils of the farm, where forage shrubs perform better than pasture or other crops, thus making them more economically viable. As the typical Mallee farming system is characterized by highly variable soil types and production potentials, we expect that the relative advantage of investing in forage shrubs will be greater for some growers with larger areas of poor cropping soils. These early findings further support the case for forage shrub research and development aimed at developing cultivar options with improved performance on soils poorly suited to cropping.

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The sustainable intensification of maize-legume farming systems in eastern and southern Africa (SIMLESA) program

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Keywords: food security, poverty, conservation agriculture, household livelihoods, resilience

Introduction

A quarter of the 925 million-undernourished people around the globe live in Sub-Saharan Africa (http://www.fao.org/hunger/) where maize is traditionally a major component of people's diet. Due to its high potential productivity and present large yield gaps (http://labs.harvestchoice.org), maize is a key strategic crop to mitigate recurring hunger and poverty. Maize is grown by resource-poor farmers using traditional tillage methods, with little or no use of fertilisers, using poor seed quality or poorly cultivars, and limited weeding, in highly variable climates, and on highly degraded soils. It is critical then that (i) in the short to medium terms, we work to reduce uncertainties and reduce food shortages by increasing the productivity of food grain crops and improving the resilience of maize-legume farming systems; while (ii) in the medium to longer terms, we develop more sustainable and diversified farming systems which are responsive to expected changes in climates and markets. Due to these multiple constraints and complex systems the task is challenging, and no silver bullet should be expected to be able to create an African "Green Revolution". Instead, we require human, social and policy transformations together with the right combination of practices and technologies; while our paradigm should be doing more with more, in contrast to the present low input low output system. The SIMLESA project was developed in close consultation with African stakeholders to specifically address regional agricultural development priorities. In SIMLESA we aim at increasing farm-level food security and productivity, in the context of climate risk and change. We are promoting more resilient, profitable and sustainable practices and farming systems and expect to impact directly on ca. 500,000 rural households over the next ten years, across five countries i.e. Ethiopia, Kenya, Tanzania, Malawi, and Mozambique. SIMLESA integrates five objectives, (i) to characterize maize-legume production and input and output value chain systems and impact pathways, and identify broad systemic constraints and options for field testing; (ii) test and develop productive, resilient and sustainable smallholder maize-legume cropping systems for local scaling out; (iii) increase the range of maize and legume varieties available for smallholders through regional testing and release, and availability of performance data; (iv) support the development of regional and local innovation platforms; and (v) support capacity building to increase the efficiency of agricultural research today and in the future. This paper describes the work framework and achievements made during the first year of the project.

Materials and Methods

A four year ACIAR funded project (AU$20M) was designed in a collaboration between ACIAR, CIMMYT, ICRISAT, the University of Queensland, DEEDI, Murdoch University, the National Research and Extension Systems (NARES) in Ethiopia (EIAR), Kenya (KARI), Malawi (DARS), Mozambique (IIAM), and Tanzania (ARS), South Africa (ARC), and the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA). The overall project oversight is driven by an independent Steering Committee, with co-chairs from Africa and Australia. The participatory nature of the program aims to achieve change by encouraging and supporting farmer's experimentation, farmer-to-farmer exchanges across the targeted regions, with potential spill-over to neighbouring countries (Figure 1), and developing skills and local capacity for the future. Key targeted regions include those that presently face high levels of food insecurity (Figure 2), i.e., Bako, Awassa, and Melkassa in Ethiopia; Kakamega and Embu in Kenya; Ilonga and Karatu in Tanzania; Kasungu and Balaka in Malawi; and Angoina and Sussudenga in Mozambique. In addition, spill-overs are aimed across regions having similar climates in neighbouring countries. SIMLESA's supporting activities include: capacity building by providing MSc and PhD training to African team members; training of researchers and extension officers on principles of conservation agriculture, climate risk management, cropping systems modelling tools, MandE, impact pathways and research and extension methods; on- station researcher-managed trials; exploratory and demonstration on-farm trials; varietal improvement and accelerated release; innovation platforms that bring together farmers, researchers, extension and marketing agents; community awareness meetings to discuss local project advances, problems and feasible solutions; household baseline surveys to help describe the socio-economic diversity across the targeted sites and regions; and field and household modelling to ex-ante and ex-post explore impacts and opportunities from systems change at the field and household level.
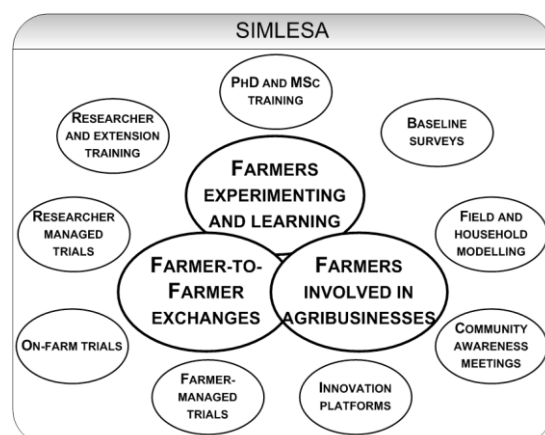
Figure 1. SIMLESA's key targets and supporting activities.

First year project achievements
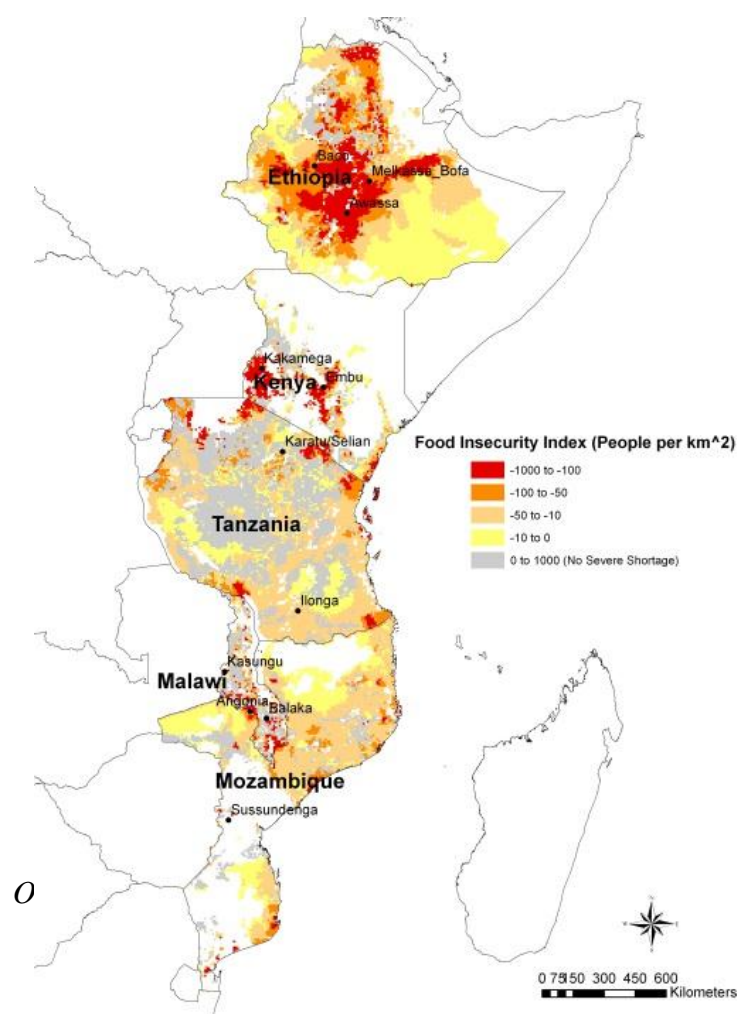
Figure 2. Hotspots for food insecurity across the five SIMLESA countries, indicating the main sites for SIMLESA activity (Potgieter et al., 2010) for the source of this map go to: http://apsrunet.apsim.info/simlesa/

Achievements since the March 2010 start up are described in Table 1 and include:

Socio-economics
The completion of a household survey over 3550 smallholder farms across the five participating countries. This massive data set will be used to develop household typologies to help us (i) describe the socio-economic diversity of smallholder farms across the five countries using a single homogeneous data set; (ii) develop household models to help explore the ex-ante impacts from alternative technological innovations or resource allocations for different farm household types with the aim of increasing farmers profits and livelihoods, while minimising risks and vulnerabilities. Local innovation platforms have been initiated in the five countries with promising results due to the participation of various players within the various value chains.

Thirteen on-research station and 215 on-farm exploratory trials were conducted over the three cropping seasons since the start of the project. These trials aimed to primarily test "best-fit" technological innovations across the different farming systems. These included comparisons between present farm management and the use of improved seeds, use of fertilisers, and conservation agriculture practices, i.e. minimum or reduced tillage, soil cover and crop rotations attuned to the local needs and existing farming systems.

Table 1. Key SIMLESA achievements during 2010

Socio-economics and value chains	More sustainable and productive practices	Improved genetic material	Scaling-out	Capacity building
3550 households were surveyed.	45 ORS trials planted	15 NARS trained on breeding methods	15 NARS and 2 ASARECA trained on MandE	26 participants on APSIM
	146 OFE trials planted	Hybrids and OPVs planted on farmers' fields	2 NARS attended the BECA scientific writing workshop	4 PhD scholarships awarded
		5 varieties per farming system identified for pre-release		
Innovative relay and intercrop cropping systems tested for Queensland	Seed multiplication is underway	7 NARS trained on gender mainstreaming	5 country level CA training	
	Stress characterisation for Queensland	More than five congress publications submitted	2 NARS trained on BNF	

ORS on research station trials; OFE on farm exploratory trials; CA conservation agriculture principles; MandE project monitoring and evaluation; BNF Biological Nitrogen Fixation

Improved access to quality seeds
Fourteen sessions of participatory pre-released variety selection were initiated across the five countries. A range of range of new maize hybrids and open pollination varieties were selected by farmers based on yield, early maturity, drought tolerance, resistance to pests, medium height and palatability.

Capacity building
ASARECA provided training on gender mainstreaming and the development of an MandE framework; Scholarships were granted by AusAid and ACIAR to SIMLESA team members to pursue PhD studies in Australia; Twenty-six NARES and CIMMYT researchers participated in systems modelling and agronomic (soil, climate and plant) data collection workshop, funded by jointly by SIMLESA and the Crawford Fund; More than 10 conference papers were submitted by SIMLESA team members to the 5th Congress on Conservation Agriculture and the 3rd Conference on Farming Systems Design (September 2011, Brisbane), and more than fifteen African SIMLESA team members are expected to participate at the conference.

SIMLESA's first year achievements have been impressive, and farmer's response has been encouraging. Though, important challenges still lay ahead such as (i) increasing the availability and affordability of farmer's inputs e.g. fertilisers and herbicides, (ii) achieving a rational management of crop residues in mixed grazing and cropping farms, and (iii) improved weed control in CA plots. We expect that we will be able to address these challenges with the development of innovation platforms; participatory analyses on improved allocations of limited resources in the household; and farmer managed agronomic trials and community awareness meetings.

Biomass shifts and suppresses weed populations under Conservation Agriculture

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Keywords: weed control, biomass, conservation tillage

Introduction

Systems involving conservation tillage (CT) with cover crops, mulch, and rotations have been identified as a soil management strategy with potential to improve food security for millions of hungry people, as well as contribute to political stability (Lal, 2008). CT typically depends on herbicides to achieve adequate weed control, but limited-input and smallholder producers may not have access to or want to use chemical controls. High biomass cover crops show promise for weed control (Bond and Grundy, 2001), as do organic mulches (Runham and Town, 1995). There are some nutrient management concerns with cut-and-carry mulching systems; however, if on-farm invasive, perennial, leguminous species are used as mulch, such as mimosa (*Albizia julibrissin* Durazz.) or lespedeza (*Lespedeza cuneata* (Dum. Cours.) G. Don), producers may achieve the simultaneous benefits of obtaining free high quality mulch, controlling invasive on-farm species, and improving soil quality (Mulvaney et al., 2010), while limiting herbicide costs. The double cover cropping system described in this paper represents a novel, innovative practice for short-term SOM increase and weed suppression on an agriculturally productive field, while simultaneously controlling *in situ* invasive, perennial leguminous species. The objective of this experiment was to quantify weed suppression effects of a summer cover crop and organic mulches under no-till collard (*Brassica oleracea* L. acepahala group cv. Champion) production during the first three years of conversion to CT. This data will enable producers to make informed decisions regarding cover crop and mulch residue management during the adoption of CT practices.

Materials and Methods

Studies were conducted near Tallassee, AL (N 32º29.29' W85º53.26, 66 m elevation) between 2005 and 2008 on a Wickham fine-loamy, mixed, semiactive, thermic Typic Hapludults soil, 0-2% slopes. The experiment was a 2 by 4 factorial randomized complete block design replicated four times. Each block was 24.4 m long and 9.1 m wide, with experimental units measuring 9.1 m long and 3.0 m wide, accommodating four collard rows, including two border rows. The two main treatments consisted of a 'Derry' forage soybean (*Glycine max* (L.) Merr.) summer cover crop and a no summer cover crop (weed fallow) control. Four sub-treatments consisted of *in situ* organic mulches: fresh mimosa prunings ≤1 cm in diameter, fresh lespedeza cuttings, wheat straw (*Triticum aestivum* L.), and a no-mulch control. Treatments remained the same on each plot from year to year. The plots were disked at the initiation of the experiment in October 2005. No tillage was used after the experiment was initiated, and the field was not subsoiled at any time. Each year, a winter cover of rye (*Secale cereale* L.) was established and fertilized with 67 kg N ha^{-1}. The rye was mechanically terminated using a roller-crimper (Ashford and Reeves, 2003) or chemically terminated if an adequate kill was not obtained in late April. Two weeks after termination, the forage soybean summer cover crop treatment was planted at 101 kg ha^{-1} on 20-cm rows using a no-till drill. In mid- to late-August, summer cover crops were mechanically terminated using a roller-crimper or chemically terminated if an adequate kill was not obtained. Two weeks after summer cover crop termination, rows were cleared using row cleaners and collards seedlings were transplanted 43 cm apart using a single row no-till transplanter on 76 cm rows. Fresh mimosa was hand cut using branches ≤1 cm in diameter. Fresh lespedeza was cut using a Carter forage harvester. Wheat (*Triticum aestivum* L.) straw mulch was obtained locally. The dry weight of mulches was determined by oven-drying a sample several days before mulch application. Mulches were hand-applied at a rate of 6.7 t ha^{-1} (oven-dry basis) 21 days after transplanting, at which time the collards were approximately 10-15 cm tall. Collards were fertilized with135 kg N ha^{-1} in three equal split applications and irrigated using a traveling gun as needed by visual observation. Collards hand-harvest operations were conducted 65-69 d after transplanting by cutting the base of the plant. Two 2 m rows from the center of each experimental unit were weighed immediately after harvest to determine fresh weight collard yield. Following harvest, a winter cover crop of rye was planted at 101 kg seed ha^{-1} in 18 cm rows. Weed coverage was determined using line-transect methodology. A marked line with 50 points was laid at a 45 degree angle across the rows, and points that touched weeds were counted. The count was repeated after moving the line 90 degrees (so that the line lay at 45 degrees in the opposite direction), such that two 50-point counts were obtained for each experimental unit during each sampling period. Weeds were classified as broadleaves, grasses or sedges. Significant effects were identified by analyses of variance as implemented in SAS 9.1.3 using PROC GLIMMIX procedures and maintaining blocks as a random effect (SAS, 2003). Reduced models were obtained via backward elimination for variable selection using $P > 0.15$ as the criteria for elimination from the model. Since P values change as variables are removed during backwards elimination, the relatively high P value was chosen so as to not reject variables that may have been significant. Variables were considered significant if $P<0.10$ unless otherwise stated. Inflated Type I error rates associated with the covariance structure in the model were limited by adjusting the denominator degrees of freedom using Kenward-Roger correction in the MODEL statement (Littell et al., 2002). Means and standard errors of significant effects of the reduced models were obtained using PROC MEANS.

Results and Discussion

The average (± standard error) of winter rye biomass obtained during 2006-2008 was 8.48 ± 0.37 t ha^{-1}, 10.48 ± 0.57 t ha^{-1}, and 5.89 ± 0.53 t ha^{-1}, respectively. The average forage soybean yield during 2007 was 2.32 ± 0.18 t ha^{-1}, and 6.72 ± 0.41 t ha^{-1}. The 2007 forage soybean biomass was low because of drought conditions. Reliable forage soybean biomass data during 2006 were not available. Mulching provided weed suppression of broadleaves, grasses and sedges. The forage soybean summer cover crop did not significantly suppress fall weeds, likely due to the fact that soybean residue decomposes too quickly to have a lasting mulching effect (Mulvaney et al., 2010). Mulching the first year was effective for suppression of broadleaf weeds (Figure 1). Suppression of broadleaf weeds during the first year appeared to lower broadleaf infestation during subsequent years. During the first year of no-till, mulching did not improve control of grasses (Figure 2), but in subsequent years, improved grass suppression was observed with mulches compared with the non-mulched control. Grass infestation remained below 10% through the application of all mulching materials in 2007 (compared with 17% for the non-mulched control), and below 6% in 2008. Our results showed that grass populations under no-till are highly variable, with populations increasing dramatically during the second year of conversion from conventional tillage, but decreasing in the third year. During the first year of the experiment, yellow nutsedge (*Cyperus esculentus* L.) control was highly problematic, with total plot coverage by nutsedge ranging from 7-21% (Figure 3). However, subsequent years of high residue no-till improved sedge suppression, generally below 5% plot coverage. Although mechanisms are unclear, it was apparent that sedge suppression was improved during subsequent years of no-till using high-biomass cover

crops with or without the application of mulches. Yellow nutsedge was the only perennial weed species present after three years. Collard yield averaged 23,109 ± 6411 kg ha^{-1} (standard deviation) in 2006, 14,005 ± 6204 kg ha^{-1} in 2007, and 16,477 ± 4442 kg ha^{-1} in 2008. Yield was not affected by any variable, including year. Using N fertilizer at 134 kg N ha^{-1} at Sand Mountain, AL, Guertal and Edwards (1996) reported fall collard yields of 10,400 – 14,700 kg ha^{-1} using various mulches, so the yields in this study are within the expected range for the area.
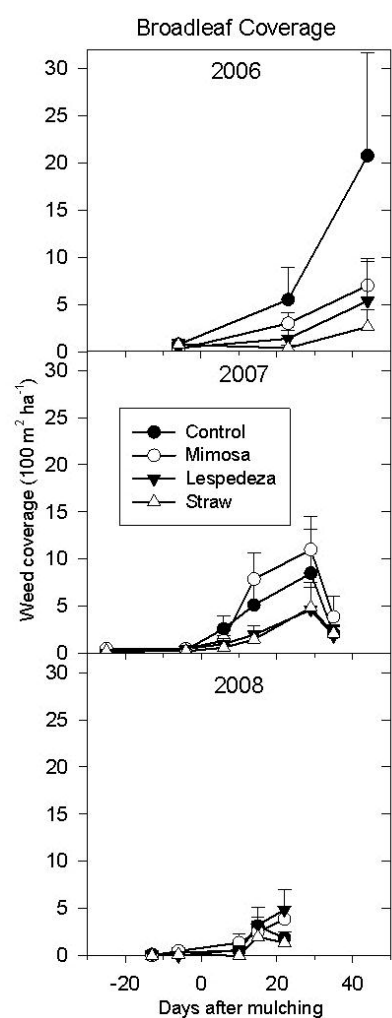
Figure 1. Broadleaf weed coverage after conversion to no-till during 2006-2008 with mulches applied at 6.7 t ha^{-1} three weeks after transplanting. Bars represent standard errors of the means.
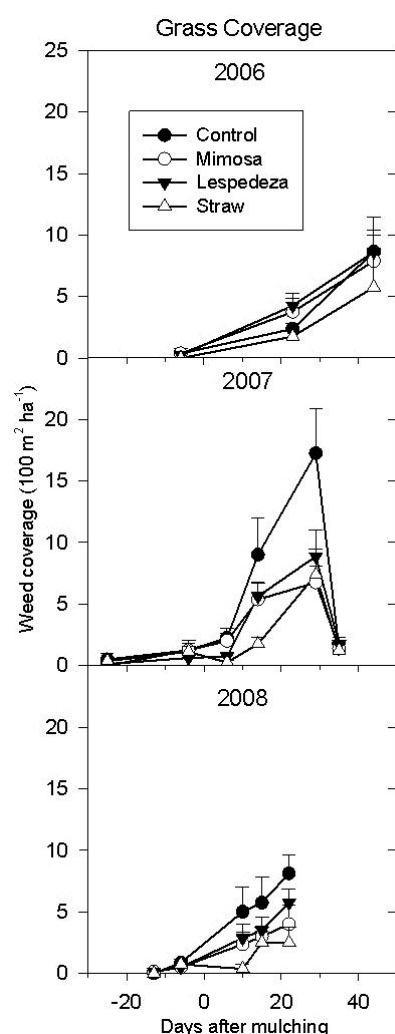
Figure 2. Grass weed coverage after conversion to no-till during 2006-2008 with mulches applied at 6.7 t ha^{-1} three weeks after transplanting. Bars represent standard errors of the means.
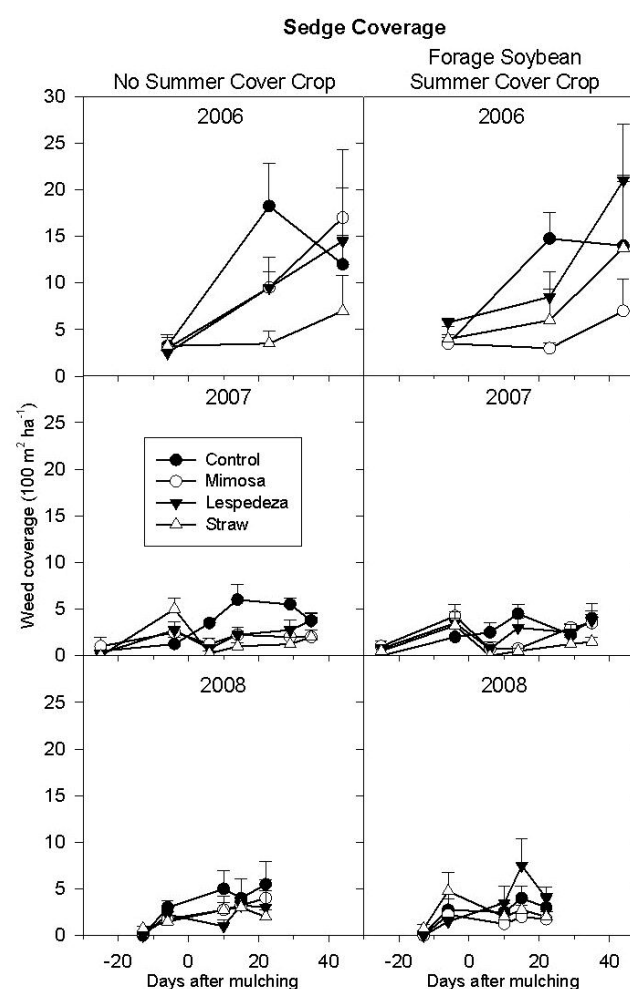
Figure 3. Sedge coverage after conversion to no-till during 2006-2008 with mulches applied at 6.7 t ha^{-1} three weeks after transplanting. Bars represent standard error of a mean. There was a significant cover crop by mulch interaction with sedge coverage.

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Modernizing traditional agriculture: optimization of maize-vegetable intercropping systems

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Keywords: intercropping, competition, maize, Chinese cabbage, bean

Introduction

Intercropping is a widespread traditional agricultural production system in the North China Plain (NCP). However, due to large migration to urban areas with higher salaries, labor scarcity in the rural areas is defining a new framework for agricultural production. The high intensity of manual labor is causing a decline of the traditional intercropping systems. In the face of severe environmental degradation of land and water resources, highly productive and sustainable agricultural systems must be developed. Strip intercropping might be an appropriate system for the NCP to meet the current challenges of labor scarcity, environmental degradation and food security. Maize, Chinese cabbage and green bean are locally important crops. However due to a multitude of possible crop combinations, spatial and temporal arrangements established intercropping systems with these crops indicate a large potential for optimization. As field experiments with all possible arrangements and combinations would be time and labor intensive modeling is seen as a crucial tool to optimize these intercropping systems. To enable and improve existing crop models like DSSAT 4.5 to simulate strip intercropping systems, there is a need for empirical understanding on how growth and production is influenced spatially and temporally across rows. This paper reports on the initial collection of empirical data to highlight the issues that need to be considered, in order to accurately simulate intercropping production systems.

Materials and Methods

In 2009, a strip intercropping experiment of alternating strips of maize (*Zea mays* L.) cv. Companero and Chinese cabbage (*Brassica campestris* L. ssp. *Pekinensis*) cv. Spring Sun in spring, cv. Kasumi in summer and cv. Beijing No.3 in autumn with four replications and in 2010 with three replications and an additional treatment with green bean (*Phaseolus vulgaris* L.) cv. Marona (bush type) in summer, instead of Chinese cabbage, were conducted at Hohenheim University´s research station Ihinger Hof (48° 46′ N, 8° 56′ E; 409 m a. s. l.). The maize strips consisted of 12 rows (85.000 plants ha^{-1}), the cabbage strips in 2009 of 20 rows and in 2010 of 9 rows (40.000 plants ha^{-1}); bush bean was planted in 9 rows (280.000 plants ha^{-1}). The distance between neighboring crops was set to 62.5 cm to allow use of machinery while maintaining low proximity to ensure interspecific interactions. All measurements were conducted on east and west sides of the maize strips and the adjacent Chinese cabbage/bush bean strips in row one, two, three and the centre row in 2009 and in row one, two and the centre row in 2010. Biomass of all plant parts was measured and soil moisture was determined from 0-60 cm in Chinese cabbage and bush bean, and in 0-90 cm in maize by auger sampling several times during crop growth. Photosynthetically active radiation (PAR) was measured once all day under clear sky conditions after full maize plant height (Feike et al., 2010). In the Chinese cabbage strips wind speed (03102 RM YOUNG Wind Sentry Anemometer, Campbell Scientific, Inc., Logan, Utah, USA) was monitored above the plant canopy, in maize the sensors were adjusted at ¾ of plant height. Soil temperature was determined continuously (Thermistor gelb 6507M, UNIDATA Europe GmbH) at 5 and 10 cm depths. In 2010, solid root barriers (HDPE, 2 mm) were installed at a ploughing depth of 30cm, inserted into a furrow made by using only one ploughshare, in the border between spring maize and Chinese cabbage to separate above- from below-ground competition.

Results and Discussion

This paper concentrates on the data obtained from the final measurements at harvest of each crop on the west side of the maize strips and the adjacent east side of the Chinese cabbage/bush bean strips. In 2009 and 2010, spring Chinese cabbage, compared to the centre row of the strips, demonstrated a 7% and 14% higher total dry matter, respectively, in the first border row. In both years a 10% lower specific leaf area was measured in the first row compared to the centre row of Chinese cabbage. No effect of the root barrier could be shown in 2010. These results indicated that above-ground competition - most probably a higher lateral incoming PAR through the open maize canopy − might have led to the higher total dry matter of Chinese cabbage in the first row. In the course of increasing plant height of maize, incoming PAR (Figure 1) and wind speed (Figure 2) decreased significantly towards the maize strips. In 2009, total dry matter of summer Chinese cabbage decreased significantly, compared to the centre row, and the first, second (-17%) and third row (-11%) in 2009, and in the first (-34%) and second (-15%) row in 2010, respectively. Bush bean demonstrated a significantly lower total dry matter in the first row (-27%), compared to the centre row.
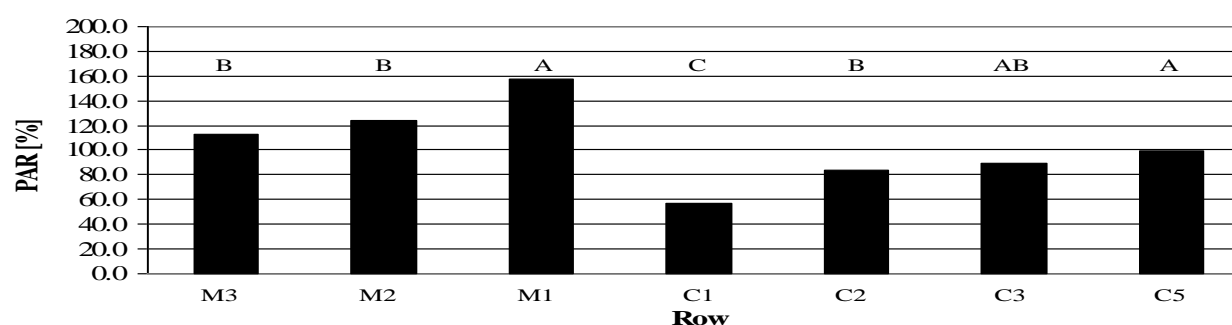
Figure 1. Percentage of incoming photosynthetically active radiation (PAR) in the first, second and third row of the spring maize (M) strips and in the first, second, third and fifth row of the Chinese cabbage strips (C) next to spring maize in relation to the spring maize and Chinese cabbage centre rows, respectively. Capital letters denote significance (α < 0.05).
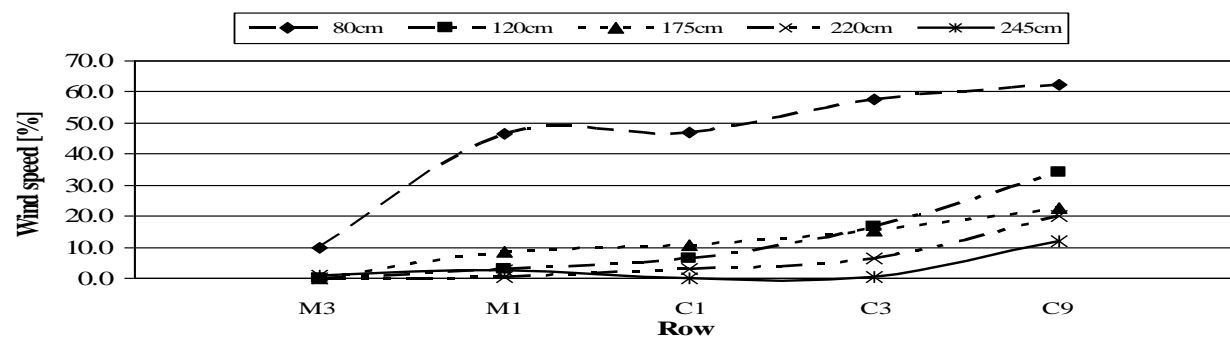
Figure 2. Percentage of open area wind speed [%] in relation to 80, 120, 175, 220 and 245 cm plant height of spring maize in the first and third row of spring maize (M) and the first, third and ninth row of Chinese cabbage (C)

Specific leaf area increased in the first two rows of both bush bean and Chinese cabbage, compared to the centre row. In the first row of bush bean as well, the number of side shoots and trifoliate leaves was lower than in the centre row. The second row of bush bean showed a slightly higher dry matter (+5%) than the centre row. This suggests a positive effect of slight shadowing on bush bean growth up to a certain threshold, where the decreased PAR significantly reduces plant growth. These results indicate that bush bean is more tolerant to shading than Chinese cabbage. The effect of wind speed on plant growth is very complex (Jurik and Van, 2004), but taking the agreement between the spatial extent of the modified radiation regime and plant growth changes into consideration, most probably wind speed played a minor role.

Yield of spring maize showed a different behavior in 2009 and 2010. In 2009, the yield in the first and second row of the maize strips significantly increased compared to the yield of the centre row by 25 and 8%, respectively. The higher yield was mainly caused by a larger number of cobs per plant. In 2010, only the first row showed a 14% higher yield than the centre row. The most probable explanation is that less PAR during the critical period of bracketing silking (Andrade et al., 2000) in 2010 (18.08 MJ m^{-2} d^{-1}) reduced the yield advantage in the second row compared to 2009 (19.87 MJ m^{-2} d^{-1}). Increased PAR could be shown in the first, second and third row of the maize strips, declining towards the centre row (Figure 1). No differences of average daily soil temperature above 1°C were measured between the rows of each crop during the cropping season. Apart from critical soil moisture at silking of maize in 2010, no water limitation occurred throughout the growing season. Increased PAR in the border rows of maize seems to be the main reason for the higher yield, taking into account that all the other measured microclimate variables showed no difference between border and centre row.

Autumn Chinese cabbage showed a significant lower dry matter in the first (-29%) and second (-7%) row next to maize compared to the centre row in 2009. In 2010, no valuable data could be obtained due to cold temperatures during the late season. The fact that the autumn Chinese cabbage was exposed to shading only until maize harvest and the third row was not influenced negatively in contrast to the third row of summer Chinese cabbage, indicated that shading is more severe at a later growing stage of Chinese cabbage.

Conclusions

The zone of occurring competition could be limited mainly to the first two border rows of spring maize, Chinese cabbage and bush bean. Above-ground competition seems to be the most important factor throughout the growing season. To optimize this strip intercropping system, researchers must consider that, on one hand, the strong competition for light by the tall maize plants has to be decreased by using cultivars with a different shape (e.g. reduced plant height, more erect leaves) and through reducing maize strip width. On the other hand, the input of fertilizers and water should be adjusted to the potential resource use depending on inner- strip position of each crop. The modified microclimate, mainly the radiation regime, will be integrated into DSSAT 4.5 to compare measured and simulated growth responses and to gain more insight into where the model has to be adapted further to represent strip intercropping.

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Long-term evaluation of dryland cropping systems intensification for sustainable production in the semi-arid tropics of India

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Introduction

We report some of the results from a 15-year long rotational trial conducted at ICRISAT in the Southern Peninsular India that will eventually form the basis for a detailed model evaluation of Agricultural Production Systems Simulator (APSIM). This model will then be used to design crop rotations that have higher productivity and lower risks than conventional rotations like rainy fallow and post rainy sorghum or chickpea. The experimental results reported here show that this is entirely feasible. Our specific objectives were to: 1) quantify the benefits of grain legumes to non-legumes in the cropping system rotations; and 2) identify improved and sustainable cropping system options for crop productivity and intensification.

Variability in the onset and distribution of monsoonal rains in June-July constitute a key risk of crop production on Vertisols. As such, fields are usually left as fallow during the rainy season (*kharif*) and cropped with sorghum or chickpea during only the post-rainy season (*rabi*) on stored soil moisture. However, due to the high water holding capacity of Vertisols, there is an opportunity to make better use of both seasons, and as such, a crop intensification approach with sequential double cropping was explored. Besides the extra crop yield gained from double -cropping, this practice may help to reduce erosion in the rainy season.

Vertisols in this part of the world are generally deficient in nitrogen (N) and phosphorus. Response to N fertilization is much higher than with any other nutrient, and the response in the rainy season is greater than in the post-rainy season (Katyal, 1988). Legume-based systems have been particularly successful in providing N inputs where fertilizer is of marginal economic benefit as well as providing grain as part of the crop production system. In India, farmers remove stalks from the field for fodder, however relatively little N is removed in this process because stalks have very low N content. Legume root material and nodules remaining in the soil have shown positive residual effects on the subsequent cereal crop equivalent to 30-40 kg N ha[-1](Kumar Rao et al., 1983). While this is not large enough to approach potential crop yields of rainy season crops, even a moderate N input could double the yield because the soils may supply as little as 30 kg N ha^{-1} to cereal crops. Such results led to the establishment of a long-term experiment at ICRISAT to examine the productivity of cropping systems with improved technologies including broad bed furrow land management, high yielding varieties, fertilizers and the inclusion of short duration legume crops in rotations.

Materials and Methods

An experiment was established with 10 different cropping system rotations on a Vertisol (Table 1) at the ICRISAT Centre (lat. 17.5°N, long. 78.2°E), Patancheru, India. The experiment was established in 1983 and continued until 1997, a total of 15 years. In this paper, we analyse the effects of four cropping systems described in Table 2. The experimental design was split-plot with cropping systems as main plots and four levels of N fertilizer application as subplots. Two of the four cropping systems were double crop sequential systems; mung bean (*Vigna radiata* (L.) Wilczek) sown in rainy fallows followed by post-rainy sorghum (*sorghum bicolour* (L.) Moench), constituted the mung bean and sorghum sequential system (MS-MS); and rainy season sorghum followed by chickpea (*Cicer arietinum* L.) rotated annually constituted the sorghum and chickpea sequential system (SCP-SCP). The other two systems were traditional rainy-season fallow systems sown to a post-rainy season crop; either annual repetition of sorghum after a fallow (FS-FS), or a two-year rotation of chickpea after a fallow and sorghum after a fallow (FS-FCP). This sequential rotation had a mirror image (FCP-FS) treatment, so that in any given year both sorghum and chickpea were grown in order to account for the effect of climate variability. Rainy season mung bean in the MS-MS rotation and sorghum in the SCP-SCP rotation were dry-sown ideally in the first fortnight of June before the onset of the south-west monsoon. The post-rainy season crops were sown soon after the harvest of the rainy season crop using the available soil moisture. Main plot size was 12 x 12 m with 8 sets of broad bed and furrows. Each plot was divided into four subplots receiving either 0, 40, 80, or 120 kg N ha^{-1} applied as urea to each non-legume crop. Details of primary tillage, fertilizer nutrient application and crop management information were provided in Rego and Nageswara Rao (2000). The same crop varieties were used throughout the experiment with the exception of a sorghum variety (CSH-8R swapped with SPV-421) during the post-rainy season.

Table 1. Soil properties at a depth of 0-15 cm in a Vertisol at the experimental site at ICRISAT in 1983.

Soil series	pH (H$_2$O)	EC (dS m^{-1})	CEC (meq 100 g^{-1})	C-org (%)	N (mg kg^{-1})
Kasireddipalli	8.1	0.25	56.6	0.61	550

Table 2. Main plots (three replicates): cropping system rotations.

1st Year		2nd Year		Rotation Abbreviation
Rainy	Post-rainy	Rainy	Post-rainy	
Fallow (F) +	Sorghum (S)	Fallow +	sorghum	FS-FS
Mung bean (M) +	sorghum	Mung bean +	sorghum	MS-MS
Fallow +	sorghum	Fallow +	chickpea	FS-FCP
Sorghum +	chickpea	Sorghum +	chickpea	SCP-SCP

In subplots N application was made at 0-N, 40-N, 80-N and 120-N kg ha^{-1} to non-legume crops.

To compare rotations of different lengths, we present grain yields per two year rotation and we use the minimum support price announced by the Government of India for 2010-11 for a simple gross return analysis. Marketable grain prices per quintal (100 kg) were mung bean, Rs. 2760; chickpea grain, Rs.1760; and hybrid sorghum grain, Rs.880. We estimate sorghum fodder value at Rs.1400 per ton.

Results and Discussion

Overall the productivity of the sequential double cropped systems (MS-MS or SCP-SCP) was greater than any of the fallow plus post-rainy crop systems. Mean grain yield of post-rainy sorghum in the MS-MS system without N application (2520 kg ha^{-1} two-year rotation[-1]) was significantly greater than the mean grain yield in the continuous fallow-sorghum system (1940 kg ha^{-1} two-year rotation[-1]), and with the added benefit of the mung bean grain yield (1000 kg ha^{-1} two-year rotation[-1]) with the MS-MS system. However, mean grain yield of FS-FCP sorghum at 0-N (2260 kg ha^{-1} two-year rotation[-1]) was not significantly different from the mean grain yield of MS-MS sorghum (2520 kg ha^{-1} two-year rotation[-1]). Total grain productivity of the MS-MS system was significantly higher than that of the FS-FS or FS-FCP

systems (Figure 1) at the same level of applied N. The residual effect of mung bean on sorghum is the difference in grain yield between the MS-MS and FS-FS systems at each N level, which was on an average lower with increased N application.

In the SCP-SCP system the additional grain yield of rainy sorghum (3400 kg ha^{-1} cycle^{-1}) ensured that the total productivity of this system was greater without N application and a small additional investment on seed and harvesting. However, farmers are generally more concerned about year-to-year yield variability and are prepared to trade-off some long-term yield benefits for short-term guarantees of minimum yields. Essentially, they use stored soil moisture from the fallow as insurance for a minimum yield and as a buffer against rainfall variability. Hence, we also investigated the yield variability of the different systems. Grain yield of sorghum in FS-FS was less than 50% of mean grain yield during 5 years and mean grain yield of chickpea in FS-FCP system rotation was less than 50% of mean grain yield during 4 years out of 15 years in these traditional systems. Sorghum grain yields with the MS-MS system were less than 50% of its mean yield in only two out of 15 years. During these two years mung bean grain yields were higher than its mean yield of 500 kg ha^{-1} annually, thus minimising the risk of productivity with this double crop system in all 15 years of experimentation. Rainy season sorghum grain yields in the SCP-SCP system were well above 50% of the mean grain yield in all 15 years, complementing the chickpea grain yields in this system and avoiding any productivity risks.

Double cropping MS-MS and SCP-SCP sequential systems without N application had greater mean gross returns (42408 and 55598 Rs. ha^{-1} two-year rotation $^{-1}$ respectively), than those achieved in the FS-FS or FCP-FS systems (19739 and 30710 Rs. ha^{-1} two-year rotation $^{-1}$, Figure 2). Similar ranking of cropping systems gross returns was evident with increasing nitrogen levels. Thus, crop yield, total productivity and economic returns were greater with double cropped sequential systems compared to post-rainy season single cropped traditional rotations. Furthermore, these systems can easily be adopted by dryland small holder farmers. However, there were significant year-to-year yield variations due to seasonal weather conditions, suggesting the need for further study of the data to identify suitable systems options for different ENSO analogue years to minimise the risks of climate variability. This dataset now forms the foundation for model validation and for model supported identification of better cropping systems options those will aid the design of future farming systems that are best adapted to the regional climate variability by minimizing risks.
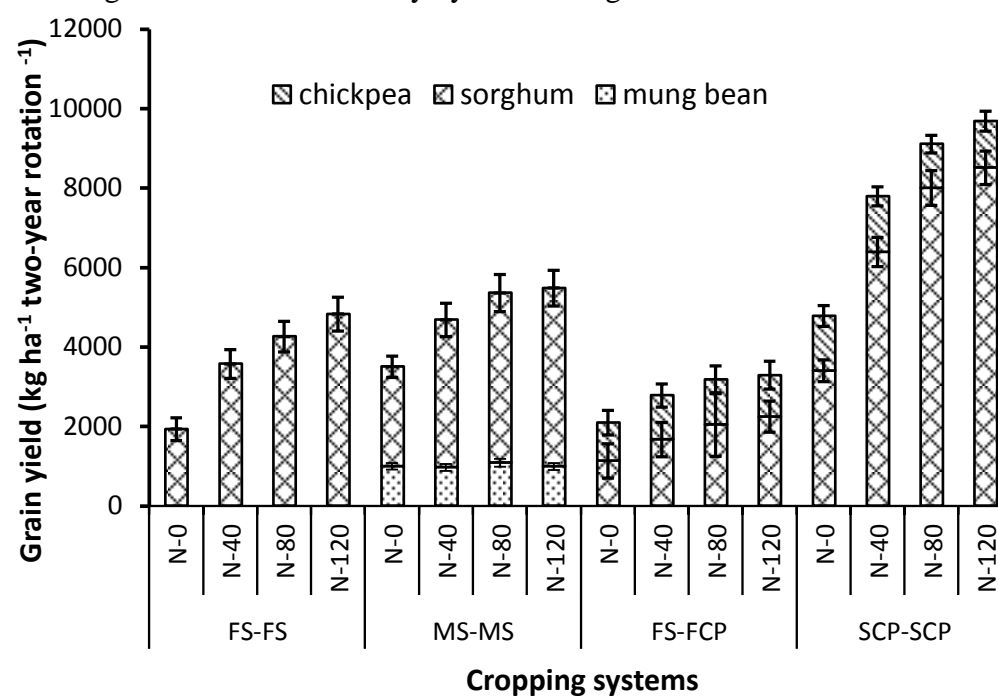
Figure 1. Grain yield of rainfed cropping systems (Table 2) with increasing levels of nitrogen application, averaged over 15 years. Bars represent ±1 SE for each crop type.
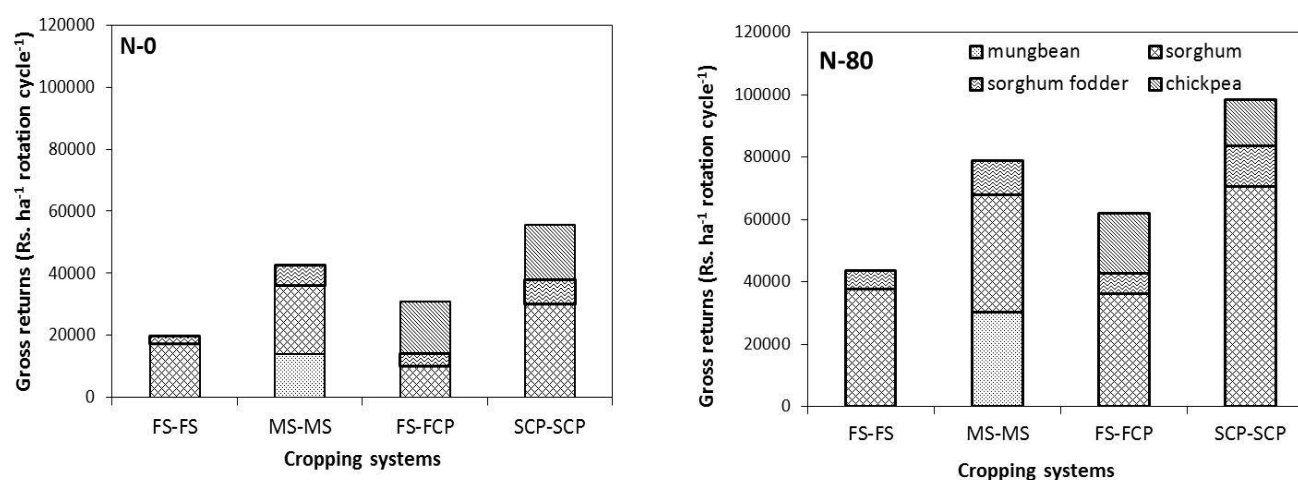
Figure 2. Gross returns from rainfed cropping systems (Table 2) with no added nitrogen, averaged over 15 years.

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Assessment of tradeoffs for biomass uses between livestock and soil cover at farm level

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Introduction

One of the main constraints for implementation of CA in smallholder farming in Africa is maintaining an organic mulch as soil cover (Giller et al., 2009). There are two principal problems. First it is difficult to produce sufficient biomass on poor soil without external fertilizer; and second, there are competing uses for the biomass produced, especially for livestock feed. Integration of Conservation Agriculture (CA) and livestock has rarely been reported, except in Brazil (Bolliger et al., 2006). In our study we focused on the production and use of biomass within CA cropping systems. The biomass can be used both as forage for cattle or as mulch for CA. The ecological functions of mulch are physical and chemical. The physical functions relating to soil cover include i) weed control (Teasdale and Mohler, 2000), ii) erosion control (Smets et al., 2008), and iii) improvement of the crop water balance due to promotion of infiltration and reduction of evaporation losses (Scopel et al., 2004). The chemical effects include provision of nutrients for plant growth and provision of chemical buffering for nutrient retention and against soil acidity, due to inputs of organic matter and nutrients (Maltas et al., 2009; Neto et al., 2010). In this study we focus on the short-term effects of mulch, which are more related to soil cover than to chemical effects. Short-term benefits including weed control and an improved crop water balance. We developed an optimization model, using multiple goals linear programming, of a representative medium-sized Malagasy farm. This model was named GANESH (Goals oriented Approach to use No till for better Economic and environmental sustainability for SmallHolders). Using this model we test the following hypotheses: i) if we do not constrain the choice of cropping systems (CA or not, minimum percent of soil cover) and offer an unlimited market for milk, with access to an improved dairy breed and fixed prices for milk, farmers will choose to use as much biomass as they can to feed their animals. Thus the remaining biomass quantity will not be sufficient to implement CA; ii) Conversely, if the market for milk is limited or prices low, only part of the biomass produced by CA systems can be used to feed cattle with a small impact on soil cover while allowing increased animal production.

Materials and Methods

The GANESH model is written in GAMS (22.5.148) with an Excel 2003 interface. It includes 24 variables and 51 equations. The model structure can be divided into three main components: i) the crops, ii) the animal herd, iii) the farm (Figure 1). In the crop component we made a distinction between four kinds of fields: hillside fields (*tanety*), alluvial soils (*baiboho*), poor water control paddy field, and irrigated paddy fields. For each kind of field a list of possible crops for the growing season and the off-season was established. Each crop was characterized by an input-output table. Inputs include total labour and chemicals (e.g.: fertiliser, herbicides and insecticides). Outputs are grain and above-ground biomass and its quantity and quality (protein, energy). The biomass produced can be used to feed cattle. Part of the crop biomass produced during one year can be used to feed cattle and the remainder used as mulch. The relation between mulch quantity and soil cover as described by Gregory (1982) was locally calibrated (Naudin et al., in press). The livestock component comprised four kinds of animals: zebu male, zebu female, dairy cow improved breed, and dairy cow local breed. The inputs for these production activities were the labour requirement and forage parameters (protein, energy, quantity of dry matter ingested). The outputs were milk, manure, heifers and calves sold, and draught power. The farm component comprised the number and type of people (for estimating household food demand and workforce available), and the number and area of fields. Beside these three components, external factors influencing the functioning of the farming system were included in the model: milk price, quantity of milk marketed, and price of hired labour.

CROP

Poor water control paddy field

Season	**Off season**
CT rice	Vicia
CA rice	Fallow

Hillsides

Season
Brachiaria
CT groundnut
CT rice
CT cassava
CT maize+dolichos
CT grounut+stylo
CT cassava+brachiaria
CT maize
CA rice
CA maize+dolichos
CA groundnut+stylo
Stylosanthes

Alluvial soil

Season	**Off season**
CT rice	Vicia
CT maize	Fallow
CT maize+dolichos	Dolichos
CA rice	
CA maize+dolichos	

Irrigated paddy field

Season
CT rice

Needs
Work Manure
Chemical inputs

Outputs
Grain
Aboveground biomass
Soil cover
Forage available

External factors

Milk price
Max. quantity of milk marketable

FARM

ople
Nb of fields for each kind

Needs
Work force
Self consumption needs

Final results
Total income
Margin from animal
Exported biomass
External labor

Farm plan
Margin from crops
Soil cover

Optimisation

Constraint
% of soil cover at crops seeding

LIVESTOCK

Needs
Work
Forage (energy, protein, biomass)

Outputs
Milk
Solded heifer and calves
Solded draught power
Manure

Zebu male
Zebu female
Dairy cow improved breed
Dairy cow local breed

Figure 1. Conceptual scheme of the GANESH model. Other input variables are: milk prices, maximum quantity of milk marketable, inputs prices, hired labour prices. Results are: total farm income, economic margin from animal products, quantity of hired labour, detailed farm plan over three years for each field included in the model. The main constraint, which determines the quantity of biomass available for cattle feeding and mulch, is the percent of soil cover. This value of minimum percent of soil cover is parameterised by the user to draw, by iteration, the relation presented in Figure 2.
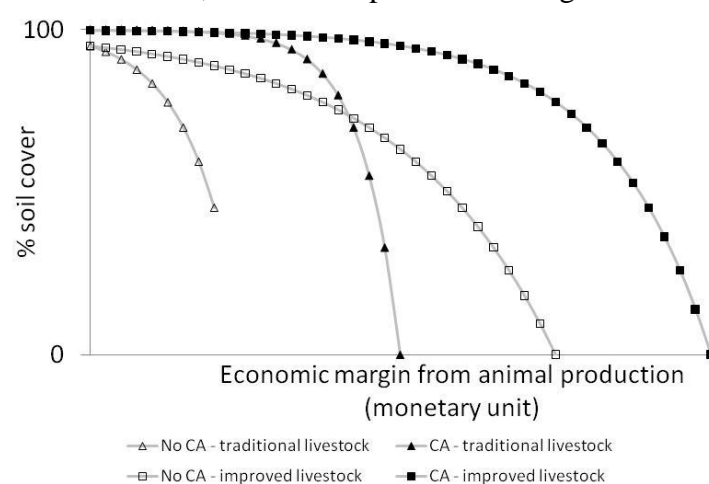
Figure 2. Proposed theoretical relationship between soil cover of a field, or group of field, and economic margin from livestock (milk, meat, young animals) coming from biomass uses as forage. The relation is non -linear as the relationship between soil cover and biomass quantity on soil is non-linear. Thus when the biomass produced is sufficient to begin with biomass exportation has only a small influence on soil cover but can allow increased animal production.

Results and Discussion

The model is currently being validated. At present we do not have complete output from the GANESH model and thus we present probable results. Concerning the hypothesis i and ii (see introduction), we expected a theoretical relation between soil cover and economic margin from livestock as shown in Figure 2. The first hypothesis is that in a context of high pressure on plant residues due to dairy production, the farmer tends to favour animal feeding at the expense of soil cover. Supporting this hypothesis and model output is the weak CA adoption in the Vakinankaratra region. In this region, almost none of the CA systems were adopted by farmers, because it is more profitable to give crops and cover crop residues to dairy cows than to leave it as soil cover (Penot and Duba, 2011). The second hypothesis is that part of the biomass from CA can be used as forage, improving animal production, with small impact on soil cover. This hypothesis is more difficult to observe in real conditions; especially when the biomass exportation threshold has a strong impact on soil cover. Thus modelling could be a useful tool to investigate this relation and threshold. However, the CA adoption rate in the Lake Alaotra region seems to be partially due to a low pressure from cattle feeding. Biomass production is higher in CA systems due to better resource efficiency in time (off-season cover crops) or in space (crop-cover crop associations) (Balde et al., 2011). This additional biomass can be shared between livestock and soil

cover. At field level, among the potential effects of soil cover, only weed control was taken into account as it is a short-term effect. Below a threshold, biomass exportation starts to have a negative impact on margins and/or returns to labour of the cropping system because a low soil cover does not provide effective weed control. Thresholds of biomass exportation, below which the gains from animal production compensate for the loss from crop production, vary depending on the biomass production, potential animal production and the market prices of animal products. Relationships between crop and animal production for labour, income, field allocation, are required to model these trade-offs at farm level. Indeed the objective is to propose a choice of various cropping systems management (with more or less biomass export) coping with farming goals as a whole and not only to focus on crop or livestock components.

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Exploring hotspots in the carbon footprint and energy use profiles of tomatoes grown for the Sydney market

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Introduction

One of the key issues with the consumption of horticultural products is the depletion of fossil resources and greenhouse gas emissions along the production and supply chain. Australia's horticultural sector contributes about 6% of the total greenhouse gas emissions from agriculture. Although this figure appears to be smaller as compared to other sectors within agriculture, agricultural sector as a whole may come under closer government scrutiny in the future to reduce its greenhouse gas emissions (Australian Government, 2010). It is estimated that the vegetable industry contributes close to 60% of the greenhouse gas emissions within horticulture (Deuter, 2008). In response to national and international initiatives on food labelling, vegetable products may be required to identify their energy and carbon footprints as a way to reduce some of the environmental impacts. This is where Life Cycle Assessment (LCA) as a tool could be applied to estimate key environmental impacts of agri-food products. The key feature of LCA is that it considers the system-wide environmental impacts and not just those occurring at the farm. LCA enables to assess the trade-offs between various environmental impacts and in this way helps to guide informed decision making at the individual and policy level. We apply LCA to study two key environmental impacts namely the global warming and the resource depletion potential from tomato production systems. We identify environmental hotspots in carbon and energy footprints by assessing the growing phase of tomato production and the key operations that influence the results. We have chosen tomato as a case study because it is an important vegetable following potato and there are different pathways (example greenhouse vs. field production) in which fresh tomato reaches the Sydney consumer. The results from this research along with other environmental considerations such as impacts of freshwater scarcity will help provide guidance in the design of more sustainable vegetable production practices for the Sydney region.

Materials and Methods

Life Cycle Inventory data was collected through a face-to-face semi structured interview with the growers/managers from two regions in Australia: Bundaberg in Queensland and Sydney in New South Wales. Information was collected on the typical quantities of inputs and outputs for a cropping season such as the use of fertilisers, pesticides, electricity, fuels, transport and yields. It is assumed that the role of capital inputs towards environmental impacts is insignificant when considered over the working life and therefore they were not considered. Three systems were described based on the information from the growers: field production in Bundaberg region of Queensland and two greenhouse production systems in Sydney. A decision to describe two separate greenhouse systems (low-tech and med-tech) was based on the differences in the level of automation and yields obtained for the studied systems (Table 1). The field tomato production in Bundaberg region takes place throughout the year (a cropping cycle ranging from 3 to 6 months depending upon the season) and is fertigated with drip irrigation system. Typically the same amount of fertilisers and pesticides are applied in a cropping season irrespective of the season. A tomato cropping cycle in the low-tech Sydney greenhouse takes place for about 5-6 months usually overlapping the summer months while that of med-tech takes place for 10 to 11months of the year. The present heating system in the low-tech greenhouse uses LPG fired burners which circulates hot air in the greenhouses. The med-tech greenhouse uses coal fired boiler to heat water, which is then circulated through pipes in the greenhouses. Fossil energy is depleted and associated greenhouse gas emissions occur directly when farm inputs such as diesel or coal is used. Similarly energy is consumed and greenhouse gas emissions occur indirectly during the extraction of raw material and energy sources such as coal or LPG and for the manufacture of farm inputs (eg. diesel, fertilisers). The impact assessment characterisation factors for energy use and greenhouse gas emissions were taken from LCA Simapro software using Australian and international databases. The carbon footprint (CF) and energy footprint (EF) were expressed for a kg of fresh tomato at the Sydney market.

Table 1. Description of key information of the studied systems for a typical cropping season

	Field production Queensland	Greenhouse Sydney	
		Low-tech	**Med-tech**
Yield t/ha	60	160	340
Planting density (per m^2)	1.2	2.5	2.8
Distance to Sydney market (km)	1400	25	25
Artificial heating/cooling	No	No	Yes
Diesel (L/ha)	1300	650	2100
Planting medium	Soil	Cocopeat	Cocopeat
Growing season	Year-round	Mainly summer	Year-round

Results and Discussion

The results indicated that fuel sources used for winter heating is the major hotspot in the carbon and energy footprints of tomatoes produced in greenhouses (Table 2). The energy use hotspot varied from 79 MJ/m^2 to 649 MJ/m^2, while the environmental hotspot varied from 6 to 54 kg CO$_2$/ m^2 for the low-tech and med-tech greenhouse systems respectively. The difference between these two greenhouse systems in terms of energy use and greenhouse gas emissions is due to the type of greenhouse technology and the length of growing season. The biggest share of energy use and greenhouse gas emissions from field tomato production is for transporting the fresh tomato to the Sydney market. It

is interesting to note that other things remaining the same if the most energy intensive operations such as transport and climate control were to be eliminated from field tomato production and the greenhouse systems respectively then the energy use and carbon emissions of the systems were comparable for every kg of tomato produced (2.5 to 3.3 MJ; 0.18 to 0.20 kg CO_2).

Table 2. Percent (%) breakup of energy and carbon footprint per kg of tomato production for the Sydney market

Inputs	Field production Queensland		Low-tech greenhouse Sydney		Med-tech greenhouse Sydney	
	MJ	kg CO_2	MJ	kg CO_2	MJ	kg CO_2
Fertilisers	6.5	7.7	21.3	24.2	2.9	3.2
Pesticides	1.2	0.9	0.7	0.6	0.1	0.1
Diesel	8.3	8.3	5.8	7.5	1.9	1.6
Artificial heating	NA	NA	41.2	43.8	89.2	92.4
Packaging	8.7	3.7	22.4	10.4	4.6	1.5
Electricity	9.6	12.8	6.4	10.8	0.6	0.8
Transport	65.7	66.5	2.2	2.8	0.5	0.4
Energy footprint	8.31 MJ/kg		4.95 MJ/kg		19.1 MJ/kg	
Carbon footprint	0.59 kg/CO_2		0.35 kg/CO_2		1.6 kg/CO_2	

NA = not applicable

The results indicated that the CF and EF of fresh tomatoes consumed in Sydney varies depending upon the season. Realistically it would not be possible to grow tomatoes year round in Sydney without artificial climate control. In season, the low-tech greenhouse has the best environmental outcome in terms of a lower CF and EF, however it only operates for 5-6 months. This implies that the luxury of eating fresh tomatoes out of local season means that CF and EF will be higher due to 1) long distance transport from Queensland; or 2) heating if grown locally in climate control greenhouse. Australian vegetable industry may come under closer scrutiny in the future as a part of Australia's commitment to the Kyoto Protocol and other carbon pollution reduction initiatives (Australian Government, 2010). The introduction of carbon tax at the current price of 23$/tonne for fuels (diesel/coal/LPG) consumed by the studied tomato systems suggests that there would be an extra cost ranging from as low as 66$/ha to as high as120000$/ha, which could have implications on the consumer price. The following areas could be explored to reduce CF and EF per kg fresh tomato consumed in Sydney: 1) the prospect of establishing a hi-tech greenhouse which could have higher production and lower carbon emissions from the use of appropriate technologies (CO_2 enrichment); 2) the alternative of using recycled plant biomass along with other renewable energy sources such as waste wood and packaging material as a fuel source for heating the greenhouses (Nederhoff and Houter, 2007); 3) the option of consuming processed tomatoes out of season; and 4) the scenarios to reduce GHG emissions from trucking fleet and the possibility to use sea transport (which usually has a lower energy and carbon footprint than road transport) for tomatoes supplied from Queensland. CF and EF is not an assessment of overall environmental performance; management practices and policy interventions often involve trade-offs within other environmental considerations. With LCA it is possible to assess trade-offs with other environmental impacts such as the potential to contribute freshwater scarcity. These issues will be explored in the ongoing research to guide environmental improvement in the vegetable industry.

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Improving cattle profitability in mixed crop-livestock systems in south central coastal Vietnam using an integrated modelling approach

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Introduction

South-central coastal Vietnamese farming systems are based on growing subsistence rice crops and cash crops such as cassava, peanuts, and cashews. Increasing demand for beef in the major urban centres and consequent high beef prices provide opportunities for increased farmer income. However, cattle production is constrained by limited resources, low fertility sandy soils, and harsh climatic conditions, including high temperatures, a long dry season and flooding in the wet season. Expanding cattle production is restricted by the limited quantity and quality of feeds, and poor husbandry practices leading to long calving intervals, high calf mortality rates, low growth rates, and consequently low cattle productivity and efficiency. The strategic use of improved forages, better animal nutrition, and cattle management (e.g. controlled mating, early weaning, and preferential feeding) can address these constraints; however these changes may introduce conflicts with resource demands (especially land, capital and labour) and the practices of typical cropping systems. While a number of forage species are environmentally suitable, little use has been made of them, as they do not readily suit the current farming system, social and economic structure, and land and labour resources. This paper describes a farming systems research approach to explore the opportunities and constraints to increasing the cattle production of smallholders in south central coastal Vietnam.

Materials and Methods

Commencing in 2009, an Australian-Vietnamese multi-disciplinary team has been working with smallholder farmers in one commune in each of three provinces; Binh Dinh, Phu Yen, and Ninh Thuan. The communes were chosen in consultation with local authorities as representative of the farming systems of the province. To define the current farming system, benchmarking activities included detailed household surveys (~60 households/commune), on-farm biophysical monitoring (~10 households/commune), workshops with farmers and other stakeholders (~20 people/ commune), and focus group discussions (~5 people/commune). During the biophysical monitoring process, cattle were weighed regularly to identify growth patterns, inventories of local feedstuffs were identified and potential suitable forage varieties were screened for local application.

A site-specific version of the Integrated Analysis Tool (IAT) (Lisson et al. 2010) was developed. Crop production was externally simulated using APSIM, and the cattle model was based on that developed for Indonesia with modifications for known production potentials in Vietnam. Crop and livestock data were linked via the IAT with a household socio-economic model that identifies economic returns and resource constraints associated with new management opportunities. The IAT interface allows users to set up and run a series of scenarios and compare the results with a baseline case. The IAT was used to simulate the introduction of various crop, forages and livestock activities within local farming systems and assess their economic and social feasibility. These `best-bet' options were chosen based on the expert knowledge of the research team and application of practices that have been successful in other similar situations.

Results and Discussion

Because the farming systems in the three provinces are very different, results are presented from one Commune, Cat Trinh, in Binh Dinh Province, as an example.

Benchmarking results
A current farming calendar along is presented in Figure 1. The main crops grown are rice (three crops), two in the dry season on irrigated lowland and one in the wet season on rainfed upland; cassava, one crop sown at the end of the rainy season; peanut, a winter-spring main crop and sometimes a second summer-autumn crop; cashew, with the main harvest in May. Farmers often earn extra income by labouring, mostly outside the commune and from March to September. The typical farmer has 2-3 animals (1 cow, 1 calf, and at times, a young steer or heifer). Most farmers use natural weaning at 10-12 months. Cattle are typically sold at 3 years old at 300kg for approximately10M VND (AUD 450). The most common forms of cattle production are exclusive stall feeding, or grazing with supplementation; grazing with no supplementation is less common. Most farmers offer rice straw (4.5kg /cow/day), some of which is purchased off-farm, and supplement with cassava powder and rice bran; very little cut and carry is used. Some farmers grow elephant grass (*Pennisetum* sp.) in the backyard (~150 m^2); and required labour for three animals is approximately 3 hours/day.

Analysis of Scenarios
Analysis of the baseline situation in Binh Dinh indicated farmers were making sufficient income to cover their living costs, but had a forage deficit of around 1600kg (Table 1) and taking 3 years to get animals to a marketable size. Growing 0.1ha of sown grass (elephant grass) in the upland and another 0.1ha in the backyard, and increasing the cut and carry to 25kg/day (Scenario 2) and selling animals at 2 years old, improved the feed supply to animals, increased the animal sale weight, and eliminated the forage deficit. Growing tree legumes improved forage quality and increased calving rate and liveweight gain (Scenario 3), as well as providing a forage surplus. Introduction of controlled mating (annual calving) and early weaning of calves increased cattle sales to 9 over the 10-year period (Scenario 4). Utilising the surplus feed by keeping an extra cow and increasing cut and carry to 35kg/day increased animals sales to 14-15, with weights of 300kg (Scenario 5), compared to a baseline output of 5-6 animals weighing 200kg (Scenario 1). There was little impact on costs or labour because the introduction of forages and tree legumes involved little cost, and the labour required for the initial planting of these was offset by the reduction in time to collect daily feed for the animals.

	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall	Drizzling rain			Dry Season					Very high rainfall			Rain
Main crops												
Rice	Winter – Spring rice crop			Summer-Autumn rice crop				Third rice crop				
Cassava	Growing season											
Peanut	Winter - Spring crop				Summer - Autumn crop							
Cashew	Harvesting								Planting		Harvesting	
Cattle activities												
Breeding	Calving			Mating								
Grazing	Grazing			Less grazing				More grazing				
Rice Straw use	More in ration							Less in ration				
Cultivated grass use												
Cut and carry grass												
Peanut vine use												
Body condition	Low		High							Low		
Prices	High											

Figure 1. Seasonal farming calendar for Cat Trinh Commune, Binh Dinh Province, Vietnam.

Table 1. Model output from baseline and various intervention strategies in Binh Dinh, run over a 10 year period. Final cash balance values do not take into account hired labour costs.

Cut and feed kg/day	Animals sold over 10 years	Cattle sale weight (kg)	Fodder surplus (kg/month)	Gross Margin (M VND/year?) *	Final cash balance (M VND)
Scenario 1. Baseline: 0.2 ha rice (3 crops); 0.1 ha cassava on upland; 0.2 ha peanut on upland; 1 cow; fed cut and carry of 20 kg/day plus supplements; 90 % retention of rice and peanut straw.					
20	5-6	200	-1600	10	48
Scenario 2. Grow 0.1ha grass on upland, plus 0.1ha in backyard; increase cut and carry to 25kg/day					
25	5-6	225	0	10	51
Scenario 3. As above, and grow 100m of tree legume					
25	7-8	300	4000	10-15	79
Scenario 4. As above with seasonal mating and early weaning					
25	8-9	350	3500	10-20	95
Scenario 5. As above, increase number of cows to 2, cut and carry to 35kg					
35	14-15	300	-1500	15-20	154

* 1AUD = approximately 22,000 VND (June 2011)

Implementation of best-bet options

A farming systems analysis approach has identified numerous possible options to improve livestock production and household welfare. The simulation results suggest that sowing a small area of improved pasture, introduction of tree legumes, and improved cattle management, can allow an increase in herd size and greatly improve the profitability of a household. These options are currently being tested in collaboration with 15 farmers in each study commune.

Acknowledgements

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A spatial analysis: creating similarity domains for targeted research sites in Zimbabwe

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Introduction

There is agreement that food security in the developing world is under threat. Particularly as since the early 1960s, increases in cereal grain yields are failing to compensate reductions in per capita area harvested due to rapid increases in population growth (Funk and Brown 2009). The problem is likely to be further exacerbated as the world's climate changes (Brown and Funk 2008; IPCC 2007), while political instability and recurrent crises makes poverty and hunger a highly resilient and complex problem, as experienced by Zimbabwe since the early 2000s. In Zimbabwe the recent downward trend in maize yields (the main staple food) is exacerbating hunger across the country (Funk and Brown, 2009), while the total crop production is plateauing as a result of an expansion in cropped area rather than an increase in yields. Furthermore, regional information required to inform policy and drive research development and extension (R,DandE) investment to intensify agriculture, and the magnitude of the yield gaps, is not available. In this study we categorised 'similarity domains' according to regional information on climate and soil properties to identify regions where targeted R,DandE investment would have maximum impact at reducing food insecurity.

Material and Methods

Site Locations and Criteria

Six regions in total were selected for the development of the domains. The regions were defined around the following sites: Bindura, Madziwa, Zimuto, Wedza, Gweru and Gwanda. The criteria for scaling out the site characteristics into similarity domains were obtained from the International Maize and Wheat Improvement Centre (CIMMYT). Spatial modelling techniques and geographic information systems (GIS) were used to create similarity domains based on their agricultural productive capacity, which were defined as a function of both climate (rainfall and temperatures), and soil information (maximum rooting depth and texture) (Batjes 2010). In addition, population data for the years 2000 and 2005 (http://sedac.ciesin.columbia.edu/) and distance to markets and cost of transport (Sonder and Gomez 2010) were used as a surrogate for assessing trends in food demand and market accessibility within each region. Simulated yield differences between crops grown under high and low inputs were used as an indication of the likely yield gap currently existing within each region (Koo 2010). Thresholds around the means for the summer dominated period (November to March) were used to assist in delineating areas, which had similar climate within these thresholds. Final scaling out inputs were: (i) Summer climate: $\pm$ 100mm precipitation, $\pm 2^o$ max temp, $\pm 2^o$ min temp, and (ii) Soil classes of maximum rooting depth and soil texture to each location.

Yield potential

Simulated yield data (Decision Support System for Agrotechnology Transfer (DSSAT) v4.0.2 (Jones et al. 2003), was used to determine the envelope of yield responses between low input yields (local cultivar: C0) and high input yields (hybrid cultivar: C1) at different fertiliser levels (0, 20, 40 and 60 kg/ha) within each domain (Koo 2010). In addition, aggregated actual yields were collated from FAO and MAMID reports at the province level for 2006/07, 2007/08 and 2008/09 (FAO 2008; MAMID 2009). The yield gap and actual yield data were used to determine the agricultural potential for each domain.

Results and Discussion

Domain extraction

Although the domains were selected based on site specific climate and soils information, some overlap existed between regions. Specifically, the Wedza and Zimuto sites showed some level of overlap mainly due to the similarity in soil classes (depth and texture) (Figure 1). All sites have a summer (November to March) dominant rainfall with very little rainfall recorded during the winter period (April to October) (Table 1). Bindura and Madziwa havethe highest summer rainfall with 830mm and 783mm, respectively. Gwanda had the lowest summer rainfall with 407mm on average. Very little difference was observed in average minimum summer temperatures (17 − 19 ^{o}C). Maximum rooting depth is deepest in Gweru (Very Deep (X), >150cm) and Bindura (Deep; 100-150cm), while Zimuto and Wedza had the shallowest soil depth for cropping purposes (Shallow; 30-50cm). Soil texture varied between clay-loam (CL), loam-sand (LS) and sand (S) between sites. Average travelling times to the nearest market hub with more than 10,000 people varied from 3.4 hours (Gwanda) to 4.6 hours (Zimuto) (Table 2).

Agricultural potential

The average actual maize yield (over 2007, 2008, 2009) varied across the region from 0.34 t/ha (Midlands - Gweru) to 0.81 t/ha in the Mashonaland province (Bindura/Madziwa) (Figure 2). Actual yields are currently well below the expected yields across most of Zimbabwe. With the expected average maize yield across all regions to be at least 2 t/ha (FAO 2008) the actual maize yield during 2009 and the 3-year average did not exceed 1.75 t/ha at district level (Figure 2). When comparing the actual yields to the aggregated simulated maize yields for each domain region it is evident that the gap between what is currently realised (< 1.75 tonnes/ha on average) and what the likely to be achieved remains large within each domain as well as between regions (Table 3). Overall, the differences in agricultural potential between domains aligned well with the selected climate (rainfall and temperature) and soil types. With population growth increasing at a rate of > 1% per annum and limited access to markets (Table 2), it is anticipated that hunger will be further exacerbated in almost all these regions. The yield gaps presented here have been simulated for generic soils and climates and assuming good management practices and give an indication of what is achievable under different management systems for each domain. It was evident here that application of fertiliser plays an important role in increasing maize yields and thus enhancing future food security across all domains. Further, this study showed that regional information on climate and soils properties can be effectively utilised to extract similarity domains and identify regions where targeted R,DandE investment would enhance research efficacy and thus have maximum impact at reducing food insecurity.
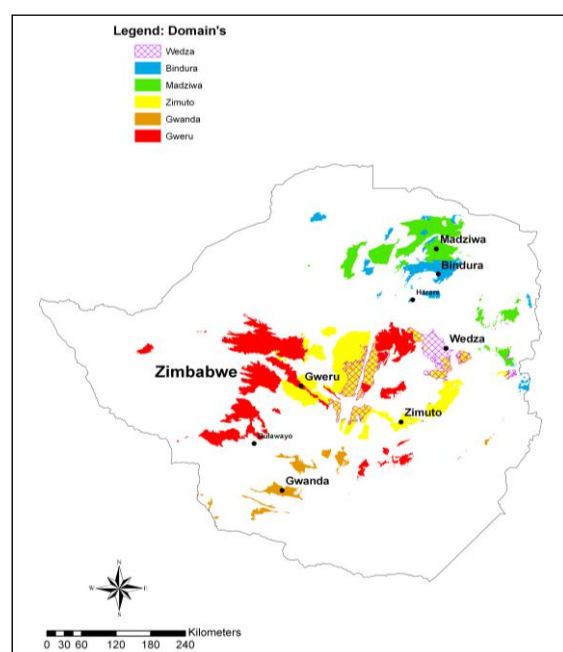
Figure 1: All six similarity domains
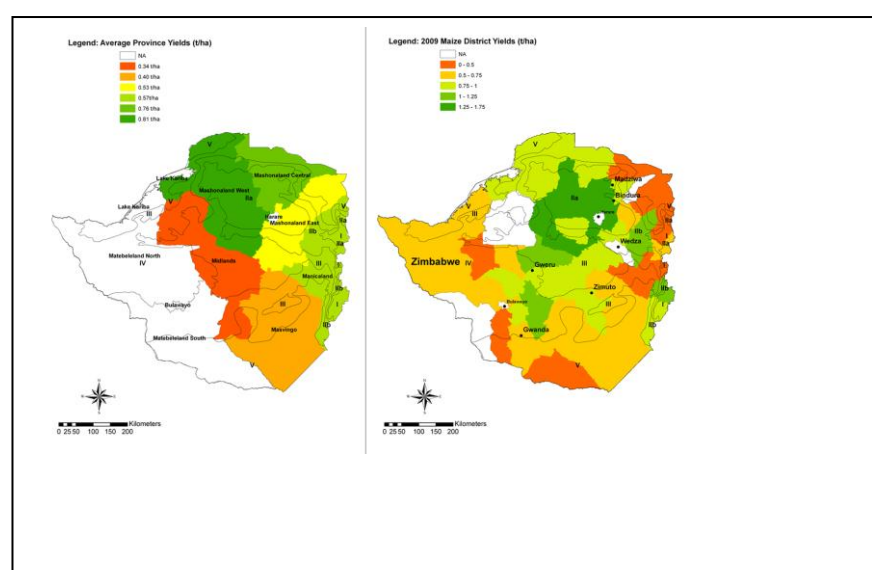
Figure 2: Actual maize yields: (a) 3-year provincial average and (b) the 2008/2009 season. Natural regions and six locations are superimposed.

Table 1: Total rainfall and average temperatures for winter (WT), summer (SM) and annual (AN)

	Rainfall (mm)			Temperature oC					
	AN	SM	WT	SM Max	WT Max	SM Min	WT Min	AN Max	AN Min
Bindura	902	830	72	27.92	26.29	18.72	9.37	26.97	13.27
Zimuto	647	575	72	26.58	23.86	17.7	9.59	24.99	12.97
Madziwa	834	783	51	26.42	23.99	17.82	8.21	25.00	12.22
Gwanda	474	407	67	29.06	26.10	19.12	9.33	27.33	13.41
Wedza	816	709	107	25.46	23.23	16.96	9.64	24.16	12.69
Gweru	630	568	62	27.02	25.20	17.58	9.31	25.96	12.76

Table 2: Site location soil and market access parameters and Area and population statistics for each domain.

Location	Rootable Depth (cm)	Soil Texture	Market Access (hrs)	Avg travel time	Domain Area	Population 2000	2005	Growth	%Change
Bindura	D	CL	4	3.89	404729	209499	232214	22715	10.84
Zimuto	S	LS	8	4.60	1645682	516219	553792	37573	7.28
Madziwa	M	LS	3	4.49	870442	330721	363542	32821	9.92
Gwanda	M	CL	0	3.38	283184	50409	51356	947	1.88
Wedza	S	LS	2	4.20	694153	193099	204221	11122	5.76
Gweru	X	S	4	4.30	1696315	536207	589658	53451	9.97

Table 3: Simulated weighted average domain yields at different management levels (N0 [no fertiliser], N20 [20 kg N/ha] N40 [40kg N/ha], N60 [60kg /ha]). C0 - Proxy for local long growing cultivar; C1 - Hybrid

Domian	C0_N0	C0_N20	C0_N40	C0_N60	C1_N0	C1_N20	C1_N40	C1_N60
Gweru	0.73	1.58	2.63	3.53	1.19	3.17	4.24	4.66
Gwanda	0.36	1.30	1.82	2.18	0.93	2.93	3.68	4.03
Zimuto	0.72	1.73	2.82	3.63	1.26	3.14	4.48	4.99
Madziwa	0.80	1.54	2.50	3.40	1.30	2.99	3.99	4.43
Wedza	0.49	1.38	2.65	3.69	0.83	2.69	4.30	4.91
Bindura	1.34	2.18	3.05	3.72	2.89	3.98	4.66	5.05

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The expected value of seasonal stream-flow forecasts to a grain-cotton irrigator in the Condamine-Balonne catchment

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Keywords: seasonal stream-flow forecast, whole farm systems modelling, APSIM

Introduction

Water for irrigation is often the limiting resource that prevents grain-cotton growers from planting more area and increasing farm business returns. The potential exists for grain-cotton irrigators with river harvesting entitlements to increase farm profits by utilising the Bureau of Meteorology's (BOM) seasonal stream-flow forecasts (BOM, 2010). However, for any climate forecast to be effective it must provide information that generates actionable and beneficial changes in the management of the targeted system (Hammer, et al. 2000). This paper provides an example of how a seasonal forecast of river stream-flow could be used to support a relevant and actionable decision, in this case varying cotton area by adjusting the amount of water at sowing required to plant each hectare of cotton. This results in a potential increase in the profitability of an irrigated farm business from the Darling Downs in Queensland, Australia through capitalising on relatively high summer river flow forecasts by increasing the area sown to cotton.

Methods

Case study farm

Semi-structured interviews with the case study farmer from Dalby, Queensland, Australia, were used to describe farm resources and its management. The farm is 616 ha of furrow irrigated cropping land, with 3 on-farm water storages having a combined capacity of 2,400 ML. Sources of irrigation water include bores (170ML total annual allocation), water captured from on-farm runoff, and water-harvesting entitlements from the Condamine River. Here, for simplicity we assumed cotton was grown as a monoculture.

Modelling framework

The information collected during the interviews with the farm manager was used to parameterise the multi-field configuration of the process-based model APSIM (Keating et al. 2005), described in Power et al. (2011). Farm operating constraints, such as pumping capacities and machinery work rates, as described by the farmer, were included in the model. We ran the model using patched historical climate records (Jeffrey et al., 2001) for 51 years (1958 to 2009) using 2010/2011 prices and costs. Fallow costs are driven by a simple weed emergence model as in Power et al., (2011). Integrated Quality and Quantity Model (IQQM) provided daily Condamine River flow data (ML/day) near the case study farm (State of Queensland, 2010).

Stream flow forecast

At the time of writing this manuscript BOM's Seasonal Stream-flow Forecasting service (www.bom.gov.au/water/ssf/) was not yet operational in Queensland catchments, therefore a climate index was used to provide proxy forecasts. The NINO3 index with a 2 month lag has the best skill at predicting summer rainfall (DJF) in the area under consideration (Schepen et al., in review). This corresponds to the value of the NINO3 index for October, which coincides with cotton sowing month in southern Queensland. We used historical October NINO3 values in a hindcast to evaluate its ability to predict Condamine River flows for summer. A relatively high summer river flow is more likely when October's NINO3 anomaly is less than -0.8 and conversely a relatively low flow season is more likely when the NINO3 anomaly is greater than 0.8. Otherwise (-0.8≤NINO3≤0.8) there is no indication of either above or below median flow for the coming season. Figure 1 shows cumulative distribution functions for aggregate flows for the Condamine River separated into analogue prediction types. It demonstrates the NINO3 index has reasonable ability (F test p-value = 0.03) to predict the relative size of summer Condamine River flows, especially for the prediction of high flow seasons and justifies its use as a predictor of stream flow.
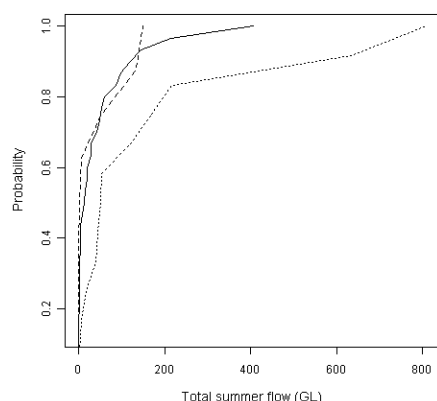
Figure 1 (left). Aggregate modelled Condamine River flows (GL) for summer (D,J,F) for the NINO3 predicted: low flow seasons (dashed curve); high flow seasons (dotted curve); and when no prediction is available of either above or below median flows (solid curve).

Change in management

For the case study farm, the area planted to cotton each year depends on the amount of stored water available for irrigation at the time of sowing. Here, we incorporated NINO3 predictions of river flows in the farmer's decision framework by adjusting the amounts of stored water required at sowing for each hectare of cotton being considered for planting. When a higher river flow than normal was expected less stored water at sowing per hectare of cotton was required due to the increased probability of both additional river flows and in-crop rainfall. This then allows for a greater area of cotton to be sown for that season. Similarly, when a relatively lower river flow is expected for the season, then more stored water per hectare of cotton is required and the area sown is reduced. The actual amounts of stored water (ML/ha) were optimised to maximise farm returns. When no additional information about the subsequent seasons is available from the NINO3 climate index, management is un-changed.

Results and Discussion

Twenty out of the 51 seasons simulated a forecast of either high or low flows, and hence the potential for a change in area of the farm allocated to cotton in order to maximise farm returns. Figure 2a, shows probability density functions of farm gross margins for those seasons when the stream-flow forecasts indicated either higher or lower flows as the most likely outcome, and adaptive management is thus undertaken (dashed curve); and those seasons when the farmer's current management strategy is employed (solid line). In those 20 years farm returns increased significantly (one sided t-test p-value = 0.05). However, when all years were compared (Figure 2b) the statistical significance was lost. The optimal amounts of stored water for sowing cotton were 0 ML/ha when a high flow season was the more likely outcome of the forecast i.e. corresponding to sowing all 616 ha of the farm to cotton. This indicates that during high flow seasons available cropping area limits farm profits. When a low river flow season was the most likely, the optimal strategy was found to be the farmer's current management (i.e. setting cotton area based on 4ML/ha), which indicates no change in the cotton area for the season (ca. 232ha). This agrees with the results in Figure 1, which shows the NINO3 index has no ability in forecasting low flow seasons.
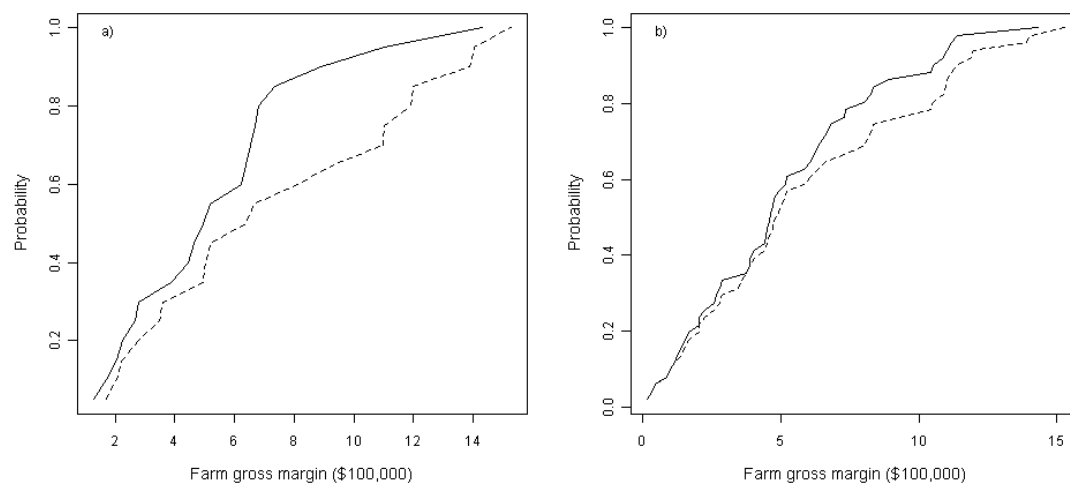
Figure 2. Current management (solid curve) and adaptive management (dashed curve) for those seasons when a NINO3 based prediction of either high or low flow was available a) and all years b).

We conclude that for this case study farm the expected value of a seasonal river stream flow that uses NINO3 as a predictor would be ca AU$31,000/year. For simplicity, here we only considered changes in sown cotton areas. However, many other strategies relevant to the farmer could have also been explored e.g. crop choice, sowing densities, etc.

Acknowledgments

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Irrigated lucerne and dryland sorghum are effective crop options for reducing deep drainage in the farming systems of the Lockyer Valley, Australia

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Keywords: Howleaky, Lucerne, Sorghum, Transpiration, Water balance

Introduction

The Lockyer Valley in the south eastern part of Queensland is an important area for agriculture and horticulture, producing nearly 35% of the irrigated vegetables grown in Queensland (Cox and Wilson 2005). However, significant areas of this valley have poor quality, saline groundwater that is used for irrigation (Bajracharya and Ellis 1999). Saline groundwater is not unexpected, as parts of the regolith contain large amounts of salt, and much of the diffuse recharge in the valley is likely to be saline. Conversely, recharge from surface water is high quality. Any land management practice that increases deep drainage and diffuse recharge or otherwise results in saline contamination of ground water is a threat to sustainable production in the valley.

Deep drainage occurs when infiltration from rainfall and irrigation exceeds the soil moisture deficit, resulting in moisture content above the drained upper limit (DUL) and some "excess", "drainable" or "gravitational" water. The soil moisture deficit can be managed by crop selection (soil water output via transpiration) and irrigation management (soil water input). This implies that deep drainage can be minimised by growing crops with high rates of transpiration and irrigation that maintains a reasonable trade-off between a high soil moisture deficit and yield reductions. Planting deep-rooted perennial crops has been an important technique for reducing deep drainage, rising water tables and the outbreak of dryland salinity in diverse situation in Australia (e.g. Ward et al., 2001, Robinson et al., 2010). We anticipate that similar plant-based strategies can also be effective in an irrigated situation in northern Australia, like the Lockyer Valley.

In this study we compare deep drainage estimates from an existing farming system with that of a system in which shallow-rooted, stress-sensitive vegetable crops were replaced (for the selective periods) with deep-rooted, drought-tolerant crops (lucerne and sorghum). Sorghum is often grown without irrigation – reducing irrigation demand and potentially reducing deep drainage to low levels. The objective of this study is to estimate the reductions in deep drainage with these crops under a well irrigated system. Understanding the managerial controls over deep drainage will allow the development of farming systems that minimise the contributions of saline, diffuse recharge to groundwater resources in the Lockyer Valley.

Materials and Methods

The HowLeaky? model (Rattray et al., 2004, Robinson et al., 2010) V5.28 was used to simulate the water balance of each scenario. HowLeaky? is a daily-time step, 1-dimensional (vertical) model of water inputs from rainfall and irrigation, and water outputs of runoff, soil evaporation, transpiration and deep drainage. Data for simulations are contained in a variety of parameter files, including climate, soil, vegetation, tillage and irrigation.

The simulations were for the period from November 1997 to April 2010, using climate data for Forest Hill, Australia (27°36′ S 152°20′ E, about 83 km West of Brisbane), downloaded from the Patched Point Dataset (http://www.longpaddock.qld.gov.au/silo/). The soil at the study site is a Black Vertosol (Isbell 1996) of which two types are the main soils used for irrigated agriculture and horticulture. The landholder's crop sequence for the period included beetroot, broccoli, cotton, mung bean, sweet corn (all irrigated) and wheat (dryland), and bare fallow of varied duration between crops. The simulated crops were irrigated when a critical soil water deficit was reached; 25 mm for beet and broccoli, 50 mm for cotton, sweet corn and mung bean. Irrigation amount was determined by an irrigation "end-point", such as drained upper limit. The hypothetical sequences added (i) irrigated lucerne (2 crops, 4.8 years total duration) and (ii) irrigated lucerne and dryland sorghum (3 crops, 1 year total duration). The crop cover model for lucerne had inputs of green and total cover (%), residue cover (%) and root depth (mm) for various times of the year, while the dynamic crop model for sorghum had detailed management and biophysical parameters concerning phenology, growth and other processes. Fallows were simulated as bare soil.

We report several indices of deep drainage and its relation to water supply; (i) the long-term average (mm/year), (ii) the ratio of deep drainage to irrigation and rainfall, and (iii) the ratio of transpiration to irrigation and rainfall.

Results and Discussion

The average annual rainfall for the study period (697 mm/year) was below the long-term average (770 mm/year), resulting in higher irrigation demand. Adding irrigated lucerne to the crop sequence increased irrigation and transpiration, but deep drainage was reduced by 80mm/year. This is approximately 30% less than the default (Table 1). Figure 1 shows the annual pattern of deep drainage for three cropping sequences. Perennial growth and consequent year-round water use by lucerne, and access to deeper soil moisture, help to minimise the risk of deep drainage (data not shown). Lucerne and other perennial pastures have previously been found to reduce deep drainage on a range of soil types and in a range of locations (Ward et al., 2001, Robinson et al. 2010).

Adding dryland sorghum to the crop sequence with irrigated lucerne resulted in an additional, though small, reduction in deep drainage (Table 1). A potential benefit to landholders of this system is that irrigation demand is reduced by approximately 10% (overall), even though the sorghum was included for only 12 months out of more than 12 years (Figure 1). The characteristics of sorghum that reduce deep drainage are drought tolerance and a moderately deep root system (deeper than vegetables, shallower than lucerne).

Deep drainage as a percentage of irrigation and rainfall was 6% lower with both lucerne and sorghum while transpiration was about 8% higher than the default system (Table 1). Given that runoff is a small proportion of the water balance, and soil evaporation and irrigation did not change very much, it is not surprising that the increase in transpiration is similar to the decrease in deep drainage. We conclude that lucerne and sorghum have considerable potential to reduce deep drainage in this farming system under the simulated conditions of

unrestricted irrigation. Economic studies are required to determine whether these are viable options for landholders. Also, further measurements of the soil and plant systems, and more detailed descriptions of irrigation management will assist future simulations and analyses.

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Figure and Table
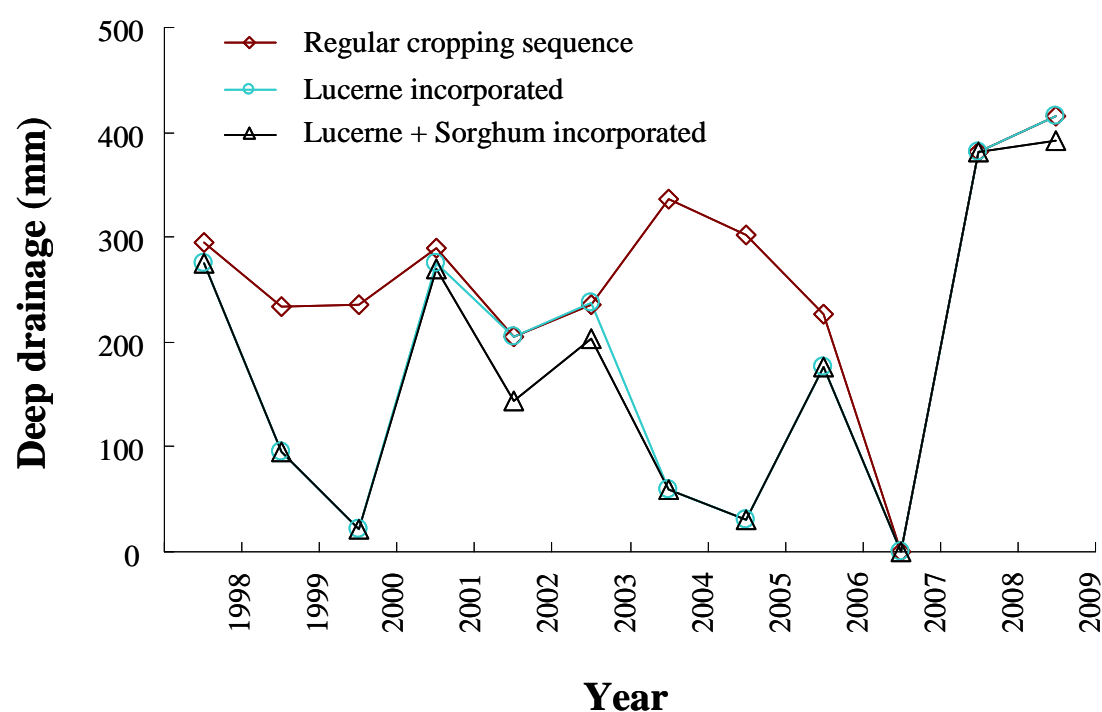
Figure 1. Simulated deep drainage for 3 cropping sequences at Forest Hill, Lockyer Valley.

Table 1. Average annual water balance, and deep drainage and transpiration as a percentage of rainfall (R, mm/year) and irrigation (mm/year).

Cropping Sequence	Irrigation (I, mm)	Deep drainage (DD, mm)	Transpiration (T, mm)	Evaporation (mm)	DD/(I+R) (%)	T/(I+R) (%)
Regular	751	265	667	453	18	46
+ Lucerne	808	185	826	431	12	55
+ Lucerne + Sorghum	721	169	762	430	12	54

Adapting to change: more realistic quantification of impacts and better informed adaptation alternatives

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Introduction

Existing analyses on climate change impacts (Challinor et al., 2009), adaptation options (Howden et al., 2007), and policy recommendations (Garnaut, 2008) are mostly based on empirical and/or simulation work pursued at the individual crop level, where the key metric is changes in individual crop yields. This contrasts with the fact that farm managers and policy makers support their decisions with information on farm business profits, risks, and cost benefit analyses between alternative options or scenarios. This mismatch of scales was reported in Rodriguez et al. (2011), where they showed that at the farm level, changes in the yields of individual crops can be rather irrelevant to changes in farm profit-risk trade-offs in a changed climate. They concluded that *"impact assessments and the identification of opportunities for adaptations to climate change should be conducted at scales most relevant to the decision maker; this is paramount in order to adequately account for the large number of interacting factors"*; and proposed that "in the case of adapting cropping systems to climate change the farm level should be the spatial scale of choice". This is because farmers manage complicated farms rather than just crops, where changes in one enterprise at any point in time can limit options spatially across the farm (e.g. due to land, labour or machinery constraints); and temporally across seasons (e.g. due to follow on implications on soil water and nutrients availability, or the need for breaks for pests or diseases between successive crops). Thus, when the analysis is removed from the farm business context, the disconnect between the more technical issues, e.g. choosing a cultivar or a particular rate of fertilisation, and the final decision made on the farm, conspires against understanding why an individual piece of technology is not adopted, or why an apparently "sub-optimal" decision is finally made. In this work we used a whole farm dynamic simulation model (APSFarm, Rodriguez et al., 2011; Power et al., 2011) to capture and quantify as many possible factors acting at the farm level, to more realistically evaluate options and opportunities for adaptation to climate change across four contrasting real farm case studies across Queensland, Australia.

Methods

Farmers from four case study farms were interviewed and the physical, socio-economic, and production characteristics of each farm, including field and farm management rules, were recorded. This information was then used to parameterise a whole farm dynamic simulation model (APSFarm) and create a virtual representation of each case study farm. The farm case studies included, (i) a rainfed cropping farmer from Emerald (-23.53 °S, 148.16 °E); (ii) a mixed grain-grazing farmer from Roma (-26.57°S, 148.79°E); (iii) an irrigation farmer from Dalby (-27.17°S, 151.27°E); and (iv), a rainfed cropping farmer from Goondiwindi (-28.33°S, 150.31 °E), all in Queensland, Australia. After validation with the participating farmers, the model was accepted as capable of realistically representing the impacts (i.e. economic, financial, environmental), of present practices, tactics and strategies. The validated model was then run for a baseline climate scenario (i.e. using SILO climate records from 1890-2009, http://www.bom.gov.au/silo/), four climate change scenarios, and a factorial combination of values for key management rules relevant to each farm case study (Table 1). The four climate change scenarios originated from combining two emission scenarios A1FI and A2, and two global circulation models MRI-GCM232 and MIROC-H that represent extreme points in projection scenarios. Results are described in terms of changes in the efficiency frontier for the trade-offs between average annual farm profits and their variance (a measure of economic risk). In the efficiency frontier graphs, each point represents the average profit – risk characterisation of a particular combination of management rules.

Results and Discussion

Here we only present results from the analysis of the baseline and A1FI 2030 - MRI-GCM232 climate scenario. Our simulations indicate that climate change % reductions on farm profit (Figure 1) could easily exceed % reductions on the expected yields of individual crops (Challinor et al., 2009; Rodriguez et al., 2011). In our case study farms, this was the particular case of farmers being unable to sow crops during slightly dryer autumns and springs; or not having enough irrigation water in their dams to allow the planting of an irrigated crop. A small reduction in the water availability at key times in the cropping calendar directly affects the number of crops in a crop sequence, reducing the cropping intensity and the farm profit. Though, the different case study farms showed different levels of sensitivity to the tested climate change scenario. As expected, the irrigated farm business showed greater resilience than the rainfed cropping case studies. Comparing the two rainfed cropping systems, the more "plastic" and opportunistic farmer (Emerald) seemed to be relatively less affected by the change scenario than the more "rigid" farm management style from Goondiwindi (also observed in Rodriguez et al., 2011). Interestingly, the impact from the climate change scenario was as severe in the mixed grain-grazing case study as in the rainfed cropping farms. We also observed that the relative changes in profits and risks, in the efficiency frontier, were slightly different for the different farms. Visually, in the case of the irrigated farm the shape of the efficiency frontier tended to be "flatter" than that of the mixed grain – grazing farm, and rainfed cropping farm businesses. This indicates that in the irrigated farm, while moving over the efficiency frontier, average profits would remain high. In the grain-grazing farm, farm management could be used to achieve different trade-offs between profits and risks, though for the rainfed cropping farms, with more vertical frontiers, fewer options might be available to trade reductions in risks by lower profits. We also found that in general, if the present farm business performance falls below the efficiency frontier under present climate, then it would be easier to find opportunities to improve the performance of the farm under the projected climate scenarios. Counter intuitively, farms and farmers already operating on the efficiency frontier would have fewer "easier" options to adapt to climate change. Though, still opportunities to increase profits or reduce risks could be identified. For example adaptation options to increase profits for the irrigated farm would involve changes in the allocation of water and land across alternative enterprises (not shown). For the Emerald farm, changes in soil water thresholds for sowing crops could be used to move towards a different region in the efficiency frontier, e.g. higher profits at similar risks, or reduce risks at similar profits (Figure 2). For the Goondiwindi and Roma farms, options to maintain profits or risks in a climate changed environment seem to be rather limited. This might indicate that more transformational changes in the farm businesses might have to be explored to identify adaptation options to expected changes in climate.

Table 1. List of key tactical and strategic changes evaluated at each farm business and the expected outcome in terms of changes in farm profits and its variability (risk).

	Tactical / strategic change	Expected outcome
Mixed grain-grazing	Land allocation to cropping (values varied at 0.1 intervals between 0.1 and 0.9).	A higher allocation of resources to grazing enterprises reduces profits and risks.
	Proportion of the non-cropping area allocated to forages, (values varied at 0.1 intervals between 0.2 and 0.6).	A higher allocation of non-cropping area to forages (forage sorghum) adds a quality source of forages increasing farm profits
Irrigated cropping	Minimum stored irrigation water required for sowing a crop (values varied at 1Ml/ha intervals between 0 and 12)	Sowing crop with reduced amounts of stored water increases the farm cropping intensity, risks and profits.
	Alternative water allocations across crops (values varied at 1Ml/ha intervals between 0 and 12)	Increasing the allocation of water to the riskier crops (maize and soybean) increases profits and reduces risks.
Rainfed cropping	Soil water required for sowing wheat and sorghum crops (values varied at discrete intervals between 50 and 250mm).	Sowing crops with lower soil available water imply taking higher risks for individual crops, higher cropping intensities, and potential higher farm profit.
	Maximum land area allocated to individual crops e.g. the wall to wall planting rule, (values varied at discrete intervals between 0.1 and 0.9).	As more land is allocated to individual enterprises, crop diversity is reduced and risk exposure increases.
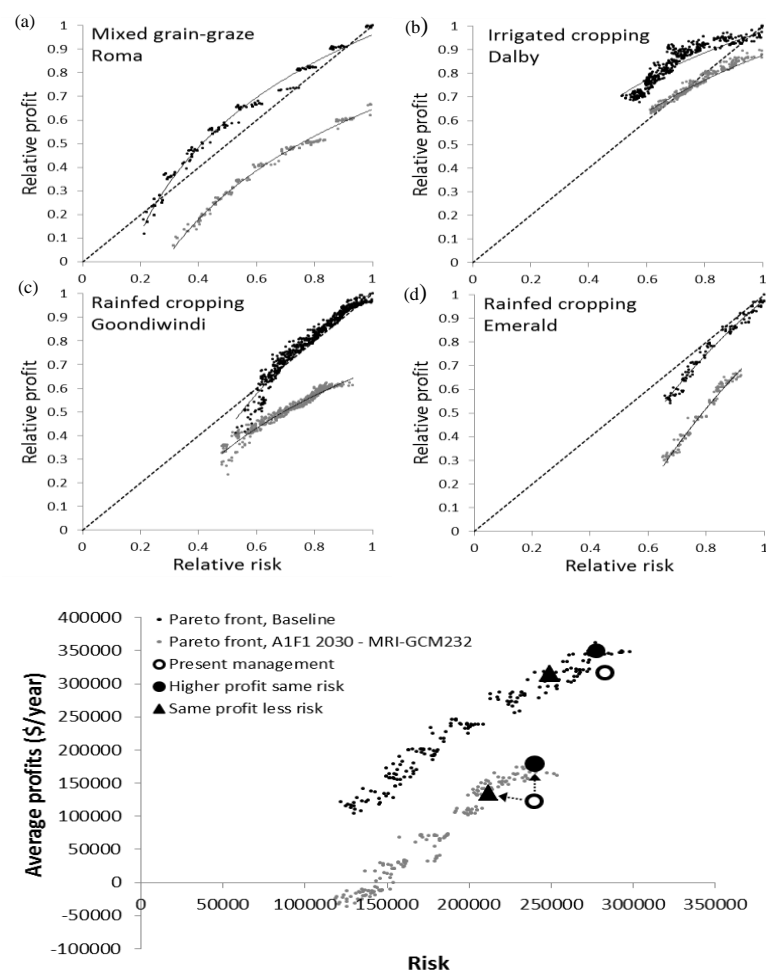
Figure 1. Efficiency frontier for the trade-off between profits and risks (i.e. top 5 percentile in the Pareto rank), for the Baseline (dark symbols) and A1FI 2030 - MRI-GCM232 climate change scenario (grey symbols), for (a) a 4000ha mixed grain and grazing farm from Roma; (b) a 500ha irrigated cotton-grains farm from Dalby; (c) a 3000ha rainfed cropping farm from Goondiwindi; and (d) a 2000ha rainfed cropping farm from Emerald. Results are relative to the farming system providing the highest profit for the Baseline simulation. The dashed line is the 1:1 relationship.

Figure 2. Efficiency frontier for the trade-off between profits and risks (i.e. top 10 percentile in the Pareto rank), for the Baseline (dark symbols), and A1FI 2030 - MRI-GCM232 climate change scenario (grey symbols), for a 2000ha rainfed cropping farm near Emerald, Queensland. Risk is the variance of the profits. Open circles show the performance of present farm management, closed circles show a management strategy having higher profits and similar risks; closed triangles show a management strategy having similar profits though lower risks.

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Effects of Conservation Agriculture and manure application on maize grain yield and soil organic carbon: a comparative analysis

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Keywords: continuous maize cropping, degraded soil, animal feed, mulch cover, tradeoffs

Introduction

In southern Africa, most farming systems exhibit a close integration of crop and livestock components, with an output of one component being an input of the other. The allocation of crop residues for livestock feed meets two out of three critical objectives; it ensures feed during the dry season (De Leeuw, 1996), improves quantity and quality of manure to restore soil fertility (Murwira et al., 1995) but does not ensure permanent soil cover required under conservation agriculture (CA). Thus under CA, there are strong trade-offs for either allocating crop residues for livestock feed or using the crop residues directly for mulch thereby reducing the amount and quality of manure available and compromising the condition of livestock. The objective of this study is to perform a comparative analysis of maize grain yield and soil organic carbon (SOC) changes in CA systems versus conventional tillage systems with manure application. Crop residue retention and reduced tillage are options that are expected to increase SOC in the long-term, in a similar way to manure application. Therefore, it is necessary to perform a comparative analysis to quantify the differences and to identify the most sustainable system. Crop yield is important for ensuring food security and income, and SOC is an important determinant of soil fertility, productivity and sustainability (Lal, 1997).

Materials and Methods

Data were obtained from two sets of long-term experiments under continuous sole maize (*Zea mays* L.). The experiment on manure application was established in 2002 until 2010 on both clay (Chromic Luvisols) and sandy (Haplic Lixisols) soils (FAO, 2006), and two field types (homefield and outfield) in Murehwa, Zimbabwe. The treatments included a control, 100 kg N ha^{-1}, 100 kg N ha^{-1} + 5 t manure ha^{-1} and 100 kg N ha^{-1} + 15 t manure ha^{-1}. The tillage experiment was established in 1988 to 1999 at three sites, Domboshawa (sandy soils, Haplic Lixisols), Makoholi (sandy soils, Ferralic Arenosols) and Institute of Agricultural Engineering (IAE) (red clay soils, Chromic Luvisols) (FAO, 2006). Conventional mouldboard ploughing was carried out to a depth of about 23 cm. Mulch ripping (MR), was achieved by ripping to a depth of 20 – 25 cm while maintaining the crop residues on the soil surface. Mulch cover at the beginning of the season ranged between 40 and 60 %. All treatments received annual fertiliser additions of 114 kg N ha^{-1}, 22 kg P ha^{-1} and 25 kg K ha^{-1}, the full experimental details are found in Moyo (2003).

Results and Discussion

The addition of 5 t ha^{-1} manure more than doubled maize grain yield of the control (Figure 1) while the effect of mulch and reduced tillage on yield was marginal with a yield gain of only 0.2 t ha^{-1} over a nine year period (Figure 2). Results of Larbi et al., (2002) showed that the effects of mulch on maize grain yield were site specific and generally depended on the amount of mulch retained. Applying too much mulch causes waterlogging and induces immobilization of soil nutrients (Burrows and Larson, 1962). Manure application (5 t ha^{-1}) under conventional tillage increased SOC by 0.13% and 0.09% per year on clay and sandy soils respectively (Figure 3) while the CA practice led to an increase of 0.02% per year for both sandy and clay soils (Figure 4). However, the quantities of manure applied are not achievable under smallholder farming systems. The quantity of manure produced from stover is a function of digestibility and feed intake. Given the low productivity of maize on smallholder farms of 1 t ha^{-1} and assuming that all is available for livestock feed with a digestibility of 56% (Tubei and Saidi, 1981), the amount of manure produced will be 440 kg i.e. ((100-56)/100) × 1000 kg. Assuming a 50% loss due collection and handling, about 200 kg of manure will be produced per ton of maize stover, hardly enough to contribute significantly to the improvement of soil organic carbon and nutrient supply. However, the opportunity cost of losing mulch is offset by gains in animal productivity given that communal grazing is not adequate during the dry season. The results suggest that the decision by farmers to allocate crop residues to animals as feed is most suitable for their circumstances because manure application in combination with fertilizer provides calcium, magnesium and micronutrients that ensure high yields especially on degraded soils. An optimal procedure for retaining adequate crop residues while providing sufficient feed for livestock is thus required to facilitate the adoption of CA on smallholder farms.
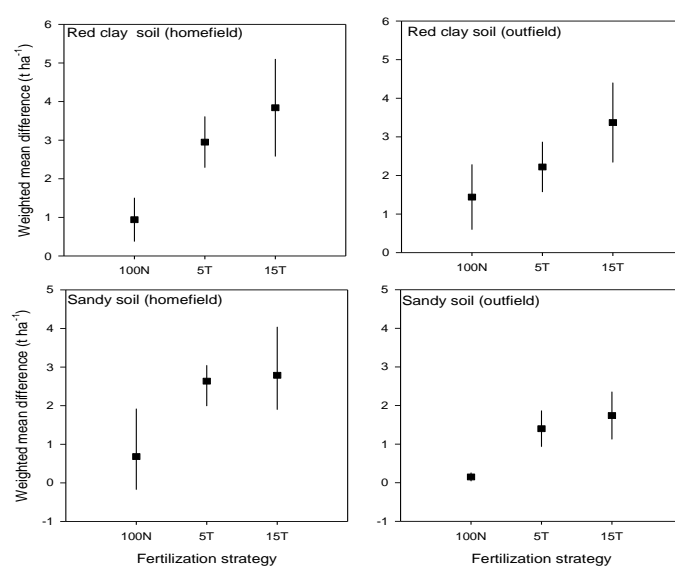
Figure 1 Weighted mean difference in maize grain yield between control and fertilizer as well as different rates of manure application in combination with fertilizer after nine years in different soils and fields at Murewa, Zimbabwe.
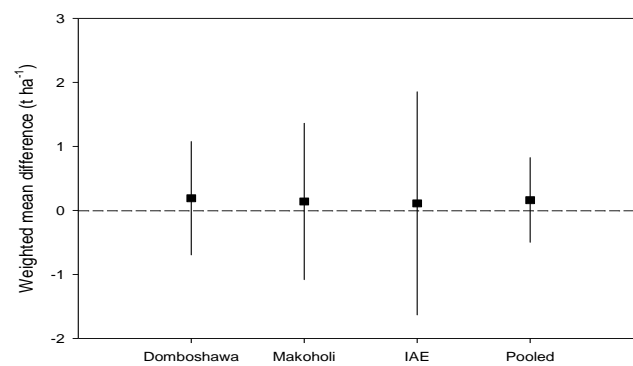
Figure 2 Weighted mean difference in yield between conservation agriculture and conventional tillage at three sites (Domboshawa, Makoholi and IAE) in Zimbabwe (Moyo, 2003).
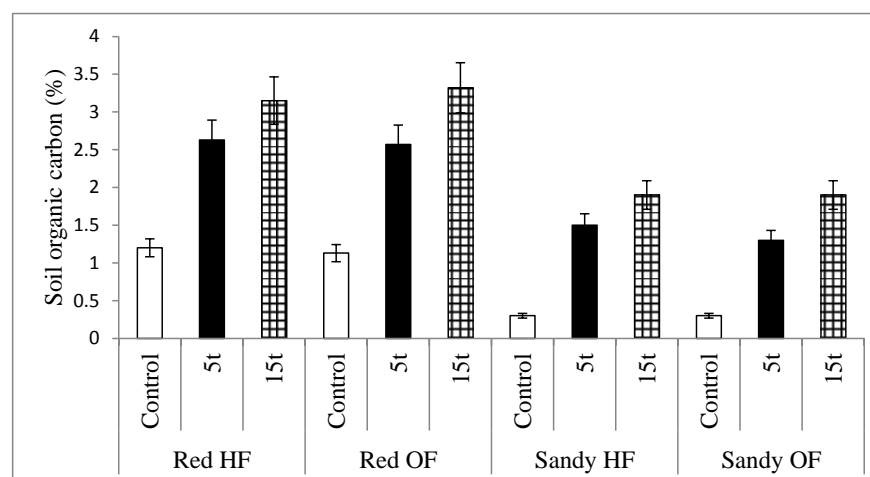
Figure 3 The long-term effect of different manure application rates in combination with ammonium nitrate on SOC (%) on home and outfields in clay and sandy soils after seven years.
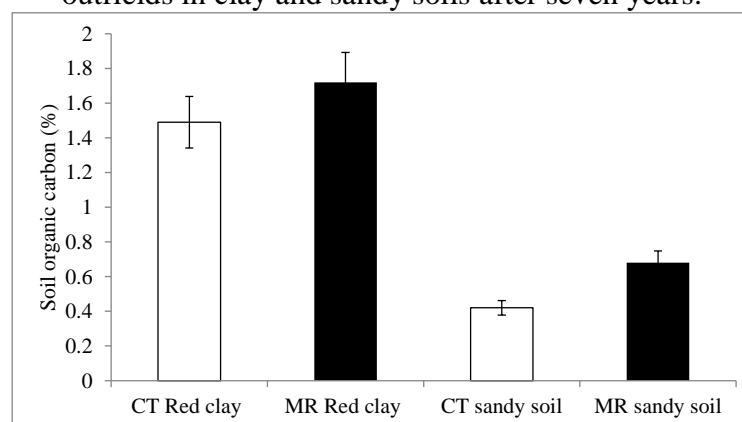
Figure 4 The long-term effect of conventional tillage (CT) and mulch ripping (MR) and on SOC (%)– after nine years at IAE (red clay soils) and Domboshawa (sandy soils).

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Short term intensive rotational grazing in native pasture: I. Results of a plot scale experiment on runoff and soil loss in association with catchment scale's outcomes

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Keywords: rotational grazing, runoff plot, runoff event, soil loss, ground cover, intensive grazing

Introduction

Grazing systems have been shown to greatly affect vegetation cover which is the primary layer in soil protection against water erosion. Decrease in vegetation cover increases the exposure of soil surface to raindrop impact, reduces soil organic carbon and aggregate stability and enhances surface crust which in turn increases runoff and sediment loss. Grazing continuously leads to surface soil compaction with associated loss of pore structure and connectivity reducing infiltration capacity (Greenwood and McKenzie 2001). For these reasons in continuous grazing, as the stocking rate increases, runoff and soil loss are expected to increase.

Short period intensive rotational grazing (called also time-controlled grazing in Australia) as an alternative to continuous grazing has shown soil recovery to occur during 30 days rest periods (Warren et al. 1986). This was evident from the higher infiltration rates and lower sediment loss recorded at the end of the rest periods compared with the beginning of them. In another study and under a catchment scale experiment Sanjari et al. 2009, found lower runoff and soil loss as well as higher percentage of ground cover in short intensive rotational grazing over continuous grazing. In this paper we endeavor to present and discuss unpublished results of a plot scale experiment on the effects of intensive rotational grazing on runoff and soil erosion as compared with the already published outcomes on catchment scale.

Materials and Methods

The runoff plots experiment was conducted at "Currajong", a grazing property in the semi-arid region of south-east Queensland, Australia. The annual rainfall is 645 mm, with around 70% occurring during summer, characterized by a relatively high frequency of medium to large events of short (thunderstorms) and long (cyclonic depressions) durations. In the dry season (April to September), there are smaller events both in magnitude and intensity associated with frontal depressions. Vegetation is open Eucalypt woodland with an understorey of native and naturalized perennial grass species.

Two runoff plots varying in areas from 650 (P1) to 700 (P2) square meters with modified Gerlach troughs at the down slope of the plots were fully instrumented to record rainfall and runoff parameters. Sediment loss for each event was estimated by adding the bed load collected in the troughs to the suspended load calculated from the product of the total flow and the average suspended sediment concentration during the event. The two runoff plots and their corresponding catchments of C1 (8 ha) and C2 (7.5) had had a long history (decades) of continuous grazing until 2001 where the grazing practise was converted to short intensive rotational grazing. Geomorphological similarity between the plots and the catchments provided the possibility of scale effect investigations by comparing results of P1 with C1 and P2 with C2. It is noted that both catchments are adjacent to each other and together with plot are within one research paddock. The paddocks were stocked to a high rate of 12.6 ± 6 DSE/ha in differing short grazing durations of 14 ± 9 days depending on feed on offer and rate of grass growth. After each grazing operation, the animals were stocked out to apply long rest periods of 101 ± 60 days.

Results and Discussion

Results from the experimental plots, show a decrease in both runoff volume and sediment loss (Figure 1) from the first period of the study (2001 – 2003) to the second (2004 – 2006) which is in agreement with the results already published under a catchment scale experiment (Sanjari et al. 2009). The reduction in runoff and soil loss took place despite the same rainfall erosivity calculated for the second period in P1 and P2 compared with the first period. The findings also illustrate a better soil loss control in plots with soils of gentler slope and greater depth (P1).
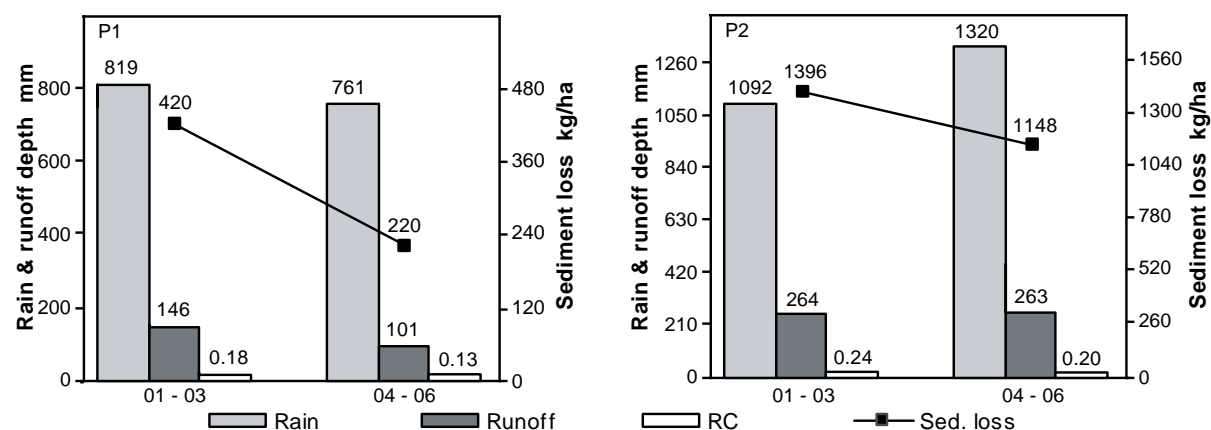
Figure 1. Rain, runoff, sediment loss and runoff coefficient (RC) over the first (2001-2003) and the second period (2004-2006) of the study for both plots (P1 and P2)

The decrease in runoff and soil loss under the rotational grazing is largely attributed to the long rest period which is necessary for recovery of the plants defoliated by grazing animals. In the study area, there are high chances of having some consecutive favourable wet conditions over the rest periods, which can lead to mass regrowth. The results on ground cover (not shown here) show that over the growth season of 2003-2004, the catchment was rested for 156 days, during which a total of 480 mm rainfall occurred. Such a coincidence produced large amounts of organic matter building up a high level of surface residue.

The effects of the increase in ground cover and residue could be seen in the troughs where the coarse organic materials (more than 2 mm in size) were washed away by surface flow and trapped in the troughs. Figure 2 indicates the ratio of coarse organic material to the total bedload which increased significantly in both P1 and P2 ($p < 0.01$) from early 2004 onwards. This could be an indication of the substantial

increase in ground cover beyond a level (critical threshold of 70% for the study area) that played a major role in reducing raindrop impact and soil detachment under the rotational grazing.
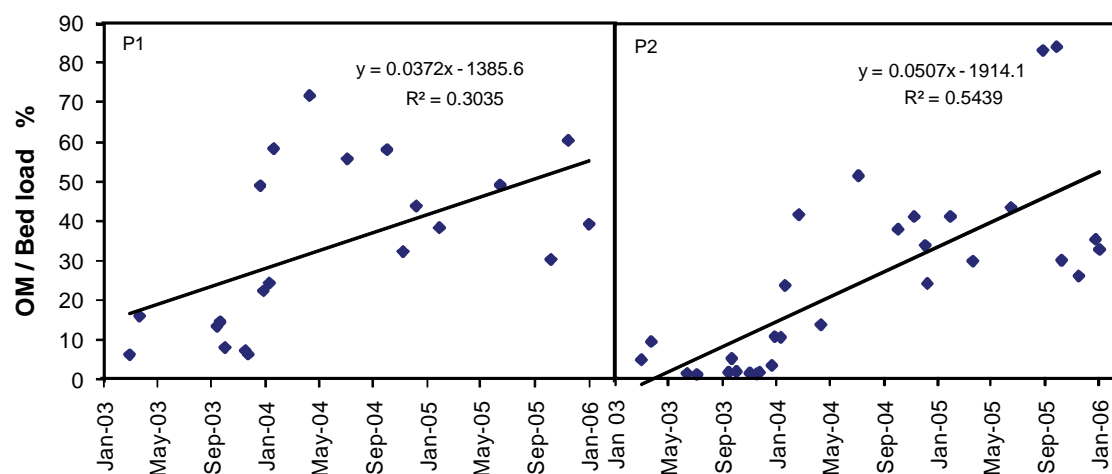
Figure 2. Increase in organic material fraction (by weight) of bedload from early 2004 to 2006 in both plots

Runoff generation is a complicated process and involves mechanisms in which ground cover even in full surface coverage may have little or no effect on runoff control. In the study area ground cover had positive effects on small events in reducing runoff but not on large events. In soil loss however, ground cover above a level decreased sediment load irrespective of the event sizes.

Comparing the results of the plots and the catchments (Table 1), runoff depth and the coefficient increased from plot (15.6% in P1 and 21.8% in P2) to catchment (19.5% in C1 and 37.1% in C2). Such a reduction in runoff with the increase in scale has also been reported by Dabney (1998) in a cropping experiment. He found runoff amount to be about twice for the catchments as compared with the plots with the same treatment. One of the reasons for lower runoff production in plots as compared with the catchments can be the contribution of emerging subsurface flow to the total runoff which is the case in catchments but not in plots. In catchments, sub-surface flowing water, after satisfying soil moisture capacity, ex-filtrate at any knick point in the landscape, and contribute to the measured surface runoff. In this study there were several knick points upslope of the measurement flumes in the catchments from which interflow ex-filtrated and merged with the surface flow.

Table 1. Summary of the total results (brackets show the correspondent values for catchments)

Plot (catchment)	Rain (mm)†	Runoff (mm)	RC (%)	Sediment loss (kg/ha)	Event (no)
P1 (C1)	1580 (1383)	247 (269)	15.6 (19.5)	640 (439)	59 (27)
P2 (C2)	2412 (1943)	527 (720)	21.8 (37.1)	2544 (2064)	103 (46)

† Only the rain events contributing runoff generation are considered

In contrast to the increase in runoff coefficient from plot to catchment, sediment loss declined with such increase in scale. Similar decline in sediment yield with increasing scale has also been reported by Schumm (1977), although in some cases the spatial distribution of vegetation may override the scale effect. Sometimes the presence of severely disturbed small patches of land within a large catchment may result in higher sediment loss than in a plot with a better vegetation cover (Bartley et al. 2006).

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The promotion of Conservation Agriculture in the South African LandCare Programme during the last decade: evolution and impact of action research

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Introduction

The Agricultural Research Council-Institute for Soil, Climate and Water (ARC-ISCW) has been one of the key institutions involved in the promotion of Conservation Agriculture (CA) in South Africa during the last decade. Many of their initiatives have been funded by the National LandCare Programme of South Africa, a community-based natural resource management approach, which aims to implement projects that place people at "the starting point, the centre and the end of each development intervention … and constructing appropriate interventions or technology around their mode of production, cultural patterns, needs and potential". The situations and processes that have been experienced are complex and require an innovative approach of research and development. A major dilemma facing researchers working in these situations, all of whom were trained in natural sciences, is the dearth of knowledge and skills needed to design, manage and facilitate such a process. This situation forced researchers to explore and apply a 'new' paradigm introducing a 'family of methodologies' that would assist to investigate, develop and integrate CA principles and practices, mostly with small-scale farmers.

Methodology

Under the paradigm of *constructivism*, which promises to be much more powerful in complex situations than conventional or positivist approaches, practitioners have to become part of the target group in constructing their own reality and agreeing on their reasons for collective action. Furthermore, constructivist methodology sees 'true' participation *or* interaction as necessary to the acts of discovery and analysis. Without such participation there can be no truly constructivist inquiry. One of the most fundamental insights gained from initial experiences in this process was that sustainable agriculture is not a simple model or package to be imposed - *it is more a process for learning*. This has alerted researchers to the now growing family of *action research* methodologies and methods that enable participants to share, act, observe, reflect, plan and learn.

Application and 'testing' of theories and methodologies
A number of theories and methodologies that were seen as potentially appropriate to promote CA among resource-poor farmers in South Africa, were progressively applied and tested during a decade of CA promotion within the ARC's LandCare projects, which were mostly funded by the National and Provincial LandCare programmes. *Experiential learning* (the cycle) was initially found to be the most suitable model to focus on the elements of learning in groups (Kolb, 1984). There are similarities between the concept of experiential learning and that of action research as Kurt Lewin (1946) is considered to be an important contributor to the development of both of these. The three methodologies (or concepts) of inquiry, i.e. action research, experiential learning and action learning, consequently formed the foundation of the action research approach followed to facilitate learning and the promotion of CA with resource-poor farmers.

Action research hence provided a framework for an innovative learning process in LandCare projects. A specific challenge was to make each step in the cycle practical and real for the participants. *Critical reflection,* which is as important as the action, was particularly difficult. Since it is the critical reflection which provides the "research" (Dick, 2002) and the improved understanding [of theory and practice], then it should be seen that all participants in the action research process are 'guided' through that stage.

A range of other complementary methodologies that could fill the gaps at certain stages of the process were also considered along the road. One of these methodologies was the *Farming Systems Approach (*Norman et al.*,* 1995; Matata et al., 2001). The study of *Farmer Participatory Research (*Selener, 1998)*,* emerged from a need by the researchers to use research approaches that would result in technologies beneficial to and therefore to be adopted by resource-poor farmers. The *Farmer Field School* (FFS) approach (FAO, 2000) was seen as a methodology that could contribute to the action research approach in many respects. One of the most enriching contributions of FFS was that of its educational philosophy, which rests on the foundations of communicative action (Habermas, 1984) and reflects the elements of the *experiential learning cycle,* as well as *social learning*.

The LandCare processes designed with at least elements of these methodologies, *facilitating* the wide involvement of people in problem-solving and decision-making, helped to transform many situations into active and living *systems*. 'Facilitation' has therefore been identified as central to the ARC researchers' role and to the success of the approach. Indeed a paradigm shift was needed by most researchers involved in the process in the direction of more facilitation.

Results and Discussion

A number of milestones (results) were achieved over the decade of implementing and managing various of the ARC-ISCW's LandCare projects in South Africa. Some of the most critical milestones were:

Action research as "umbrella methodology"
Around 2001, *action research* was adopted as the 'umbrella' methodology, most closely related to the *constructivist paradigm*. Action research worked in harmony with a family of research methodologies which aim to pursue action and research outcomes. Understanding in essence what action research could contribute, i.e. *action* and *research* to bring about *change* in the farming communities *and* in the project processes, was a major leap in methodological thinking and design. As the definition put it, action research is: a) pursuing action *and* research, through b) a cyclic process, alternating action with critical reflection. The main role of the action researcher emerged to be a *facilitator* (guide or catalyst) of communities (participants) through all the stages of the action research cycle. Action researchers are also responsible to develop a learning environment in the multi-stakeholder process, using various participatory action research methodologies, techniques and tools.

Development and application of an action research model

From 2000 to 2006, an attempt was made, through a PhD research process (Smith, 2006), to synthesize a process theorising the experiences described above. The most suitable approach for a synthesis of the theorising results appeared to be the integration of the results into an improved theoretical framework. This improved framework proved to be that of a process model based on the major phases, methodologies and techniques of the action-research cycle. The proposed six phases of this model are: a) Stakeholder analysis, b) Diagnosis (Situation analysis), c) Planning strategically, d) Implementing and managing, e) Learning and adapting, and f) Exit strategy. This model provided a means of creating a culture of learning that would allow people to be innovative and interactive in the management of natural resources and to collectively care for and manage these resources in a sustainable manner.

To date, this model has been applied to many LandCare projects across South Africa, of which most have been aiming to promote CA. Because reflection is embedded into action research, this model is continuously improved and adapted. The two key action research methodologies used in the implementation phase and which have been experienced as extremely powerful, are experiential and social learning. *On-farm, farmer-led trials* are the main type of experiential learning method being introduced. The objectives of these trials are to facilitate the modification and adaptation of CA technologies to local farming situations, to increase awareness among farming communities and to provide data and experiences feeding into social learning events. The experiments are closely integrated with the training or FFS process. As far as social learning is concerned, the ARC-ISCW follows the practice promoted by the FFS approach, which is to work with a large group of 25 people divided into smaller groups of five people each. These small groups are doing various activities together, such as implementing and monitoring of their experiments. Ideally, the small groups meet at least once a week, while they come together at least once a month in a social learning event to give feedback, reflect and modify/adapt their farming practices collectively.

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Acehnese farmers trial conservation farming techniques

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Keywords: minimum tillage, Aceh, food security, conflict, skip row

Introduction

Agriculture along the lowland coastal areas of Aceh is dominated by rice farming. Whilst irrigation buffers against climatic variation in some catchments, farmers need to grow more than rice to ensure food security and nutrition. There are large areas of land with little or no access to irrigation where rice, legumes and vegetables can be grown. The wet season rice crop is primarily directed to the family's staple food needs, additional crops provide an opportunity to improve diets and create income.

Fields are traditionally cultivated by hand, though some mechanised ploughing is observed. There are opportunities for dry season crops like corn and soybean, however during the intensification of the civil conflict in Aceh until the 2005 peace accord, crop production dropped and is only now slowly recovering. Fluctuating prices for legume crops against a stable rice price partially explain the reluctance of farmers to take on riskier dry season crops.

As part of an ACIAR project, farmers are trialling conservation farming methods including skip-row, minimum tillage and direct drill rice planting. The primary driver is not only soil moisture conservation, but the ability to grow more crops in a year, reduce labour, and increase income.

Results and Discussion

Farmers in Blang Tingkeum, Bireuen, share a 6 hectare dryland site. This site is one of eight permanent sites established in four districts of Aceh. The aim is to create long term best practice research and demonstration sites. The farming system is rice-based with the option to rotate with legumes, grains, forage or vegetables, depending on local conditions. The skip-row package for rice farming implemented at each site is based on a national program aimed at increasing rice production and food security.

The site at Blang Tingkeum has been historically underutilised. An intense civil conflict contributed to a major reduction in farming in this area. The district of Bireuen has a short wet season (October – February) contributing to a total annual rainfall of 1484 mm. In the dry season, most fields are left fallow, especially on sites that have no access to irrigation systems. During the past two years an erratic wet season has made planning for crops difficult.

Depending on the type of agro-ecological zone, the application of minimum tillage techniques in combination with other crop management practices can optimize the use of irrigation water, reduce cost of production, increase crop intensity, minimize crop failures due to drought, minimize yield losses due to pests and diseases, and reduce the workload for soil preparation (Kaartamadja 2004). Minimum tillage has been researched and practised in some parts of Indonesia but is not common in Aceh. There have been some trials of direct seeding of rice paddies in Aceh Barat, but they have suffered due to difficulties handling the equipment. In Blang Tingkeum farmers have grown successful minimum tillage soy bean, mung bean and corn crops in 2010. Minimum tillage is one of a number of technologies being trialled by the farmers. The technology with the most appeal has been skip-row planting for rice. Adoption of skip-row has been observed in fields and villages adjacent to Blang Tingkeum and other project sites in Aceh. The advantages of skip-row include increased yields and better pest control, and it facilitates the minimum tillage crops that follow.

In an area where farming remains traditional with set cropping patterns, cooperating farmers have endured initial ridicule, especially in the adoption of skip-row. They are "wasting space, how can the yields be better?" However adoption by other farmers has been immediate. After witnessing improved growth, farmers are convinced of the value of skip-row even before harvest. Skip-row yields have outperformed traditional layout yields for rice at all project sites in 2010/2011 in Aceh, see Table 1.

Table 1. Rice yields for skip-row layout versus local practice at eight sites in Aceh, Indonesia, 2009-2011

Project site	Rice yield (t/ha)[1] 2009/10 and variety[2]		Rice yield (t/ha) 2010/11 and variety	
	Local practice	Skip row system	Local practice	Skip row system
1.Blang Tingkeum	4.1 Ciherang	5.2 Ciherang	5.0 Ciherang	6.2 Inpari 13 7.1 Mekongga
2. Mon Mane	3.6 Ciherang	5.6 Ciherang	4.1 Ciherang	5.6 Inpari 6
3. Drien Bungong	4.5 Ciherang	7.0 Inpari 6 7.9 Ciherang	5.2 Ciherang	7.2 Ciherang 7.4 Mekongga
4. Manyang Lancot	-	-	7.0 Ciherang	7.8 Ciherang 8.1 Inpari 13
5. Sukun Peudaya	4.8 Ciherang	8.5 Ciherang	5.6 Ciherang	6.1 Inpari 13 7.2 Mekongga
6. Keutapang Bambung	4.5 Ciherang	7.9 Ciherang 5.9 Ciherang 7.9 Mekongga	5.5 Ciherang	6.6 Ciherang 8.2 Ciherang
7. Naga Umbang*	3.8 Ciherang	5.67 Ciherang	4.0 Ciherang	5.4 Ciherang
8. Empetrieng*	4.5 Ciherang	5.83 Ciherang	4.9 Ciherang	8.8 Inpari 13

[1] Average rice yield in Aceh = 4.5 T/ha
2 Ciherang the preferred variety for local consumption

In 2011, the farmers at Blang Tingkeum elected to trial a direct drill rice crop following a conventionally tilled crop. Whilst their preference would be to follow the successful, profitable pattern of last year's minimum tillage legume and corn crops, wet conditions meant that rice was the only option. Direct drilled rice is an experiment and reflects a dramatic change in attitudes by farmers and advisory staff to new ideas. The response by farmers to planting zero till rice by hand was less enthusiastic after the trial. Traditional planting methods are faster and cheaper. No yield results are available yet and comparisons of the performance of subsequent crops can only be speculated at this stage. Eliminating the puddling of rice improves the chances of success for the following dry season crops (Kartaatmadja 2004); however Blang Tingkeum farmers seem unlikely to adopt zero tillage for rice.

Soil conditions will be monitored over the next two years to see whether the farmers in Blang Tingkeum, can maintain a healthy, productive soil and farming system under a more intensive cropping regime, and assess the impacts of minimum tillage methods. This will then allow local extension staff to better advise local farmers about both the merits of increased cropping intensity as advocated nationally and the conservation farming techniques demonstrated at Blang Tingkeum.

Conclusion

Traditionally farmers in Aceh have followed a set cropping pattern. Flexibility in cropping patterns could enable farmers to maintain income and food security during variable climatic conditions. Using conservation farming techniques for their grain and legume crops reduces the labour and financial investment, helping to minimise risk. Dry season crops with only average yields are more profitable to farmers and add value to the rice-based cropping system.

There are a range of the barriers to achieving a more diverse and profitable farming system in Aceh, including the availability of quality seed, reducing inorganic fertiliser rates, limited understanding of integrated pest management, regular market price fluctuations for crops and limited training and support for local extension staff. The improvements in yields and income to date in Blang Tingkeum indicate that more intensive farming systems are possible, but farmers need to understand that this system requires careful management. Utilising minimum tillage for the non-rice crops can become an important part of this system. It is hoped that the local extension staff will gain the knowledge and experience necessary to assist the farmers with their decision making in the future.

Acknowledgements

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Agroecology-based aggradation-conservation agriculture (ABACO): targeting resource-limited and degraded environments of semi-arid Africa

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Keywords: smallholder farming, soil restoration, innovation systems, modelling, sub-Saharan Africa

Introduction

Poor soil fertility and soil physical degradation are major limitations to food security in sub-Saharan Africa, placing many smallholder farmers in a vulnerable position. Conservation Agriculture (CA) is increasingly promoted as an alternative to address soil degradation resulting from agricultural practices that deplete the organic matter and nutrient content of the soil, aiming at higher crop productivity with lower production costs (e.g. Kassam et al., 2009). In areas of climatic variability, CA may represent a low-investment strategy to increase water productivity and mitigate risks, by breaking the vicious cycle of low rainfall, poor yields, low investment, soil degradation and food insecurity. In spite of experimental evidence showing increased water productivity and crop yields under CA, its adoption by smallholder farmers in sub-Saharan Africa seems to be hampered by (Giller et al., 2009): (i) Concerns on initial yield decreases often observed (or perceived) with CA; (ii) Lack of sufficient biomass for effective mulching due to poor crop productivity or to competing uses for crop residues in crop-livestock systems; (iii) Increased labour requirements when herbicides are not used, and a gender shift towards female labour for weeding (since labour saved from ploughing is typically male labour); (iv) Lack of access to and use of external inputs such as mineral fertilisers and herbicides. A fundamental problem with the adoption of CA is its promotion as an indivisible package that farmers find hard to adopt in full, lacking the contribution of farmers to the design/selection of CA alternatives, overlooking the fact that the process through which innovation systems emerge are complex and non-linear (i.e., not as unidirectional research-extension-farmer flows).

The ABACO initiative

An EU-funded project on agro-ecology based aggradation-conservation agriculture (ABACO) emerged as a need for *action* identified during the implementation of the CA2Africa initiative (cf. Corbeels et al., this conference), which brought together a large number of partners working on CA in Africa, including those from international research centres, and the African Conservation Tillage (ACT) network. ABACO aims at establishing site-specific innovation systems that rely on agroecology principles and aggradative measures to restore soil productivity in semi-arid regions of West, East and Southern Africa. This will be done by fulfilling the following *specific objectives*: (1) To **target** CA to smallholder African farmers by studying which principles of CA, and under which conditions, contribute to the effects sought in terms of food production and land rehabilitation in the face of climatic variability; (2) To involve farmers and research in co-**innovation** platforms to promote the adaptation/appropriation of technologies by local communities; (3) To assess the social and economic viability and **tradeoffs** of implementing CA at farm and village scales, and across scenarios, to inform policies; (4) To promote **dissemination** of targeted CA alternatives and approaches through divulgation, training and capacity development. Project activities in West, East and Southern Africa are organized around four themes: (I) Water productivity and climatic risks; (II) Soil fertility and land rehabilitation; (III) Agroecological functions and environmental services; and (IV) Livelihood, gender and policy analysis. These themes are addressed by four multi-disciplinary work packages: WP1, diagnosis design and testing; WP2, innovation support; WP3, model-aided feasibility and trade-offs evaluation through participatory, multi-scale scenarios; WP4, dissemination, impact and networking.

The various constraints that hamper widespread adoption of CA in Africa do not have the same origin, and they operate at different scales. If widespread adoption of CA is to be achieved, current technical knowledge and innovations should be targeted to meet the particular demands and constraints of smallholder African farmers. The promotion of CA benefits should be based on:

i. **Rehabilitation of degraded soils** to restore biomass productivity, in order to secure the various functions of CA that depend on above and belowground plant biomass;
ii. Increased **water productivity** and soil water buffering capacity to face risks associated with climate change, creating more conducive conditions for farmers' investments;
iii. Intensifying **agroecological functions** to capitalise on natural interactions, increase resource use efficiency and reduce dependence on external inputs;
iv. Embeding these principles in sustainable **innovation support systems** that recognise the complexity and non-linearity of agricultural innovation processes;
v. Institutionalization of **enabling policies and market conditions** so as to facilitate uptake and promotion of CA among smallholder farmers

The implementation of these five principles should be done while embracing the diversity of situations that characterise African agriculture.

Aggradation-conservation agriculture

The term 'aggradation' has been coined in physical geography to refer to the raise in grade or level of a river valley, a stream bed, etc. by depositing detritus, sediment, or the like. Here, we use this *analogy* to refer to the gradual rehabilitation of soils that underwent physicochemical degradation. ABACO's approach of aggradation-conservation agriculture consists of implementing measures that have been traditionally promoted as "soil and water conservation", "water harvesting" technologies in semi-arid environments or (indigenous) agroforestry, during an initial phase of soil restoration or 'greening'. Initial investments aiming at increasing agroecosystem primary productivity are necessary, prior to the implementation of the classical CA principles. Particularly in dry environments, and under rainfed agriculture, the response of agroecosystem primary productivity to soil restorative measures may exhibit a faceted pattern (Figure 1). This pattern is characterised by an initial response to increased water availability (i.e., the 'greening' effect) with a slight loss in water productivity (or use efficiency), followed by a response to increased soil fertility once nutrients become available (resulting in greater water productivity).
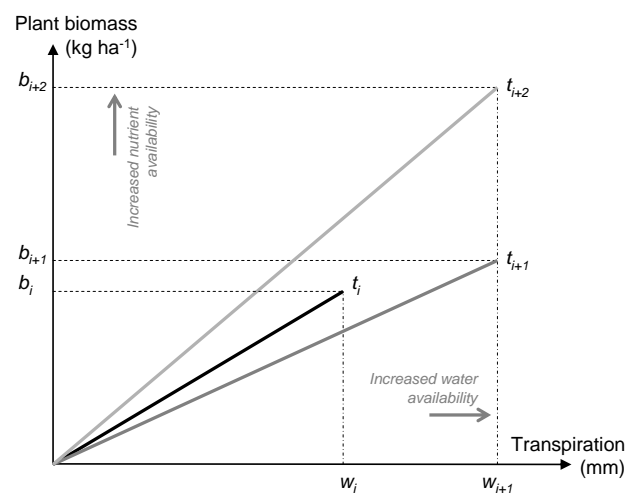
Figure 1: Scheme representing the faceted impact of aggradation-conservation agriculture on water productivity. Crops that used the available water w_i to produce an amount of biomass b_i under the baseline conditions (t_i) may exhibit a less than proportional increase in biomass (b_{i+1}) as a result of increased water availability (w_{i+1}). Once nutrients become available (t_{i+2}), water can be used more efficiently to produce greater amounts of biomass (b_{i+2}).
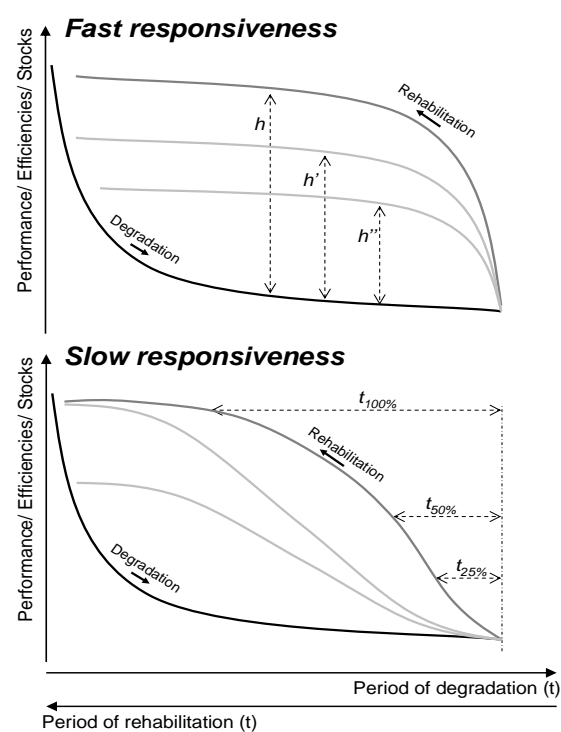
Figure 2: Theoretical schemes representing the concept of hysteresis (h) of land rehabilitation. After having undergone a degradation phase, the response of the agroecosystem to rehabilitation measures may be fast or slow, and exhibit weak or strong hysteresis (i.e., h, h' or h''). The periods $t_{25\%}$, $t_{50\%}$ and $t_{100\%}$ represent the delay necessary to achieve 25 to 100% of the original performance, efficiency or stock level. Measures to restore productivity may be hysteretic or not, and exhibit fast or slow responsiveness. Whether a response can be considered to be fast or slow, hysteretic or not depends on the indicator chosen to characterize the response (productivity, efficiencies, stocks), on the type of measure(s) implemented to restore productivity, on the biophysical properties of the agroecosystem under consideration, and on the behaviour of external drivers (e.g. rainfall).

Rehabilitating degraded soils, depending on the extent and type of the degradation process, may require sustained efforts for long periods of time, and responses to interventions may be weak. Slow and weak responses to soil restoration are a disincentive to smallholder farmers. The theoretical curves drawn in Figure 2 illustrate what some authors termed as 'hysteresis' (h) of land rehabilitation, represented by the deviation between the trajectories of soil degradation and rehabilitation (purposely plotted towards the opposite direction). The various technologies and measures that may fall under the general umbrella of CA should be strategically targeted according to the phase in which the system is, either in degradation, rehabilitation or stabilization. Situations (fields) that allow hysteretic, fast responsiveness are typically those that farmers prioritize for the allocation of their scarce resources (labour included), as the perceived returns to their efforts are more attractive and less risky (e.g., Tittonell et al., 2007). On the other extreme, severely degraded fields that exhibit weak hysteresis and slow responsiveness are often considered to be non-resilient, and may require profound reconversion of land use rather than investments to increase productivity under the current land use. The intermediate situations between these two extremes are those that must be the target of agroecology based aggradation-conservation agriculture.

Discussion

The presentation will offer an overview of the experience already gathered in the various project sites in West, East and Southern Africa, will discuss the major concepts underlying the five ABACO principles (Soil rehabilitation; Water productivity; Agroecological intensification; Innovation platforms; Policy and market support), and the major challenges for the promotion and widespread adoption of CA in the resource poor, degraded and climatically variable environments of semi-arid Africa.

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Stubble retention in cropping in South-East Australia: benefits and challenges

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Introduction

Late stubble burning just prior to sowing is commonly practiced in the south-eastern cropping areas of Australia. With large stubble loads before sowing, late stubble burning in March/April minimises the duration the soil surface is exposed before the establishment of soil surface protection, usually by early winter (June/July). However better alternatives are needed because burning may become prohibited due to the perceived public health hazard from smoke. Consequently, we reviewed information from southern Australia, particularly from southern and central NSW, relative to other areas, to identify the basis for non adoption of stubble retention (Figure 1). We sought to highlight gaps in knowledge of stubble retention practice, and reasons why perceived benefits from adoption may not accrue, as these may contribute to non adoption.
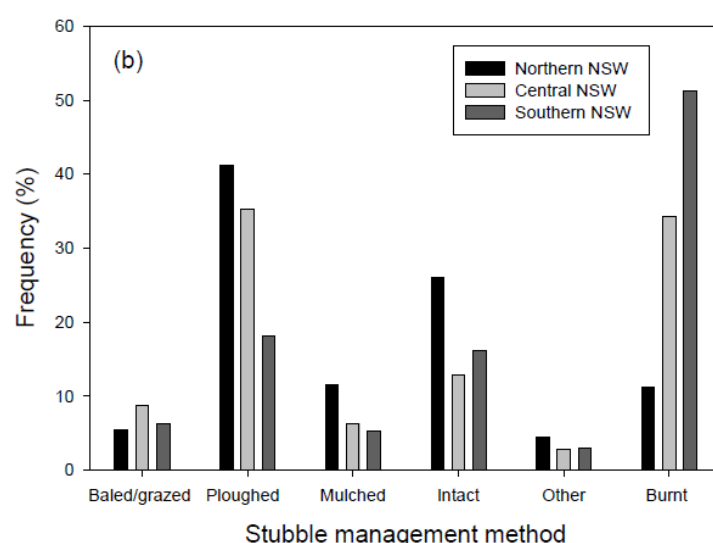
Figure 1. Methods of stubble management within New South Wales. (All data from Australian Bureau of Statistics: 2001 Agricultural Census – reproduced from Fig 2b of Scott et al 2010)

Soil Water, Nitrogen, Carbon and Acidification

The presence of stubble can increase water infiltration and slow evaporative moisture loss, thus increasing soil moisture storage at sowing (Figure 2). These effects are likely to be of most value in Queensland and northern NSW, where production of winter cereal crops is highly reliant on stored soil moisture, but likely to be of less importance in the southern cropping areas where winter crop growth is more dependent on incident rainfall. In central and southern NSW, there is a component of summer rainfall which could be stored in the soil, and be of benefit to a subsequent crop, particularly in lower rainfall years or environments. It is unclear what the effect of late stubble burning has on stored soil moisture.
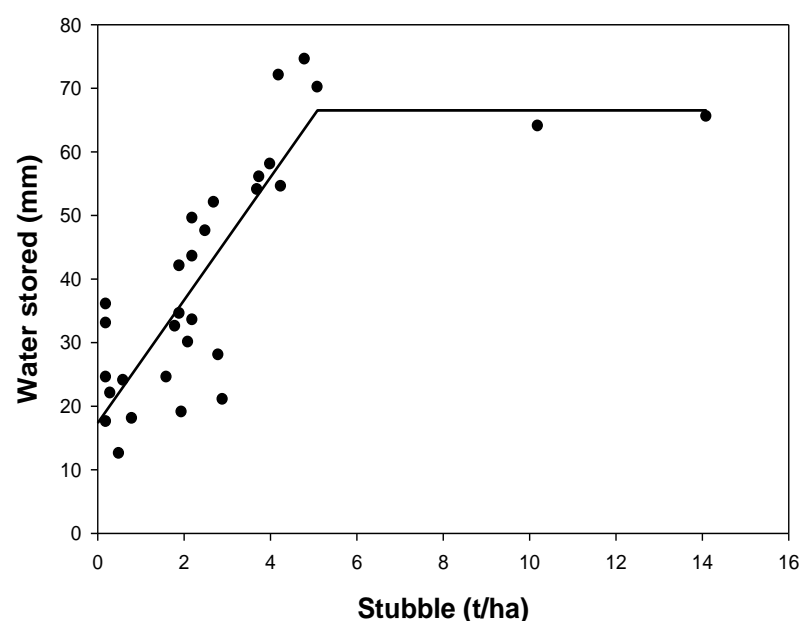
Figure 2. Soil moisture storage at Wagga Wagga NSW in May 1985 under a range of stubble loads following 140 mm of rain, and 35 mm of additional irrigation (Reproduced from Cornish 1987).

Nutrient impacts were comprehensively reviewed by Scott et al (2010). In dryland crops, burning of stubble causes losses of approximately 4 kg N/t of wheat stubble burnt; with average losses of 26 kg/ha of N in high yielding areas. These losses are less than suggested elsewhere. Furthermore, in stubble-retained systems, N may be immobilised. While immobilisation rates of 5-13 kg N/ha from the decomposition of 1 t/ha of wheat stubble are reported from European research, the optimal rate of N fertiliser was only increased slightly by stubble incorporation in WA. Soil organic carbon (OC, t/ha) was less in stubble-burnt or -removed systems than in stubble-retained systems. However, there was no evidence of sequestering of C in stubble-retained systems; rather the amount of OC in the soil declined at a slower rate with stubble retention than stubble burning in cropping systems. Organic carbon was greater in the shallow surface soil (0-5 cm) with stubble retention, than when stubble was burnt. This may contribute to greater structural stability and water infiltration in the soil surface and greater earthworm populations.

Acidification of the surface soil (0-10cm) was greater under stubble retention than stubble burning, in both southern NSW and South Australia. The effect was confined to the shallow surface soil (0-5cm). Some nutrients (P, Zn, Cu) accumulate in the soil surface under conservation tillage. Stubble retention may contribute to this stratification, and increased fertiliser input or occasional cultivation are suggested amendments. Similarly, stratification of soil pH can be amended by the addition of lime and its incorporation through cultivation.
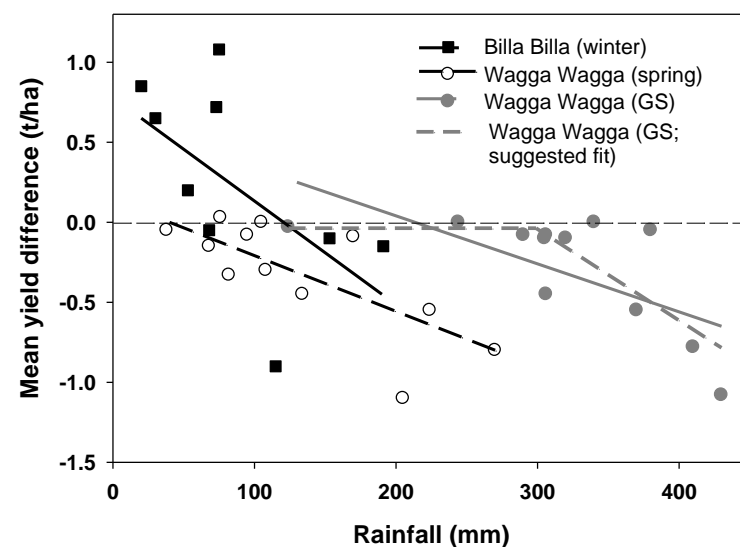
Figure 3. Relationship between rainfall parameters (GS, growing season, May-October; spring; winter) and the mean difference in yield between stubble-retained and stubble-burnt/removed wheat crops in two long-term experiments (Billa Billa and Wagga Wagga; from Kirkegaard 1995). A fitted line (grey, broken) to the Wagga Wagga (GS) is also shown – Reproduced from Figure 27 of Scott et al 2010.

Pests, Diseases, Weeds and Mechanisation

Blockages of sowing implements by stubble are the primary reason for non adoption of stubble retention by farmers in southern and central NSW, where stubble load is high. Existing sowing machinery is limited to sowing through 2-3 t/ha of cereal stubble; modification of machinery combined with pre-treatment of stubble (slashing, harrowing) can enable sowing into 4 - 5 t/ha of stubble. Scott et al (2010) have estimated from field reports that 20-49% of the stubble biomass at harvest is decomposed and lost by sowing in southern Australia compared with 57-84% in Queensland, where greater rainfall in summer would hasten decomposition.

Burning stubble rather than its retention reduced the disease and pest carry over to follow-on sensitive crops. The temperatures achieved in a stubble fire influenced the effectiveness of the fire in controlling some plant disease on the stubble and we have recorded Australian field examples of the effectiveness of stubble burning in the control of crown rot, common root rot, eyespot, and yellow spot. Similarly, stubble retention increased the populations of some grasses in subsequent crops.

Conservation farming systems with stubble retention rely on herbicide use for weed control, and this may lead to a problem with herbicide resistant weeds, particularly annual ryegrass, wild oats, and wild radish. The integrated management recommended for control of resistant weeds includes, as one component, a reversion to stubble burning.

Conclusions

Stubble retention is often claimed to increase cereal yield. The evidence, however, is that there is often no effect on yield, or more frequently, that yield is lower with stubble retention compared to stubble burning or stubble removal. In most experiments, the small yield loss is not related to seasonal rainfall, but in a few experiments, the adverse effect of stubble retention on yield is greater in wetter seasons (Figure 3). Interaction with growing season rainfall needs to be better understood, as yield reductions with stubble retention may be high (up to about 1 t/ha of grain) in seasons with high yield potential (EH Graham Centre 2010). Further research is needed to explain these interactions.

We suggest that research is also needed into systems maintained in long-term conservation farming in which the system is "disturbed" by infrequent cultivation and/or stubble burning. These practices appear necessary to control weeds, mix the surface soil to de-stratify nutrients and incorporate lime in acidifying soils. If the benefits of conservation tillage accumulate in the longer term, however, such disturbances may negate the benefits.

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A modelling approach to explore the impacts of root distribution and citrate release on phosphorus use efficiency of crops

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Keywords: root citrate flux, APSIM, phosphorus uptake

Introduction

Phosphorus (P) is a macro nutrient required by crops, and addition of P through fertilisation is needed to maintain soil fertility. Modern agriculture is dependent on P derived from phosphate rock, which is a non-renewable resource. At present rates of consumption global P reserves may be depleted in 50-100 years (Cordell et al. 2009). Increasing P use efficiency (PUE) is therefore essential to maintain crop productivity, avoid negative impacts on the environment, and sustain the resource base. In addition to agronomic measures, such as precision application of P fertilisers, development of new crop varieties with enhanced root growth and increased root citrate efflux to solubilise soil P is considered to have great potential to increase PUE (Jones 1998). However, in spite of the assumed benefits of citrate efflux for mobilization of P in soils, it remains unclear: 1) what level of citrate efflux is needed to have significant impact on crop PUE in different soils, 2) how the citrate solubilisation effect on soil P interacts with enhanced root growth to affect crop P uptake, and 3) what data are needed to quantify these processes and their system-wide impacts. In this paper, we: 1) briefly review the current understanding and available data on citrate release from plant roots and its impact on PUE, 2) show how a modelling approach helps address these issues, and 3) discuss the potential of combining farming system modelling and crop breeding to advance our understanding.

Methods

A literature review was conducted with a strong focus on modelling of PUE as affected by citrate release from crop roots. The range of citrate efflux was collated, together with information available on citrate efficiency to solubilise P, citrate decomposition, and response of crop growth to citrate efflux in P deficient soils. This information was used to support the further development of the farming systems model APSIM (Keating et al., 2003). APSIM's capability to model crop P responses was originally developed for soils where P availability can be represented in terms of P sorption using the Freundlich isotherm (Delve et al., 2009). It simulates P availability in soil and its impact on crop growth through the SoilP and crop modules. The new development here aims to enable APSIM to simulate the impacts of root length density (RLD) distribution and citrate release on soil P availability to crops. Modifications to APSIM-SoilP include: (1) linking the potential P supply in each soil layer to RLD and the P uptake power of unit length of root, (2) relating change in P concentration in the soil solution to the citrate efflux from roots, the efficiency of citrate to solubilise soil P and the citrate loss due to decomposition and sorption, and (3) P solubilised by citrate surplus to crop demand being added to the banded P pool. Parameters for (1) were derived by comparing the performance of the new model with the original one against three datasets, and parameters for (2) were based on information from the review. The new model was then used to explore the impact of citrate release on crop growth in soils that varied in their sorption capacities.

Results and Discussion

Our review revealed that the current understanding on the impact of root citrate release on plant PUE is limited. It seems to be clear that (1) citrate can enhance P mobilisation into soil solution (Jones, 1998), and (2) release of citrate (also malate and oxalate), mainly from root tips, increases with P deficiency (Ryan et al., 2001). The main mechanism in P solubilisation involves chelation of metal ions and formation of soluble citrate-metal-P complexes (Kirk et al., 1999). Plants with high citrate efflux from roots include Brassica napus, Lupinus albus (white lupin), and the Proteaceae family. The range of root citrate efflux for wheat and rice are lower, 5-185 (Bryan et al., 2009) and 155-360 nmol/g fresh weigh (FW)/h (Kirk et al., 1999), respectively, as compared to 1656-2373 in white lupin and 3600-9000 nmol/gFW/h in Proteaceae (Roelofs et al., 2001). Most of the data were from plants grown in hydroponics or artificial media. No data are currently available on comparison of genotype response under field conditions. There is also no field scale modelling conducted thus far. We found only one modelling study on rice P uptake in controlled laboratory conditions, and the limited data show that the rate of citrate decomposition is around $0.97d^{-1}$ (Kirk et al., 1999), and the citrate efficiency to solubilise P varies significantly in different soils, ranging from 0.010 to 0.40 mol P/mol citrate (Gerke, 1994; Kirk et al., 1999).

Figure 1 shows the performance of the modified model as compared to the original model in term of simulating wheat yield in response to P fertiliser applications. Very similar model performance was achieved across the three sites and different levels of P fertiliser inputs. Figure 2 shows the simulated response of wheat growth to citrate efflux with the modified model and a citrate efficiency of 0.4 on four soils assuming four different sorption capacities. The results indicate that: (1) at any given citrate efflux, biomass is higher in soil with lower P sorption, consistent with observations, (2) If the citrate efflux is relatively low, the impact of citrate release on biomass is marginal (Fig 2b), (3) higher citrate release, either by more root or by higher effluxes, increases the biomass significantly, with the highest increase on soil with highest P sorption, and (4) the biomass increase resulting from citrate release diminishes with increased P fertilisation rates. The new development extends the capability of APSIM to explore the impact of plant root distribution and root exudates on the interaction between crop growth and P dynamics in soil.

The modified model provides a framework to evaluate the impacts of new plant traits (such as citrate release, root distribution change) and to assist in breeding efforts in the assessment of performance of new genotypes under different soil and climate conditions. Further measurement data are needed to quantify the citrate efficiency and crop performance in different soils, which can be obtained from growing plants in different soils, either in pots or the field. Further development and testing of APSIM is required for simulation of crop-P responses in acid and alkaline soils where P availability is controlled by sparingly soluble aluminium and calcium phosphates. Information is also needed to understand the efficiency of different organic anions to solubilise P, the diffusion, sorption characteristics, and decomposition of anions in different soil environments.

Acknowledgement
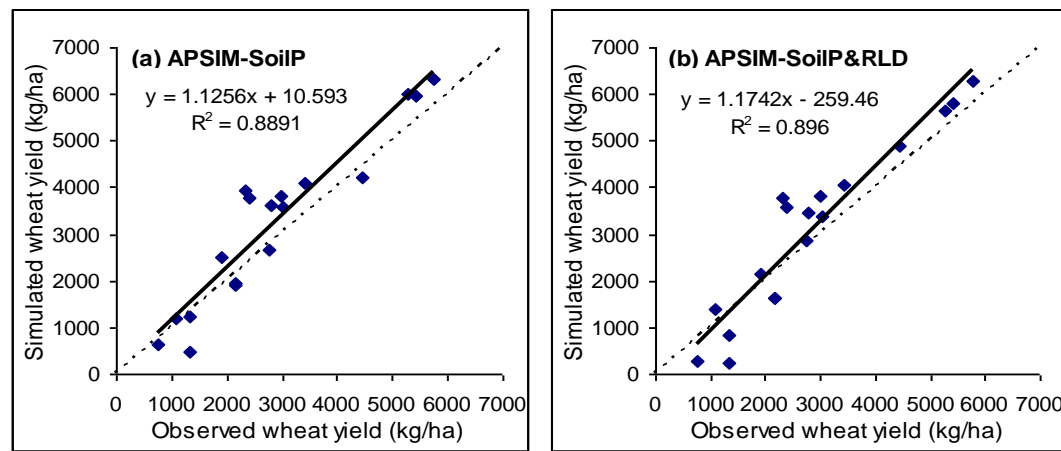
Figure 1. Comparison of simulated and observed wheat grain yields under different levels of P fertiliser inputs at one QLD site and two NSW sites: (a) original model, (b) modified model.
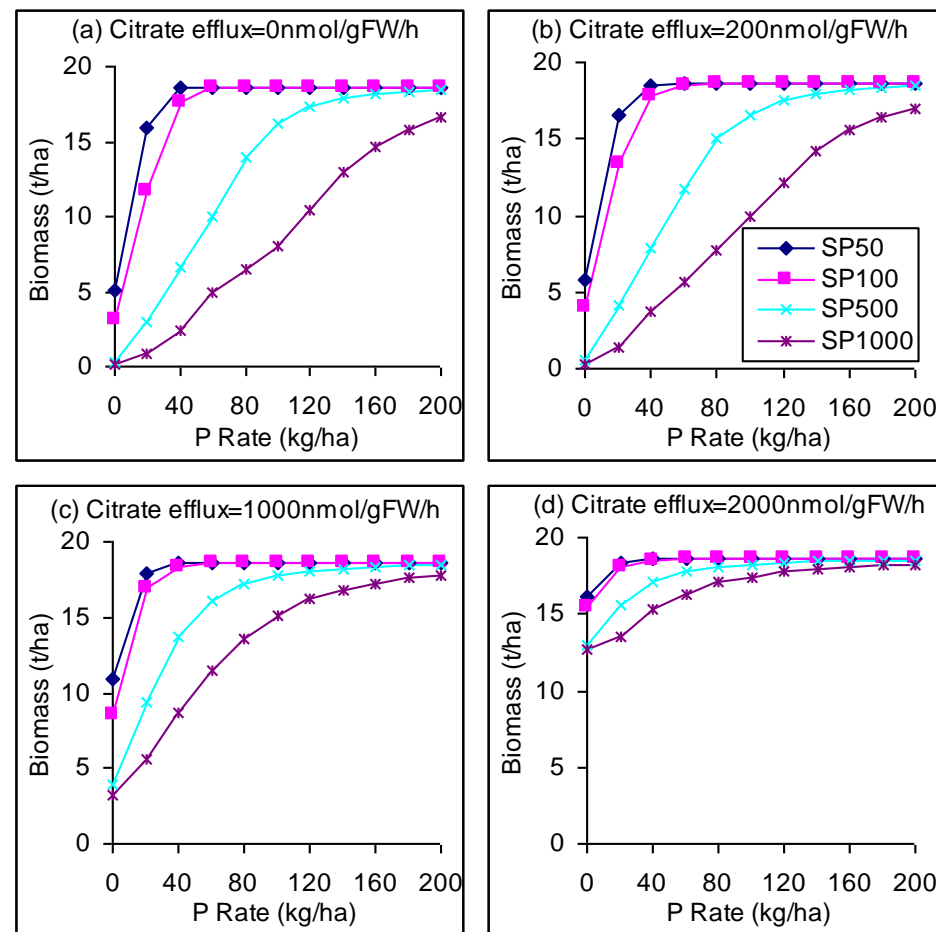
Figure 2. Simulated impact of citrate efflux from wheat roots on wheat biomass in four soils with low (SP50), medium (SP100), high (SP500) and very high (SP1000) sorption capacity. Four levels of citrate efflux (0, 200, 1000, 2000 nmol/gFW/h) were simulated for P application rates ranging from 0 to 200 kg/ha.

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A framework for exploring rural futures through collective learning

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Keywords: rural futures, collective learning, social-ecological systems, strategic planning

Introduction

The New Zealand pastoral industry faces many simultaneous drivers including market and policy compliance that operate from local to global scale. To continue to exist and thrive in the future, the New Zealand pastoral industry has to extend their ability to explore, learn, plan and innovate and thus gain confidence to proactively and effectively respond to the many simultaneous drivers that include: market (e.g. accreditation, product price, input costs, land values, skilled labour), societal (e.g. consumer perception) and policy (e.g. environmental regulation) (MAF 2007). These drivers do not operate independently, but interact to produce complex and uncertain system behaviour on- and off-farm, adding to the complexity of the challenges facing the sector and its multiple stakeholders. This paper outlines the tools and processes being designed in a research programme "Rural Futures" to support the development of a framework to enable adaptive capacity in the primary sector.

Materials and Methods

A review of collective learning principles and system methodologies applied to complex systems (Maani and Cavana 2007; Blackett 2009) was undertaken to assist in the identification of tools and design of processes for use in enabling farmers, industry representatives and policy to explore and test future scenarios. Process design was tested in the Manawatu in a series of four workshops held between December 2009 and August 2010. The stakeholder group included: farm consultants, industry advisors, leading dairy and sheep and beef farmers, and individuals that represented the perspectives of MAF, Horizons Regional Council, Federated Farmers and Maori Incorporations and Trusts.

The drivers impacting on New Zealand pastoral farming in the next 10-15 years were identified through a literature review and a subsequent situational analysis using a PESTE framework (political, economic, social, technological and environmental) (Manhire 2009) and presented to the stakeholder group. The stakeholders addressed the question "what are the pressures and their relationships influencing New Zealand Pastoral systems within the Horizon's region" using system methodologies that included, affinity diagrams and causal loop mapping (Maani and Cavana, 2007). The resulting conceptual map was used to choose drivers for design and exploration of hypothetical 2020 future farms, constructed with the stakeholders, starting with base representative farm-models for both dairy and sheep/beef for the region in 2010. System performance was evaluated using live simulations of FARMAX® Pro, FARMAX® Dairy and OVERSEER® nutrient budget model to allow immediate interaction and evaluation of questions related to the impact of the drivers on future farm systems.

Results and Discussion

We have designed a framework for exploring futures through collective learning (Figure 1) based on the concept of a "learning lab" that integrates systems thinking, complex decision making skills, group learning and participatory management (Maani and Cavana 2007; Maani 2011). The framework has at its core the collective learning cycle with a focus on future agricultural systems and consists of six iterative steps. **Step 1 Future driver identification:** The range of drivers and their relationships identified through literature review, PESTE analysis and stakeholder knowledge are captured and represented as a system using a causal loop diagram (CLD) (Figure 2). This demonstrates the link between drivers and between economic, social, and environmental systems represented by five integrated subsystems: environmental monitoring and farmer behaviour; good management practice; economic signals; innovation and family and community. **Step 2 Future Scenarios:** The Manawatu stakeholders used the CLD to identify five drivers (leverage points) that have the potential for major farm system impacts. These were: productivity and profitability; labour and staff skills; regulation; environmental constraints/limits and continued well being (survivability). These drivers were used to guide the development of the 2020 farm systems. **Step 3 System representation and behaviour:** The characteristics believed by the stakeholders to be prominent among dairy and sheep and beef farms within the Horizons region in ten years (2020) including: productivity gains: 1250 kg milk solids/cow and 138 percent lambing; 3.6 cows/ha and 10.4 stocking unit/ha sheep and beef. **Step 4 Evaluation of system performance:** The 2020 future farm systems performances were evaluated using FARMAX® Pro, FARMAX® Dairy and OVERSEER® nutrient budget model. Discussion from the group generated a lot of debate about how well the base farm models would represent the 'average' farmer in the region in 2020. Many of the farm parameters, e.g. stocking rate, MS per cow and per hectare were not significantly pushed beyond the current top performing farms in the region. There was general agreement that in 10 years time it may be reasonable to expect that the 'average' farmer would continue down a business as usual pathway, shifting to a position that reflected the current top 10% of the industry. **Step 5 Testing strategies, policies and decisions:** Using live simulations of FARMAX® Pro and FARMAX® Dairy interactively with the stakeholders gave them the opportunity to gain instant feedback on the consequences of farmer decisions on farm productivity and profitability.

Step 6 Reflect: The following are some of the insights that we have gained from testing the framework thus far. The selection of participants is critical in order to assemble a group of end users with a range of world views to encourage diversity of thinking. Interestingly, we did not get transformative future farm systems, but rather expansion of the current business-growth model. Even though we had a wide exposure to the diversity of drivers and their relationships, the focus remained on "the business we know". The lack of stretch might reflect the limitations of starting from a current base and projecting out. Additional elements that would facilitate transformative and beyond-current-reality thinking such as design thinking (Martin 2006) and idealised design (Ackoff 1999) will have to be explored to stretch the view of the stakeholders. Not all participants found the building of a CLD as part of driver identification intuitive and the stakeholders indicated a preference for being given a set of pre-prepared drivers. This would be due to the fact that thinking in feedback loops is not intuitive or apparent to many novice users of systems tools. The strength of the CLD was making transparent the

linkages between the drivers and demonstrated where particular drivers had key leverage throughout the system. This would not have been achieved through having only a list of drivers and other research has shown that decision makers often miss the dynamics of complex issues (Morecroft 1983; Senge1991;). The CLD is a precursor to the development of a systems dynamic model or Bayesian Belief network that allows stakeholders to interact with the system to explore changes and follow their consequences. This is the basis for building new experiences and knowledge.
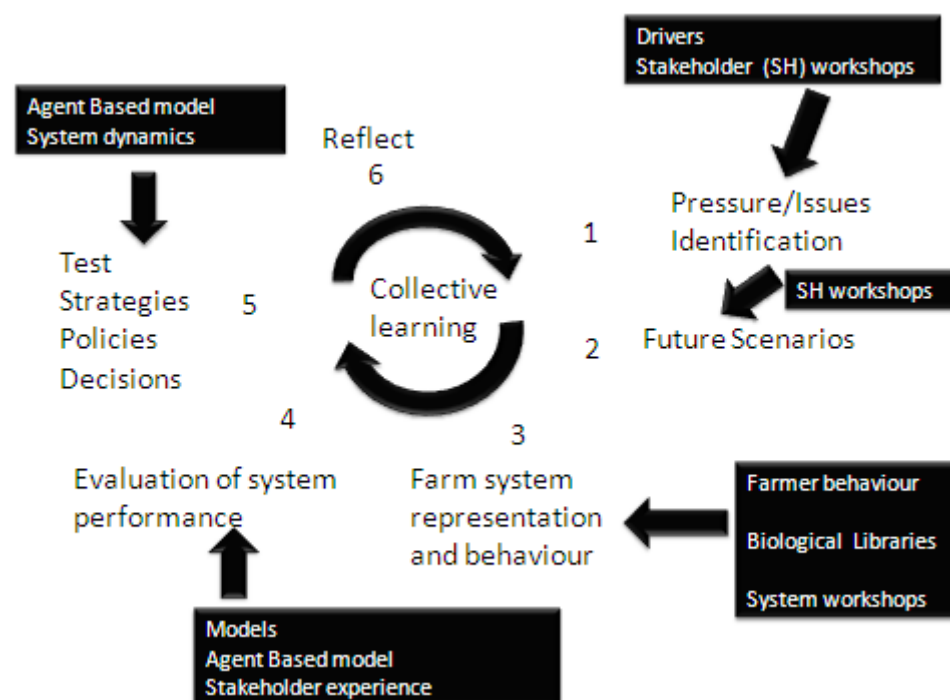
Figure 1. Framework for exploring futures through collective learning.
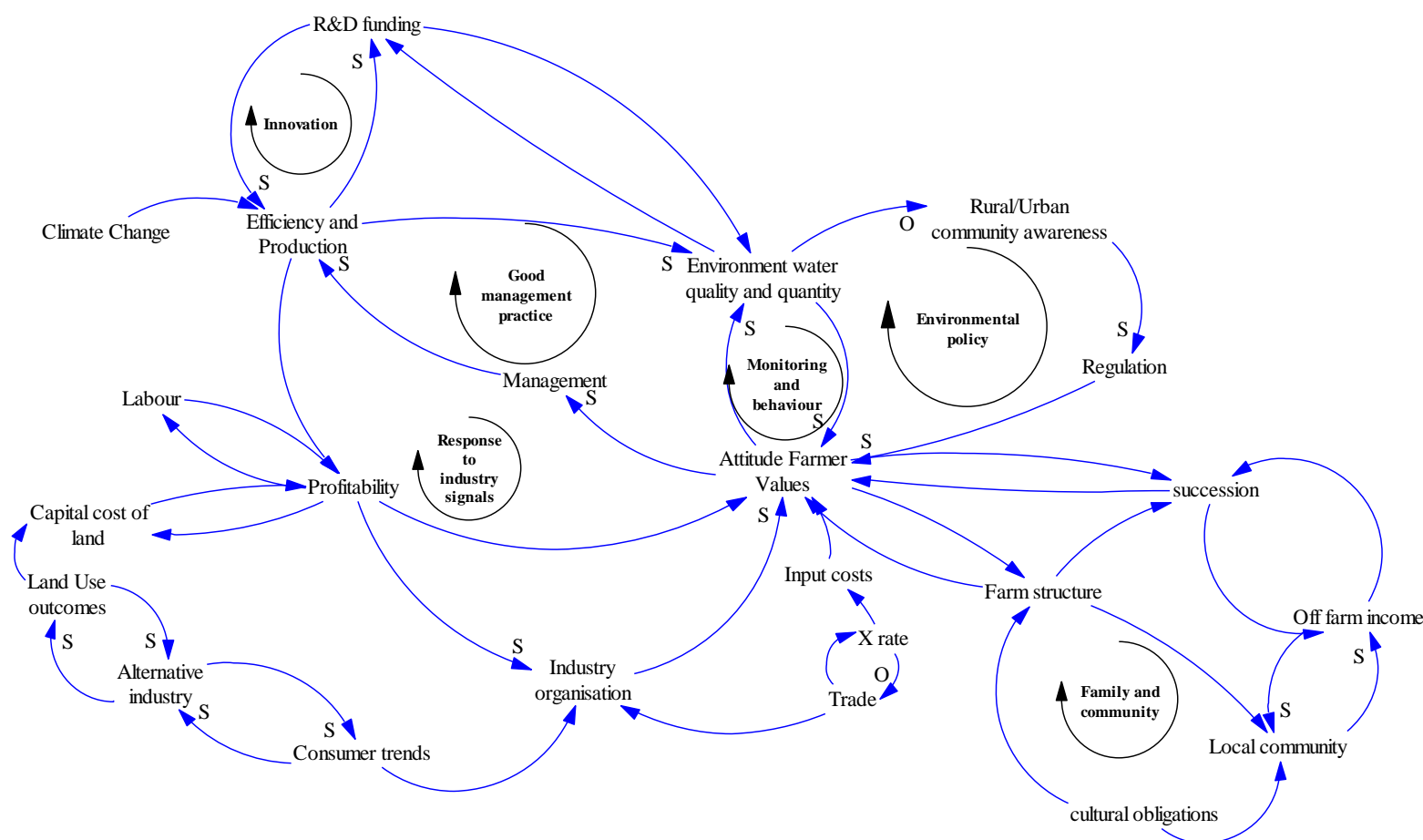
Figure 2. Causal Loop Diagram (CLD) of future drivers influencing New Zealand Pastoral systems within the Horizon's region S means variables are moving in the same direction, O means they are opposite.

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Natural resource conservation through watershed approach vis-à-vis economic sustainability in foothills of Northwest Himalayas, India

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Introduction

The Shivalik foothills forming part of outer Himalayas in India are spread in the states of Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Uttarakhand covering an area of 4,178,000 ha (F.A.O. 1999). These low hills are considered to be one of the eight most degraded and highly fragile agro-ecosystems of the country. The Shivalik ranges of the North-West Himalayas lies between $28^o45'$ to $33^o37'$ N latitude and $73^o37'$ to $80^o19'$E longitude where the climate is sub-tropical to sub-humid and humid with warm summer and cold winters. The mean annual rainfall varies from 800 to 1400 mm, 80% of which is received during monsoon months of July through September. Erratic distribution of rainfall, small land holdings, lack of irrigation facilities, heavy biotic pressure on natural forests, inadequate vegetative cover, heavy soil erosion, land slides, declining soil fertility and frequent crop failures resulting in scarcity of food, fodder and fuel in this region (Grewal 1995; Arora 2006). The flood waters erode banks, deposit senile sand on fertile land and inundate large areas in the plains disrupting communication and causing colossal loss of human life, livestock and property. Large scale migration of male population in search of work, drudgery of women due to scarcity of drinking water, food and fodder and a general lack of education, are the common socio-economic problems of this region. The benefits of green (cereal production) or white (dairy development) revolution did not reach the foothill farmers because of lack of irrigation facilities, scarcity of arable land and undulating terrain. This resulted in increasing unemployment, out migration to plains, malnutrition, poor health and enlarged economic disparities and regional imbalances within the states.

Agriculture in the Shivalik Foothills

Agriculture still continues to be primarily of subsistence nature due to lack of irrigation facilities. More than 82% of the cultivated area in the Shivaliks is rain-fed or un-irrigated. Undulating topography, deep water table, cultivation on steep slopes, age old agricultural practices and frequent crop failures, due to rain-fed condition, force the people to keep livestock. Grasslands are infested with noxious weeds which have eliminated both fodder as well as commercial grasses.

Although maize-wheat is one of the important crop rotations in the area, other crops grown by the farmers of the foothill region include pearlmillet, sorghum and barley. Pulses like cowpea, pigeon pea, beans, peas, gram, mash, green gram and lentil are also cultivated. Crop yields in the area are quite low compared to rest of the state and country, owing to scarcity of water and low soil fertility. A large number of dry spells of sufficient duration occur to affect yields adversely.

Management Practices for Soil and Rainwater

Soil and water conservation measures are aimed at management of rainwater, soil and vegetation resources in a manner that perceptible changes with regard to water resources development take place in the watershed so as to increase land productivity on a sustainable basis (Arora et al., 2006). Not only the surface water storage should increase as a result of soil water conservation interventions, but increased ground water recharge should take place. Some of the effective and feasible soil and water conservation practices either indigenously followed or adopted through technological interventions in watershed programmes by the farmers of the Shivalik foothills includes field bunding, pre-monson ploughing, terracing, contour trenching, earthing-up in maize, straw and soil mulching and tillage management (Arora et al., 2006; Sharma and Arora 2008; Arora and Hadda, 2003). Conservation of soil and water resources on watershed basis, resulted in improving the socio-economic status of the farming community. The paper describes some of the successful watershed programmes aided by different agencies including World Bank that were based on farmers' participation, implemented in the foothill region of Shivaliks in Northwest Himalayan tract of India. The soil and water conservation practices adopted by the farmers were the key inputs that resulted in ecological rehabilitation of degraded lands apart from creating awareness and generating income avenues for the rural poor of the region.

Farmers Perception for Soil and Water Conservation

According to the survey conducted and data of the same presented in Table 1, about 89 per cent of the respondents, out of the contacted 120 in each Jammu and Punjab region spread over 15 villages, faced the constraint of non-availability of the agricultural machinery and implements used for rainwater harvesting, as these are costly and the farmers are unable to purchase them. The specialized and improved implements were also not available for rainwater management.

Table 1. Constraints in adoption of soil and water conservation practices in foothill region (n=120 from 15 villages)

Soil and water conservation practices	Jammu foothill	Punjab foothill
	Per cent	Per cent
1) Problem in adoption		
Non-availability of design and implements used for improved conservation practices	89.20	51.30
Lack of technical know-how	76.60	78.00
Topographical problems	95.00	90.00
Ignorance for rainwater management practices	57.50	58.75
Small and fragmented land holdings	85.00	70.60
Poor socio-economic condition	87.50	75.20

Lack of technical knowledge of some improved rainwater management practices is also one of the constraints. About 76.6 and 78.0 per cent of the respondents from Jammu and Punjab foothill region feel that they had lack of skill in handling the practices like contour bunding, staggered trenches etc. About 85-95 per cent of the respondents had problems due to undulating topography and poor economic condition, which causes problem in application of different practices. They had to rely more on human labour rather than machinery because they had sloping and fragmented fields.

Socio-Economic Development and Eco-Restoration

The watershed development programme in agricultural and forest catchments in foothills of Shivaliks aiming soil and water conservation resulted in several ecological benefits viz. reduction in soil loss, development of vegetative cover, fodder production, increase in crop yields, wasteland development, etc. Various works were carried out under micro-watersheds development projects like raising of nursery, bench terracing, gully plugging and afforestation, etc, generated lot of employment which eventually enhanced economic conditions of the people of the area. Moreover, environmental degradation due to overuse, misuse and mismanagement of life supporting systems (Land, water and forests) which had vastly disturbed the natural ecological balance, has been ameliorated.

Productivity and Income Generation through Watershed Programmes

Watershed management programmes will not be self sustainable, if improvement in productivity and generation of additional income does not commensurate with investment. Analysis of time series data in a 370 ha middle Himalayas watershed showed that there was remarkable improvement in the average yield of all crops ranging from 2.2 to 7.4 times during the intervention phase (Samra 2002). The local community continued to invest and sustain productivity till today.

Increased biomass and fodder production resulting from integrated management of watershed at Bunga (Haryana) changed the composition of livestock to more economical animals and reduced seasonal migration of herds due to assured fodder supply during the year.
The harvested rainwater in small storage tanks/structures/farm ponds can be effectively utilized for supplemental irrigation during lean periods to boost crop production. Evaluation of water harvesting in different agro-ecological regions showed that the productivity of arable lands increased by 4.2 to 15.4 q ha^{-1} with benefit:cost ratio varying from 1.48 to 3.89 (Table 2; Samra 2002). Water harvesting structures proved to be economically viable, environmentally sound and socially acceptable. The economic analysis of 21 watershed management programmes conducted in different regions showed that investment in these programmes is a profitable proposition from both economic (B:C ratio >1.2) and banking (IRR>17%) point of view. Casual employment opportunities @215 man-days/ha/year during implementation phase and @20 man-days/ha/year in the post-intervention phase were generated.

Table 2. Economic analysis of water harvesting structures

Type of structure	Location	Capacity (ha-m)	B:C ratio	Remarks
Unlined pond (natural)	Dehradun (Uttarakhand)	1.65	1.85	Pre-sowing irrigation to wheat
Lined tank	Fakot (Uttarakhand)	-	1.48	Protective irrigation to wheat after terrace improvement
Unlined pond	Sukhomajri (Haryana)	5.5	1.63	Life-saving irrigation to wheat
Unlined pond	Bunga (Haryana)	59.6	3.89	Pre-sowing and flowering stage irrigation to wheat

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Engaging local communities in negotiating their own pathway towards conservation-oriented agricultural practices

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Introduction

Since the opening of the country to the market economy in 1986, the Government of Laos (GoL) has invested considerable efforts into modernizing its agriculture. Village land use planning and land registration are being used by the GoL to promote an intensification of agriculture - from extensive subsistence-oriented shifting cultivation, deemed unproductive and poverty-creating, to more intensive and market-oriented cropping systems. Lao agriculture is changing from extensive chemical-free slash and burn to conventional intensive practices with high reliance on chemical inputs. This shift from traditional subsistence to a market-oriented agriculture is expected to lift upland populations out of poverty while reducing their dependence on forests, and is therefore contributing to the conservation of the natural resource base. Such a transition entails significant risks, i.e. in the case of an adverse climatic event, price fluctuations or market crisis, which would potentially trap smallholders in a treadmill of indebtedness. For poor upland farmers, a convincing alternative would consist of moving directly from extensive to agro-ecological practices supported by a national decree on conservation agriculture (CA) promulgated in 2007. Agro-ecological techniques that increase the land use intensity by mobilizing relevant ecological knowledge have been successfully designed and tested in Laos (Bouahom et al. 2005). However their diffusion and adoption are not straightforward (Lestrelin et al. 2011). Lestrelin and Castella (2011) have identified two windows of opportunity for dissemination of CA in Lao PDR that correspond to distinct stages in an agricultural intensification pathway. A high proportion of CA adoption is observed during the initial intensification phase when farming households shift from traditional subsistence farming to more intensive market-oriented agriculture, and during the last stage of intensification when intensive mono-cropping systems lead to high levels of land degradation (i.e. soil erosion and nutrient depletion) that impose a change in agricultural practices. In this paper, we address the conversion from shifting cultivation to conventional and/or conservation agriculture. A learning platform combines participatory land use planning and promotion of conservation agriculture in village action plans. A case study in Viengkham District, Luang Prabang Province, illustrates an innovative method that engages marginal upland communities into multi-stakeholder negotiations about land use planning within a context of transition towards agro-ecological practices.

Material and Methods

While substantial external support through food security programs is provided to target upland villages of the study site, participatory land-use planning (PLUP) is used as a policy instrument to reorganise the rural space and to convert cropping practices and patterns. Past and current experiences with LUP have shown many drawbacks, often caused by methodological deficiencies. Bourgoin et al. (2011) demonstrated that improvements were possible through the establishment of clear participatory principles and the usage of appropriate tools to shift from individual processes of adoption to collective negotiations of landscape level changes.

Described in Bourgoin et al. (2011), the land use planning activities undertaken in early 2011 in three villages of Viengkham District - Houay Kou, Had Houng and Nam Xoy - were combined with dissemination of agro-ecological practices (e.g. vigna cover crop in association with maize, improved pastures using a combination of *Bracharia* and *Stylosanthes*, and domestication of Non Timber Forest Products to reduce pressure on natural resources). During 5 days, twelve villagers selected as members of the land management committee of their village (i.e. a balanced sample of social classes, gender, ethnicity in the village), are involved in a series of learning and planning activities. After the elicitation of information related to the village's spatial organisation of land-use and economic returns, a role-play called 'PLUP Fiction' involves the villagers in a learning experiment of land use planning based on a virtual landscape. Under pressure from external forces, the players have to negotiate development scenarios and to reach a consensus amongst different household types (Bourgoin and Castella 2011). Participatory 3D modelling is then used to facilitate the negotiation and the visualisation of landscape issues during village boundaries delineation and land zoning activities (Figure 1). A Geographic Information System is coupled with a simple cost/benefit analysis model parameterized by the villagers themselves. Facilitators can capture real-time information on the different areas of the land use plan under discussion, and present corresponding socio-economic and environmental returns. Using this iterative system, the villagers gradually refine their land-use plan and test the introduction of alternative cropping and animal husbandry systems by changing the parameters of the simulation. Using this 'boundary object', different stakeholder groups are invited to explore several scenarios of transition towards agro-ecological systems, and to compare them with a shift towards market-based agriculture, while visualizing short - and long - term economic and ecological effects on their village landscape.

Figure 1. 'Boundary objects' facilitating the participation of local communities in landscape planning and management. From left to right, landscape simulation with 'PLUP Fiction'; negotiating village zoning and agroecological innovations on a participatory 3D model; villager presenting land use plan and land management rules during a village meeting.

Results and Discussion

The environmental impact and socio-economic returns were computed at landscape level under different management scenarios. For example, the delineation of livestock areas with living fences was combined with a strategy to develop plantations of marketable castor bean (*Ricinus communis*) under cover crop. An action plan was developed to put into practice land use options including agro-ecological alternatives that had been negotiated virtually.

An international NGO is now working in these villages with district extension agents to transform the plans into reality. By empowering poor communities in participating in decision-making, the proposed participatory approach provides a negotiation platform that facilitates the emergence of a local demand, which would not be feasible with a 'quick and dirty' participatory rural appraisal (PRA). As expressed by the Governor of Viengkham District, "this approach puts the keys development in the hands of local communities and avoids making people dependent on foreign projects by engaging them into endless assistance programs".

Enhancing the effectiveness of industry-farmer-science-policymaker consultative platforms has direct impacts on traditional extension systems with three major shifts:
- From technology transfer to learning and discovery approaches to innovation,
- From monitoring plot-level adoption rate of CA systems to assessment of landscape-level agro-ecological system,
- From individual decision making to collective management of CA adoption.

When extension programs deal with individual beneficiaries, village consensus is usually poor, limiting the innovation uptake. Our proposed landscape planning perspective allows defining management strategies and rules at the village level (Bourgoin et al., 2011).

While extension services are the natural follow-up of land-use planning, PLUP also delivers a robust village diagnosis that legitimizes and rationalizes further village action plans. Impact is achieved by linking individual decision making with higher level institutional changes through more effective consultation, participation and knowledge sharing.

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Barriers and emerging success factors towards effective Conservation Agriculture adoption in the Uluguru Mountains, Tanzania

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Keywords: smallholder farmers, land, Farmer Field Schools (FFS), Contact Farmers (CF)

Introduction

The Uluguru Mountains (UM) lie 200 km inland from Indian Ocean Coast and South of Morogoro town in Tanzania. They are one of thirteen mountain ranges that form the Eastern Arc Mountains (EAM), and are also recognized as part of a Global Biodiversity Hotspot (Mittermeier et al., 2004; Myers et al., 2000; Olson and Dinerstein, 1998; ICBP, 1992; cited in URT, 2005, p.8). In addition to that, the UM are inhabited by approximately 151,000 people in 50 villages and are also of exceptional interest for being an important water catchment area[7] in the country (URT, 2005). The people in UM are predominantly smallholder farmers who are also the main food producers in the country, and are perceived as degraders of their own environment (EAMCEF, 2005-2007).

In spite of the biodiversity richness, the UM is faced with a host of human pressures causing rapid land use changes. These include: felling trees for timber, firewood and building pole collection; uncontrolled fires; clearance subsistence; and cash-crop cultivation (Buckley and Bhatia, 1998). While agricultural land in the area has historically been relatively well suited for agriculture, land and water resources have been deteriorated, and have led to an increase in soil erosion, loss of soil fertility, and a subsequent increase in sediment loading. In turn, crop yields, household incomes, and any other hopes of livelihood security have declined significantly (CARE Tanzania, 2008). Yet, without proper extension or education on alternative farming methods and livelihoods strategies, little progress seems possible for a country that 80% of the rural poor heavily depend on rain-fed agriculture, which accounts for over half of the Gross Domestic Product (GDP) (URT, 2007).

Thus, in order to overcome this situation, CARE Tanzania is implementing the *Hillside Conservation Agriculture for Improved Livelihoods in the South Ulugurus, Tanzania* (HICAP) project, whose overall goal is to sustain and enhance livelihoods through improved family food security, better resource conservation, and gender sensitive support services. This is done through the use of conservation agriculture (CA) practices that are culturally and environmentally sound. Within this unique, fragile and underserved ecosystem, HICAP promotes minimum tillage, cover cropping (i.e. using leguminous crops), crop rotation/association, and permanent organic soil cover. This goes hand in hand with soil and water conservation techniques on the steep slopes and crop diversification. Based upon CARE Tanzania efforts in the UM, this paper seeks to identify barriers, emerging success factors up to date, and opportunities contributing to successful learning and CA adoption in underserved communities and deteriorated ecosystems.

Materials and Methods

A group-based learning process including Farmer Field Schools (FFS), Participatory Technology Development (PTD), Participatory Variety Selection (PVS), and a Village Savings and Loans (VSL) component to ensure financial sustainability is what HICAP is all about (CARE Tanzania, 2008). Farmers' empowerment and social mobilization coupled with a combination of technical, social and economic approaches that focus on skills development and capacity building of rural women and men farmers are at the heart of the project methodological approaches.

Guided by a facilitator[8], the FFS approach provides a learning environment in which a group of farmers gather in the field to learn about their crops and the factors that affect them through the PTD and PVS processes. Farmers try different CA techniques, and implement their own locally-specific and informed decisions about crop management, land use practices, seeds, and pest management, and analyse the lessons learned from their own demonstration plots. Under the PTD framework farmers reflect upon their farming systems, and methods to improve soil fertility and conserve water. This process helps them to experiment, adapt and develop innovations for managing agricultural and natural resources sustainable, and adapted to the local conditions. In addition, the PVS enables farmers to conduct on-farm testing of different crop varieties (both improved and local crop varieties) under their own local management regime, and select the most suitable and high-yielding crop varieties based on their own local selection criteria, and needs.

By trying to encourage women farmers, resource focal persons are appointed in order to form new FFS and VSL groups, and facilitate training to farmers, the so-called Contact Farmers (CFs) and Community Based Trainers (CBTs), respectively. A field office has also been built as part of the project (the so-called "Centre for Sustainable Living[9]" –CSL-). The CSL will be a model for sustainable village-based outreach and will provide a centre for CA training, and mentorship of emerging village-based extension professionals. As a result, family food security, income generation, healthy communities, better access to nutritious crops, and healthy soils will be realised.

Results and Discussion

There are key biophysical and social barriers that hinder the extent to which CA adoption is to be practiced and scaled out in the project area. Biophysical barriers include: farming systems determined by altitude ranges of 780m to 2,640m; remoteness; lack of basic infrastructure (mountain feeder roads); lack of access to information, and poor access to markets (Mvena and Kilima, 2009). Besides, prevalent slash and burn practices; forest encroachment for food production purposes; high reluctance to behavioral change; limited or no assistance from non-governmental organizations (NGOs), among others; posed additional challenges to the introduction of CA.

On the other hand, social barriers such as predominance of women and old generations in the area where farm labour falls under their responsibility; low levels of education; and high prevalence of women with children from different fathers, pose an additional challenge to

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[7] The Uluguru Mountains are the main source of water for the Ruvu River, which supplies water to more than four million people as well as major industries in the towns of Morogoro, Kibaha, Bagamoyo and Dar es Salaam.
[8] The facilitator is commonly an extension officer or a farmer who has graduated from another FFS.
[9] The CSL is mostly built with locally available materials, equipped with solar power, a composting toilet, and a rainwater harvesting system.

effectively engage women in CA as the burden of rearing children is single handedly. Apart from that, land is largely owned by the clan. Thus, individuals from a clan that control land have easier access to land resources than individuals without such background, and the latter would be obliged to rent land from the former with no right to sublet it or to make long term investments such as planting trees (Mvena and Kilima, 2009). Hence, all the above have serious implications in CA adoption.

Different cultivation seasons between lower and higher altitudes have implications with CA adoption rates. For instance, in the upland areas, the cultivation season for maize is longer than for the same crop in lowlands. In contrast, lowlands (with more available agricultural land) tend to have higher CA adoption as they are more easily accessible, and better connected to markets. In turn, farmers from higher altitudes tend to move to lower altitudes during the cropping season in search for land. On the other hand, farmers who live in transitional areas seem to be in the best position to diversify their production as they can grow crops from both the lowlands and the uplands, and they have shorter dry periods compared to the lowlands. Also, increased climate variability with unpredictable and unreliable rainfall often provokes de-motivation among farmers to adopt CA.

Up to date, the project records a total area of 98 acres covered by CA accounting for a sample size of 245 CA adopters (out of a population of 4,400 households). Although this is most likely an underestimation of the actual area covered by CA, this figure (98 acres) is assuming a sample proportion of 50%, a confidence interval of 95%, and a sampling error of 6.1%. Farmers are typically using a combination of CA practices by experimenting different options themselves instead of a stand-alone practice. Particularly in areas where farmers have been using hand hoes for long, deep digging (which is done zonally) is practiced in order to break the hardpan, enhance the water retention capacity, soil aeration and root penetration. New improved hand hoes have been introduced and offer the advantage to better suit women farmers needs, as they are lighter, and thus, have the potential to save time and energy while ensuring farm productivity.

In addition, the introduction of improved seed varieties (e.g. TAN 250 and TAN 200 for maize) in the project area lead to higher yields and take shorter to mature compared to local seed varieties. Maize intercropped with lablab has higher yields (10,685 Kg/ha) than intercropped with cow peas and pigeon peas (8,500 kg/ha, on average). In addition, roselle (*Hibiscus sabdariffa*) cultivated mainly by women farmers near their homesteads, is not only supporting CA principles, but it is also easy to cultivate as well as it can increase household revenues, women participation on the market, and has the potential to save them time to use for other activities. Also, through the project, the formation of a Small-Scale Producer Group (SSPG) has been facilitated in order to link farmers with market opportunities (i.e. sesame as a cash crop). A favorable behavioral change has been achieved through various sensitization meetings, by involving the community members in different stages of the process, and by using CFs and CBTs as key mobilizing agents. Since the beginning, women involvement has been a challenge as many were afraid to raise their voice. However, by involving women CFs and women CBTs, this has been partly overcome. While 12 women CBTs have mobilized 275 new VSL members, the same number of men CBTs has mobilized 162 members. Although the reality is that efforts put to date remain visible, some aspects yet to be tackled are: weed control, the integration of perennial plants, and the effective integration of crop-livestock systems, just to name a few. The next stage is the integration of trees in the current farming systems, in which CA effectiveness is expected to increase as it can have the potential to offer both mitigation and adaptation to climate change benefits.

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Combining different modelling approaches for a participative assessment of alternative agricultural systems at different scales

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Keywords: Land use change, bio-economic model, agent-based model, organic farming, CAP, policies

Introduction

Evaluating the impacts and performances of alternative cropping and farming systems in a region requires the use of proper systems analysis tools. Contextualizing this evaluation in a prospective scenario analysis of a region is needed, as an alternative systems may be adapted to the current context but may have serious drawbacks if the socio economic context change (Blazy et al., 2009). Models are essential tools as they can integrate the effects of change of context (i.e. policy and prices) and of systems and calculate multiple indicators at different scales for the different sustainability domains (economic, social and environmental) (van Ittersum et al., 2008). The multifunctional nature of agriculture is increasingly recognized meaning that different stakeholders, with different objectives (i.e. agricultural production, nature conservation) have interests and objectives about the evolution of farming systems in a region. Therefore, evaluating scenarios of agriculture evolution, which integrate both alternative systems and new policies, requires a prospective, integrated (multi-criteria and interdisciplinary), multi-scale and participative approach. On the basis of a comparative analysis of various modelling tools we have developed the PIMPAAS approach (Prospective, Integrated, Multiscale and Participative Assessment of Agricultural Systems; Delmotte et al, 2011). PIMPAAS combines detailed knowledge on cropping and farming systems with land use change, bio-economic and agent-based models in order to build and assess scenarios of agricultural evolution in interaction with the stakeholders in a region. This approach is targeted to assist stakeholders in the negotiations of local policies as well as consensus building on local development objectives.

This paper presents the methodology currently implemented in the Camargue Region (southern France). We first present briefly the models, data and participative methodologies that were developed and then the main results of their applications for two scenarios: foreseen changes in the Common Agricultural Policy 2013, and an extension of organic farming (OF) in the region.

Materials and Methods

Through 20 years of action research in the Rhone river delta of Camargue, a good knowledge of farming systems structures and performances and local stakeholders network was acquired. We conducted a first series of interviews with most influential stakeholders of the region (e.g. grain collectors, farmer syndicate and natural regional park) to present the project and engage them in the process of defining scenarios and indicators for their evaluation. From interviews with farmers, farmers fields surveys, crop modelling, local expert knowledge and regional statistics, a database quantifying the current and alternative agricultural activities was developed (e.g. average yield for ten most common crops, labour demand, fuel, pesticides and fertilizers consumption). A GIS was developed to get spatial information about soil types, altitude and irrigation infrastructure as well as a spatial farm typology to capture the variability of farming systems and to upscale in the models. We first conducted a retrospective land use change (LUC) analysis for 11 consecutive years (1998-2008) for the central sub-region. The results were used to enhance first discussions with stakeholders and evidence the need for participative workshops for scenarios assessment.

We then developed an interactive agent-based model (ABM) where farmers make choices for an hypothetical farm (derived from the typology) in terms of crop and style of production (organic or conventional, intensive or extensive). Simulations are done for seven consecutive years and outputs are the indicators previously identified at different scales (e.g. field, farm, water distribution area) with the farmers (e.g. gross margin, labour demand) and other stakeholders (e.g. employment, water use, subsidies). Participative workshops were conducted using the ABM with farmers to explore a scenario related to CAP reform. Other workshops are being organised with farmers and local stakeholders to assess the same scenario and have discussions about the impacts of farmers choices at sub-regional and regional scale. In parallel, bio-economic models (BEM) at different scales were developed to discuss with stakeholders plausible adaptation strategies to the CAP reform and evaluate the potential for OF in this context. The results of the BEM will serve, in a final workshop using the ABM, to delimit the solution space for different scenarios and guide farmers choices as well as the development of local environmental policy measures. Results of this final workshop will be presented during the congress. In the next part, we present the type of results that were obtained from first PIMPAAS application in the Camargue and discuss them from the point of view of participation.

Results and Discussion

Figure 1-A shows the evolution of the average proportion of farm area devoted to rice, for five farm types, resulting from a LUC analysis. While the organic livestock breeders had a stable 20% of their area in rice, the livestock breeders and the diversified cereal producers had a downslope trend. Specialized rice producers had a stable or increasing rice area. Taking into account the current CAP high subsidy level for rice production, this analysis shows the vulnerability of specialised farmers to CAP reforms. Livestock breeders and diversified cereal producers can be expected to be more resilient to the foreseen reduction of rice specific subsidy, and could more easily convert to organic production as it implies to shift to long and diversified rotations and therefore to reduce the rice area. To verify such hypothesis, we used a BEM to simulate the possibility and impact of a conversion to OF for these types of farm. Figure 1-B presents a radar graph for a specialized rice producer farm with 425 hectares when the gross margin is maximized with conventional and organic activities. Organic and conventional activities result in similar gross margin, costs, subsidies and labour while for pesticide use and water use the OF activities provide better values. Compared to the current situation, it can be seen that gross margin can be nearly doubled with both conventional and organic production options. However, it has to noticed that the BEM is optimising land use for a single year without taking into account the rotations needed to reach such optimal land use. Results from the BEM show that OF can be as competitive as conventional farming while reducing possible impacts on the environment however, the pathways for conversion are not explicitly given. Such pathways were then explored with farmers by the use of ABM.

In Figure 1-C the evolution of gross margin is shown for two different farm types as simulated by two farmers in the ABM in a participatory scenario evaluation where the specific subsidy for rice was not given from the year 3 onward. Both farmers reacted to the hypothetical CAP reform by converting part of their farm to OF. The CAP reform and consequent conversion to OF didn't have a large effect for the livestock breeder while for the rice producer, conversion to OF implies a diversification of production, and an initial decrease of gross margin linked to the reduction of rice surface in the conversion to OF. At the end of the simulation, gross margin of the rice producer is recovered as, once the transition period has ended, all productions are sold at the prices of organic products. Combining the three approaches for the evaluation of scenarios highlights their complementarities. The LUC analysis is used as a tool to make hypotheses, from a retrospective point of view, on the potential adaptability to CAP reforms by different farm types. BEM is used for assisting reflection on plausible and desired scenarios and identifying the main biophysical constraints. Finally, ABM is used to test possible adaptation strategies of farmers and to organize and focus the collective discussions.
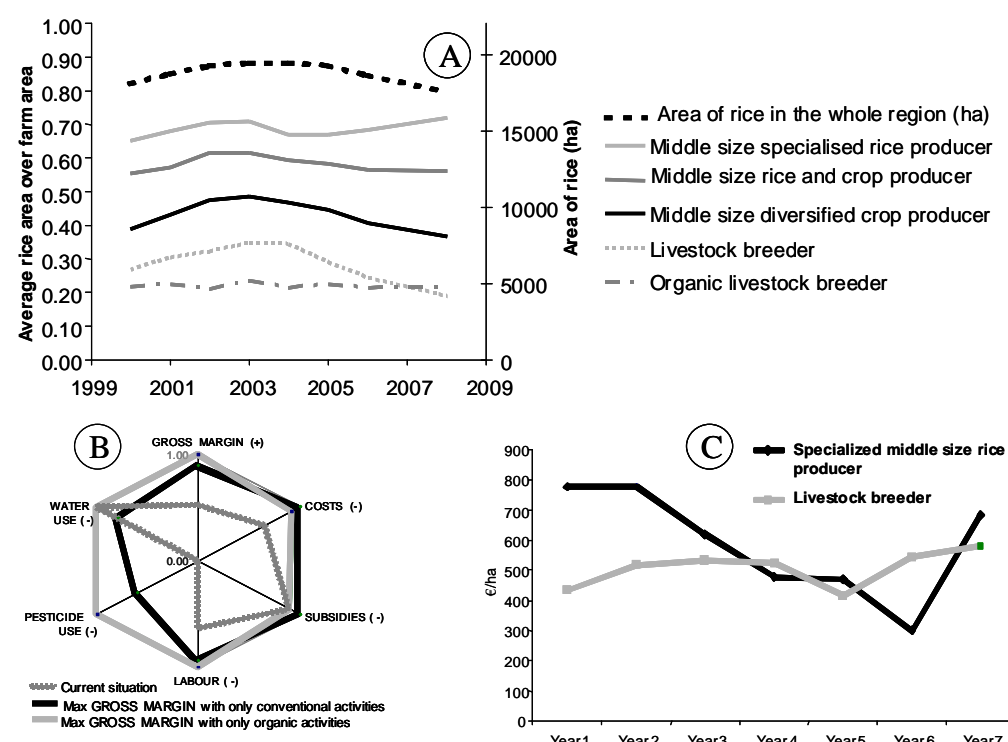
Figure 1- A: Land use change analysis of the evolution of the proportion of farm area that was devoted for rice between 1998 and 2008 (moving average of 3 years for all farms of a given type) and total area on rice in the whole region. **B**: Current situation for a chosen middle size specialized rice producer and maximization of the gross margin with conventional and organic activities scenarios (from BEM), the outer circle of the radar the best values for each indicator, (-) means that this indicator is to be minimized while (+) means to be maximized, "SUBSIDIES" is the rate of subsidies in the gross margin, LABOUR is the gross margin divided by the labour demand. **C**: Evolution of the gross margin as simulated by two farmers using the ABM during an interactive simulation workshop about the CAP reform.

Farmers found the approach powerful to help them thinking of possible adaptation they could do on their farm, while other stakeholder appreciated the transparency of the tools as an advantage for negotiation among them. Uncertainty and validation of data and models was a recurrent subject of discussion between scientist and participants, and the capacity to change the value of certain parameters during interactive simulations was found as a necessary characteristic to enhance confidence in the simulation. The case studies reported here focus on two specific scenarios with conventional and organic activities. However, conservation agriculture (CA) is being tested in on-farm experiments, allowing to include CA activities in further scenarios analyses. Other regions where environmental concerns and agriculture are issues at stakes could benefit from this experience in the combination of approaches.

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Global overview of the spread of Conservation Agriculture

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The global empirical evidence shows that farmer-led transformation of agricultural production systems based on Conservation Agriculture (CA) is already occurring and gathering momentum globally as a new paradigm for the 21st century. The data presented in this paper, mainly based on estimates made by farmer organizations, agroindustry, well-informed individuals, show an overview of CA adoption by country, as well as the extent of CA adoption by continent (Table 1).

Table 1: Area under CA by continent*

Continent	Area ('000 ha)	Per cent of global total	Per cent of arable crop land
South America	55,630	47.6	57.5
North America	39,981	34.1	15.4
Australia and N	17,162	14.7	69.0
Asia	2,630	2.2	0.5
Europe	1,150	1.0	0.4
Africa	368	0.3	0.1
Global total	**116,921**	**100**	**8.5**

*Some figures may change as updated figures are awaited from several countries

CA, comprising minimum mechanical soil disturbance, organic mulch cover, and crop species diversification, is now practiced globally on about 117 M ha in all continents and all agricultural ecologies, including in the various temperate environments. A useful global overview of adoption of CA in individual countries is given in Derpsch and Friedrich (2009a, 2009b) and Kassam et al. (2010).

While in 1973/74 the system was used only on 2.8 M ha worldwide, the area had grown in 1999, to 45 M ha, and by 2003 the area had grown to 72 M ha. In the last 11 years CA system has expanded at an average rate of more than 6 M ha per year showing the increased interest of farmers in this technology, mainly in North and South America and in Australia and New Zealand, and more recently in Asia where large increases in the adoption of CA are expected..

The growth of the area under CA has been especially rapid in South America where the MERCOSUR countries (Argentina, Brazil, Paraguay and Uruguay) are using the system on about 70% of the total cultivated area. More than two thirds of no-tillage practiced in MERCOSUR is permanently under this system, in other words once started the soil is never tilled again.

As Table 1 shows, 47.6% of the total global area under CA is in South America (corresponding to 57.5% of its arable crop land), 34.1% in the United States and Canada (15.4% of its arable crop land), 14.7% in Australia and New Zealand (69%), and 3.5% in the rest of the world including Europe, Asia and Africa (1%). The latter are the developing continents in terms of CA adoption. Despite good and long lasting research in these continents showing positive results for no-tillage systems, CA has experienced only small rates of adoption.

Except in a few countries (USA, Canada, Australia, Brazil, Argentina, Paraguay, Uruguay), however, CA has not been "mainstreamed" in agricultural development programmes or backed by suitable policies and institutional support. Consequently, the total area under CA is still relatively small (about 8.5% of arable crop land) compared to areas farmed using tillage. However, area under CA is on the increase in all parts of Asia, and we expect large areas of agricultural land to switch to CA in the coming decade as is already occurring in Kazakhstan, India and China.

CA is not widely spread in Europe: no-till systems do not exceed 0.5% of the arable cropland. Only Africa has a smaller absolute area under CA than Europe. Since 1999 ECAF (European Conservation Agriculture Federation) has been promoting CA in Europe, and adoption is visible in Spain, Finland, France, and Ukraine, with some farmers at 'proof of concept' stage in the UK, Ireland, Portugal, Germany Switzerland, and Italy.

Asian and African countries have seen uptake of CA in the past 10-15 years. In Central Asia, a fast development of CA can be observed in the last 5 years in Kazakhstan which now has 3.5 M ha under reduced tillage, mostly in the northern drier provinces, and of this 1.3 M ha (5.7% of crop area) are "real" CA with permanent no-till and rotation that puts Kazakhstan amongst the top ten countries in the world with the largest crop area under CA systems. China too has equally a dynamic development of CA. It began more than 10 years ago with research, then the adoption increased during the last few years and the technology had been extended to rice production system. Now more than 1.3 M ha are under CA in China and 3,000 ha in DPR Korea where the introduction of CA has made it possible to grow two successive crops (rice, maize or soya as summer crop, winter wheat or spring barley as winter crop) within the same year, through direct drilling of the second crop into the stubble of the first.

In the Indo-Gangetic Plains across India, Pakistan, Nepal and Bangladesh, in the wheat-rice cropping system, there is large adoption of no-till wheat with some 5 M ha, but only marginal adoption of permanent no-till systems and full CA. In India, the adoption of no-till practices by farmers has occurred mainly in the wheat-rice double cropping system and has been adopted primarily for the wheat crop.

In the CWANA (Central and West Asia and North Africa) region, much of the CA work done in various countries has shown that yields and factor productivities can be improved with no-till systems. Extensive research and development work has been conducted in several countries in the WANA region since the early 1980s such as in Morocco, Tunisia, Syria, Lebanon and Jordan, and in Turkey. Similarly in Central Asia, work on CA practices for Eurasia has been reported for Kazakhstan and Uzbekistan.

In the Sub-Saharan Africa, innovative participatory approaches are being used to develop supply-chains for producing CA equipment targeted at small holders. Similarly, participatory learning approaches such as those based on the principles of farmer field schools (FFS) are being encouraged to strengthen farmers' understanding of the principles underlying CA and how these can be adapted to local situations.

CA is now beginning to spread to Sub-Saharan Africa region, particularly in eastern and southern Africa. Building on indigenous and scientific knowledge and equipment design from Latin America, and, more recently, with collaboration from China, Bangladesh and Australia, farmers in at least 14 African countries are now using CA (in Kenya, Uganda, Tanzania, Sudan, Swaziland, Lesotho, Malawi, Madagascar, Mozambique, South Africa, Zambia, Zimbabwe, Ghana and Burkina Faso). CA has also been incorporated into the regional agricultural policies by NEPAD (New Partnership for Africa's Development).

In the specific context of Africa with resource-poor farmers, CA systems are relevant for addressing the challenges of climate change, high energy costs, environmental degradation, and labour shortages. So far the area in ha is still small, but there is a steadily growing movement involving already far more than 100,000 small-scale farmers in the region including in: Ghana 30,000 ha; Kenya 15,000 ha; Morocco 4,000 ha; Mozambique 9,000 ha; Sudan 10,000 ha; Tanzania 6,000 ha; Tunisia 6,000 ha; Zambia 40,000 ha; Zimbabwe 7.500 ha. In Africa CA is expected to increase food production while reducing negative effects on the environment and energy costs, and result in the development of locally-adapted technologies consistent with CA principles.

Originally the adoption of CA was mainly driven by acute problems faced by farmers, especially wind and water erosion, as for example southern Brazil or the Prairies in North America, or drought as in Australia. In all these cases farmers' organization was the main instrument to generate and spread knowledge that eventually led to mobilising public, private and civil sector support. More recently, again pressed by erosion and drought problems, government support has played an important role in accelerating the adoption rate of CA, leading to the relatively fast adoption rates for example in Kazakhstan and China, but also in African countries as Zambia and Zimbabwe, among others, and this is attracting support from other stakeholders.

CA represents a fundamental change in production system thinking and is counterintuitive, novel and knowledge intensive. The roots of the origins of CA lie in the farming communities, and its spread has been largely farmer-driven. Experience and empirical evidence across many countries has shown that the rapid adoption and spread of CA requires a change in commitment and behaviour of all concerned stakeholders. For the farmers, a mechanism to experiment, learn and adapt is a prerequisite. For the policy-makers and institutional leaders, transformation of tillage systems to CA systems requires that they fully understand the large and longer-term economic, social and environmental benefits CA paradigm offers to the producers and the society at large. Further, the transformation calls for a sustained policy and institutional support role that can provide incentives and required services to farmers to adopt CA practices and improve them over time (Friedrich and Kassam, 2009; Friedrich et al., 2009b).

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CA coordination in Zimbabwe, through the Zimbabwe Conservation Agriculture Task Force

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Background and Current Work

Using Conservation Agriculture (CA) to increase production and productivity for small-holder farmers in SAA is a relatively new approach, initiated initially to improve the impact of agric input support interventions. CA is used to improve agriculture productivity, livelihoods and income of small holder farmers and has been in the last few years widely promoted and adopted by various stakeholders, including governments, donors/NGOs and private sector.

However, as the CA is new to most farmers and supporting originations, consistent promotion and standardized extension approaches are essential. As extension services are not fully aware of CA and the promotion and lobbing for CA needs some coordinating institution, to ensure adoption and maintain standards.

A comprehensive coordination of CA is encouraged by stakeholders to improve the impact of CA and avoid "mixed messages" and seen as the basis for lobbing and advocating.

The Zimbabwe Conservation Agriculture Task Force (ZWCATF) has been initiated with the 1st CA support in Zimbabwe from 2003, initially to standardize input packs and extension messages. Originally, the purpose of the task force was that of identifying and developing appropriate guidelines and suitable input packages for CA programs implemented by NGOs with donor relief funds.
The mandate and activities extended into an overall CA coordination, including, extension, monitoring, research and guidelines. The CA coordination also facilitates the information exchange on CA technologies between partners.

Coordination Objectives

The objectives of the ZWCATF are to develop mechanisms for cooperation and working collaboratively to implement solutions for issues on CA, provide a mechanism for the coordination as well as monitoring and evaluation of all conservation agriculture projects in the country and facilitate the exchange of information among stakeholders.

Membership

Ministry of Agriculture, NGOs, Farmers Unions, Donors, research, private sector, FAO.

Structure

The ZWCATF is currently co-chaired by the ministry of agriculture and FAO.
FAO provides secretariat services for the group, including:

Scope of Work

- The ZWCATF is harmonizing CA approaches among stakeholders
- Collecting and disseminating CA messages and material
- Coordinate, monitor and evaluate CA activities in Zimbabwe.
- The ZWCATF is advising stakeholders on interventions and practices on   conservation agriculture
- The ZWCATF is lobbying with stakeholders for the promotion of conservation agriculture.

Output

Over the last years CA has been promoted by NGOs and Government with over 250.000 farmers currently practicing CA, supported through generally accepted guidelines and standardised extension set up.

The Task Force supported the drafting of a national CA strategy and investment plan formalising CA, and encompassing approved CA coordination mechanism. This will be the basis of government and donor interventions and support, based on the CA strategy, envisaging 500.000 farmers practicing CA in 20115 on at least 250.000 ha in Zimbabwe.

The task force initiated and implemented the drafting and implementation of a CA college curricular in use at all agricultural colleges currently. Additionally the task force together with the national extension service is coordinating CA training for extension and NGO staff, as well as for private sector and farmers unions involved in CA.

The task force is currently coordinating and promoting the mechanisation of small holder CA, as a mean to increase area under CA, improve efficiency and impact of CA. This is done through extensive research and field testing in cooperation with government and agric industry.

Also, through CA coordination the role out of CA as a mean to commercialise small holder farmers has been promoting CA to various private sector partners who are working with small holder farmers, most of which have adopted CA as a mean to improve productivity and also promote CA.

Conclusion

The experience of the ZWCATF is demonstrating the impact and potential of CA coordination subscribed to by all stakeholders, it also shows the possibility of getting very divers partners to agree to and cooperate in coordination.

However, to have the desired impact of CA at national levels an even more formalized coordination with more authority is required.

Extension and determinants for adoption of direct seeding mulch-based cropping systems in smallholder agriculture, LAO PDR

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Keywords: smallholders; agricultural innovation; conservation agriculture; adoption;

Introduction

Since the 1930s and the so-called Dust Bowl that affected the American Great Plains, growing concerns have been raised regarding the long term ecological and economic impacts of tillage in agriculture. As a response to these concerns, a variety of alternatives have been developed worldwide. Practices like direct seeding for instance emerged in the 1970s among soybean and wheat farmers confronted with severe soil erosion issues in southern Brazil (Bolliger et al. 2006).

According to global assessments, some 106 million hectares of agricultural land would be cultivated with CA or (at least) no-till systems (Derpsch and Friedrich 2009). However, important questions have been raised concerning the potential and actual extent of CA in contexts of resource-poor smallholder agriculture (e.g. Erenstein 2003; Bolliger et al. 2006; Giller et al. 2009). This paper contributes to advance the debate by looking at the dissemination and adoption of conservation agriculture in Lao PDR where two research-development initiatives have supported experimentation and dissemination of direct seeding mulch-based cropping systems (DMC). It does so through a 4-year agroeconomic monitoring of 2,160 smallholder farmers and a coupled, statistical and qualitative approach to the farm-level determinants for adoption of CA. The study aims at examining diverse local socioeconomic and environmental situations (i.e. four districts and twenty-one villages studied) and providing robust empirical evidence on the dynamics of CA adoption in small holder agriculture.

Materials and Methods

This paper presents the results of a 5-year monitoring and evaluation study conducted in twenty-one villages targeted for dissemination by research and development projects. A rapid questionnaire survey was conducted annually, from 2005 to 2008, to assess several basic farm characteristics (e.g. land tenure, land uses, incomes, farm inputs) among a random sample of 2,160 households in twenty-one target villages. A more detailed questionnaire survey, including variables like education, wealth and environmental perceptions, was then conducted in 2006 and 2008 among 462 households of four villages. On-farm monitoring data collected among members of farmer groups has also been used for characterizing the agroeconomic productivity of different DMC systems and tillage-based maize monoculture (i.e. crop yields, labour inputs, incomes and production costs). In order to get more qualitative information, a series of twenty-two semi-structured interviews was conducted in four villages selected as representatives of a gradient of environmental constraint. Southern Sayaboury province spans across three main geomorphologic zones with different characteristics in terms of slopes, erosion-risks and soil productivity: from the west (Thai border) to the east (Mekong river), a steeply sloping and erosion-prone sandstone-argillite area, a productive and moderately sloping clayey-illite schist area with basic rock intrusions, and a productive and relatively steeply sloping clayey-ferruginous schist area.

Results and Discussion

In 2008, after four years of dissemination, CA had become an important constituent of the agricultural landscapes in southern Sayaboury province (more than 1000 family for a total of 1500 ha cultivated under DMC). However, significant spatial variations could be observed as regards the numbers of farms engaged in CA and the extent of CA relative to other crop management practices. Indeed, CA covered from 1 to 40% of total rainfed area in the four different district. Four observations emerge from statistical analysis: (i) farmers engage in CA independently of their workforce, wealth, age and education level, (ii) farmers that have access to important rainfed land resources are more inclined to engage in CA, (iii) farmers that engage in CA can more easily expand their cultivated surfaces, and (iv) farmers cultivating soils with limited agricultural potential are more inclined to engage in CA.

Qualitative data show that, reduced production costs and improved labour productivity are likely to represent key incentives for the adoption of alternative cropping systems – this time, regardless of the local biophysical context. DMC presents clear benefits in terms of reduced production costs (-18% in average), increased net incomes (+12% in average) and enhanced labour productivity (+23% in average). However, interview data also suggest that environmental concern and engagement in CA can hardly be considered independently from project sensitization activities. Field demonstrations and project meetings figure relatively high among the motivations of farmers to experiment CA. As described by several interviewees, project operators can play a significant role not only in promoting solutions to environmental issues experienced locally but also in providing external assessments and raising environmental awareness. However, the extent of CA in the study area cannot be exclusively attributed to the members of the projects farmer groups. As shown by disaggregated data on adoption rates and cultivated surfaces, CA had spread beyond the farmer groups for up to 20% in Kenthao District.

More generally, in line with the assessment of Knowler and Bradshaw (2008), the study indicates that the factors influencing farmers' decision-making are highly context-specific (e.g. local land degradation and production costs issues, involvement of local elites, markets for secondary crops).

Thus, the question of environmental awareness appears fundamental. Without sensitization efforts, it is likely that CA adoption in areas benefiting of productive soils will remain low until the resource base has degraded significantly. Although labour-related issues may appear unjustified in view of the agroeconomic performances of CA, an observation that emerged recurrently during interviews can provide the explanation: the absence of private operators providing technical services specific to CA. Cover crop or residue management, herbicide spraying and sowing in DMC systems require access to specific equipment and technical know-how. Thus, beyond research and farm extension, the dissemination of CA may also require a transformation of the agricultural industry itself.

Table 1. Correlation coefficient matrix (Pearson): household capital assets, age and education level of the household head and relative extent of DMC in household rainfed land (2006, n=456).

	% DMC	Capital assets	Age	Education
% DMC	1	-0,078	0,004	-0,088
Capital assets	-0,078	1	0,047	0,090
Age	0,004	0,047	1	**-0,373**
Education	-0,088	0,090	**-0,373**	1

Note: Underlined values represent significant correlations (at the 0.01 level). Household capital assets were derived from household property in transportation and agricultural equipments.

Table 2. Reasons for experimenting and not experimenting CA in Nongphakbong, Houaylod, Paktom neua and Bouamlao (frequency of answers, 2008)

Experimentation (232 respondents)		Disinterest (205 respondents)	
Reasons	Freq.	Reasons	Freq.
Curiosity	36%	Important labour charge	26%
Follows experience of neighbours	23%	Strenuous sowing	21%
Needs soil conservation issues	12%	Strenuous herbicide spraying	10%
Needs lower production costs	9%	Toxicity of the pesticides	10%
Motivated by meetings/demonstrations	5%	Lack of information	9%
Needs weed control	4%	Important production costs	5%
Needs soil fertility control	3%	Non adapted to dense fallows	4%
Confident in project experience	2%	Plots too far from road	3%
Others	6%	Others	12 %
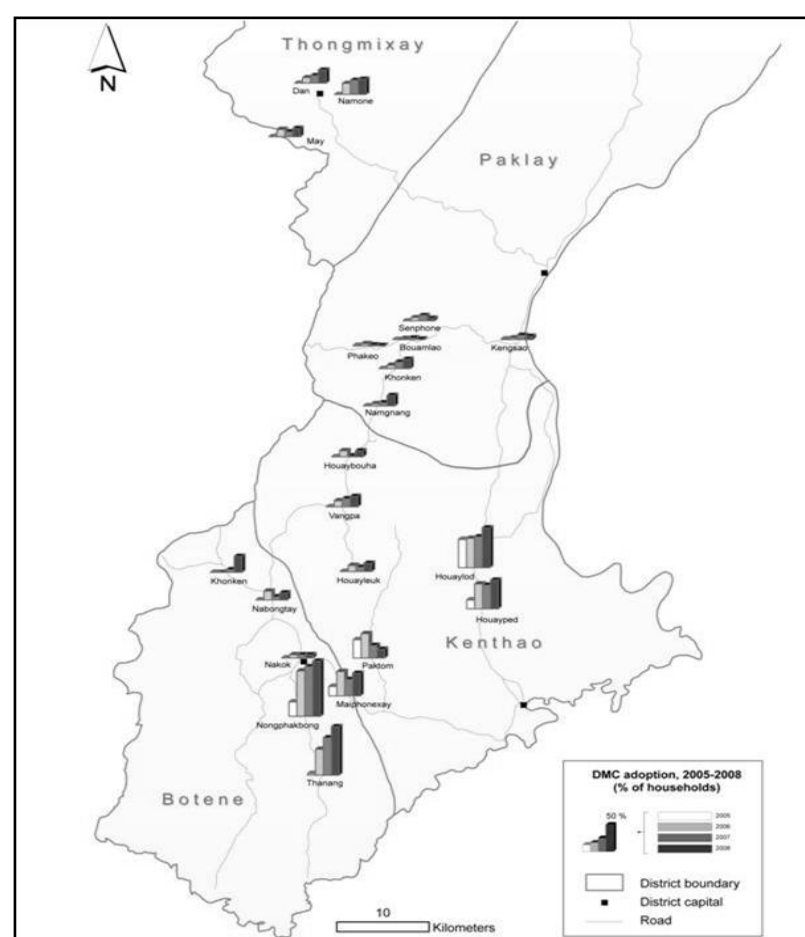
Figure 1. Adoption of DMC 2005-2008 (% of household practising)

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The role of social capital in the adoption of Conservation Agriculture: the case of *likoti* in Lesotho

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Key words: Conservation Agriculture, *likoti*, social capital, Lesotho

Introduction

Lesotho is a small mountainous country characterized by extensive land degradation and erratic climatic conditions. It has a population of 2 million people of whom 68% live below the poverty line. The country is beset with high unemployment rates, rapid spread of HIV/AIDS and low standards of food and nutrition security. This complex interaction of socio-economic factors and environmental constraints has dramatically affected agricultural productivity – maize yields have fallen from an average 1,400 kg/ha in the mid-Seventies to a current 450-500 kg/ha in most of the districts.

In spite of such adverse conditions, hundreds of subsistence farmers in Lesotho have been able to boost agricultural yields and increase food production by adopting a planting basin system locally known as *likoti*. The paper discusses the major advantages associated with the adoption of *likoti* in terms of higher agricultural productivity, greater environmental sustainability and improved livelihoods. It then enquires into the determinants of adoption with a special focus on the role of social capital and participation at community level. The special attention to social capital is motivated by two reasons. On one hand, poverty and inequality are at the same time a cause and a consequence of social breakdowns, which in turn affect people's capability to cope with shocks and vulnerability. The consequences may be especially severe for rural communities, since they traditionally depend on various forms of co-operation and sharecropping agreements to farm. On the other hand, the role of social capital is even more important when farmers shift from conventional to conservation agriculture (CA). Enhanced cooperation and collective action facilitate extension and adaptive research through participatory activities. As a means to support institutional agreements, avoid conflicts and foster community participation, social capital may also help to solve the problems related to the use of common pool resources, such as land tenure and grazing rights, which can seriously affect the adoption of CA in Africa (Calegari and Ashburner, 2005).

Materials and Methods

The analysis relies largely on a set of primary data collected in 2006 by the FAO Representation in Lesotho in order to assess the socio-economic impacts of *likoti* on small-scale farmers. Under the initiative, two sub-sample populations (117 CA and 112 conventional farmers, or a total of 229) were monitored through a household survey in selected sites of Butha Butha, Berea and Qacha's Nek districts. CA farmers were selected randomly, whereas conventional farmers were selected partly randomly and partly purposively, in order to compare soil fertility and yields in the *likoti* and the ploughed fields. To compare nutrients and organic matter contents, 123 composite soil samples were tested for soil fertility and soil texture, the results being compared through a Soil Fertility Index. In order to get a good estimation of the yields, after the harvest the output was directly measured for a sub-sample of farmers.

Each farmer was interviewed twice – before and after the harvest. The information collected through the questionnaires allowed two datasets to be organised, comprising of about 300 variables on demographic and social features, wealth, food security, social capital, agricultural production activities, knowledge and perception of CA. This vast amount of information has been analysed using descriptive statistics, frequency analysis, composite indexes and significance tests, the choice of the tools depending case by case on the nature of the data and the purpose of the analysis.

The role of social capital in the adoption and the performance of *likoti* has been investigated using an *ad hoc* methodology. First, ten social capital variables were built: four express the rate of participation in formal and informal networks such as membership in associations and groups, attendance at public gatherings and occurrence of sharecropping agreements; six variables represent the "cognitive" aspects of social capital, such as the quality of the relationships among community members, generalized trust, respect of traditional rules and so on. In order to assess possible relationships among social capital variables and between social capital and different groups of variables, such as socio-economic and the farming related variables, the empirical analysis was supported by Bayesian networks. Bayesian networks are graphical models built as directed acyclic graphs made of nodes and arcs: the nodes represent random variables, each variable assuming certain values or states; the arcs express the likelihood that two variables are (conditionally) dependent. The structure of the Bayesian networks is thus learnt inferentially from the data in order to test the (conditional) dependencies among selected variables.

Results and Discussion

Impacts on sustainable crop intensification
The analysis of the survey data has shown that the adoption of *likoti* had brought about significant advantages compared to conventional tillage practices. The most important are:
- Higher agricultural productivity, due to improved efficiency in the use of inputs and other resources;
- Greater environmental sustainability, due to improved soil structure and enhanced fertility;
- Higher social sustainability, due to the accessibility to the technology by all social categories, including the most vulnerable.

The maize yields obtained by the *likoti* farmers in selected sites in Butha-Buthe district (1.36 t/ha) were higher than those obtained in the ploughed fields (0.87 t/ha), the difference being statistically significant at the 0.1 level. In Qacha's Nek district, CA farmers got about 0.73 t/ha of maize, which is more than three times the district average yield for that growing season – 0.2 t/ha, according to WFP and FAO (2006). By comparing the value of the output with the costs of the inputs showed that farmers producing maize with *likoti* in Qacha's Nek returned a profit while those who ploughed incurred a loss. In Butha-Buthe, CA adopters' average profit was double the one obtained by farmers who employed draught power whilst it was almost four times the one obtained by farmers who used tractor power. Also the economic analysis and the assessment of returns to labour suggest that the CA practice is profitable, notwithstanding the significant workload needed especially in the first two seasons in setting up the basins. The spread of the CA practice is having significant impacts on the environment. According to the Soil Fertility Index, the overall soil quality is significantly higher in the no-tilled fields. Improved

fertility and a stronger soil structure are the primary causes of the increase in yields. At the same time, they contribute to stop and reverse the process of soil erosion and land degradation which dramatically affects Lesotho.

The adoption of *likoti* is also associated with several positive socio-economic outcomes. Most households practicing *likoti* rely on a reduced or unstable livelihood capital base. Taking into account the increased crop yields and the higher profitability, the findings suggest that CA has been effectively employed by vulnerable households as a means to cope with scarcity of resources. Moreover, according to a Food Consumption Score, after the harvest the improvement in the household diet diversity was much more significant for the *likoti* adopters (19%) than for the conventional farmers (6%), suggesting that the former rely more on their own production.

Determinants of adoption: the role of social capital and the importance of participatory training
According to the findings, so far three factors have mostly determined the adoption of *likoti*. These are: (i) the economic incentives provided to vulnerable households in the very early stages of adoption, (ii) the level of education of the head of the household (especially relevant in case of female adopters) and (iii) the degree of trust and cooperation, especially when combined with a participatory approach pursued by committed trainers.

With regard to social capital, the analysis has shown that the households who adopted *likoti* are more trustful and cooperative than those who did not, suggesting that a higher endowment with social assets has fostered the adoption of the innovative practice. The suitability of *likoti* is in fact counterbalanced by a number of cultural and institutional issues. For instance, some Basotho stigmatize the practice due to the fact that labour is provided by people instead of animals, being the ox-plough traditionally identified with a particular social status. Also, the customary rules which allow villagers to collect crop residues and herd livestock in the harvested fields prevent CA farmers from keeping an adequate mulch cover and avoiding soil compaction.

The dependency analysis conducted through the structural learning of Bayesian networks also found that the degree of knowledge on CA is strongly correlated to the attainment of training, and that the effect of training on the degree of knowledge is more effective when trainers pursue true participation and when social capital among farmers is stronger. Attending appropriate training is indeed the most important prerequisite for the correct adoption of CA, whose performance largely depends on the timely and co-ordinated management of all farming activities. However, equally important is the approach used by the trainers, since a closer interaction between farmers and trainers has helped to better assimilate and apply the CA principles. And this formula is more likely to succeed where the degree of trust and cooperation among farmers, i.e. social capital, is higher. A more participatory approach to the spread of the practice would also help farmers – both CA and conventional – to better address other issues, for instance, the need to look for alternative fodder and fuel sources in order to limit the access by herders and other villagers into CA fields.

Stronger policy and institutional support to all the aspects mentioned above would thus help address the cultural and the resource constraints that may limit the full potential of *likoti* to be harnessed and ultimately hinder its further spread throughout the country.

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Inclusive research for agricultural development: farmers' participation and innovation

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Key Words: conservation agriculture, resource conservation t echnologies, agricultural system network, business model

Introduction

Dissemination or extension of technologies among the farmers is a complex issue. More often than not the scientists, having developed and tested the technologies, are not able to transfer these t o the farmers widely. W hy the farmer is not ready to adopt the new technology is an issue that haunts planners and scientists alike. Farmers today need a variety of information about protection, inputs & services (Van den Ban, 1998). Factors such as the size of landholding (Adhiguru et al. , 2009), production system of the farmers and availability of inputs and services affect the information needs of the farmers (Rivera, 1996; Farrington et al., 1997; Planning Commission, 2006). Agricultural extension must be seen as a wider concept, including agricultural and marketing skills, organizing farmers and other stakeholders, developing social capital, sustainable natural resource management and food and livelihood security (Swanson, 2008).

Method: Inclusive Research and Development

The business model of the Cereal Systems Initiative for South Asia (CSISA), funded by the Bill & Melinda Gates Foundation and USAID, uses t he agricultural innovation systems approach by creating a network of stakeholders and facilitating their interaction (Figure 1). The World Bank (2007) and Clarke et al. (2007) define an i nnovation system as a network of organizations and agents whose interactions, together with the institutions and policies, determine the impact of their interventions. The project is operating as an 'innovation broker' or 'innovation intermediary' as defined by Klerkx (2008) and Klerkx et al., (2009) by linking vari ous actors and moving beyond the traditional agricultural extension model (Figure 2). T hi s paper analyses the business model for research and extension for agricultural development in four Hubs viz., Punjab, Haryana, Eastern Uttar Pradesh and Central Bi har of (CSISA) project.
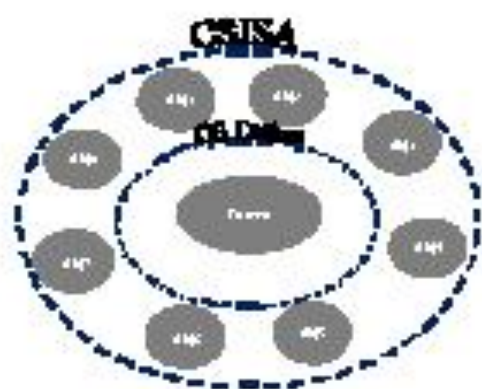
Figure 1. Farmers at the Center-stage of CSISA Project

Figure 2. Generic Business Model for CSISA

Figure 3. Two Wheel Tractor Based Laser Land Leveler

Results and Discussion: Enhanced Participation and Innovation

The networks encourage introduction and adoption of improved technologies from research, ensure input and service support through private players and encourage innovation and finetuning by farmers on their field by creating new communication pathways and strengthening existing ones.

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Training programme to overcome barriers and to intensify the adoption of Conservation Agriculture in the Eastern Cape Province, South Africa

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Keywords: Practical Conservation Agriculture, long-term training, experiential learning, extension

Introduction

In 2002, the then Eastern Cape Department Agriculture and Rural Development (ECDARD)[10], South Africa, embarked on a farmer support programme aimed at stimulating the production of food grains in the high potential areas of the Province; part of the programme was the introduction of Conservation Agriculture (CA) as one of its conditions. However, CA was not introduced during the first 5 years of the programme due to the lack of knowledge of CA and about its principles. Following this, the ECDARD made the decision to undertake training to equip ECDARD extension officers with the necessary knowledge and skills in order to introduce on-farm CA demonstrations, to manage the CA production process, and to identify and prevent possible problems that might occur during the implementation of CA.

Methods

In 2007, ECDARD entered into a partnership with the University of Fort Hare (UFH) and established the Conservation Agriculture Thrust (CAT), tasked with *inter alia* stimulating establishment of economically successful and environmentally sustainable crop/livestock production systems among communal smallholders. CAT's primary work is the training of extension officers.

The main areas on which the training programme focuses are (i) CA principles and practices; (ii) basic agricultural arithmetic calculations (calibration of equipment; determination of estimated and actual crop yields; etc.); (iii) soil fertility and plant nutrition; (iv) weed and pest control (manual, mechanical and chemical, including Integrated Pest Management); (iv) utilization and maintenance of CA machinery (hand tools, animal traction and mechanical); (v) utilization of and safety in the use of agro-chemicals; (vi) post harvest seed selection and storage; (vi) green manure cover crops (GMCC) and crop rotations; and (vii) introduction to value adding.

The course is divided into three phases. Phase 1: A **3-week**[11] **basic training** of extension officers using a mixture of theory and practice. This includes an exposure tour to successful CA projects in the region (KwaZulu-Natal Province in South Africa, Swaziland, Lesotho), as well as a basic CA starter kit that includes equipment, documentation and inputs. Phase 2: **Season-long, on-the-job training** of extension officers in selected, on-farm CA demonstrations. Phase 3: A **Cross Visit Tour** towards the end of the growing season whereby all trainees visit one CA demonstration from each of the learners. The duration of the training is approximately one year, with follow-up during the **next 2-3 years**.

During the training period, the on-CA-field-performance of each trainee is recorded through a yearly monitoring system, which was adopted and adapted from the very successful Paraguayan CA project *Proyecto de Manejo Sostenible de Recursos Naturales* (PMRN). The results of each monitoring report are analysed and feedback is provided to the trainees and their respective farmers. Furthermore, the monitoring results, i.e. the on-CA-field-performance, serve as an indicator of the quality of the training and help to continuously improve the CA training programme.

Results and Discussion

The following key outcomes during the training process are relevant: a) **Experiential learning is key to CA adoption**; (b) 38 (of 40) extension officers completed field demonstrations successfully in the first year; and c) No-till practices were the more widely adopted entry points to CA during the first year, followed by soil cover and the utilization of GMCCs in the second year**.**

Nevertheless, these are only 'technical' CA issues that influence the adoption of CA. During the yearly monitoring, other key issues could be identified that have a negative impact on extension officer's performance, e.g.:

1. Basic agronomic skills are not sufficient,
2. Socio-economic conditions in South Africa, i.e. hand-out mentality deriving from state grants,
3. Loss of indigenous knowledge, and
4. Ageing of the agricultural active population.

Some issues are now being tackled through closer cooperation with other ECDARD training initiatives. Likewise, the identification of motivated farmers that are not biased by the hand-out mentality seems to be understood as a prerequisite for successful CA implementation. However, it is clear that some of the constraints to CA adoption have to be appreciated as they are out of influence or control of projects.

Finally, the following key aspects are recommended for overcoming barriers and for intensifying the adoption and adaptation of CA:

- Formal accreditation of CA training;
- Implementation and **long-term practical learning** with innovator farmers **together** with trainees;
- CA training should be a broad strategic objective for the extension service in the Province;
- Awareness and training for extension supervisors and managers; and
- A cluster approach to training, which would, for instance, bring together 4 trainees from 5 areas each instead of one trainee each from 20 areas.

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[10] Today, Eastern Cape Department of Rural Development and Agrarian Reform (ECRDAR)
[11] Equalling 15 days or 120 hours.

The Conservation Agriculture Network for South East Asia (CANSEA) an initiative to Develop dnd disseminate CA in South East Asia

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Keywords: Conservation Agriculture, Network, South East Asia

Introduction

Different contexts explain the development and the dissemination of conservation agriculture in South-East Asia and consequently the emergence of a sub-regional network for the development and the coordination of Conservation Agriculture activities.

Under the influence of rapid changes related to population growth, conditions of market integration, private or national initiatives (corn, rubber crop, jatropha, etc.), some agrarian systems of Southeast Asia are undergoing a true mutation. Although this change allows immediate socio-economic benefits, it has medium-term negative environmental impacts with long-term repercussions on natural resources, conditions of production and people's health. The simultaneous processes of deforestation, new lands extension (slash and burn) and agricultural intensification have led to critical soil erosion and gradual soil exhaustion. Yields have been continuously decreasing. Conservation Agriculture brings a global answer to these fertility problems, and makes it possible to gradually restore the soil production potential. No tillage, direct seeding into cover crops and permanent cover crops that play the role of fallow, allow a return to the physical and chemical fertility of these soils. The introduction of fodder crops into farming rotations allows, in addition to improvement of soil nitrogen, a better integration agriculture-livestock.

In view of these issues, several Research for Development (R4D) projects in the sub-region have developed and disseminated systems of Conservation Agriculture based on direct seeding mulch-based crop systems (DMC-SCV) which contribute to ecological intensification and a sustainable diversification. These projects have produced a significant set of results and data on CA farming systems in Southeast Asia. The Conservation Agriculture Network for South-East Asia (CANSEA) was created in September 2009 to address various regional problems of research and development, which cannot be solved at the national level. CANSEA is a structured regional organisation aimed at implementing projects of regional interest with regional comparable research designs, harmonized environmental and economic assessment methods and comparable impact indicators.

Organization of the CANSEA Network

This regional network of research for development is made up of 8 institutional partners from 6 Southeast Asian countries.
The 8 founding members of the network are:
- Cambodia: the Ministry of agriculture, forestry and fisheries (MAFF);
- China: the Yunnan Academy of Agricultural Sciences (YAAS);
- Indonesia: the Indonesian Agency for Agriculture Research and Development (IAARD);
- Laos: the National Agriculture and Forestry Research Institute (NAFRI);
- Thailand: the University of Kasetsart;
- Vietnam: the Northern Mountainous Agriculture and Forestry Science Institute (*NOMAFSI*) and the Soils and Fertilizers Research Institute (SFRI);
- Le Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), which cooperates with all the partners of South East Asia.

According to comparative advantage, each network member is leading a theme of action having both national importance and regional interest (see table 1). The network is managed by a Steering Committee and a Regional coordination unit.

CANSEA Objective and Activities

The overall objective of the CANSEA network is to optimize the similarities and the complementarities among countries and institutions in the Mekong region to: i) improve the efficiency of research carried out by the various programmes; ii) go beyond the "pilot" diffusion of CA systems in Southeast Asia; and iii) optimize resources and means.

As a newly structured organisation the CANSEA's Regional Coordination (CR) gives priority to: i) generic set of actions; and ii) preparing regional specific R-D projects on common thematic of regional interest.

The generic actions are those conventional activities aimed at: i) facilitating exchanges of results and experiences between members; ii) proposing mechanisms of cooperation; and iii) developing common regional projects. The network plays the role of catalyst. This is all the more important in South East Asia since national institutions of R4D have historically had very few exchanges between them and had not really developed strong cooperation. CANSEA is contributing to improving the situation.

The generic types of action include:
- **Supporting exchange between partners** to define, prepare and jointly submit R4D projects. These are meant to seek new funding for new regionally-based projects consolidating previous national achievements.
- **Updating the database on Conservation Agriculture** linked to the CANSEA web site www.cansea.org.la for dissemination of results. Generic activities of the network will initiate exchanges to prepare projects on issues of regional interest.

The projects of regional interest are the following:
- Regional Component 1: *To develop CA systems at watershed scale (uplands and lowlands) to improve agricultural production and control soils and environment degradation.*
The objective is to develop farming systems that are more productive in the uplands while preserving natural resources and the environment. Slash and Burn systems based on two years rice cropping following by fallow period can be replaced by a CA based on no tillage, direct seeding, cover plants and crops rotation. In uplands leguminous cover crops contribute to restoring soil fertility and animal

production. In low lands direct seeding and integration of rice within a crop rotation which includes leguminous cover crops make it possible to reduce production costs, control weeding, improve water balance, improve soil fertility and provide fodder biomass to intensify livestock production.

- Regional Component 2: *CA development for diversification of rice-based cropping system in uplands areas*.

In the mountainous area rainfed rice is the staple food. Traditional practices are no longer compatible with the demographic pressure and the reduction in land availability. Without interim protective measures, erosion becomes important and the soils on steep slopes quickly become unproductive. In these upland areas CA techniques allow a return to a physical and chemical fertility as well as a better integration agriculture-livestock.

- Regional Component 3: *Restoration of the fertility of degraded acidic soils with aluminum toxicity*.

Acidic soils are abundant in South-East Asia. There are Acrisols (albic, alumic or plinthic) issued from very diverse origins (Sandstone, Claystone and even on fluviogenic soils). They all have a very low pH (4 to 5), with strong deficiencies in nutrients and often an aluminum toxicity. When they come from sandstone, these soils are sandy, very poor, with low water holding capacity, which accentuates the risks of drought. Their weak exchange capacity largely saturated by aluminium exacerbates the risk of aluminum toxicity.

The objective is to restore the fertility of these soils transforming them back to an economically-attractive production level. The NAFRI-CIRAD experience showed that within a few years conservation agriculture techniques (no soil tillage, permanent coverage of the soil and rotation with leguminous plant with strong biomass) can gradually restore the fertility of these soils and make them economically productive.

- Regional Component 4. *To understand the determining factors of the CA adoption and to identify the socio-economic conditions for its diffusion*.

For multiple reasons (cultural, historical, economic, technical) the adoption of CA technologies is slow, especially when these new methods target subsistence farmers without investment capacity. It is important to understand at farmers' level what the determining factors of this adoption are. At environmental level, it is also important to identify the conditions of diffusion of these new CA technologies.

- Regional Component 5. *To Support the development of various curricula on CA.*

The overall objective is to contribute to building a regional programme based on a network approach developing synergies and coordinating among Faculties and Colleges of Agriculture within the region. This component is based on:

- o A tailored agroecology teaching programme for each Faculty or College according to local requirements, objectives and means.
- o Focused faculty programmes on concept and theory and fundamental themes (carbon flows and carbon sequestration, organic matter dynamics in soils, soil biology research and studies) and focused college programmes on practical aspects of Conservation Agriculture and Direct Seeding on plant cover (SCV).
- o A specific short term training course in Agroecology and Conservation Agriculture targeted to researchers, teachers and technicians

Table 1. Network Members andselected thematic areas according to both their comparative advantage to lead the theme and the regional interest of the theme for other countries

Founding Institutions	Thematic areas selected by institution according to their comparative advantage to lead the theme and the regional interest of the selected theme for the other countries.
Cambodia GDA-PADAC	Methodological approach to link Research and Extension.
China YAAS	CA development for diversification of rice-based cropping system in uplands areas
Indonesia IAARD	CA development in watershed area (uplands and lowlands) to improve agricultural production and control soil and environment degradation
Laos NAFRI	CA to restore fertility of degraded soils and more specifically of acidic soils
Thailand KU	Curriculum development (Masters) on CA integrating (amongst others) C sequestration and soil Biology
Vietnam NOMAFSI SFRI	Soil conservation and CA-DMC systems in Uplands zones

Key lessons learned from the experience of the CANSEA network

These key lessons are the following:

- The difficulty to mobilize grassroots partners, stakeholders and to make emerging relevant and useful information and results from this basic level with ongoing CA programmes and projects.

- The difficulty to develop and use relevant Participatory Information and Communication Technologies for Development (PICT4D) tools which allow network members to share their information and experiences.

- The necessity to have a lean structure to avoid heavy structural and transaction costs. Multiplying management committees is very costly in terms of meetings (travels, per diem…).

- In defining and implementing regional programmes (transnational) objectives and activities of these programmes are collectively defined. Institutions do together what can't be done alone. Some national institutions are reluctant to be involved in regional programmes since they consider they not have the full control over them.

Conservation Agriculture (CA) in Tanzania: the case of Mwangaza B CA Farmer Field School (FFS), Rhotia Village, Karatu District, Arusha, Tanzania

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Introduction

Agriculture plays an important role in the economy of Tanzania; it accounts for 60% of the export earnings and employs 84% of the rural population. Crucial components of the agricultural sector are food crops, at 55% of the total agricultural GDP, livestock at 30%, and traditional export crops at 8% (URT, 2004a). In Karatu district, crop and livestock production are by far the most important economic sectors employing over 90% of the labour force (Douwe and Kessler, 1997).

However, it is a common practice for farmers in Tanzania to graze or remove all crop residues from their fields after harvest. This practice leaves the soil bare and susceptible to water and wind erosion. The top fertile soil is eroded over time leaving unfertile and degraded soil for crop production. This coupled with low use of organic or inorganic fertilizer results in declining yields, leaving families with less food and money (GTZ Sustainet, 2006).

In view of the above problems, in 2004 CA SARD (Conservation Agriculture - Sustainable Agriculture and Rural Development) project intervened in the Rhotia village, and farmers were taught about Conservation Agriculture as a sustainable way of growing crops and managing soil health that conserves the soil and maintains or enhances soil fertility and productive capacity (Kassam et al. 2009). CA comprises three principles applied simultaneously, namely: minimum mechanical soil disturbance, permanent soil organic matter cover, and rotation/crop association (www.fao.org/ag/ca).

Karatu district is one of the five districts in the Arusha Region, located in the northern part of Tanzania (Figure 1) with 102,573 ha of arable land. The district has four administrative divisions, 13 wards and 45 registered villages, Rhotia being one of them. The administrative headquarters is in Karatu town, approximately 150 km west of Arusha town.

Methodology

The 1st phase (2004-2006) of the project covered three districts -- Arumeru, Karatu and Bukoba. The dissemination approach was based on Farmer Field Schools (FFS). In the 2nd phase (2007-2010), the project continued with up-scaling of CA as a Sustainable Land Management tool with CA-FFS groups. During the 2nd phase, the project extended to Babati, Hanang, Moshi districts and Meru council in Arumeru district.

When the project started it provided training on CA concepts and FFS methodology to extension workers who became facilitators of the FFSs. Training was also provided to farmers on how to apply CA practices which included the use and maintenance of CA implements, running FFS groups etc. The FFS groups were assisted with the start up CA equipment which included sub-soilers, rippers, jab planters, Direct Animal Planter (DAP), zam-wipes etc. The FFS groups also received 10 kg of maize seed, 8 kg of *Dolichoas lablab* seed, 1 litre bottle of glyphosate herbicide, and stationery (note books, pens, pencils, erasers, flip charts and marker pens). To facilitate the promotion process the project enhanced the supply and availability of CA equipment to FFS, by stimulating private sector participation in the manufacturing, retailing and hiring of appropriate equipment including jab planters, rippers, sub-soilers, DAP and zam wipes.

Each group tested various CA options depending on their priority problems. Mwangaza FFS tested five practices, namely:
1. Ripped plot, planted with maize intercropped with lablab (Maize 3.75 t/ha; Lablab 1.63t/ha)
2. Ripped plot, planted with maize intercropped with pigeon pea (Maize 3.38 t/ha; Pigeonpea 0.75t/ha)
3. Non ripping plot, planted with maize intercropped with lablab(Maize 3.5 t/ha; Lablab 1.0t/ha)
4. Non ripping plot, planted with maize intercropped with pigeon pea (Maize 2.0 t/ha; Pigeonpea 0.75t/ha)
5. Farmer's normal practice; ploughing twice, then planting maize intercropped with pigeon pea, beans and pumpkins (Maize 1.88t/ha; Beans 0.50t/ha; Pigeonpea 0.63 t/ha)

Each plot was 0.2 ha in size. Figures in bracket above are yields of maize and cover crops in t/ha.

Results and Discussion

31 FFS groups comprised 765 farmers. Together with some spontaneous FFS founded by farmers themselves the total number reached 44 FFS at the end of the 1st phase. During the 2nd phase, 85 new FFS were established, making a total of 129 FFS. By 2009, the project reached more than 3,600 farmers (CA SARD, 2009).

For the case of Mwangaza FFS, the most preferred option was: ripped plot direct seeded with maize and intercropped with *Dolichos lablab*. It gave the highest maize yield, conserved moisture, and controlled soil erosion. The 2nd most preferred option was: ripped plot planted with maize intercropped with pigeonpea which also gave high maize yield, controlled erosion, high litters from dropping leaves, improved soil fertility. The 3rd most preferred option was: non-ripped plot, planted with maize intercropped with *Dolichos*. The farmer practice was the least preferred option due to its low yields, high cost and time of managing the crop.

Control of insects in *Dolichos* and pigeonpea is done through the use of mixture of different herbs prepared by farmers themselves. Due to good management of soil, currently farmers of Mwangaza B are no longer using inorganic fertilizers. This has been replaced by the use of *Dolichos* and/ or pigeon pea which fixes significant amount of nitrogen (200 kg N per ha). Weeds were well managed by ensuring that the soil is continuously covered by crop residues and/or cover crops as well as slashing and /or hand pulling of the weeds; no herbicide is used. *Dolichos* as a cover crop softened the soil and changed it into darkish colour due to increase in soil organic matter. Good water infiltration, increase in earthworm population, reduction in evaporation and soil fertility improvement were observed. Farmers also reported that pigeonpea successfully breaks soil hard pans. Farmers sold *Dolichos* or pigeon pea at 1,100 Tsh per kg (approx 1 USD). Table 1 and Figure 2 indicate that maize yields under CA increased from 2.05 t/ha in 2004 and 7.22t/ha in 2006 to 14.0 t/ha in 2009. Farmers experienced

reduction in labour and time requirement in farm operations after one season of CA. This was brought about by reducing number of operations during land preparation (using rippers), planting (using direct planters), weeding (using cover crop + roughing) etc. Table 2: shows reduction of labour and time for farm operations in Mwangaza B Marera sub-village.

CA technologies have been adopted on 7,000 acre (2,857 ha) in the northern zone of which 600 acres are within and outside Rhotia village in Karatu district. The adopted practices include pigeonpea, 90% of adopters, *Dolichos* 30%, ripping 30%, crop rotation 60% (CA SARD, 2009).

Mwangaza B FFS- Marera Sub village in Rhotia village Karatu district, Arusha
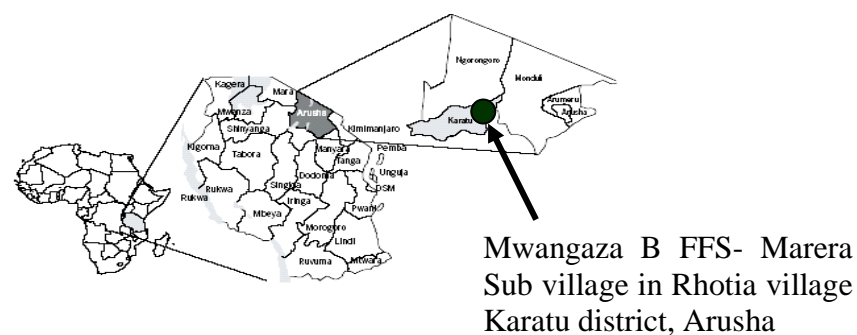
Figure 1: Map of Africa showing Tanzania and Karatu district
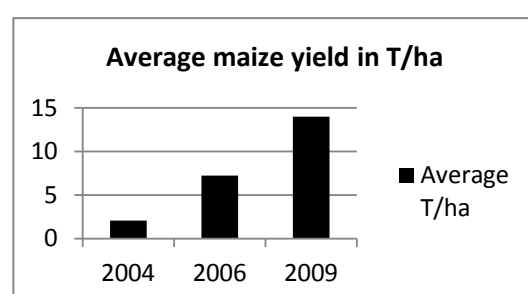
Figure 2: Yield trends

Table 1: Maize yield trend of Mwangaza B adopted

Year	Average T/ha	Comments
2004	2.05	CA adopted
2006	7.22	
2009	14.0	

Table 2: Labour and time reduction under CA in Mwangaza B Marera sub-village

Operation/acre	Conventional tillage		Conservation Agriculture	
	Time	Labour	Time	Labour
Land preparation	8 hours	4 persons	3 hours	2 persons
Seeding using DAP	7 hours	6 persons	2 hours	2 persons
Weeding	2 days @ 9 hrs	4 persons	1 day @ 8 hrs	2 persons

Conclusion and Recommendation

Conservation Agriculture as practised by Mwangaza B FFS and other farmers in Tanzania indicates positive elements that can help reduce the problems of drought, low soil fertility, poor yields and labour, resulting into higher yields, income and improved livelihood. Partners are encouraged to join hands with CA SARD project to promote CA. This would make a major contribution towards combating climate change, and fighting hunger and poverty, hence reaching the Millennium Goal of halving hunger by 2015.

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Developing and adapting mechanized conservation agriculture machinery for smallholder systems of southern Africa

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Key words: conservation agriculture, direct seeders, ripper tines, equipment development

Introduction

Animal traction conservation agriculture (CA), has benefits to smallholder farmers in overcoming chronic labor shortages associated with other minimum tillage practices. In southern Africa CA has generally been promoted based on a hoe basin type, and development agencies have targeted vulnerable communities to use this technology. These vulnerable farmers are poor, face severe labor constraints, and are sometimes victims of the HIV/AIDS pandemic. With the introduction of animal traction mechanized CA, farmers are able to finalize planting earlier, and can even free the equipment for service hire to neighbors. Mechanized CA equipment such as a direct seeder drawn by trained oxen can enable a farmer to plant 2-3 ha per day compared to 1-1.5 ha per day for conventional animal draft tillage practice. This minimum tillage equipment can reduce the delays in planting and also benefit neighbors who can hire this equipment and be able to plant within the first planting window, commonly associated with better yield gains. Smallholder farmers can also form groups to mobilize resources for equipment purchase to overcome the equipment cost problem.

Local production of CA equipment for the smallholder agricultural sector has been almost non-existent prior to 2010. Only some ripper tine attachments for mouldboard plows were locally produced by few equipment manufacturers. There have been some attempts to promote imported equipment such as direct seeders and jab planters from Brazil, but the prices have been prohibitive, and the equipment did not come with back-up spares. Grownet Investments is a Zimbabwean small-scale agricultural equipment manufacturer, which has had previous interests in producing appropriate technologies for emerging smallholder farmers, and related post-harvest equipment. Since 2009, Grownet has established collaborative initiatives with research institutes, non-governmental organizations and the national agricultural extension services in efforts to design and manufacture direct seeders and jab planters for CA purposes. The first direct seeder prototype produced by Grownet was tested during the 2010/11 cropping season and has undergone modifications based on observations from all stakeholders involved. The governments' Institute for Agricultural Engineering was tasked to evaluate the prototype development, and this has significantly helped the company in the modification of equipment to make it more appropriate to the farmers of southern Africa. Some direct seeders have since been taken to Zambia for further testing. The outcome is a new design seeder with inclined plate seed metering, which is more appropriate to local farmers needs than imported machines.

Approaches to mechanized CA development

The role of Grownet Investments has been to develop, modify and evaluate animal traction CA machinery in conjunction with research institutes and agricultural extension services. This project focused on the promotion of CA systems for farmers using animal traction, together with the development and dissemination of functional and adapted CA machinery for smallholder farmers in southern Africa. Key components of the project included participatory on-farm development and testing of animal traction CA systems with more innovative farmers; support to machinery development through direct interaction with machinery manufacturers; private sector involvement and support to local equipment suppliers including marketing, and provision of credit for equipment purchases. This project by Grownet Investments enabled partners to understand and use mechanized CA systems, improve the equipment itself and facilitate its promotion to encourage widespread future adoption in this region.

Achievements in mechanized CA equipment development

One of the project objectives has been to develop a fully functional locally manufactured direct seeder and Grownet Investments has made great progress in achieving this objective. In 2010 Grownet made the first prototype of an animal drawn direct seeder. This had cracked a horizontal plate seed meter which could be used for planting maize, soyabean, sunflower and cowpea. During the 2010/11 seeding time season weaknesses of this first prototype were recorded and passed on to Grownet, which was the basis for development of a second direct seeder prototype with an inclined plate meter, called the Jambo Direct Seeder (Figure 1). Preliminary testing of the second prototype has begun at CIMMYT, Institute of Agricultural Engineering and in Zambia. Farmers can now seed groundnuts and other crops using the direct seeder with an inclined seed plate, which was not possible with the imported Brazilian direct seeder.

Challenges in improving small scale mechanized equipment

The national extension services in Zimbabwe (AGRITEX) and nongovernmental organization (NGO) partners faced multiple challenges will when establishing demonstrations with the first prototype of the direct seeder. Operational problems highlighted by farmers and partner organisations included seed crushing by the seed plate, the seed failing to drop, and failure of gears made of self lubricating plastic under this work load. GROWNET has addressed all these weaknesses and incorporated improvements into the second seeder prototype. Some ripper tines could not be fitted to the locally available plough beams and adjustments have since been made to hole sizes on these attachments. Farmers have also complained about seeding with the ripper on sandy soils, which sometimes caused collapse of the rip-line before any seed could be dropped. Wings for the ripper attachment have been tested to use in such soils

Lessons Learnt

Appropriate mechanized CA equipment is still not widely available in local markets, so an extensive participatory process is required to test mechanized CA technologies and demonstrate the improved performance compared with conventional tillage practice. More than one season of on-farm testing is also needed to perfect this equipment. Farmers purchasing mechanized CA equipment need extensive training on calibration, operation and maintenance of the new implements, and the CA system.

Recent projects that are supporting the development and promotion of mechanized CA will assist in creating a demand for this equipment, which in turn will help manufacturers continue to produce the equipment. Farmer demand should take over after some time, and make the project sustainable. Equipment manufacturers also need pre-financing to allow an initial investment in the production of mechanized CA equipment, and support production of sufficient quantities to meet the growing demand. Equipment development funds that were accessed

from research organisations, particularly CIMMYT, was essential for the development of the two direct seeder prototypes by Grownet. There is an ongoing need for additional innovation funding to improve the equipment and promote the technology across the region.

Figure 1: Jambo Direct Seeder, extensively tested in Zimbabwe and Zambia

Way forward

Grownet Investments continues to have interests in supporting the development of mechanized CA equipment prototypes (direct seeders, ripper tines and jab planters) based on recommendations from end users – the farmers. Grownet will continue testing direct seeders with inclined seed plate for planting groundnuts and other crops. In order to establish sustainable systems for future equipment purchase, and actively participate in initiatives that facilitate linkages between farmers, agro-dealers and equipment manufacturers. As part of the equipment development and promotion process Grownet Investments will also support implementation of socio-economic surveys on challenges and farmer acceptance of new mechanized CA equipment.

Conservation Agriculture practices and challenges in Zimbabwe

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Keywords: conservation agriculture, planting basins, rotation, adoption, labour

Introduction

An increasing number of non-governmental organizations (NGOs) through funding from multiple donors are promoting conservation agriculture (CA) in the smallholder areas of Zimbabwe. CA has been seen as technology option that can increase yields of a wide range of crops by resource-poor farmers even in drier agro-ecological regions. Farmers across Zimbabwe have shown a growing interest in the CA technology with evidence of yield gains of between 10 and more than 100% depending on input levels and the experience of the farm household (Mazvimavi et al., 2008). Cases of spontaneous adoption are being observed in areas where demonstrations and training programs have been well supported by NGOs, research and extension institutes. However there have been arguments that CA adoption in sub Saharan Africa (SSA) is low due to the socio economic conditions in which CA is implemented (Giller et al.,2009) and that CA can only improve food security in SSA if farmers have access to herbicides and fertilizers (Gowing and Palmer, 2008).

This study was aimed at assessing the adoption trends of CA principles and practices in smallholder areas of Zimbabwe. The study also assessed the socioeconomic impacts of CA technologies to vulnerable farm households.

Methodology

The study is based on a panel survey approach that started in 2006/07 cropping season and repeated in 2007/08 and 2008/09. The study was implemented in 15 districts of Zimbabwe where different NGOs under the Department for International Development's (DFID's) Protracted Relief Programme (PRP), European Union (EU), and European Commission Humanitarian Aid Office (ECHO) funding have been promoting CA over the past five years. The panel study targeted 30 households per district with CA experience of at least 2 years. The majority of the sampled farmers were vulnerable households typically targeted by NGO relief programs. The questionnaire interviews collected information on CA practices, adoption, and associated gains and constraints.

Results and Discussion

Over the years, there has been generally a reduction in the proportion of farmers practicing CA components (Table 1). Marked decreases were with application of inorganic fertilizers which decreased from 71% for basal fertilizer and 94% of farmers for top dressing fertilizers in the 2004/05 cropping to 38% and 70% respectively in 2004/05. Basin digging has also dropped with 89% of farmers practicing it in 2008/09 from 100% in 2004/05. The digging of planting basins is done using hand hoes and may require more labor in clay soils. As an option to improve labor demand associated with digging basins, there is need for adopting mechanized CA technologies. For resource endowed farmers, the use of rippers and direct seeding equipment could be good options particularly if the linkages to both input and output markets are secured for improved profitability.

Table 1. Proportion (%) of farmers using the particular components of CA techniques

Technique	Cropping season				
	2004/05[a]	2005/06[a]	2006/07	2007/08	2008/09
Winter weeding	51	87	76	71	63
Application of mulch	40	75	69	70	56
Digging of basins	100	99	99	97	89
Application of manure	89	88	89	87	80
Application of basal fertilizer	71	75	74	66	38
Application of top dressing	94	92	92	88	70
Post-planting timely weeding	94	98	99	96	85
Crop rotation	8	13	13	18	19

[a] Data for 2004/2005 and 2005/2006 seasons was obtained during the 2006/2007 survey

Farmers practising CA are expected to keep their plots weed free throughout the season. Weeding should commence as soon as weeds appear. This activity however increases labor requirements for CA plots as they require an average of 2−3 times weeding per season compared to once for conventional draft tillage plots. Because of other off-season household commitments farmers find it difficult to practice winter weeding. The trend over the years shows a decline in the proportion of farmers doing winter weeding and this could mean farmers are adopting only CA components that fit into their current farming practices. Forty-four percent of the interviewed farmers did not mulch their plots during the 2008/09 cropping season, although this number dropped from 60% in 2004/05 cropping season. These farmers indicated they had fed crop residues to livestock. Competing uses for crop residues for dry season feeding and roofing in some parts of Zimbabwe are the most important factors that affected adoption of this practice. Another constraint to the practice of mulching is low production of biomass in smallholder farms which limits farmers' ability to meet the minimum recommended mulch cover of 30% in CA (Giller et al., 2009). However, various other materials can also be used as mulch including leaf litter and grass. There were also some farmers who tried mulching, but discontinued since they could not really notice any immediate benefits and some had no knowledge about the benefits of mulching. Crop rotation (cereal –legume) is the CA principle, but it is only practiced by 19% farmers in 2008/09 cropping season. Although this number increased over the years from 8% in 2004/05 cropping season, crop rotation has hardly been adopted by farmers across the 15 districts of Zimbabwe. The reasons for not practicing rotation varied with many farmers (45.1%) preferring to continue growing the staple food on their CA plot, an indication of food insecurity. Fifteen percent stated the unavailability of legume seed as the reason for not practicing rotation with legumes.

CA promotion has commonly been associated with free input packages where farmers were given seed and fertilizer for their plots. These input handouts were usually just enough for small CA plots. There was evidence to show that access to inputs influenced the area allocated to CA. Farmers tended to expand the area under CA on the basis of support from NGOs in the form of inputs (Figure 1). Increasing CA plot size results in an increase in labor requirements for weeding and digging planting basins since these activities are labor intensive (Baudeon et al., 2007). Labor saving technologies such as introducing other CA implements other than the hand hoe and encouraging use of herbicides should be promoted to ensure CA is implemented at a large scale.
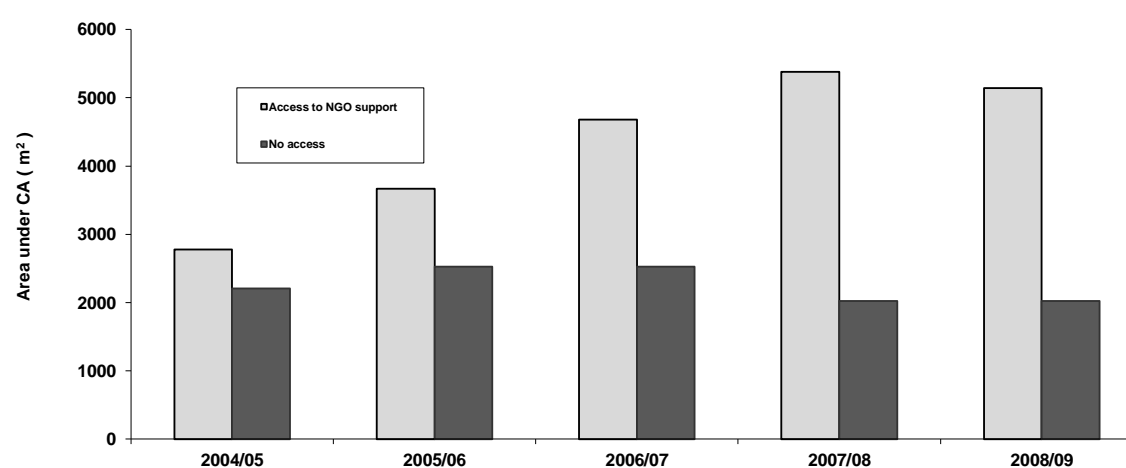
Figure 12. Influence of NGO support on CA plot area

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Factors affecting adoption of conservation agriculture in Malawi: a case study of Salima District

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Keywords: Farmer participation, CA practice

Introduction

Agriculture is the single most important sector of Malawi's economy as it employs about 80% of the workforce, and contributes over 80% of foreign exchange earnings. Most of all, it also contributes significantly to national and household food security. However, agriculture in Malawi is characterised by low and stagnant yields (IMF, 2007) and production of crops relies heavily on rainfall. The agriculture sector is facing a number of environmental challenges, which include soil erosion, low soil organic matter (SOM), nutrient deficiency and water shortage caused by drought (Munthali et al 2008). To counteract these problems different technologies are being promoted among which is Conservation Agriculture (CA). CA is defined as a system of crop production based on the three principles of minimum soil disturbance, continuous soil cover and crop rotation. The objectives of conservation farming are to increase crop production, while at the same time protecting and enhancing land resources on which production depends. It integrates ecological principles with modern agricultural technologies (FAO, 2008). Despite the efforts being employed and benefits that CA has over conventional land management practices the adoption still remains low. This study therefore was carried out to determine factors affecting/restricting adoption of conservation agriculture and also to identify challenges farmers are facing in the application of conservation agriculture and draw recommendations that may help in the upscaling of the technology.

Materials and Methods

The study was carried out in Salima District within the Salima Agriculture Development Division The district is located in Central Region of Malawi and it lies along the lakeshore plain 100km to the east of Lilongwe City. The district was chosen because it is one of the areas where CA is being intensified owing to its semi-arid conditions and accessibility. For agriculture purposes the district is divided into 7 *Extension Planning Areas (EPAs)* namely Chipoka, Katerera, Makande, Tembwe, Chinguluwe, Matenje and Chiluwa. The study was conducted in Katerera, Makande and Chinguluwe EPAs and it used both primary and secondary data. Primary data were collected from a sample of selected farmers through administration of a semi-structured questionnaire. The questionnaire comprised closed- and open-ended questions. An open-ended questionnaire was also used to support interviews with as many of the Agricultural Extension Development Officers working in the selected EPAs as possible. Secondary data were obtained from published and unpublished documents. The study involved total of 60 farmers and involved comparisons between three equal-sized sub-groups based on differences in their practices. The first group comprised farmers who had been practicing conservation agriculture for a minimum of three years, the second involved farmers who once practiced the technology but were no longer doing it, while the last one comprised farmers who had never tried the technology. The respondents were selected from three randomly selected EPAs within Salima District, and the study villages were also randomly selected within each EPA. These farmers were selected from each village on a semi-random basis, using lists provided by the local Agricultural Extension Development Officers. The lists indicated farmers who were practicing the CA, who once practiced the CA but stopped, and who never practiced the technology. The final selection of the farmers from each of these lists was also random. The data were coded and fed into the Statistical Package for Social Scientists (SPSS) for statistical analysis and presentation. Descriptive statistics in the form of frequencies and percentages were used when analysing, presenting and interpreting the data because the data collected was mainly qualitative. In some instances Chi-square was used to determine the significance of some variables on CA adoption.

Results and Discussion

This study found out that the great majority (90%) of the respondents were aware of CA and its associated benefits. However, awareness in CA alone was found not to be enough to enhance the adoption and continued use of CA. Unexpectedly, age of the respondent, household size, level of education, level of land control, and size of the garden were found no significant relationships with the adoption of CA. Judging from a review of relevant literature, positive correlations might have been expected with level of education (Weir and Night, 2000), land ownership (McCulloch, et al, 1998; Lastarria-Cornhiel, 2009), and size of the garden (Onyenweaku et al, 2007), while negative correlations could have been expected with age (Thangataa and Alavalapati, 2003; Uematsu and Mishra, 2010), and household size (Adeoti, 2009). However, the data did provided suggestions of non-significant relationships: between current CA practice and smaller families, between secondary education and who have tried CA, and between current CA practice and larger gardens. A male household head, membership of a Farmer Group, and having attended farmer trainings were all found to have significant positive impacts on adoption and continued use of CA technology at 95% confidence interval and 2 degrees of freedom (df). This is not surprising as these results are consistent with the findings from other researchers (Thangataa and Alavalapati, 2003; Masuki et al, 2007; Adeoti, 2009; Mazvimavi and Twomlow, 2009). The sample of female-headed households was too small to make really meaningful interpretations, but their low involvement in CA could be explained by a cultural reluctance of women to be seen to be taking radical decisions, or by the heavy existing workload of women who would then be taking on additional 'male' roles. Respondents indicated that all those who had got involved in CA adopted it as a result of practical example. Therefore, membership of a Farmer Group and participation in training probably initiated decisions to adopt CA.

As previously indicated, it was expected that land control/ownership might have been a significant factor in getting involved in CA, since land tenure has been established as a major factor in encouraging the investments needed for land improvements (McCulloch, et al, 1998; Lastarria-Cornhiel, 2009). The interpretation for this previous finding is that people are more inclined to put long-term investment into enterprises that are secure. In the current study, it is likely that the sample of respondents was too homogeneous to detect any influence of land tenure. Furthermore, although no respondent had clear title to the land they cultivated, all of them operated in a fairly secure situation that included de-facto rights of inheritance. Similarly, it might have been expected that level of income would positively be correlated with the uptake of CA since better-off farmers would be able to get involved without financial assistance if they thought CA was a good technology. In the event, there was no significant difference in income levels between farmers who are practicing the technology and those who had never practiced it. However, the study did reveal a positive correlation between income and long-term commitment to CA, with those who abandoned the technology after taking it up being less well off. Furthermore, there was a positive correlation between maintaining CA and having made a personal financial outlay to acquire the initial inputs. There are two, probably inter-linked, explanations for these observations. First, adoption of CA has associated costs that will be both better appreciated and better absorbed by those making personal investments than by those who are kick-started by grant-aided inputs. The second explanation parallels the psychological

explanation of the link between land tenure and willingness to invest, in that those who have invested their own money have more incentive to put in the additional effort necessary for a successful outcome.

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Predisposition for Conservation Agriculture in North West Ghana

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Introduction

The Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM) Technology Networks cross-cutting research activity (CCRA) is studying innovation processes for the successful development of conservation agriculture production systems (CAPS) for smallholders. This part of our study of innovation processes focuses on farm men's and women's knowledge and perspectives (technological frames) concerning their agricultural production practices; subsequent analyses will address other agricultural sector actors and the networks that support them.

For adoption to occur, it is argued that a change in mindset is required. Farmers, limited by the conventional agriculture mind-set, cannot conceive of attaining high yields without plowing the land (Hobbs, 2007; Wall, 2007). Changing mindsets, or technological frames, involves developing a shared recognition of agro-ecological deterioration that leads to reframing and extending farming sector networks to generate alternative solutions (Röling and Jiggins, 1998; Ekboir, 2003; Buck and Scheer, 2009). It is not a matter of simply training farmers but negotiated social learning that leads to the transformation of whole sets of highly interdependent actors from conventional or risk averse farming practices to sustainable conservation agriculture. But how is this dialog to be stimulated? Where do we start?

Research Methods

The data on which the following analysis is based were collected in 2010 in farming communities near Wa, North West Province, Ghana. Two hundred farm men and 157 farm women were interviewed concerning extension agent contacts and twenty agricultural production perspectives.

Drawing on a wide range of literature investigating farmer mind-sets (Lamb et al. 2010), we constructed a set of propositions to serve as indicators applicable in a wide range of agricultural production and livelihood circumstances. Respondents were asked to indicate on a scale of 1-5 the extent to which they agreed or disagreed with each statement (a response of 5 indicated strong agreement). These measures of local technological frames were examined with respect to the following hypotheses:

1. Farmers (both men and women) who have a higher level of contact with extension agents for information and inputs will hold strong Conventional Agriculture perspectives.
2. Farmers (both men and women) who have few or no contacts with extension agents for information and inputs will hold strong Risk Averse perspectives.
3. Women farmers are more likely to hold Conservation Agriculture perspectives than men farmers, regardless of extension agent contact.

Analysis of Farmer Technological Frames

Factor analysis conducted separately for farm men and for farm women determined (multi-indicator) dimensions of local technological frames characterizing conventional and risk averse agriculture. For simplicity of interpretation, factor scores were then created through simple addition.

Examination of Tables 1 and 2 indicates that contact with extension agents has little influence over the technological perspective of farm men and women. There are only a few differences in mean scores for core technological frame measures. Farm men with one extension contact during the year are less likely to support the traditional staple-based mixed crop-livestock farming systems than those with none or several extension contacts. There are no significant differences between levels of contact with extension agents among farm men for dimensions such as farming as a capital intensive business, crop diversification, or market participation. For farm women, contact with extension agents is only statistically related to interest in farming as a cash-cropping activity. Otherwise there is no relationship with the other dimensions of farm women's technological frame: the importance of the traditional production system, local food security and technological innovation. Thus, the first two hypotheses have not been confirmed. Contact with extension agents is unrelated to either conventional or risk averse technological frames.

Table 1: Mean scores for men's technological frame dimensions by contact with extension agents

	Contact with extension agents		
	No contacts	Contact with one extension agent	Contact with more than one agent
Farming is a capital intensive business	3.60	3.66	3.44
Farming requires the interdependence of staple crops and livestock	3.38[a]	2.98[ab]	4.08[b]
Extensive diversification of crop production is important	3.29	3.48	3.23
Market participation is necessary for sustainable farming	3.12	3.13	3.38
N	106	81	13

Note: "a" and "b" signify that the associated means are statistically different at the .01 level.

Preliminary correlational analysis of the three Conservation Agriculture principles demonstrated that there was no interpretable relationship among indicators. Overall, both men and women agreed that crop rotation is a best practice and many agreed that maintaining a permanent crop cover is not necessary. The greatest degree of diversity among both men and women is over whether "tillage causes land degradation". Hypothesis 3, whether farm women or men have a greater proclivity for Conservation Agriculture, was tested in Table 3. No significant differences were found in either direction for any of the three CA principles.

Table 2: Mean scores for women's technological frame dimensions by contact with extension agents

	Contact with extension agents	
	No contacts	Contact with at least one extension agent
Farming requires growing staple crops and supporting livestock	3.22	3.49
Local food security is important	4.12	4.09
Technological innovation is important for agriculture	3.89	3.97
Farming is a cash-cropping business	3.52[a]	3.90[a]
N	128	29

Note: "a" signifies that the associated means are statistically different at the .05 level.

Table 3: Comparison of mean scores for farm men and women's agreement with CA principles

	Gender	
	Farm men	Farm women
One should maintain a permanent crop cover	2.67	2.63
Tillage causes land degradation	3.05	3.10
Rotating crops is always best practice	4.17	4.13
N	200	157

Discussion

Noting the significant disagreement among farm men and among farm women over whether "tillage causes land degradation"; we decided to explore the significance of this with respect to their technological frames. Agreement among farm men that "tillage causes land degradation" is positively correlated with the perception that farming should be based on the interdependence of staple, mixed crop-livestock systems, diversification of crop production, and the importance of market participation. However, this relationship is reversed for the view that farming is a capital intensive business. That is, a positive view of investment in modern capital intensive technologies is inversely related to the perception that "tillage causes land degradation", consistent with the Conventional Agriculture technological frame. Farm women's perspectives echo these relationships with technological innovation and cash-cropping as negatively related to the idea that tillage causes land degradation. The only positive relationship is with the belief that farming should be based on the growing of staple crops and raising livestock on the fodder. Tables 4 and 5 demonstrate that in Northwest Ghana, farm men and women are both about equally divided on the issue of whether "tillage causes land degradation". This suggests that there is a significant group of Risk Averse farm men and women who would be amenable to the ideas of Conservation Agriculture.

Table 4: Mean scores for belief that tillage causes land degradation by farm men's technological frame

	Tillage Causes Land Degradation		
	Agree	Neutral	Disagree
Farming is a capital intensive business	3.50[e]	3.52[f]	3.76[ef]
Farming requires the interdependence of staple crops and livestock	3.61[a]	3.45[b]	2.85[ab]
Extensive diversification of crop production is important	3.55[e]	3.03[e]	3.31
Market participation is necessary for sustainable farming	3.34[cd]	2.91[d]	3.03[c]
N	83	33	84

Note: "a", "b", "c", and "d" signify that the associated means are statistically different at the .01 level; "e" and "f" signify that the associated means are statistically different at the .05 level.

Table 5: Mean scores for belief that tillage causes land degradation by farm women's technological frame

	Tillage Causes Land Degradation		
	Agree	Neutral	Disagree
Farming requires growing staple crops and supporting livestock	3.63[ab]	2.84[b]	3.09[a]
Local food security is important	4.08	3.95	4.23
Technological innovation is important for agriculture	3.74[c]	3.79	4.13[c]
Farming is a cash-cropping business	3.43[d]	3.50	3.80[d]
N	66	29	62

Note: "a", "b", and "c" signify that the associated means are statistically different at the .01 level; "d" signifies that the associated means are statistically different at the .05 level.

This analysis is still preliminary and requires further investigation of other intervening factors that might better explain the relationships discovered. Nevertheless, the analysis suggests that there are opportunities at the local level to advance the dialog with respect to changing the mind-set of farmers. It also suggests that those most likely to be accepting of these new ideas need not be the traditional favourites of technology transfer specialists. Messages should be tailored to the particular clientele, but the messenger(s) must also be selected with care.

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A Qualitative expert Assessment Tool (QAToCA) for assessing the adoption of Conservation Agriculture in Africa: selected application in Kenya and Tanzania

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Keywords: Conservation agriculture, adoption potential, Africa, Expert Assessment Tool

Introduction

Conservation agriculture (CA) is often promoted to reduce production costs and soil erosion and to maintain soil fertility. However, it shows lower adoption rates in Africa as compared to other continents e.g. South and North America or Australia. Small holder farmers in Africa do not readily adopt CA and its various components due to various reasons, such as limited access to CA inputs (no-till seeders, herbicides, cover crop seeds), labour constraints, or insufficient resources (Baudeon et al. 2007; Giller et al. 2009). Poor infrastructure, small farm sizes and the low educational level are further major constraints to adoption of CA. While technical problems may play a role in preventing adoption, they seem much less important than constraints related to resources such as land, labour at key periods during the cropping cycle, feed for livestock, manure for soil amendment and financial capital to invest in external inputs (Knowler and Bradshaw 2007). Ehui and Pender (2005), for example, mention the general lack of support for smallholder agriculture in much of Africa, which leads to economic disincentives to invest in CA, leading to a slow adoption rate. In spite of the large amount of available literature on constraints to CA adoption, a comprehensive self-assessment tool is lacking that allows a systematic evaluation of the determinants of CA adoption from field, farm to regional scale and for use in a range of regional contexts. This knowledge gap led us to develop a Qualitative expert Assessment Tool for the assessment of CA adoption (QAToCA,) within the EU-funded project 'CA2Africa' (www.ca2africa.eu). QAToCA is designed to assess in a semi-qualitative manner the socio-economic, institutional and cultural conditions that, according to experts, actually or potentially promote or hinder the adoption of CA in the heterogeneous farming contexts in Africa.

The objective of this paper therefore is to provide 1) a brief description of this tool, 2) an outline on its use, and 3) exemplary results of its application in two selected case studies located in Kenya and Tanzania.

Material and Methods

Based on a simple Excel spreadsheet file, QAToCA specifically looks at the contextual factors for adoption that are not handled by the more quantitative, explanatory modelling approaches such as the use of bio-economic optimisation models. Guided by existing diffusion theories and conceptual models of innovation and adoption, the tool covers seven thematic areas (A-G):

- A Object of adoption (CA)
- B Capacity of the implementing organisation(s)
- C Attributes of scaling up
- D Political/institutional framework at regional level
- E Political/institutional framework at village level
- F Economic conditions
- G Community's attitude towards CA

Each of these areas is underpinned with a systematic, expert-based list of adoption criteria with associated questions and possible scenarios for regional CA experts and practitioners to self-assess their CA diffusion activities in their respective regions. The issues covered focus on the regional or contextual scale, but with some overlap to the field and farm levels. After two rounds of pretesting among partners of the CA2Africa project and during case study workshops (Tanzania, Zimbabwe, Burkina Faso, Madagascar, and Tunisia), a final version of the tool was developed. QAToCA is applied by filling one spreadsheet file for one case study. As no single expert has knowledge about all levels and issues considered in the tool, several experts knowledgeable about a given case study are convened and asked to respond, including a researcher, an extensionist/promoter of CA, a farmer with appropriate CA knowledge (an adopter) and a farmer, who adopted, but stopped practicing, or who considered adoption, but then did not implement it (a non-adopter). This multi-stakeholder expert group convenes for a half-a-day workshop and is guided through the questions of the tool by a facilitator who has a good knowledge of QAToCA. Discussions are documented reflecting the diverting opinions within the group if they arise.

Results and Discussion

QAToCA was first applied in 2 case studies: Ndindikuru (Kenya) and Karatu (Tanzania) in September 2010 with a group of CA experts. The assessment yielded an overview of the relevant supporting and hindering factors (Table 1) to CA adoption. With regard to specific thematic areas (Figure 1), factors that fall under the area "object of adoption (A)" and "CA inputs plus market conditions (F)" were observed to have outstanding negative influence on its adoption especially for Ndindikuru. On the other hand, those related to the "capacity of implementing institutions (B)" were identified as having a major positive influence on adoption for Karatu. "Attributes of scaling up (C)", the "political and institutional frame conditions at village and regional levels (D and E)" as well as the "community's attitude towards CA (G)" were identified as positively influencing its CA adoption especially for Ndindikuru.

For both regions, a close look at the underlying factors of each thematic area reveals that there are in total more supporting factors to adoption than hindering factors (Table 1), hence high chances for CA adoption. Nevertheless, a scaling up in CA adoption can only be expected if efforts are made towards improving on the needed basic infrastructures such as market access and roads, credit facilities and adapted CA equipments to this region. The comparative analysis of the two case studies yielded in a better understanding of the specific regional socio-economic, cultural and institutional settings that determine adoption of CA and can help in targeting the promotion of CA technologies within smallholder farms in the region. The tool is currently applied in ten heterogeneous African countries (Kenya, Tanzania, Zimbabwe, Zambia, Malawi, Burkina Faso, Benin, Morocco, Tunisia and Madagascar).
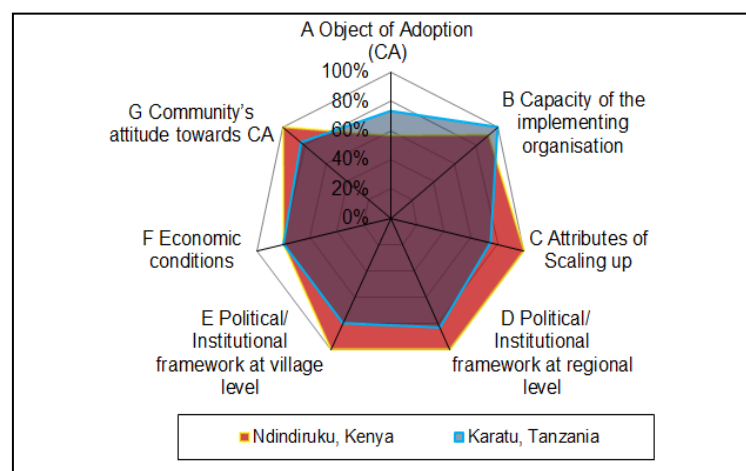
Figure 1. Exemplary results for two case studies aggregated over the seven thematic areas of QAToCA

Table 1. Exemplary QAToCA results (excerpt) with supporting and hindering factors to CA adoption for two case studies in Kenya and Tanzania

| Thematic area | ID | Indicator | Case study regions | |
			Karatu, Tanzania	Ndindikuru, Kenya
A Object of Adoption (CA)	A01	Cost of CA and liquidity issues	-	-
	A02	Availability of CA knowledge	-	-
	A03	Complexity of CA	-	-
	A04	Labour requirements vs. endowments	-	-
	A05	Availability of social networks/org.	-	-
	A06	Residue and seeds requirements vs. availability	+	-
	A07	Machinery + fuel requirement and availability	-	-
	A08	Land requirement and availability	+	+
	A09	Observability of CA	+	+
	A10	CA yield response and time	-	-
	A11	Relative economic risk	+	-
	A12	Trialability	+	+
	A13	Flexibility/adaptability	+	+
	A14	CA and social status + prestige of farmers	+	-
	A15	CA and conflict over resources	+	-
B Capacity of the implementing organisation	B1	Concept of organisation	+	+
	B2	Availability and quality of human resources	+	+
	B3	Leadership and reputation	+	+
	B4	Organisational linkage to other CA organisations in the region	+	-
	B5	Organisational linkage with target group	+	+
	B6	Organisational linkage with stakeholders in the CA innovation systems	+	+
C Attributes of Scaling up	C01	Scaling up area, target groups and characteristics	+	+
	C02	Clarity of scaling up strategy	+	+
	C03	State and level of documentation, monitoring and evaluation	-	+
	C04	Usage of established communication channels	+	+
	C05	Diffusion strategy	+	+
	C06	Compatibility of selected diffusion strategy with the target groups	-	+
	C07	Linkage of promoting organisation with farmers	-	+
	C08	Organisation and level of involvement in capacity building	+	+
	C09	Type of communication channel	-	+
	C10	Usage of incentives in the diffusion process	-	+
.. …	…	…		

+ Supporting factor; - hindering factor

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Adaptation of Conservation Agriculture by smallholder farmers in Malawi: drivers, intensity, benefits and problems for up scaling

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Keywords: labour savings, yields, soil fertility, CA equipment, knowledge sharing

Introduction

Eradicating hunger in the coming decades within smallholder rain fed agriculture systems will require production practices that preserve the environment and reduce the vulnerability to climate change (Hobbs et al., 2008). Conservation Agriculture (CA) technologies are deployed in developing countries as solutions to increase and stabilize yields, reduce production costs as well as risk, increase rain water use efficiency thereby help in adapting to climate variability and change while at the same time improve the natural resource base dedicated to agriculture (Thierfelder and Wall, 2010; Erenstein et al., 2008; Wall et al., 2008). CA is characterized by three principles: minimal soil disturbance; permanent organic matter soil cover; and diversified crop rotations and associations. CA benefits have been widely reported in Americas and Australia (Wall, 2007; Kassam et al., 2009). Since the establishment of exploratory trials and on farm demonstration plots by CIMMYT, local partners and farmers in Malawi in 2004; some farmers have been systematically encouraged to experiment with, and adapt the CA oriented technologies. This paper presents the intensity of farmer adaptation with CA practices and its associated benefits.

Material and Methods

A total of 300 farmers were interviewed in the study using structured questionnaire supplemented with field observations as well as key informant interviews. A household study was conducted in ten communities in central and southern Malawi where CIMMYT has been operating. The questionnaire was pre-tested and modifications were made to control its validity in addressing the relevant issues. Three types of farmers were included in the farmer sample: farmers who are currently using CA (adopters), farmers who used and later abandoned CA (disadopters), and farmers who have never used the CA package (non-adopters). Of the total 300, 50% were adopters while non-adopters and disadopters contributed 25% each. The last two categories were included to capture information on reasons for non-adoption. The intensity of farmer's adoption of the different component technologies; farmers' perceptions of CA; CA benefits and problems associated with expanding CA were analysed.

Results and Discussion

Drivers of farmer adaptation with CA

The major driver of adaptation of CA oriented in Malawi has been the provision of improved seed and herbicide in form of loans to interested registered farmers with local NGOs such as Total Land Care (TLC) – complemented with subsidized fertilizer to farmers by government. The major reasons cited by farmers as the key motivation behind their decisions to embark on CA include: labour savings, higher yields, soil moisture retention, soil erosion control, enhanced soil fertility among others (Figure 1). It is important to note that despite the overall area under CA gradually increasing over time, farmers across communities rarely allocated more than 30% of the cultivated land to CA (Figure 2). The major reasons cited by the majority of farmers are limited access to inputs (43%) and lack of suitable equipment for CA (22%). The results also show that the adoption of CA occurs partially and incrementally with dibble stick, no-till, residues and herbicides cited as widely used components.
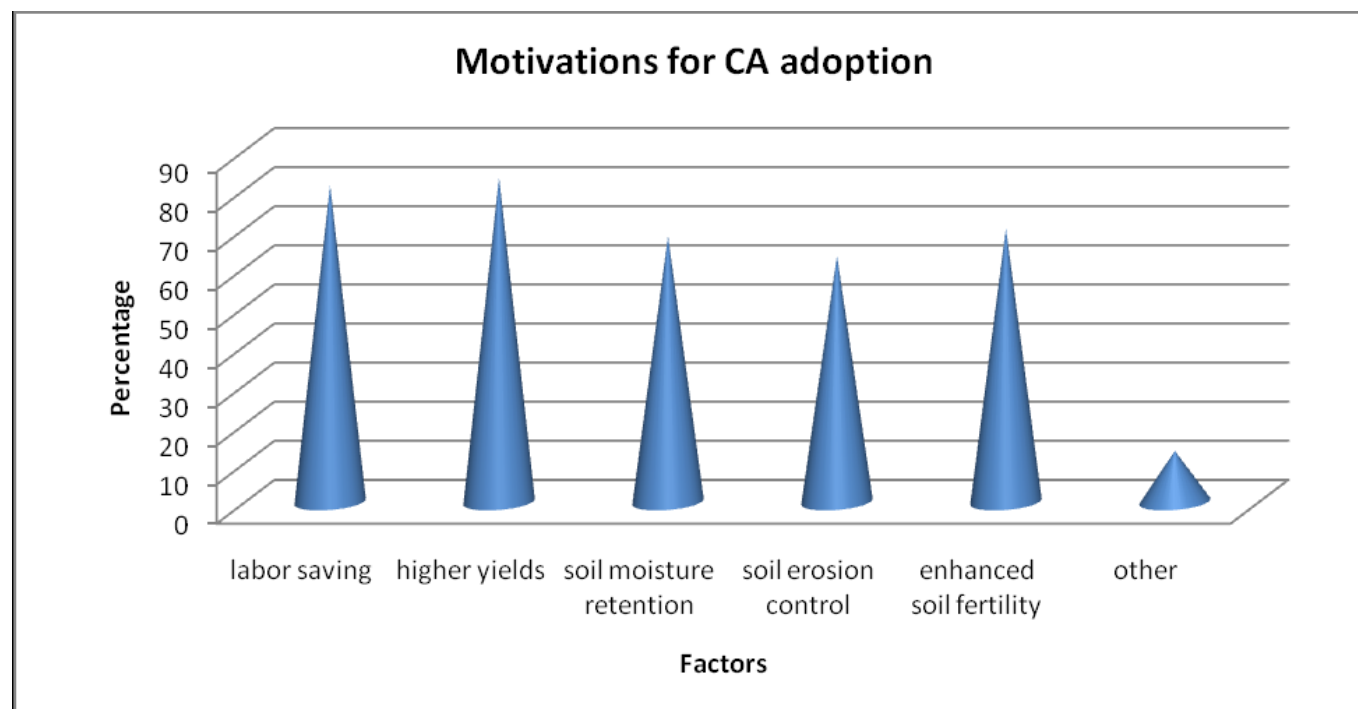
Figure 1 Motivations for Conservation Agriculture adaptation by smallholder farmers in Malawi
[Source: survey data [proportions may not add to 100% due to multiple responses]

Farmers' scenarios and experiences with CA

A review of scenarios and farmers' experiences show that farmers have limited use of CA seeding equipment; crop rotations and intercropping with few problems in managing crop residues. The only common used equipment is dibble stick (78%) that is used to make shallow holes into which the seed is sown. Malawian farmers have generally shunned the jab planters arguing that it is very hard to use especially when farmers intend to utilize the first rains by which time the ground is still too hard to work with. The majority of farmers cited prioritizing food security concerns as the major reason affecting widespread use of crop rotations in CA systems. Other binding constraints of including rotations include: general shortage of legume seed (46.3%); inadequate knowledge on rotation systems (39%); undeveloped produce markets (27%) among others.

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CA adoption and pathways

Practicing farmers have benefited from the labour savings and enhanced yields as well as considerable reduction in production risks mainly through increased resilience of crops to moisture stress and recurrent droughts. The CA initiative, particularly farmer-led demonstration plots has encouraged farmer to farmer knowledge sharing. Early adopters and the champion farmers have been training other farmers in CA practices using demonstration plots as knowledge and learning centres for potential adopters. Though farmers tend to allocate relatively smaller proportions of their land to CA, the yields realized from CA plots are significantly higher than that of conventionally tilled plots (Figure 3). By reducing labour requirements for the main operations such as land preparation and weeding; CA also results in cost savings. Farmers argued that labour saved from CA is used in other livelihood activities such as poultry production; production of horticultural crops; high value commodities such as paprika and tomatoes.
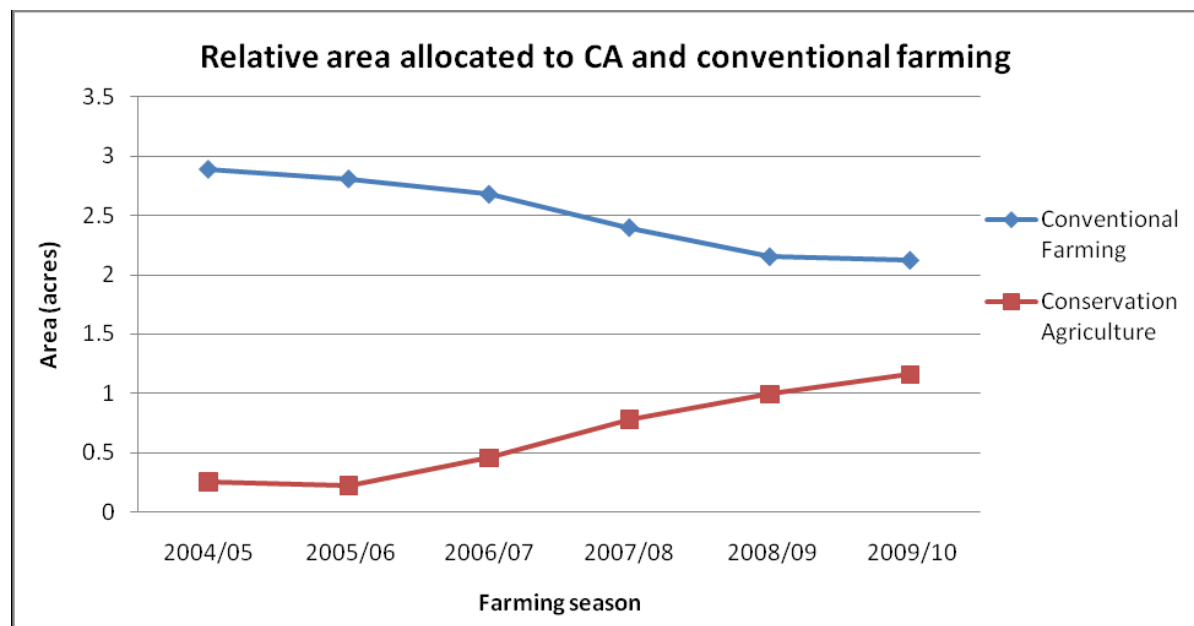
Figure 2 Relative cultivated land area allocated to Conservation Agriculture and conventionally tilled plots by smallholder farmers in Malawi across five years (2005 to 2010)
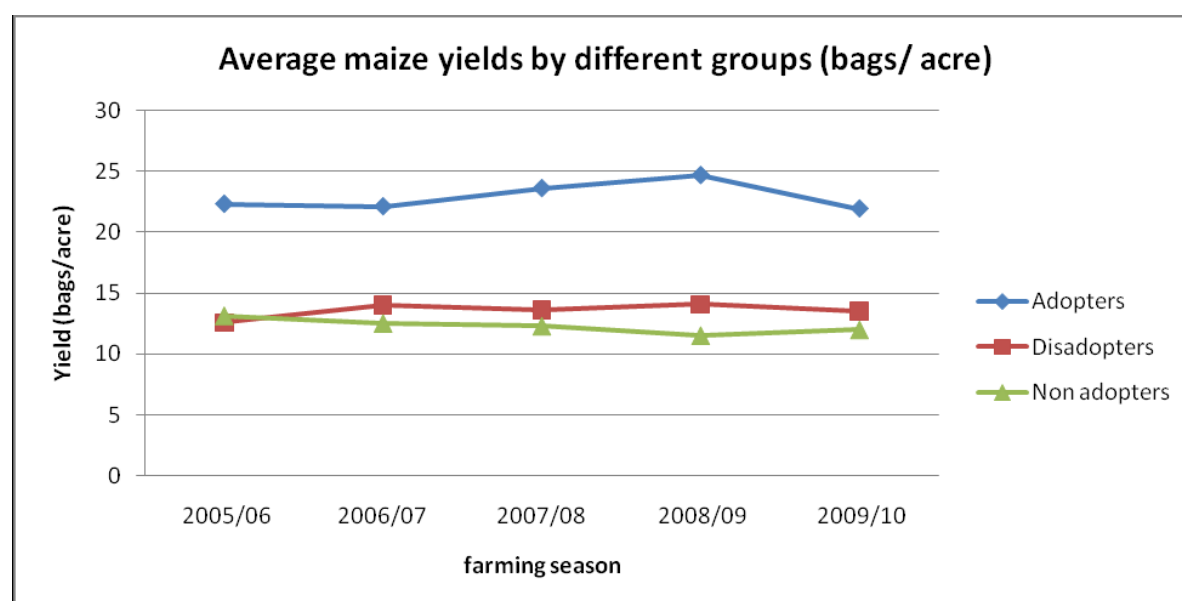
Figure 3 Average maize grain yields (bags/care) obtained by different groups of farmers from across five years (2005 to 2010)

Reasons for disadoption and non adoption

A number of factors influence farmers' decisions to disadopt improved farming technologies. Most farmers (54%) identified limited access to inputs as the major reason for discontinuation with CA. Discontinued donor support before farmers fully embrace the newly introduced technologies was another factor mentioned by farmers (43%). The majority of non adopters (70%) cited lack of information as one of the reasons for not embarking on CA. Others mentioned labour shortage (23%) and perception that herbicides destroy soils (12%) as major constraints for non-adoption.

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Up-scaling of Conservation Agriculture in Zambia: some key practical barriers in practice of minimum tillage among smallholder farmers

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Introduction

Zambia is one of the countries in Sub-Saharan Africa that has recorded impressive progress in transforming conventional agricultural system (CV) to conservation agriculture (CA). FAO reports 120 000 smallholder farmers having already benefited from CA in Zambia (FAO 2011a). Nyanga et al (2011) show that 65% of smallholder farmers had area planted under CA in Zambia as of 2009/10 farming season. The hunger period among smallholder farmers under Conservation Agriculture Programme (CAP) has significantly reduced from an average of 4.4 months in 2006/7 to 3.2 months in 2009/10 season (Nyanga et al. 2011). There have been frantic efforts to upscale CA promotion without much pragmatic attention to addressing some practical barriers to the adoption of CA. This paper argues that, for CA up-scaling efforts and further improvement in the transformation of conventional agriculture to CA to a level of sustainability beyond project periods, cultural, institutional, environmental, technical, political and ontological barriers need to be addressed by all actors: donors, policy makers, project implementers, farmers' unions and cooperatives, and individual farmers in the stream of CA promotion.

Materials and Methods

This study is based on a random sample of 640 farmers drawn from updated CFU registers of targeted farmers under CAP in 2006/7, the baseline season. Data was collected from same households for four consecutive farming seasons. Data was collected using structured questionnaires, focus group discussions, direct observations, key informant interviews and review of literature. Descriptive statistics, z-test and student t- test were used along with content analysis of qualitative data.

Results

Results show significant increase (p<0.0001) in the percentage of households in 2009/10 having an area under CA basins and ripping from the baseline 2006/7 season while there are no significant changes for conventional hand hoe (P-value=0.540) and ploughing (P-value 0.502) (Table 1). Results further indicate that CA basins and plough were the most wide spread tillage methods among smallholder farmers over the period considered. Conventional hand hoeing and ripping are the least spread tillage methods (Table 1 and Figure 1). However, the steady increase in percentage of household ripping suggests an increased usage of the technology in future (Figure 1). In terms of share by different tillage methods of the total cropped land and changes over the four farming seasons, results show that there has been a steady decrease in total area under plough as percentage of total cropped land from 2006/7 to 2009/10 and steady increase for ripping (Figure 1). Total area under CA basins as percentage of total cropped land has stabilised around 16% for the whole sample during the last two seasons after an increase from baseline while conventional hand hoe area has reduced from baseline and remained quite stable for the last two seasons at 8% (Figure 1). FAO also reports of percentage area under CA in Zambia being not more than 20% of cropped land among lead farmers (FAO 2011b). However, at household level and by tillage method, results show an increase from 14% in 2006/7 to 25% in 2009/10 on average area under CA basins as a percentage of total cropped area while ripping increased from 2% to 9%.of the cropped area (Figure 2).

Table 2: Percentage of households using various tillage methods in 2006/7-2009/10 seasons

Households using conventional hand hoe tillage (%)				Households using CA basins (%)			
2006/7	2007/8	2008/9	2009/10	2006/7	2007/8	2008/9	2009/10
26.02	33.33	15.73	24.37	22.21	45.20	54.79	58.54
Households using Plough (%)				Households using Ripper (%)			
68.40	74.53	69.15	66.44	3.45	10.92	14.79	21.64

Note: Valid observations were 636 in 2006/7; 531 in 2007/8; 480 in 2008/9 and 438 in 2009/10

Adoption intensity at household level expressed as average percentage area of the total cropped area allocated under various tillage methods shows significant increase for CA basins and ripping from baseline to 2009/10 (Figure 2). The average area under CA basins increased significantly (P< 0.0001) from 0.19 to 0.31 hectares per household and from 0.04 to 0.24 hectares for ripping over the same period. Results suggest that an average household may not go beyond an area of 0.3 hectares in practicing CA basins as other factors like labour could become limiting. Ripping has shown a steady increase over four seasons suggesting room for further adoption and need for continued promotion of the technology (Figure 2).The intensity of ploughing has significantly reduced (p<0.0001) and so has conventional hand hoeing (p<0.0001) (Figure 2). This change in ploughing intensity is not because of the reduction in area under ploughing but due to increase in area under basins and ripping. The change in average area under ploughing from baseline 1.40 to 1.32 hectares in 2009/10 season shows no significant difference (p-value=0.498). On the contrary, a significant decrease in intensity of conventional hand hoeing was due to both significant reduction (p-value=0.001) in average area under conventional hand hoe tillage from baseline 0.29 to 0.16 hectares in 2009/10 and significant increase in area under basins and ripping. However, the stabilisation of the average area under hand hoe tillage at 0.16 hectares during the last two seasons suggest that households could be using conventional hand hoe tillage on certain crops such as sweet potatoes where CA methods may not be appropriate from farmers' perspective.

Discussion

Achievement of desired results in CAP has not been without practical barriers. The recommendation for early land preparation when soils are increasing getting dry and hard is a practical barrier because some farming communities consider the practice as being ruthless to cattle and culturally unacceptable. Better resource endowed farmers who often have oxen and better access to labour may not see any need to
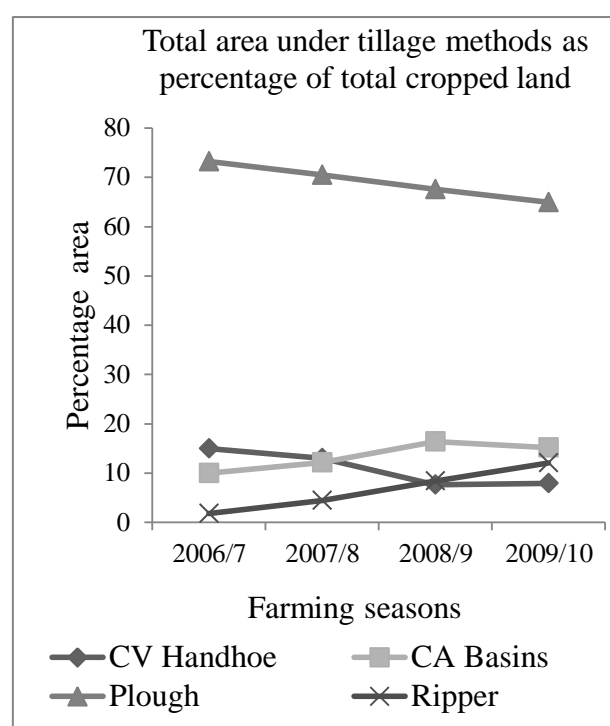
Figure 13: Total area under various tillage methods as percentage of total cropped land
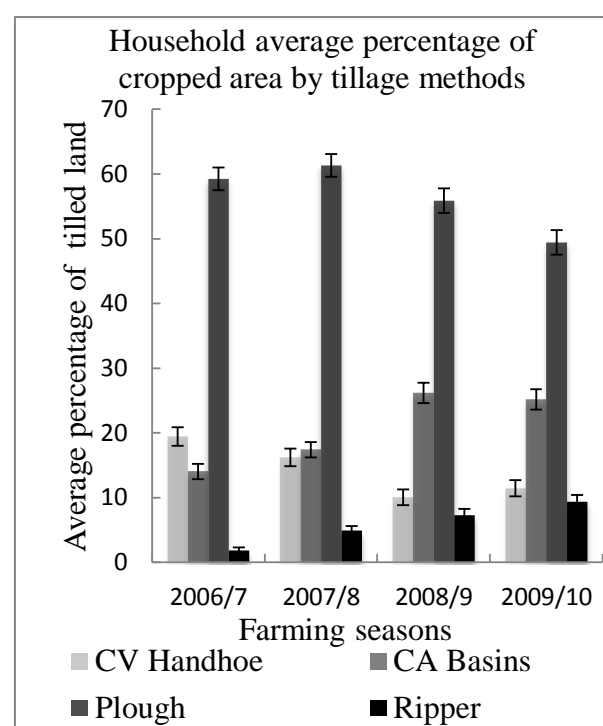
Figure 14: Average percentage of cropped area by tillage methods

shift from ploughing to ripping. This could account for lack of significant change in the area under plough. Rather than using technical approaches only there could be need for social approaches targeting at influencing attitudes and behaviour in relation to farming systems. CA may provide a way out of poverty but as soon as farmers accumulate wealth especially cattle, they may revert back to ploughing as already evidenced by few cases during the data collection. The slow pace of commercialisation of a ripper and access of the equipment by farmers adds to practical limitations. Strengthening CA supporting sectors such as supply of appropriate equipment could be necessary for up-scaling of ripping among smallholder farmers. Timely access to seed and fertiliser is also a practical barrier in that farmers often argued that there is no need to invest into the labour intensive CA basins or dry land preparation in general under CA when there is no timely access to hybrid seed and fertiliser. This reflects the need for synergies between government input support programmes and CA projects, and well coordinated pragmatic collaboration among actors involved. Political factors are equally a challenge and there is need to have not only a clear policy on CA but operationalise the policy prescriptions. CA supportive policy environment could enhance up-scaling of CA. Extreme climate variability especially flooding has proved to be a practical barrier especially for CA basin farmers as they experience water logging though most of the farmers argued that they had to back fill and even make ridges around the maize. Limited access to labour during peak periods is also challenging especially in the case of digging of basins whose labour intensive and drudgery nature has been widely reported. Reconciling the ontological positions of some farmers and CA promoters has proven to be a challenge. Farmers are more concerned with diversifying tillage systems as a means to spread risk rather than a complete shift from conventional tillage to CA tillage systems as evidenced by increase in area under CA while maintaining area under conventional agriculture while CA promoters hope for intensification. This reflects the need to build a robust agricultural system around CA for greater resilience in an era of increased uncertainty

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Development and promotion of zero tillage in Iraq and Syria

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Keywords: conservation cropping, agronomy, zero till seeders, extension, adoption

Introduction

Dryland cropping in West Asia is characterized by cultivation, grazing, burning/harvesting of stubbles and late sowing. Cereal and legume yields are low given rainfall and attainable water use efficiencies. In contrast, in Australia, many farmers now approach attainable yields using conservation cropping, sowing crops with minimal soil disturbance and stubble retention. The key to conservation cropping is zero tillage (ZT), which over the last 30 years has been adopted by 90% of Australian farmers. This paper presents some experiences in an Australian-funded project (2005-11) to develop and promote conservation cropping in Iraq and Syria, where ZT has been little known, researched or adopted.

ZT research, seeder fabrication and promotion

Zero tillage versus conventional cultivation comparisons
To verify and adapt ZT systems, a long term cereal-legume rotation trial was commenced in 2006-07 at ICARDA, on a highly calcareous, fine montmorillonite clay soil, to compare crop production under ZT and conventional cultivation (CC) with early and late dates of sowing (DOS). In 2007-08, lentil grain yield was higher (P<0.05) for ZT than CC and for early than late sowing (Figure 1). Tillage (T) accounted for 13% of total yield variation, whilst DOS accounted for 83%. In 2008-09, barley grain yield showed a T x DOS interaction, with ZT plus early planting higher (P<0.05) than other treatments (Figure 1). T accounted for 46% of total variation and DOS accounted for 52%. There were high yield penalties for delays in sowing, especially under ZT, where daily losses were 20 kg/ha with lentil for delays after 28 Nov 07 and 8 kg/ha with barley after 22 Oct 08. The importance of the T-DOS combination was clear. In 2007-08, lentil yield was 0.67 t/ha with farmer practice (CC/ late sowing) and 1.23 t/ha with conservation cropping (ZT/early sowing), an increase of 84%. In 2009-10, corresponding figures for barley yield were 3.35 and 3.74 t/ha, an increase of 12% (Figure 1). These are major increases from eliminating ploughing and planting early.
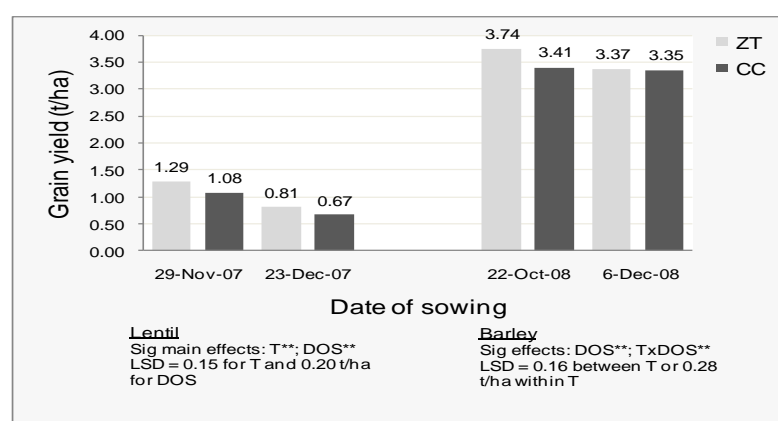
Figure 1. Yield of lentil in 2007-08 (222mm rainfall) and barley in 2008-09 (291mm rainfall) under ZT and CC with early and late sowing at ICARDA (* and ** significant at P ≤ 0.05 and 0.01)

Crop genotype responses to ZT and CC
Trials at ICARDA in 2009-10 comparing grain yield of 10 varieties, nested within crops, of cereals (barley, bread wheat, durum wheat, oats) and grain legumes (faba bean, peas, chickpea, lentil) under ZT and CC showed some significant tillage (T), crop (C) and variety (V) effects but patterns of variety performance were similar and there were no significant TxCxV interactions (Figure 2). This suggests that current varieties and lines being grown by farmers and developed in breeding programs under cultivation can be used under ZT and new varieties are not needed before ZT systems can be adopted.
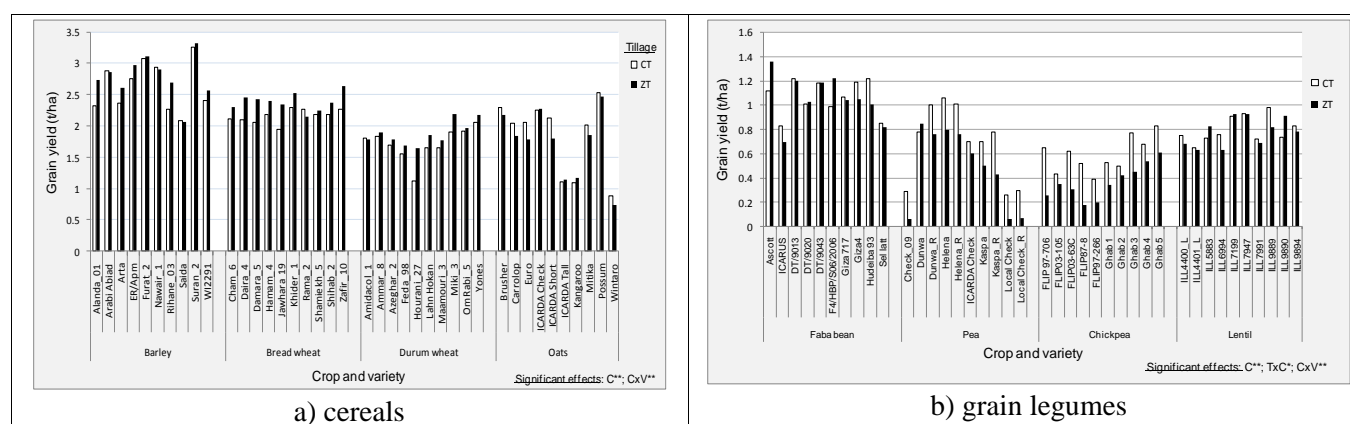
Figure 2. Yield of 10 varieties/lines of a) cereals (barley, bread wheat, durum wheat, oats) and b) grain legumes (faba bean, peas, chickpea, lentil) under ZT and CT at ICARDA in 2009-10 (272mm rainfall)

Local fabrication of ZT seeders
The lack of effective, affordable ZT seeders was identified as a major constraint to ZT adoption. To develop local production, ZT seeder technology was discussed and local fabrication commenced with seeder manufacturers and farmers in Iraq and Syria in 2007-09. Small 2.3m 3-point-linkage (3PL) ZT seeders, and wider 4m trailed and 3PL seeders, were fabricated with tines having narrow points, wide spacing, spring release and seed/fertilizer delivery. In Iraq, farmers developed ZT modification kits for local 3.6m John Shearer-type seeders. The performance of imported and local seeders was compared with early (mid-Nov 08) and late (mid-Dec 08) sowing at ICARDA. All seeders worked well and yields of wheat, barley, lentil and chickpea were similar for Indian, German and three local Syrian ZT seeders

(Figure 3), with barley, wheat and chickpea yielding more with early than late sowing. Prices are US$1250 for ZT modification in Iraq and $2500 for 2.3m and $6000 for 4m seeders in Syria. In 2008-11, 21 Iraqi and 5 Syrian farmers had seeders modified for ZT and 14 Syrian farmers and 9 NGOs/institutions purchased ZT seeders from Syrian manufacturers.
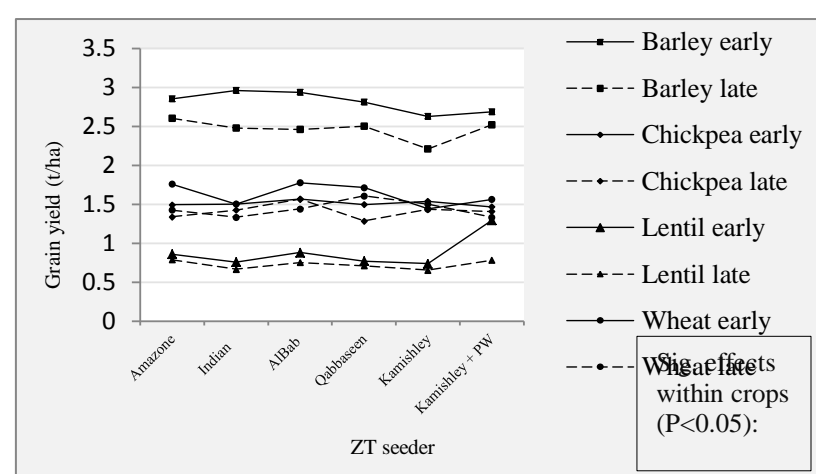
Figure 3. Yield (t/ha) of wheat, barley, chickpea, lentil sown early/late with ZT seeders from Germany (Amazone), India, Syria (AlBab, Qabbaseen, Kamishley +/- Press Wheels) at ICARDA in 2008-09

Demonstration and adoption of ZT in farmer fields
Local farmers in Iraq and Syria were facilitated to try ZT in a participatory program with ICARDA, research-extension institutions, private industry and NGOs. ZT technology was explained and local ZT seeders made available to interested farmers for testing without charge or payment; farmers supplied tractors and inputs. CC comparisons were made on-farm or with neighbors. Farmers generally found yields were better with ZT than CC, even where there was little stubble. In a survey of the 43 Syrian farmers using ZT in 2008-09, 100% responded that they:
• saved plowing costs (US$30-40 per ha), time, seed and soil moisture and got good early germination
• got a higher ZT yield than from their own or neighbors' CC fields
• were keen to continue ZT given drill access with some interested to buy/modify a drill
The program has increased experience and adoption of ZT since introduction in 2006-07. Fifty farmers used ZT on 6,000ha in Ninevah and 350 farmers on 15,000 ha in Syria in 2010-11 (Table 1), with 70-80% of these areas being actual adoption by farmers using their own or a borrowed/rented ZT seeder.

Table 1. Number of ZT farmers, crop areas and seeders manufactured or farmer modified in Ninevah Iraq and Syria in 2006-2011 (*on-going project R&D farmers/areas; ** 2010-11 data under collection)

			2006-07	2007-08	2008-09	2009-10	2010-11**
Iraq	Farmers		12*	16	18	31	≈50
	Area (ha)		52*	252	492	1806	≈6000
	Seeders	Manufactured	3 India	2 Iraq		4 Syria	1Iraq, 14 Syria
		Farmer modified		1		2	18
Syria	Farmers		3	6	43	119	≈350
	Area (ha)		15	30	2075	4918	≈15000
	Seeders	Manfd. for ICARDA	1 India		3 Syria	6 Syria	2 Syria
		Manfd. for farmers/others				4 Syria	≈19 Syria
		Farmer modified			2	3	

Conclusions

ZT is the key to conservation cropping, facilitating early sowing with minimum soil disturbance and retention of stubble. Research showed ZT was generally more productive and profitable than CC, with early planting important in achieving high yields. There was no indication that special varieties were needed for ZT. A key constraint to adoption was overcome with development of locally-manufactured or -modified ZT seeders, which were effective and affordable. Local farmers encouraged to try ZT were impressed with increased yields and cost savings. Farmers have been purchasing/modifying their own seeders and taking up ZT, and it is expected use and adoption will increase in Iraq and Syria.

Assessing production risks in agricultural systems – a modelling study with APSIM-maize in New Zealand

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Keywords: crop simulation modelling, APSIM

Introduction

Future improvement of the productivity and sustainability of agricultural production systems is a great challenge for agricultural research. For example, the New Zealand dairy industry has set a target of producing >1,750 kg milk solids/ha from home grown feed by 2015, through the use of environmentally conscious technologies (DairyNZ, 2010). The use of maize silage to supplement grazing cattle has been identified as a promising option to increase animal nutrient intake and overall farm stocking rate in current dairy systems (de Ruiter et al., 2010). In New Zealand, maize is often part of a multi-cropping combination of summer and winter forages, including its strategic use to mitigate feed shortages during pasture renewal programs. Therefore, maize yields have a strong impact on decisions regarding other farming system components such as the number of resident livestock, the area sown to additional crops and the financial requirements for the purchase of extra feed. However, maize yields vary considerably between years, particularly for rain-fed cropping systems which are common in the North Island of New Zealand. Seasonal weather patterns and soil type influence the availability of water for plant growth, generating production risks. These risks can be partially managed using crop husbandry options such as the choice of sowing date and hybrid maturity. The complex combinations of bio-physical (weather and soil) and management (sowing date and hybrid maturity) factors, which ultimately determine crop productivity and risks, are difficult to assess through field experimentation alone. Crop simulation models provide insight by quantifying these interactions (e.g. Fletcher et al., 2011, Hammer and Muchow, 1994).

In this paper, the Agricultural Production Systems sIMulator (APSIM) (Keating et al., 2003) was used to assess inter-annual variability of potential silage maize yields for contrasting locations, soils, sowing dates and maize hybrids in the North Island of New Zealand. The objective was to identify critical factors that contribute to yield variability so as to gain insights on possible adaptive measures for improving the profitability and sustainability of these agricultural systems.

Material and Methods

Simulations were performed using the Maize-module (www.apsim.info/Wiki/Maize.ashx) of APSIM to assess potential silage maize yields at four North Island locations (Kaikohe (35°25'S, 173°49'E), Ruakura (37°47'S, 175°19'E), Whakatane (37°55'S and 176°54'E) and Palmerston North (40°19'S, 175°37'E)). Weather data were obtained from the CliFlo database from the National Institute of Atmospheric and Water Research (NIWA) website (www.niwa.co.nz/). Three hypothetical soil types with different water holding capacities (WHC, 80, 120 and 160 mm), three maize hybrid maturity types (180, 240 and 300°Cd from emergence to silking) and eight sowing dates from 1 September to 15 December (1 Sep, 15 Sep, 1 Oct, 15 Oct, 1 Nov, 15 Nov, 1 Dec and 15 Dec) were tested for each location. An ANOVA was used to partition variation in simulated data to each of the following weather and management parameters: location, year, soil type, hybrid maturity and sowing date. Lack of serial correlation between results in consecutive years was confirmed by estimating several possible non-identity, variance-covariance matrices using a mixed model fitted with REML (GenStat 2006).

Results and Discussion

Across all locations, soil types, managements and seasons (for an 18-year simulation), rain-fed maize silage yields ranged from 4.1 to 23.6 t DM/ha. Environment factors (soil WHC and weather) explained 70–80% of overall yield variation at the four locations with soil WHC being the single most important environmental factor (38–54%; Figure 1). Amongst the management factors (sowing date and hybrid maturity), the most relevant was sowing date, which explained 12–16% of yield variability. A large amount of the variation in yield between locations and within years (at the same location) was explained by differences in the amount of rainfall during the crop cycle (Figure 2). There was considerable year-to-year variability in these relationships, suggesting that factors such as the timing and magnitude of rainfall, solar radiation and temperature also contribute to yield. Nevertheless, yield generally increased with increasing rainfall. For instance, at the early sowing dates (Figure 2 a–c) there was a linear relationship between in-season rainfall and yield with the slope representing the water use efficiency (ranging from 21 to 23 kg DM/mm) and the y-axis intercept representing (approximately) the product of water use efficiency and the WHC of the soil. Within each of these relationships, yields at Kaikohe were consistently at the higher end, suggesting that higher annual rainfall led to higher maize yields. Similarly, at a particular location, yields tended to be higher when rainfall was higher.

Overall, these results highlight the potential of crop modelling tools to distil the complexity of bio-physical systems, thereby allowing new insights to emerge. In our case study for the North Island of New Zealand, soil type was the most critical factor to realise attainable yields for rain-fed maize production systems. As a consequence, the advantages of differential management depending on soil type can be explored as a means of optimizing returns and reducing environmental impacts. For example, at a low WHC soil growers may reduce fertilizer application and increase sowing area according to the lower expected yields. Input fertilizer applications could be targeted to minimize both luxury consumption of nitrogen (which increases production costs) and reduce potential nitrogen losses to the groundwater environment through leaching. In addition, the modelling exercise quantified the quasi-linearity of the relationship between maize yields and rainfall. By knowing that, farmers can forecast final yields based on accumulated rainfall amounts at specific stages of crop growth, in comparison with historical records. This would enable early adaptive measures to be put in place by manipulating other components of the farming system. For example, destocking or purchasing additional feedstocks strategically early may provide economic benefits and reduce the production risks.
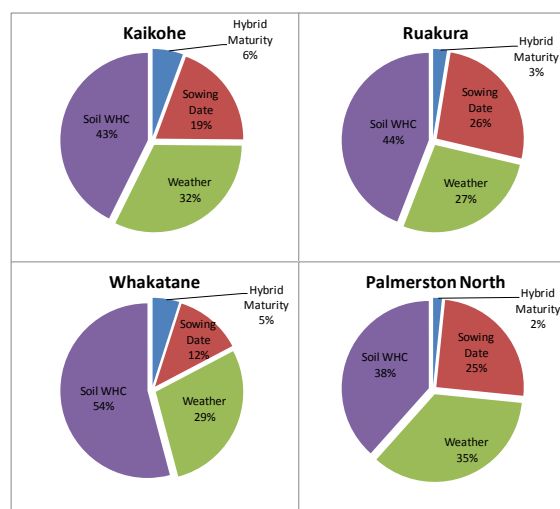
Figure 1. Relative contribution of environmental and management factors to simulated maize silage yields at four North Island sites over 18 years of historical weather data.
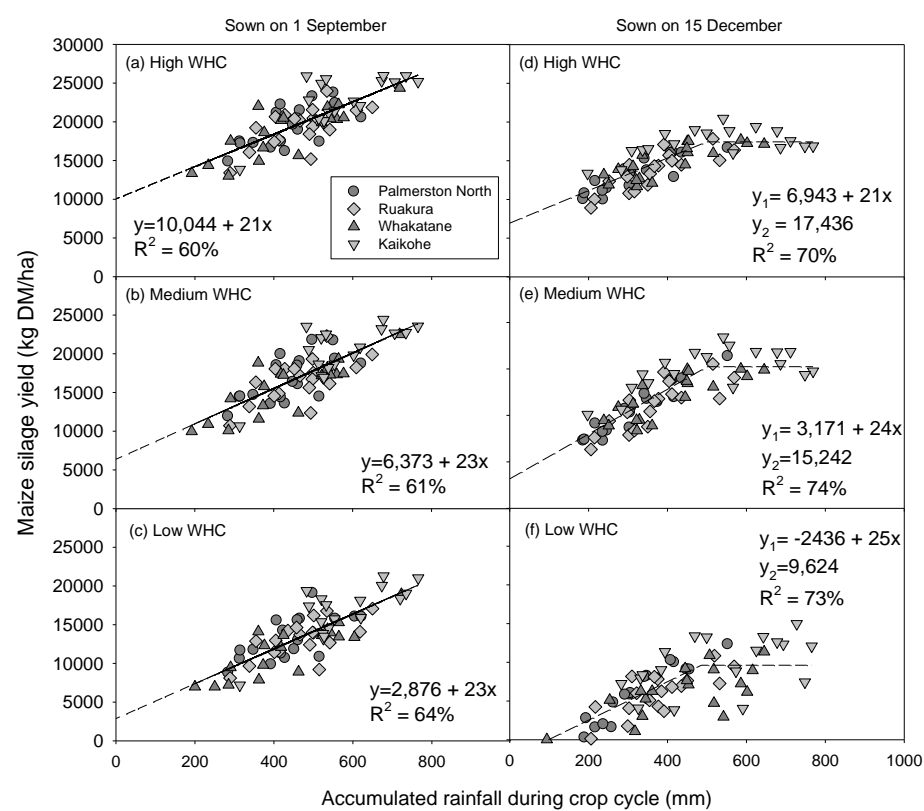
Figure 2. Simulated maize silage yield in relation to accumulated rainfall during the crop cycle for four locations, three soil water holding capacities of 160 mm (high WHC), 120 mm (medium WHC) and 80 mm (low WHC) during the earliest (1 September, graphs a–c) or latest (15 December, graphs d–f) sowing dates.

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An integrated systems thinking deliberative process to explore approaches for dealing with the impacts of land use on water quality

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Keywords: cumulative impacts, system, deliberation, water quality

Introduction

Livestock pastoral agriculture is a complex social-ecological system. It is reliant on the feedback between the condition and behaviour of the biological system and farmer behaviour to generate a range of outputs necessary for human well-being (food, fibre, income, lifestyle etc.) and ecosystem integrity (water quality, soil integrity, biodiversity etc.). The farmer, although a key decision maker, does not act in isolation but is embedded within a whole value chain system and local community network that integrates local to global scale pressures that drive behaviour. Increasing awareness of the connection between land use and farming practices and deteriorating water quality has intensified the debate around future land development and protection of water quality. The complexity and uncertainty that surrounds managing environmental outcomes while taking into consideration community values associated with social, cultural and economic outcomes means that a science- centric approach on its own will not address the issues (Bremer 2010). New collaborative forms of governance and approaches for enabling dialogue between policy makers, farmers as those members of the community who directly impact on land use and management and other community stakeholders are being trialled. We describe a systems deliberative process to investigate the issue of cumulative impacts of land use on water quality in the Hurunui catchment in Canterbury New Zealand.

Material and Methods

We adopted a six step iterative process based on the "Integraal" method as per O'Connor et. al. (2007, 2010) (Figure 1) and tested it in the Hurunui catchment through a series of five catchment workshops. We used the "common problem", as defined by regional policy, "the cumulative impact of land use on water quality". Eleven different stakeholder groups (four per group on average with variation between workshops) were formed: Iwi, Pastoral food and fibre, Dairy, Arable, Agribusiness, Recreation, Environmental NGO's, Rural woman, Energy, Tourism, Hurunui District Council, community health and Hurunui zone committee. To assist in building up a common understanding of the Hurunui catchment the stakeholders addressed the question "what are the factors and relationships that influence land, water and people in the catchment" using system methodologies (Maani and Cavana 2007). This process developed a causal loop diagram (CLD) as a conceptual model of the system. We then organised the problem into a Deliberation Matrix in terms of: eleven stakeholder groups each assessing the acceptability of three scenarios against five value criteria and three indicators per value criteria for each of four well beings: environment, economic, social and cultural. These values and indicators were obtained from a range of sources: long term community council plans, Canterbury Water Management Strategy, international literature and stakeholder groups' deliberation. The following three scenarios were developed and their impacts on a range of value criteria analysed by a team consisting of policy analysts, water, land and farm system scientists, social scientists and economists: Scenario 1: Current land use, based on the best assessment of current land use in the catchment; Scenario 2: Business as usual, assuming intensification in line with historic trends, and an increase in irrigation using efficiencies in existing water use; Scenario 3: Extensive Irrigation, assuming almost full irrigation of suitable land and included efficiency gains and more available water. After the first deliberation there was a request from the stakeholders for development of two further scenarios based on achieving certain water quality limits, these were: Scenario A: Conservative modelled, this scenario was based on achieving a very high certainty that the Natural Resource Regional Policy (NRRP) water quality objectives would be met; Scenario B 1990-95 Hurunui water quality aimed to achieve approximately the same water quality as existed in the period 1990 – 95, immediately post the introduction of the current irrigation scheme. Following the presentation of the scenarios and their impacts to the stakeholders they adjourned into their groups with a facilitator and assessed the acceptability (yes, no, don't know) of the scenario impacts across their value criteria. These assessments were then shared collectively creating an environment for learning what was important for each group.
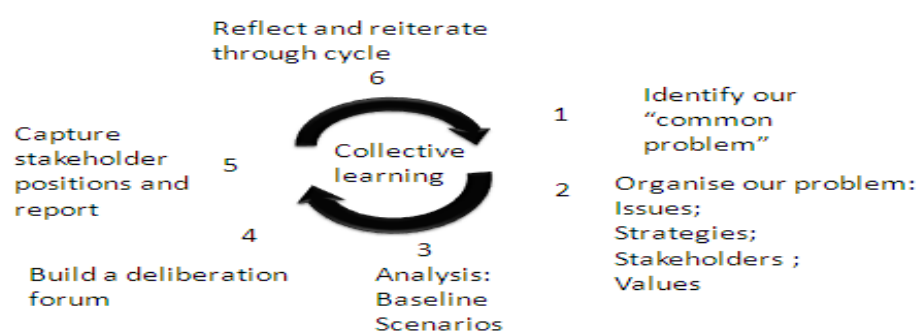
Figure 1 Integrated systems thinking deliberative process

Results and Discussion

The conceptual representation of the catchment (Figure 2) made transparent the relationships between land, water and people with a variety of subsystems related to: availability, reliability and efficiency of water; land management; profitable farming systems; recreational uses; indigenous cultural outcomes; community well being and economy. This widened the perspective of the stakeholders to take into account not only the environmental impacts of policy to address the problem but to sensitise them to social, cultural and economic outcomes. It also made transparent the importance of relationships and assisted in the identification of key systemic points of leverage and the unintended negative system consequences of actions applied to address a single issue. Three key points of leverage were identified, **water availability** as this influences what can occur on land and water ecosystems, **land use** influences a number of relationships including water quality, ecosystem and amenity values, farm profitability, local employment and community well being; **pollution** influences biodiversity, amenity

values and community well being as well as having a feedback to land use. Community well being is influenced by both economic performance generated by land use and water quality.
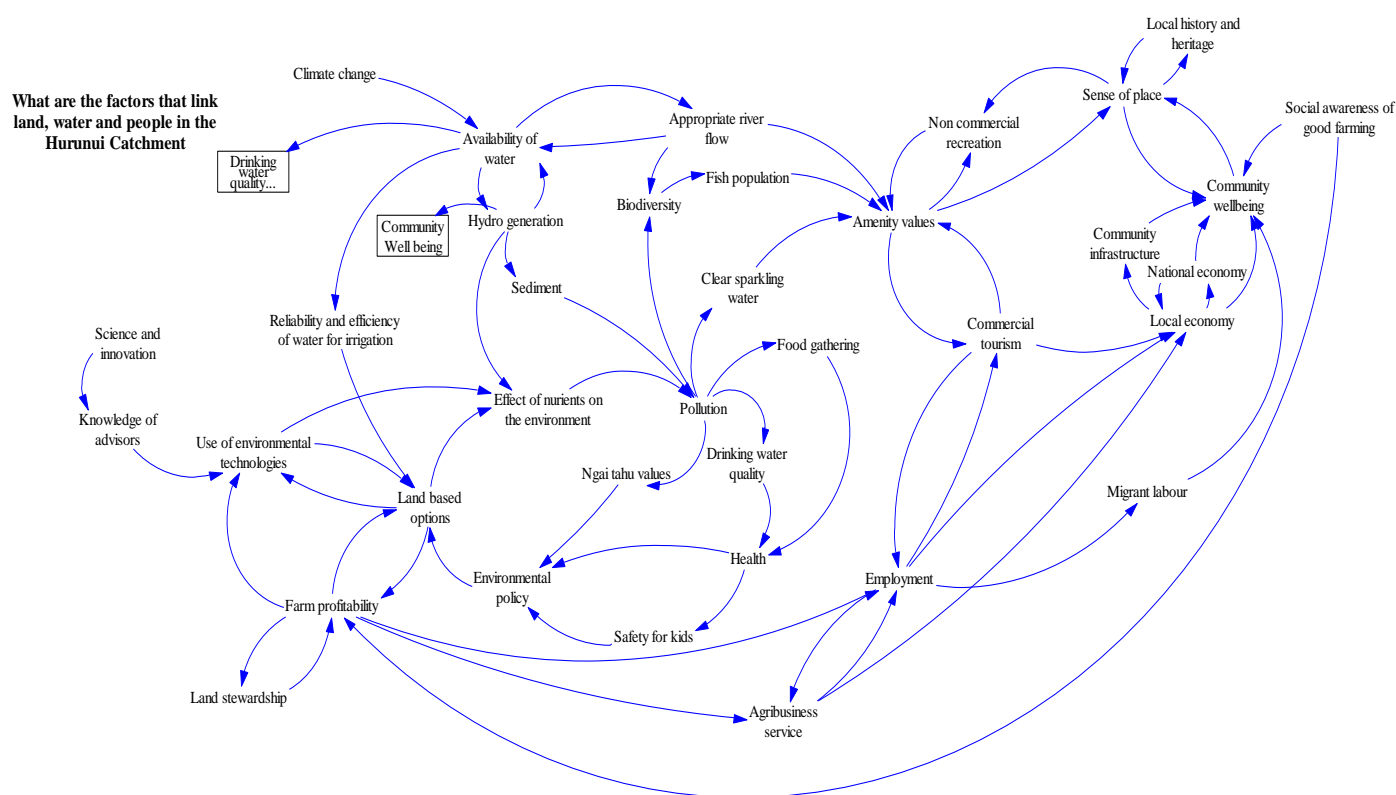
Figure 2 Causal loop diagram, describing the links between land, water and people in the Hurunui catchment

The conceptual map assisted in the identification of values pertinent to each stakeholder group for use in judging the impact of scenarios. Many of the value sets chosen by the stakeholder groups were similar e.g. water quality, biodiversity, reliable access to water, vibrant local community, employment, education, business profitability, sense of place etc. Differences were apparent in the indicators that described the values and it was by revealing this level of detail that the different perspectives of the stakeholders were made clear. There was a distinction between stakeholder groups (environmental, recreation) who chose environmental indicators related to in- stream water quality, biodiversity and associated ecosystems only and those who included agro-environmental (e.g. soil condition, vegetation quality) indicators (farmers, rural woman, agribusiness). The weighting of the value sets across stakeholders demonstrated a clear tension between environmental and economic outcomes. However environment and economy are interlinked (Figure 1) and there was a realisation by stakeholders that you cannot have one at the expense of the other.

Where unacceptable judgements of scenario impact were identified the stakeholder group utilised the conceptual systems map to look at the positioning of actions to counteract the negative consequence and from this and their own expert knowledge a number of mechanisms were identified to turn the judgement to acceptable. The mechanisms were focused in three areas aimed at (1) enabling behaviour (e.g. self auditing with back up regulation, (2) informing good management practice e.g. share principles not recipes and (3) reinforcing positive feedback cycles e.g. make available reliable water.

The systems deliberation process is a useful means by which stakeholders learn from each other, build trust and in order to inform the process of catchment management, and make the reasons for the choice of options transparent. Trade offs are also made transparent and an opportunity to test the acceptability of policy and industry strategy to meet intended outcomes prior to implementation adds value to strategic planning by taking into account of the needs of different stakeholders.

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Landcare – an adaptable community-based program for promoting environmental action, including conservation farming

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Keywords: Community action, holistic approach to NRM, overseas aid projects

Introduction

Landcare, a broad community NRM program in Australia, can help both developed and developing countries. Group-based, with a holistic approach to NRM, covering both production and conservation, it is egalitarian, democratic and respects local knowledge. It promotes partnerships between local groups and 'networks' and other organisations, in order to access resources. Landcare operates in rural regions, many members being local farmers, and in more urban areas where members take on resource protection and conservation.

Victoria's state government launched Landcare in 1986. It was accepted nationally in 1989-90 (Youl et al, 2006), and since then has motivated many farming communities to tackle and overcome, through group action, seemingly insurmountable problems such as salinity, soil erosion, water pollution, food security, community action on climate change, deforestation, skill development and biodiversity protection, restoration and enhancement. Interestingly, in 1986 a Landcare-type program with a similar name (literally 'landscape-care association') also emerged in Germany (B Bluemlein in Catacutan et al, 2009), to help farmers look after conservation values on their own properties and nearby communal land. Now fifteen countries or so in Europe, North America, Africa, Asia and the Pacific (Catacutan et al, 2009) take a Landcare approach.

In Australia, following rapid early growth, it is now a mature organisation. Many members have twenty years of practical, technical, educational, social and organisational Landcare experience, forming a wonderful resource for further expansion of Landcare at home and, increasingly, internationally. We see these people helping overseas through consultancies, volunteerism and maintaining effective links between existing and developing Landcare groups and networks.

Characteristics of Landcare

Landcare was derived from a number of other Victorian programs with various elements of government, industry and community involvement. In particular, Landcare brought together and built upon the Soil Conservation Authority's Group Catchment Areas, the farm tree groups, Potter Farmland Plan, the state-wide salinity management campaign and pest control activities. From its roots as a rural-based private land program, Landcare quickly broadened to encompass urban and public land issues.

Landcare also changed the role of government and private advisers in relation to their clients. With the community better educated and more information available from new and different sources, and farmer knowledge increasingly acknowledged and accepted, professional advisers became more coordinators and facilitators, rather than solely technical experts, their traditional status. In addition, as the development and funding of Landcare groups progressed, a new group of professionals emerged, taking on the specific role of group (and later network) coordinator. The daily skills they need include human relations, financial administration, IT, community education, ecology, communications and planning, besides physical endurance.

A central concept of Landcare important to conservation farming was that local farmers could tackle difficult issues working as a group rather than individually. The group approach extended to sourcing knowledge, and even initiating local research. For example, Birchip Cropping Group (BCG) in Victoria formed in 1992 after a group of local farmers identified a need for crop variety and management research and herbicide demonstrations in the immediate Birchip district. BCG's growth was so rapid that its research and ancillary activities now extend across the wider Wimmera-Mallee region, and encompass all of the elements that contribute to the prosperity of rural and farming communities (www.bcg.org.au).

While numerous community-based programs around the world operate well, a number of key features separate Landcare from many of these.

1. Landcare has a holistic outlook and recognises that NRM covers both production and conservation; and that there is a significant interaction between many aspects of NRM.

2. Local Landcare groups can operate individually or be part of a broader 'network' of groups. There is no requirement for a group to be part of, and subject to, a hierarchy, or to focus on issues that are directed from afar.

3. Australians have found that these 'networks', which are sub-regional or even regional clusters of groups, are frequently more efficient than groups operating on their own. At network scale they can better generate and share resources and tackle bigger projects. Indeed many have become 'community enterprises' directed by boards.

4. Landcare promotes partnerships between these local groups or 'networks' and other organisations to access resources, such as funding, skills, knowledge or other forms of support. These partnerships can be at local, state, national, corporate or international level.

5. As stated earlier, Landcare is egalitarian, democratic and respects local knowledge. Local decision-making is paramount, with strong provision for planning and monitoring.

6. Local Landcare group members are all volunteers aiming to work together to improve local natural resources and landscapes, but coordinators/facilitators (the terms are often synonymous) are paid – many of these positions are part-time.

7. Landcare can operate in rural areas, where many members are local farmers, and in more urban areas where Landcarers take on the protection and improvement of NRM on public land, such as coastal zones, state and national parks and local nature reserves.

Landcare expansion

Growth in Landcare in Australia was rapid with 5000 local groups forming in the first fifteen years, across all states and territories, becoming an accepted and vital entity in most communities. Overseas, Landcare is a growing force in the Philippines to arrest land degradation derived from severe soil erosion on steep cropping land, and to develop more sustainable food production. (Cramb et al, 2007) In Africa, the Landcare approach is seen as a viable way to improve food security for impoverished rural communities through reduction in land degradation and improving technical skills and knowledge of food production and protection (Yatich et al, 2009).

Communities usually need supporting finance and knowledge to initiate action and develop the skills required to run appropriate NRM programs. There is an opportunity here for Australian Landcare groups and 'networks' to build significant partnerships with resource providers at local, national and international levels. However experience in Australia has shown that groups also require support and guidance to develop the skills just to make effective partnerships. A program of community leader training began in early Landcare times (P Robinson in Youl, 2006), and is a strong component of the ACIAR-AusAID project in the Philippines (ACIAR, 2009).

Experienced Australian Landcare members could help groups in other countries through:

1. consultancies via corporate, national and international agencies

2. personal volunteerism, or with local, national or NGO support

3. links between developing and existing Landcare groups/networks

4. advice on fundraising, based on how Landcare collaborates successfully and substantially with Australia's corporate sector

Currently three main Landcare organisations work at an international level, often together, to support and encourage a Landcare approach. For the last thirteen years the Secretariat for International Landcare (SILC – www.silc.com.au), an Australian NGO set up in 1998 after its principals helped initiate Landcare in South Africa, has focused on showing overseas visitors how Landcare operates here. More recently it has helped promote Landcare in Indonesia and Sri Lanka. Kenya-based Landcare International (LI – www.landcareinternational.net) has the support of the World Agroforestry Center. It has stimulated Landcare uptake in Africa, and works at government and agency levels to help countries recognise Landcare benefits.

Australian Landcare International (ALI – www.australianlandcareinternational.com), another NGO, was established in 2008 to create and enhance links and support to developing Landcare groups. ALI aims to attract experienced Australian Landcare members to assist through various mechanisms the expansion of Landcare, particularly in developing countries. Currently it is establishing outreach programs to new Landcare groups in several Asian, African and Pacific countries.

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Brazilian public policy to reduce deforestation and to implement Conservation Agriculture in the Amazon

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Key-words: deforestation, conservation agriculture, public policy, Amazon.

Introduction

About 18% of the Amazon rainforest has already been deforested. In order to solve the illegal deforestation problem in the Amazon, the Federal Government in 2004 implemented the "Action Plan for Prevention and Control of Deforestation in the Amazon", coordinated by the Central Brazilian Government, which brings together 13 Ministries and related agencies. This Plan main result was the reduction of deforestation rate. For example, the reduction decreased from 21,651 km² in 2002 to 6,451 km² in 2010, as shown in Figure 1 (Brasil, 2010). In 2009, the Federal Government listed 43 counties of Legal Amazon which is the socio-geographic division of Brazil comprising the total Amazon territory. These counties are responsible for more than 55% of deforestation in this region (Figure 2). This region became known as "Arc of Deforestation" (in Portuguese "*Arco do Desmatamento*"). The government intensified the Federal Police actions in this region, which was known as "Arc of Fire Operation" (in Portuguese "*Operação Arco de Fogo*"). During this Operation were arrested loggers and closed illegal logging companies, which led to reduced rates of deforestation but also caused a socioeconomic instability in this region.
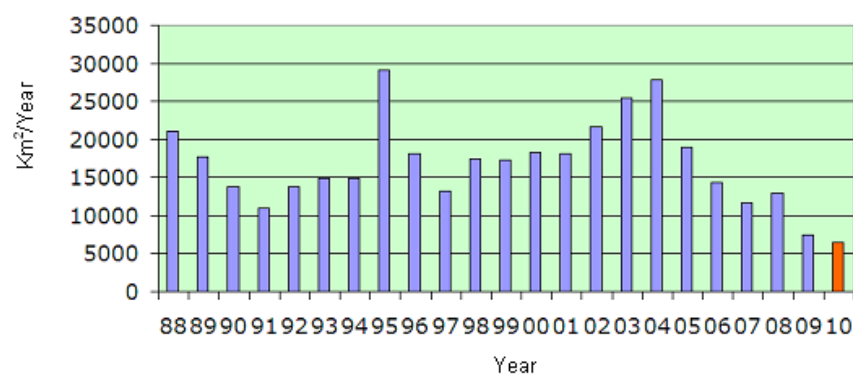
Figure 1 – Annual Deforestation Rates in Legal Amazon
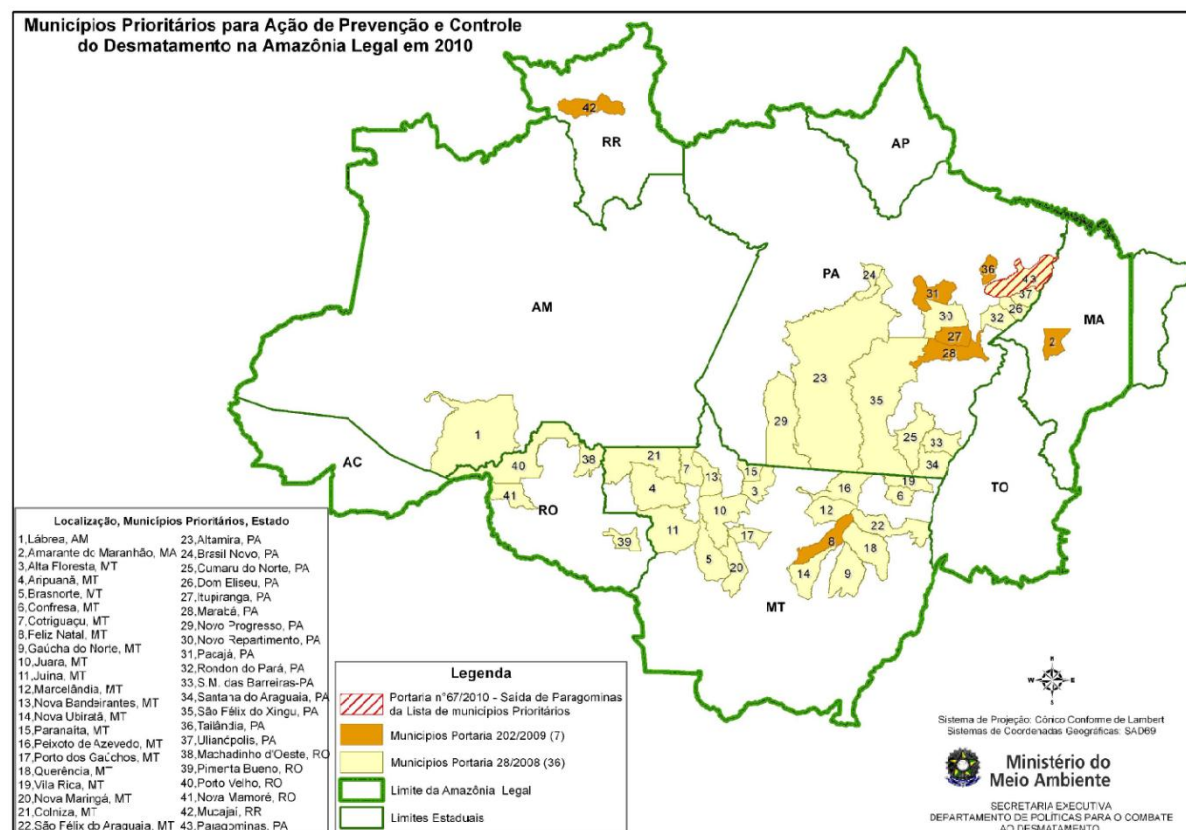
Figure 2 – Priorities counties of Legal Amazonia to Prevention and Control of Deforestation in the Amazon

Green Arc Operation: Public Policy to Reduce Deforestation and to Implement Conservation Agriculture in the Amazon

The "Green Arc Operation" (in Portuguese "*Operação Arco Verde*") was created to decrease the social impact of actions caused by the "Arc of Fire Operation". This Operation initiated in 2008 with main goals: promote sustainable agricultural systems in the counties elected as priorities for the control and reduction of deforestation in the Amazon; to stimulate the transition to sustainable agriculture model; and, complementation of the Federal Police actions to decrease deforestation. The Operation goal is to substitute the environmentally inappropriate activities by sustainable agricultural systems to support managers and farmers, politically and technically, in those counties. This support should facilitate the transformation for legal activities and sustainable agricultural production, and better use of native forests.

Actions will be undertaken for technology transfer, training technicians and farmers, location of nurseries and seed collecting of native species. Many Ministries and public government agencies are involved with the "Green Arc Operation". EMBRAPA is the Brazilian Agricultural Research Corporation and collaborates in this public policy with technology and knowledge transfer, and to the goals of the Operation, through the following technologies: Agroforestry Systems; Crop-Livestock-Forest Integration under No-tillage; Fisheries and Aquaculture; Forest Management; and, Good Agricultural Practices.

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Scope of sustainability – do castor beans and the biodiesel industry offer family farmers a sustainable development opportunity in Brazil?

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Keywords: family farming, biofuels, sustainability assessment, sustainability indicators

Introduction

Sustainable bio-energy is interwoven with sustainable rural development for family farmers. In this context, the Brazilian government is pursuing a "social inclusion" goal by means of family farmers providing a fraction of biodiesel feedstock. In 2009, the state-run petroleum company established a biodiesel plant in the north of Minas Gerais State. Family farmers in this region are faced with the prospect of entering agreements with the industry to provide castor beans (castor). Fewer family farmers than anticipated are engaging and this raises doubts regarding the sustainability of this option for family farmers (da Silva César and Batalha 2010). Exploration into the sustainability of such farmer-industry agreements from the farm-level perspective is timely. We conduct an exploratory assessment using sustainability indicators. We aim to: (i) capture and explore the scope of sustainability if family farmers choose to cultivate castor and (ii) explain sustainability as a function of current yield levels, alternative yield levels and alternative management decisions at the farm level.

Material and Methods

Case study area and farming system

Montes Claros is a municipality in the north of Minas Gerais. The mean annual rainfall is1035 mm with 940 mm falling during the distinct wet season. We focus on the most numerous family farm type within Montes Claros identified and described using a similar farm typology as Tittonell et al. (2005). This is an extensive cattle system where the mainplant production activities are Brachiaria pasture (30 ha), maize grain for cattle intercropped with beans in the same rows for the household (1-2 ha) and sugarcane for cattle (1 ha). The average herd size is 25 heads and cheese is the most common income-generating product. Labour is sourced from the household and supplementary animal feed during the dry seasonaccounts for most of the purchased inputs annually.

Sustainability assessment

We selected four farms from a household survey to represent the range in combinations of current maize and milk productivity. 'Farm 1' represents low maize and milk yields (340 kgha-1 and 436 l cow-1 year-1), 'Farm 2' represents moderate maize and high milk yields (1148kg ha-1 and 2555 l cow-1 year-1), 'Farm 3' represents moderate maize and high milk yields(2550 kg ha-1 and 2268 l cow-1 year-1) and 'Farm 4' represents high maize and moderate milk yields (4080 kg ha-1 and 1200 l cow-1 year-1). Sixteen alternative scenarios were designed to capture different combinations of castor yield levels with different farm-level management decisions relating to cropping area and animal feeding. Four levels of achievable castor yields were included (289, 560, 642, 1139 kg ha-1). These were sampled from a literature review of relevant castor trials conducted in Brazil. Two land use decisions of contrasting castor areas were included (*Castor area 1:* to replace 1 ha of area currently cropped with maize and beans with castor and beans; *Castor area 2:* to replace the total area currently cropped with maize and beans plus 1 hectare under pasture with castor and beans). Two different animal feeding strategies in the light of sacrificing on-farm fodder production were included (*Feeding strategy 1:* to replace all sacrificed maize and pasture production by purchasing supplementary maize and renting additional pasture; *Feeding strategy 2:* to sacrifice milk yields due to losses in fodder production).

Three sustainability criteria relevant to family farmers in Montes Claros while also consistent with broader debates about sustainable bioenergy were selected. These are that biofuel production should: con tribute to economic development of family farmers; increase the stability of family farmer livelihoods and; retain or improve the soil and soil fertility. Justifications for these criteria are that in Montes Claros household income is currently subsidized by the government and we observed economic motivations driving a trend away from family farming. Further, households experience high levels of climate driven risk leading to unstable incomes between dry and wet seasons as well as between dry and wet years. Finally, soil fertility decline is evident in Montes Claros. We observed bare soil, soil erosion and farmers have reported pasture productivity decline. Indicators of performance against these criteria were selected and calculated according to the methods in Table 1 for 68 farms (4 current + 4 *X* 16 alternatives). Indicator values and values relative to the respective current farms were compared between farms, castor yield levels, castor areas and feeding strategies.

Table 1. Sustainability criteria and indicators for a farm-level sustainability assessment of castor entering the family farming system in Montes Claros

Selected sustainability criteria	Selected indicators *(calculation method for a single year)*
Biofuel production should contribute to economicdevelopment of family farmers	Income (R$ household-1) *(on-farm revenues minus on farm expenses)*
Biofuel production should increase the stability of family farmer livelihood	Labour inputs and labour use efficiency (days year-1; days 100R$-1) *(sum of labour hours for each activity performed on-farm; labour inputs divided by income)*
Purchased inputs and purchased inputs use efficiency (R$ year-1; R$ R$-1) *(sum of purchased inputs such as fertilizers and animal feeds for each onfarm activity; purchased inputs divided by income)*	
Biofuel production should retain or improve the soil and soil fertility	Nitrogen balance (kg ha-1) *(change in soil nitrogen stock within one year; the sum of nitrogen inputs minus the sum of nitrogen outputs*

Results and Discussion

Table 2 shows that against the indicators in this study, on average, castor does not improve the performance of this farming system. However, the N-balance is an exception where on average more nitrogen is retained in the system due to the castor activity. Large ranges in all the indicator changes in this table demonstrate the impact of current productivity and the alternative scenarios on indicator scores. Current productivity proves to be an important determinant. E.g. Figure 1a shows that household income consistently increases due to castor for 'Farm 1' while income is reduced for the other 3 farms. For the latter 3 farms we see the importance of maize to support animal production such that the introduction of castor at the expense of current crop production proves less favourable. It is also shown that the highest yielding castor activity (open circles in Figure 1a) results in an increase in household income while the other yield levels decrease household income. As well, the high yielding activity is the only example with an average improvement in labour use efficiency (reduction of 0.1days 100R$-1 versus an average increase of 0.2 days 100R$-1 for the other three yield levels).The spatial extent of castor cultivation significantly impacts labour and purchased inputs where the larger area under castor demands significantly more cash and labour. Figure 1bshows the results for purchased inputs. This figure also shows that this indicator is impacted by different feeding strategies. Supplementing all maize replaced by castor with the equivalent in purchased feed (feeding strategy 1) is less favourable in terms inputs compared with feeding strategy 2 (open circles in Figure 1b).

Table 2. Mean (and range) of changes in indicator values relative to the current farming systems

Indicator	Mean (range)
Income (R$ household-1)	-335 (-2878 to +2125)
Labour use efficiency (days 100 R\$$^{-1}$)	+0.1* (-1.9 to +0.9)
Labour inputs (days)	+16.3 (-2.0 to +41.6)
Purchased inputs use efficiency (R$ R\$$^{-1}$)	+0.05* (+0.02 to +0.18)
Purchased inputs (R$)	+838 (0 to +3634)
Farm gate N-balance (kg ha-^{1}) +3 (-8 to +24)	

Positive change indicates a reduction in efficiency
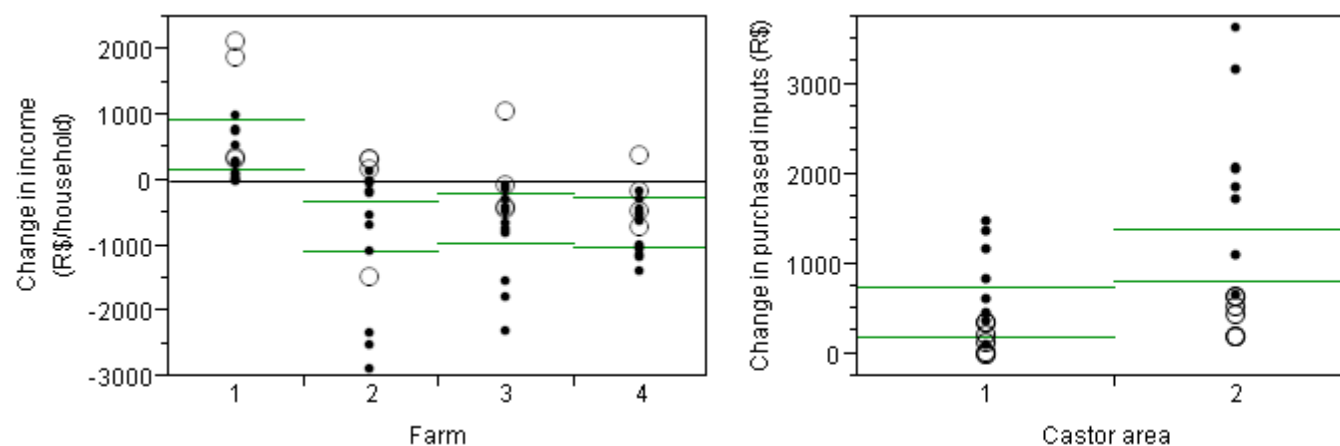
Figure 1. Change in indicators due to castor area scenarios grouped by productivity and decision variables with lines indicating 95% confidence intervals about the group means (a) Income indicator by current farms, open circles show the high yielding (1139 kg ha-1) castor activity (b) Purchased inputs indicator by alternative extent scenario, open circles show the feeding strategy 2.

In terms of the economic development, stability of livelihood and soil fertility criteria studied here there are opportunities for policy makers and farmers to enhance the sustainable development afforded to farmers through cultivation of castor. Against the economic development indicator, current 'low-productivity' farms such as 'Farm 1' have greater scope for improving performance with castor. The sustainability scope for currently 'high productivity' farms is restricted to scenarios with high yielding castor. There is a need to tread carefully when impacting current animal production as we show that increasing the area of castor beyond the currently cropped area is not desirable due to the greater demand on purchased and labour inputs.

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Opportunities for Conservation Agriculture in the EU Common Agricultural Policy 2014-2020

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Keywords: Conservation agriculture, European Union, Common Agricultural Policy, CAP, agri-environment

Introduction

In the past, many relevant European Union (EU) documents made reference to the environmental problems caused by agriculture. In those papers, the concept of Conservation Agriculture (CA) as a possible solution was either omitted or timidly named, although sustainable agriculture was proclaimed as an objective of the EU in the Amsterdam treaty in 1999. EU's position regarding several worldwide environmental problems, i.e. climate change, water and soil threats, is well known. However, to which extent these positions will be reflected in EU agricultural and environmental policies and concrete and binding measures in all member states for the period of 2014-2020 is still an open question.

Through its Common Agricultural Policy (CAP) EU claims to address the main concerns of its agriculture and rural development. In this context, EU launched a Communication (COM (2010) 672 final) named *"The CAP towards 2020. Meeting the food, natural resources and territorial challenges of the future".* Based on this paper we analyse the deliverables that CA could provide to achieve the overall objectives established for the CAP in the horizon 2014-2020.

The CAP 2020

Europe is about to redefine its Common Agriculture Policy (CAP) for the near future. The question is whether this redefinition is more a fine-tuning of the existing CAP or whether thorough changes can be expected. Looking back to the last revision of CAP the most notable change is, undoubtedly, the concern about EU and global food security. The revival of the interest in agricultural production became already evident during the Health Check as a consequence of the climbing commodity prices in 2007/08. It does therefore not astonish that the "rising concerns regarding both EU and global food security" are the first topic to appear in the list of justifications for the need for a CAP reform. Other challenges mentioned in this list such as sustainable management of natural resources, climate change and its mitigation, improvement of competitiveness to withstand globalization and rising price volatility, etc. are not new but apparently considered worthwhile to be maintained and reappraised.

Referring to the concepts of the *EU 2020 Strategy*, the Commission wants CAP to contribute to the *Smart Growth* by increasing resource efficiency and improving competitiveness, to *Sustainable Growth* by maintaining the food, feed and renewable production base and to *Inclusive Growth* by unlocking economic potential in rural areas. In its communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, the European Commission (2010) defines 3 general objectives for the future CAP:
- Objective 1: Viable food production
- Objective 2: Sustainable management of natural resources and climate action
- Objective 3: Balanced territorial development

Figure 1 resumes, in more detail, the objectives of the EU Commission proposal for the new CAP 2020. Viable food production, in simple terms, means that EU farmers are given the means to produce the same or even more food at lower costs to meet the growing demand of food, feed, fibre and biofuels and the competition from a globalized world market, and that consumers can buy food at acceptable prices and quality. Sustainable management of natural resources and climate action means matching agricultural production with the simultaneous protection of soil, water, biodiversity, etc., and expects that agriculture contributes to the mitigation of greenhouse gases. Finally, balanced territorial development includes the maintenance and diversity of production and that, despite severe natural constraints, especially in terms of soils and climate, agricultural activity is secured, which seems only viable through the adoption of low cost and probably extensive production systems.
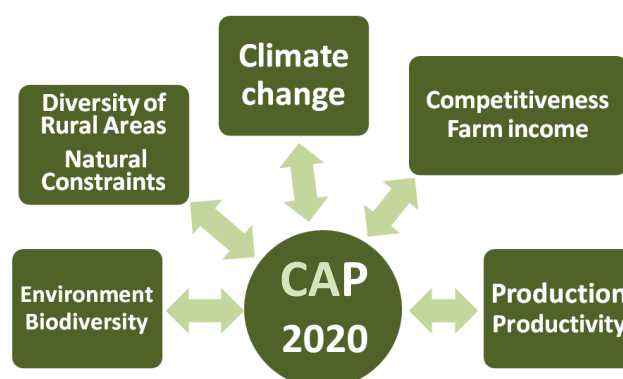
Figure 1: Main objectives to be met by the revision of the Common Agricultural Policy (CAP)

The *Sustainable Crop Production Intensification* approach proposed by the Plant Production and Protection Division (AGP) of the Food and Agriculture Organization of the United Nations (2011) goes in the same direction focussing on the need to feed a growing population while coping with an increasingly degraded environment and uncertainties resulting from climate change. This concept is supposed to provide "opportunities for optimizing crop production per unit area, taking into consideration the range of sustainability aspects including potential and/or real social, political, economic and environmental impacts". But what does this mean in practice and how can the proposed CAP 2020 objectives be made compatible with each other?

At the moment, it appears that the EU Commission wants to adjust the way of EU agriculture towards sustainability, in its holistic meaning. This means the search for the best compromise between the different dimensions of sustainability, which are economy, ecology and community (farmers and consumers). Today, in commercial farming there probably will be no single production system that can claim to be the "sustainable system". Obviously, the definition of the before mentioned best compromise depends on the priorities established. Now, with regard to the priorities defined in the revision of the CAP, what requirements should agricultural production systems meet to provide not the optimal but the best solution?

In practical terms, they should be productive both with regard to total production and per unit of land. They are expected to be resource efficient, which means to produce more with less, especially what soil and water, but also other inputs such as fertilizers, plant protection products, energy and labour are concerned. The achievement of these two goals would not only contribute to competitiveness and economic sustainability but also to environmental protection and biodiversity. Furthermore, sustainable production systems have to reduce as much as possible off-site transport of soil and water and the nutrients and plant protection products contained in eroded sediments and surface runoff. Diversity and maintenance of agricultural activity in less favoured regions are only achievable if production systems are competitive, that is cost extensive and productive at the same time.

The concomitant approach towards all these objectives requires a production process, which respects as best as possible natural conditions while taking advantage of the knowledge and means at hand to potentiate productivity while esteeming and improving the environment and the production base for future generations. This is the veracious meaning of agricultural sustainability and *Sustainable Crop Production Intensification*, which are best achieved through the concept of Conservation Agriculture (CA) based on three basic principles: a) minimal soil disturbance, b) permanent soil cover and c) crop diversity in the form of well balanced and wide crop rotations.

Discussion. The role of Conservation Agriculture

CA refers to the above mentioned set of practices which permits agricultural land use while changing the soil's composition, structure and natural biodiversity as little as possible, thus defending it from degradation processes. The soil is kept protected from erosion and surface runoff; soil aggregates are stabilised, organic matter and the fertility level naturally increase, and less surface soil compaction occurs. Furthermore, the contamination of surface waters and the emissions of CO_2 to the atmosphere are reduced, and biodiversity enhanced. Reducing costs while maintaining yields drive to a better economical result at the end of the season in most of CA fields. Therefore and regarding the three Objectives of the new CAP, CA principles allow achieving the goals by:

- Objective 1: Viable food production
    - providing similar or even higher yields through improvements in soil structure, organic matter and overall soil fertility;
    - increasing cost effectiveness by reducing inputs in form of machinery, energy, labour and fertilizers.
- Objective 2: Sustainable management of natural resources and climate action
    - reducing runoff and erosion through better aggregate stability and protective cover of the soil by crops or crop residues;
    - diminishing off-site damage of infra-structures and pollution of water bodies through less runoff and a much reduced sediment load;
    - maintaining in-field and off-site biodiversity through the absence of destructive soil disturbance, protective soil shelter and less off-site transport of contaminants;
    - mitigating CO_2 emissions through reduced fuel consumption and sequestration of atmospheric carbon into soil organic matter;
    - increasing the share of green water through better infiltration and water holding capacity and decreasing unproductive losses through evaporation.
- Objective 3: Balanced territorial development
    - maintaining the diversity of rural landscape through enhanced crop diversity and cover crops;
    - maintaining disfavoured rural areas under production through economically viable production methods.

The fact that CA is successfully applied under very different climate conditions should be an indicator that there is a potential for the adoption of CA in Europe too. Since its foundation in 1999, the European Conservation Agriculture Federation (ECAF) (2011) struggles for the widespread adoption of CA in its 15 member countries. Whereas in a few countries a moderate success could be verified (Spain, Finland), most of the others lag far behind in its adoption (Basch et al. 2008).

The opportunity for CAP measures underpinning the adoption of the principles of CA for mainstream agriculture (via Pilar I or Pilar II of the CAP measures) is the best European farmers have ever faced. More and more scientific papers support the use of CA in Europe and more and more farms are successfully implementing CA (Arvidsson, 2010, Álvaro-Fuentes et al. 2008, Basch et al., 2008, Tebrügge and Böhrnsen, 1997, Basch et al., 1995). Hopefully this solid scientific and empirical evidence will not be invisible for EU policy makers.

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Farmers group approach and stakeholder integration for the development of Conservation Agriculture: the case of Lao PDR

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Introduction

Over the past fifteen years, farming systems have changed drastically in southern Xayabury province, Lao PDR. Rotational cultivation systems and fallow periods are disappearing, being gradually replaced by a 'resource-mining' agriculture that has serious environmental costs, including increased soil erosion, loss of soil fertility, and chemical pollution of the environment. Under the Programme for Capitalization in Support of Rural Development Policy (PCADR), and its extension and research components, conservation agriculture, based on the use of direct seeding mulch-based cropping systems (DMC), was developed as an alternative to break off the degradation of the physical environment and the reduction in income and work productivity in these rainfed cropping systems. Farmers were placed at the heart of the research and development process, thereby enabling concerted construction and adjustment of innovations, with regular discussions between farmers, agronomists, researchers and extension officers, with ongoing feedback on innovations being tested under true conditions (Slaats and Lestrelin, 2009). The aim of this article is to present and discuss the approach taken to promote the dissemination of these innovations, centring research and development actions on farmer groups. This study discusses the results obtained and details the constraints for launching such an initiative and ensuring its perpetuation over the long term.

Materials and Methods

A holistic approach, based on a permanent link between research and development, was implemented by this research and development project, in partnership with the department of agriculture and forestry of Xayabury province. This approach was organised under two main principles:

- An iterative process. The technological offer, the methodology and the organization were constantly adapted to the evolution of the bio-physical, socio-economic and political context and to the demand of the various stakeholders involved. Constant evaluation at each stage enabled real-time adjustment of activities and reorientation of programmes, and so optimized the use of all resources.
- An integrating approach that united research, extension, training, communication, financial and policy decisions from the very start of the activities and throughout its cycle. This required links with all actors in rural development: farmers, extension officers, trainers, researchers, the private and banking sectors, and political and financial decision makers.

Work at the field level was based on four main components (Bouahom et al., 2005), focused on farmer groups, namely: (i) a precise analysis of the agricultural and economic environment, (ii) implementation of experimental designs encompassing a wide diversity of cropping systems but also simple technologies enabling farmers and extension officers to assess the evolution of the systems and their characteristics over the medium term, (iii) creation of an environment of professional training and exchanges between farmers, agronomists and extension officers organized around practical training in the field and (v) dissemination of these innovations on a larger scale, with close technical support for farmer groups organised.

Results and Discussion

Technologies focusing on agroecosystem processes such as organic matter accumulation, water use efficiency, soil biological activity, resource preservation and general enhancement of agrobiodiversity and synergisms between components, were to be promoted. A broad range of options was developed to enable farmers to adjust their systems in line with changing market demands. These demonstration fields, managed by researchers and extension officers, served as a basis for creating knowledge and for training. As a result, 32 extension officers were trained and involved in these research-development operations over the 2006 – 2008 period. Those extension officers were able to set up a total of 45 farmer groups involving a total of 1254 families (Table 1). The first systems to have been disseminated are based on the management of crop residues. This system is far from efficient in terms of fertility improvement and weed control, but we felt it was preferable initially only to modify part of the cropping system (soil management), in order to favour the gradual learning process. At the same time, on a smaller scale (150 ha) some intercropping between rice-bean (*Vigna umbellata*) and maize was proposed, in order to produce two commercial crops in the same wet season, generate additional income, limit the impacts of inter-annual variations in maize prices, and take advantage of the agronomic benefits of such a species. One of the greatest constraints on dissemination of that system was the control of fire and cattle grazing during the dry season. Thus, involvement of the village authority and watershed management strategy was an important point at this stage.

For many years, the development scheme adopted in the south of Xayabury is largely based on an opportunistic approach (Tran quoc et al., 2006). This "mining" approach, with serious degradation of natural resources and increasingly pronounced social differentiation within communities, is partly attenuated today by the high prices for agricultural products. It is a matter of taking advantage of this situation, which combines high export volumes with rising prices, to introduce a development scheme based on natural resource management, in order to preserve the productive potential of this region and the stability of these agricultures. To that end, Julien (2007) proposed a levy on exports, taking the example of maize production with a deduction of US$ 1 per ton exported. These funds would be reinvested initially for specific Conservation Agriculture operations and could, after a probationary phase, feed development operations in a broad sense. This development scheme combined with the introduction of agri-environmental measures, is beginning to take shape under the impetus of the provincial authorities, the Ministry of Agriculture and Forestry, and with support from PCADR.

Table 1: Evolution of the number of farmer groups, families and DMC areas (ha) between 2006 and 2008 in southern Xayabury province, Lao PDR.

District	2006			2007			2008		
	Farmer groups	Families	Area (ha)	Farmer groups	Families	Area (ha)	Farmer groups	Families	Area (ha)
Botene	5	104	82	8	137	151	10	328	574
Kenthao	7	173	213	11	287	343	13	464	627
Paklay	6	75	83	11	196	277	12	316	468
Thong Mixay	3	33	23	9	69	59	10	146	118
Total	21	385	401	39	689	830	45	1254	1787

Regarding farmers groups organisation, a lack of official statute or formal recognition by the local authorities or the economic operators could limit in the near future their development and working efficiency. Human and financial assistance will have to be identified to ensure the functioning and running of these groups and their gradual structuring towards farmer associations. Indeed, the groups will only be able to develop and evolve towards an associative type structure and play a clear role in future development if the State invests in that structuring. Eventually, crop processing and marketing will have to be incorporated into these structures.

Moreover, and as mentioned by many farmers, the lack of banking sector involvement holds back the progress of their farming systems and cultural practices. In southern Xayabury province, most credits in kind (tillage, inputs) or in liquidity is provided by the private sector. This situation generates high dependency on the private sector practising loans with high interest rates. These groups and farmers who commit themselves to environmental protection should be able to turn to incentive credits at reduced rates, particularly so that they can buy agricultural equipment and have access to seasonal credit. Additionally, whoever the stakeholders involved (farmers, extension officers, traders, decision-makers), the absence of a communication and information network, structured right from the outset of operations, is a handicap to the advancement of such an initiative. It is a matter of strengthening an existing but informal network between the different players (research – extension – private sector – farmer).

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Harnessing ecosystem services with Conservation Agriculture in Canada and Brazil

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Ecosystem Services

Societies everywhere benefit from the many resources and processes supplied by nature. Collectively these are known as ecosystem services, and include clean drinking water; edible and non-edible biological products; processes that decompose and transform organic matter; and regulatory processes that maintain air quality. Many of the key ecosystem services are considered to be important environmental services of a public goods nature (MEA, 2005). These environmental ecosystem services operate at various nested levels from field scale to agro-ecological or watershed scale and beyond. Conservation Agriculture (CA) facilitates ecosystem services on agricultural land, particularly those services related to provisioning, regulating and supporting and derived as a result of improved conditions in the soil volume used by plant roots (Kassam et al., 2009). This improvement in the porosity of the soil is effected by the actions of the soil biota, which are present in greater abundance in the soil under CA. The mulch on the soil surface in CA systems, protects against the compacting and erosive effects of heavy rain, buffers temperature fluctuations, and provides energy and nutrients to the organisms below the soil surface. When the effects are reproduced across farms in a contiguous micro-catchment within a landscape, the ecosystem services provided – such as clean water, sequestration of carbon, avoidance of erosion and runoff – become more apparent. The co-benefits of more water infiltrating into the ground beyond the depth of plant roots is perceptible in terms of more regular stream flow from groundwater through the year, and/or more reliable yields of water from wells and boreholes. The benefits of carbon capture become apparent in terms of the darkening colour and more crumbly 'feel' of the soil, accompanied by improvements in crop growth, plus less erosion and hence less deposition of sediment in adjacent waterways.

CA-based ecosystem services operate in different parts of the world and include: the agricultural carbon offset scheme in Alberta; the hydrological services from Paraná III Basin in Brazil; the control of soil erosion in Spain; the controlling of water erosion and dust storms, and combating desertification and drought in the loess plateau of the Yellow River basin in China; and reducing susceptibility to land degradation in western Australia. Controlling land degradation, particularly soil erosion, caused by tillage, exposed soils and depletions of soil organic matter, has been a main objective of most of such initiatives. These initiatives in Canada and Brazil are elaborated below.

Canada: Carbon Offset Scheme in Alberta

The province of Alberta has operated a greenhouse gas offset system since 2007 that allows regulated companies to offset their emissions by purchasing verified tonnes from a range of approved sources including agriculture projects (Haugen-Kozyra and Goddard, 2009). This compliance system for large emitters has provided a rich venue for learning on behalf of all players – the regulated companies, government, scientists, consultants, aggregator companies and farmers. Climate change legislation was amended in 2007 to require regulated companies to reduce their emissions to a set target below their 2003-5 baseline. If they could not achieve their target in any year, they could settle their accounts with any of three options: pay into a research fund at a fixed rate of C$15 per tonne CO_2e; trade emission performance credits if they were generated by any company reducing emissions beyond their target or; purchase verified offsets generated within Alberta using Alberta government approved protocols. The latter option triggered interest and activities in developing protocols across all industrial sectors including agriculture. Offset tonnes trade at a discount to the C$15 fund payment option in order to cover the aggregation and transaction costs.

The Alberta government provides the enabling legislation and regulations. They also provide oversight of protocol development and approvals. Beyond that, the private sector invests in development of protocols, aggregation of offsets and assembly of projects, third party verification of projects and, the bilateral sales to the regulated emitters. A non-government agency, Climate Change Central also plays a role of facilitator and is the designated operator of the Registry of the offsets. All verified tonnes are serialized and tracked by the registry through to the retirement (used for a compliance year) of a particular tonne. The regulator/government ministry holds annual review meetings with the players in the market to review performance, new developments, regulatory changes and guidelines.
Over the last two years the amount of offsets used by companies for compliance has been steady at about 36% of the total annual accounts (Climate Change Central, 2011). Agricultural offsets have contributed about 36% of all offsets. The most popular protocol has been the Tillage System protocol which acknowledges the soil carbon sequestration through implementation of No-Till practises. The Tillage System protocol has contributed over 5 million tonnes of offsets worth about C$60 million over the last four years of the offset system.

The offset system has had many co-benefits beyond reducing greenhouse gas emissions and reducing the footprint of industries. Scientists come together in helping to develop protocols and share a systems view of the production system under review. Science and policy come together and integrate to form protocols and develop a market. The private sector of aggregator and verification companies have integrated efforts and developed streamlined systems to bring offsets to market efficiently. Farmers have developed improved production and record systems. Very often the financial benefits to the farmer by adopting a protocol far exceed any offset payment for the greenhouse gas savings portion. All players are now further along the capacity curve to be in a better position to see and take advantage of other ecosystem good and services opportunities.

Brazil: Watershed Services in the Paraná Basin

As part of a strategy for improvement, conservation and sustainable use of natural resources, the Itaipú Dam *Programa Cultivando Água Boa* (cultivating good water), has established a partnership with farmers to achieve their goals in the Paraná III Basin located in the western part of Paraná State on the Paraguay's border (ITAIPU 2011; Mello and van Raij, 2006). The dam´s reservoir depends on the sustainable use of soil and water in the watershed for efficient electricity generation. Sediments and nutrients entering the reservoir resulting from inappropriate land use pollute the water used by the turbines to generate electricity. This phenomenon shortens the reservoir life´s and increases the maintenance costs of power generating turbines increasing therewith electricity generation costs. Thus, in principle, payments could be made through a programme to improve the conditions of electricity generation. The spatial unit in this programme is the

watershed. Functioning as a community joining many farmers in the watershed, they reach a scale where environmental impact can be monitored with suitable indicators to establish a system for payment for environmental services.

One of the partnerships built in the *Cultivando Água Boa* programme developed through an agreement with the Brazilian no-till federation (FEBRAPDP) is the Participatory Methodology for Conservation Agriculture Assessment Quality (Laurent et al., 2011). Through this programme, at first, the partners plan to measure impacts of farm management through a scoring system indicating how much each farm is contributing to improving the water conditions. The system is available online in Portuguese at: http://plantio.hidroinformatica.org/. Consolidating this phase and adapting the principles established for the "water producer" by the National Water Agency, the partners plan to assign values to ecosystem services generated from farms participating in the programme (ANA, 2011). Considering the polluter/payer and provider/receiver principles set in the Brazilian Water Resources Policy, farmers with good scores will be paid for their proactive action to deliver watershed services once the Paraná Watershed Plan is established,. This will be a new framework for services provided by farmers as compensation for their proactive approach to improve the reservoir water quality and reduce costs for electricity generation by the Itaipú Dam.

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A framework for international standard for Conservation Agriculture: towards stewardship for sustainable production

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Introduction

The strategic objective A of FAO for the plan period 2010-2019 agreed at the FAO Conference is: *sustainable intensification of crop production*. This objective is meant to respond to some of the important concerns facing food and agricultural sector including: 1) expected population growth; 2) increasing demands for food due to higher life expectancy and a better nutritional status and life style; 3) considerable pressures on natural resources; and 4) demands on agriculture to provide multiple outputs instead of only food, feed and fibre. Along with the increasing demands for food, the need for improved environmental services also becomes greater. Therefore, FAO is promoting sustainable crop production intensification through ecosystem or agro-ecological approaches based on biological processes. For example, Conservation Agriculture (CA), integrated pest management (IPM), management of agricultural biodiversity below and above the ground are considered as agro-ecological approaches for which related knowledge, information and capacity building should be provided by FAO.

Conservation Agriculture is one of the most promising concepts and a set of principles in terms of maintaining acceptable profit as well as conserving and enhancing the resource base. Three interlinked principles of CA are: 1) continuous minimum mechanical soil disturbance, 2) permanent soil cover with plant residue and cover crops and, 3) species diversification in crop rotations and sequences. These when applied along with other good agricultural practices have been shown to have a positive contribution to productivity (yield) and profit, other ecosystem services such as reduced soil erosion and improved water resources, to lowering production costs, and to climate change adaptability and mitigation. CA is also called "no-till" or "zero-till" farming system. Currently, there is a total of about 117 M ha of no-tillage area worldwide, expanding at the rate of some 6 M ha per annum, and this trend is expected to continue. CA offers many of the productivity, socio-economic and environmental benefits desired by the producers and societies, and represents good stewardship standard for managing agricultural lands sustainably. In recognition of this and to accelerate its spread, it is important to consider the feasibility of designing a standard system for CA so that not only can CA be recognised for its sustainability characteristics but also can qualify for various kinds of market and non-market recognition for sustainable production and, where feasible, payments for improved ecosystem services.

Conservation Agriculture and Payment for Environmental Services or for Good Stewardship

The agricultural sector has been considered to be responsible for 17-32% GHG emissions and considerable degradation of some ecosystem services (EcS). Food, feed and fibre production are major provisioning ecosystem services which concern the farmers most; however impacts are generated along with the production on other EcS like soil carbon storage related to climate change mitigation, flood and erosion control, biodiversity conservation, and groundwater recharge. They are also called ecosystem services but are also referred to as environment services (EnS) and are of a public goods nature. Since the perception is that many of nature's services are 'free', no one owns them or gets rewards from protecting or enhancing them, they can deteriorate and degrade easily if no attention is paid to protect them when increasing production. A straightforward concept is to provide incentives to famers by transforming EnS into tangible forms of outputs where the additional farm profits are visible and attractive to farmers. Further, the concept should be made to benefit the society because EnS are the natural resources everyone depends on, including the farmers and their communities. A system of payment for environmental services (PES) is a potential tool to serve the above purposes which builds the connection between farmers and the market, and between farmers and the society. CA has a role to play in this system as seen in the Alberta Offset System (AOS) which is one prominent programme in North America in which farmers are paid through a carbon offset credit scheme based on no tillage production system for sequestering carbon. Chicago Climate Exchange (CCX) is the other example where continuous conservation tillage practice is taken into account for carbon credits, although the Chicago market has not attracted much trade due to very low price set for carbon. Both programmes were developed to respond to local no-till farmers and focus only on carbon offset. On the other hand, there is not yet a payment scheme established for water resource conservation services derived from CA. However, Itaipu, the world largest hydroelectric plant, together with FEBRAPDP are developing a point system to be applied to farmers within the watershed who manage their farms according to certain CA management protocol or standard for good stewardship. An existing example of rewards for watershed management is coordinated by RUPES programme in Indonesia. In this case, a farming community in Lampung province is rewarded by a hydropower company for adopting environmentally friendly farming practices (e.g. agroforestry) that prevents sediment flowing into the dam. Different from climate change mitigation, more specific beneficiaries are identified in watershed service and the payments are made for change in land use management instead of directly for water quality improvements. The necessity of having an assurance system against variability in service supply is one similar characteristic of these two EnS schemes. Several scoring systems or point systems have been developed for this purpose.

There are several CA Communities of Practice (CoP) in existence such as AAPRESID (Argentina), FEBRAPDP (Brazil), CAAPAS (America), CASA (North America), No-Till on the Plains Inc. (USA) and so on. Although AAPRESID is developing the certification scheme for CA, called Agricultura Certificada (Ac), none of the CoPs is ready to host an international scheme like International Federation of Organic Agriculture Movements (IFOAM) does for organic agriculture certification. Following the sustainability standards movements, there has been a proliferation of sustainability standard initiatives. Therefore, our challenge is how to come up with a standard that is able to be integrated within most of the existing standard initiatives including those that may be used to certify good stewardship or to label products from sustainable production system which could increase the market share of the product and/or fetch a higher price.

Framework of International Conservation Agriculture Standard

International Conservation Agriculture standard system is meant to serve three purposes: 1) promote CA application by providing extended benefits to farmers who practice the concept; 2) assure the integrity of CA by setting up Good Agriculture Practices specifically for CA; and 3) mitigate the gaps between different initiatives regarding certification schemes. Six sustainable production certification systems were reviewed including Round Table on Responsible Soy Association (RTRS) for soy production, Rainforest Alliance for agricultural products, IFOAM for organic agriculture, Agricultura Certificada for Conservation Agriculture, GLOABAL GAP for agricultural products, and Roundtable on Sustainable Biofuels (RSB) for biofuel production. Additionally, sustainable agriculture network (SAN) and ISEAL alliance which are two associations dedicated to establishing worldwide accepted sustainable agriculture standards and good practices will be included in the full review. Figure 1 shows a proposed scheme for international certification for CA standard. The boxes with double outlines contain FAO mandates regarding the construct of a harmonized standard.
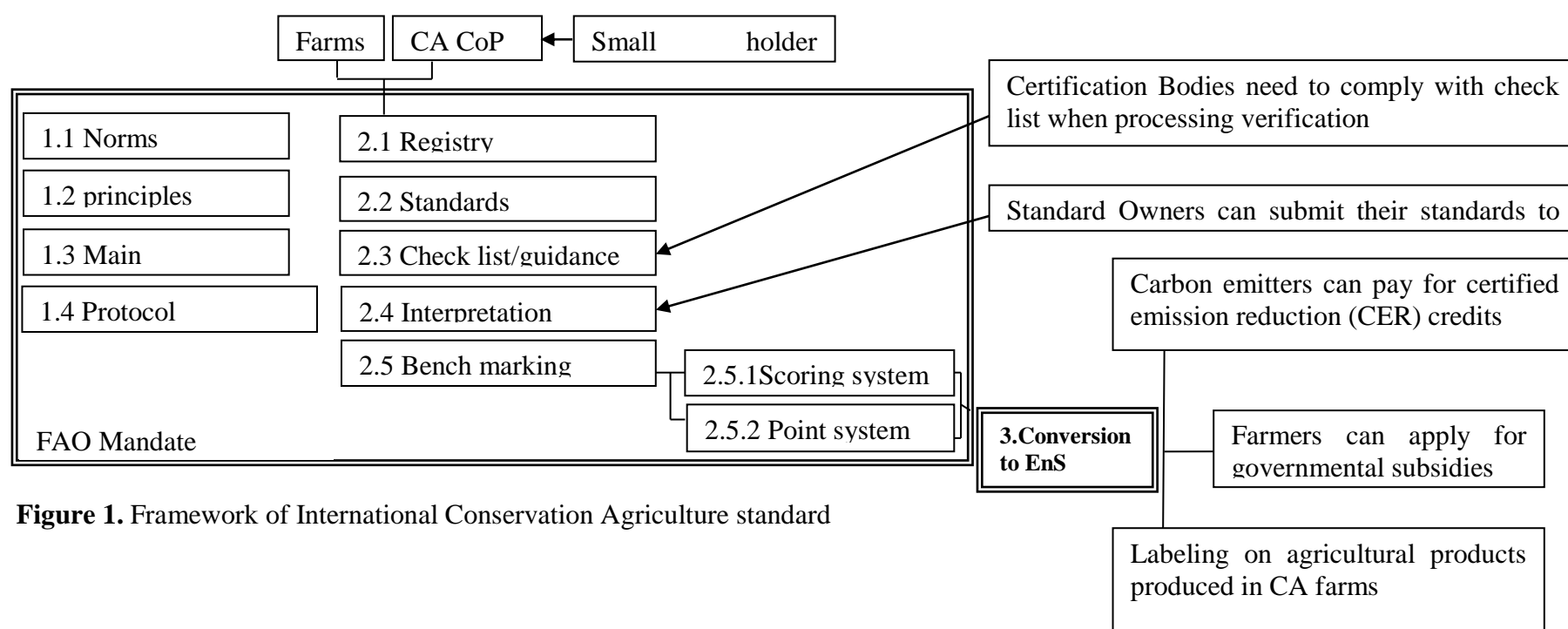
Figure 1. Framework of International Conservation Agriculture standard

1.1 Norms: Three principles of CA as defined by FAO are the basic norms for the certification scheme.
1.2 Principles: Principles of this scheme should be able to address the broader goals of sustainability which contains social, economical and environmental aspects. Legality including land rights and labour rights will be addressed. Also, environmental services of interest derived from CA should be included in principles such as soil health and productivity, water quality and usage, carbon sequestration, and biodiversity conservation Good agriculture practices for CA stewardship implementation and labelling will be described.
2.2 Standards: The standards should be complied with most commonly used international standards. For example, International organization of standards owned standards: ISO 65 (General requirement for bodies operating product certification schemes) and ISO 95 (Code of good practice for standardization). To be easily integrated with other system, the standards should be complied with the code of good practice for setting social and environmental standards constructed by ISEAL alliance or SAN.
2.5 Bench marking: This is the step which can be further linked to payment schemes. Through scoring system or point system, contractual applicants should have the baseline condition of their farm recorded when register. The points/scores can be given for certified improvement of farm condition including soil, water and biodiversity.
3. The points/scores can be exchanged with the amount of environmental services provided by applicants and further link to several stewardships.

Regional Conservation Agriculture project proposal in degraded annual cropping systems areas in South East Asia

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Keywords: Conservation Agriculture, South East Asia, Regional project proposal, degraded area.

Introduction

The Conservation Agriculture Network for South East Asia (CANSEA) was created in 2009 to develop conservation agriculture (CA) cropping systems in South East Asia in 2009. The interest of such a network is that each country can contribute to conservation agriculture (CA) advances as CA principles are not yet widespread. In all countries involved there are specific areas where negative environmental impacts with long-term repercussions on natural resources such as, production decrease and health risk increase due to chemical input. In extreme cases loss of soil fertility would be irreversible for cash-crops. So Conventional agriculture vs. conservation agriculture conversion should be an opportunity where the current practices are questionable to counteract all negative environmental and economic externalities of crop intensification. The aim of this paper is to put the milestones of a conservation agriculture research for development project which would be proposed to funders such as ADB, IFAD, by three Southern Asia research institutions, the National Agriculture and Forestry Research Institute (NAFRI, Lao PDR), the Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI,Vietnam), the Yunnan Academy of Agricultural Sciences (YAAS, China). All three partners have belonged to the Great Mekong Sub-region (GMS) program since 1992 in different sectors such as agriculture, to improve coordination focus mainly on remote areas and small-farming systems.

Material and Methods

Definition of concepts and choice of target areas
Each country has its own problematic (Julien et al., 2008; Tao *et al.*, 2008; Doanh *et al.*, 2008); and we first tried to define what soil degradation means for farmers mainly with economic aspects such as income returns in the short term, as well as for the civil society with environmental aspects such as soil quality. We are convinced therefore that it would be useful to integrate environmental and economic studies. In our project we integrated the two meanings of land degradation, both for natural and human causes.

Agronomic research for development methodology
CA extension is low because many problems occur at the same time such as, lack of government subsidies, landscape management, specific machinery and low market access for secondary crops. Our concept all throughout the project, is simultaneously to work with different levels: field, household, village and region, and to begin with all expected stakeholders, farmers organizations, private sector, as well as government agencies.

Choice of indicators
Our concept is to mix formal knowledge and local practices at each scientific work level in a win-win approach as scientists can learn more if they could benefit from farmers' experiences. Validated results should be explained in a comprehensive way.

National skills
Since national institutions are reluctant to be involved in regional programmes because they consider they do not have full control over developing synergies, it is also important to highlight each country 's field of expertise.

Results and Discussion

Target areas and objectives (Table 1)

Table 1. Characteristics of the degraded area in the three countries.

Country Domain		Location	Degraded area	Level of poverty	Degradation type	Soil texture	Wet season duration	Main crop based cropping systems	Labour input
Laos	Upland	Xayabury, Oudomxay, Bokeo Provinces	10,000 km^2	Medium	Human	From sand to clay	8 months 1,300mm	Maize-Legume	Manual, 2 and 4 wheel-tractor
	Lowland	Savannakhet Province	15,000 km^2	High	Natural	Sand	7 months 1,300 mm	Rice-Legume	Manual, 2 and 4 wheel-tractor
Vietnam	Upland	Son La Province	20,000 km^2	High	Human	Clay	8 months 1,100 mm	Maize-Legume	Manual and animal
	Lowland	Binh Dinh Province	4,000 km^2	High	Natural	Sand	8 months, 1,600 mm	Maize-Peanut-Sesame	Manual and 2 wheel-tractor
China (Yunnan)	Upland	Dehong Prefecture	10,000 km^2	High	Human	Clay	6 months 1,100 mm	Soybean-Citrus tree	Manual and animal
	Lowland	Dali Prefecture	6,000 km^2	Medium	Human	Clay	6 months 1,100 mm	Rice-vegetable	Manual and animal

In Xayabury, Oudomxay and Bokeo Provinces in Lao PDR, land degradation increased with increasing market access for maize as a cash-product in areas near the borders of Thailand, Vietnam and China, totalising about 10,000 km^2. The traders encourage the farmers to use heavy mechanization by providing credit (Julien *et al*., 2008). At the same time herbicide is reaching high levels, such as 20 l/ha for commercial products. Farmers commonly use government prohibited products such as atrazin and paraquat. Soil and pesticide run-off then occur. We also find the same problem in Son La Province in Vietnam and Dali Prefecture in Yunnan where the use of chemical fertilizer,

respectively with maize and rice based cropping systems varies from 400 to 5,000 kg/ha, as well as widespread use of herbicides and insecticides (Tao *et al.*, 2008; Doanh *et al.*, 2008). Large flat areas also are not yet cultivated because the soil has a very low fertility status and the cost of fertility management would be too high. We find this in Savannakhet Province in Lao PDR, where specific parent material gives the soil a coarse texture, as well as in scattered plains in Binh-Dinh Province in Vietnam. Soil pH water is below 5, increasing the cost of soil fertility build-up. In Yunnan in rice cropping systems the high cultivation rate combined with continuous tillage and insufficient organic soil matter, contribute to a decline of soil organic matter and high emissions of C in the atmosphere. In upland areas a large amount of crop residue is burned and shortage rainfall events provide high risk of a human food crisis. In all target areas water management at the watershed level should be taken into account in order to secure farmers incomes and food security.

Methodology and Technologies (Table 2).

Table 2. Expected outputs for each given methodological level.

Methodological level	Environmental	Economical	Social
Perennial Experiments	C, N, water budget	Basic economic data	Window of knowledge
Farm Reference System	Input requirements	Technical books	Use farmers as extension facilitators
		Perennial and annual crops, livestock integration	Farmers 'field school
Stakeholder Network	Subsidies coming from environmental service	Links between production and market	Large scale Extension
	Land use planning		

At the beginning of the project we would conduct a multidisciplinary Rapid Rural Appraisal (RRA) showing the capacity to update socioeconomic factors. The record of farming and non-farming activities, land tenure, livestock, perennial and annual product links, market access with also soil quality, slopes, climate variability, would be the baseline survey, permitting us to select pilot areas and representative farms which could be representative of the rest. A Farm Reference System (FRS) would be created as a set of representative farms that show various biophysical and economical characteristics where few technologies would be applied as support for similar farms. Perennial experiments innovations on CA cropping systems would be compared with conventional cropping systems on selected watersheds managed by a research team with a close relationship with selected farms. A permanent Stakeholder Network (SN) would join government authorities as decision makers, traders as for technology suppliers and products buyers, extension services and farmers' organizations. This SN would play a major role in the definition of subsidies coming from expected environmental services created by CA technologies. Also it would be useful to supply specific mechanization and input, market access of diversification products, such as livestock, perennial crops and forage crops. According to different works on CA promotion (Julien *et al.*, 2008; Tao *et al.*, 2008; Doanh *et al.*, 2008), adequate equipment for direct seeding is a prerequisite for successful CA. New machine constructors with no-tillage tools begin to be recognized in such places as China. Even though they are not located in Yunnan Province, their support would be sought, in engaging them in the process of innovation. Further expertise from more advanced countries in CA technologies such as Brazil or Australia would be proposed. Particularly Southern Brazil has a large range of direct-sowing machines for all kinds of work power, manual, two-wheel tractors, animal or four-wheel tractors (Table 1). Mechanization would be also useful for managing weed and crop residue to provide better weed control by avoiding seed maturation and better residue soil cover. *Let's start at the end.* In conclusion, lessons from the past have shown that the decrease of farmers 'income is the most important motivation that would convince them to adopt CA technologies (Kassam et al., 2009). Degraded areas integrate economical, environmental and social impacts in small-farming systems which concern with the entire the human community. To inverse this trend a strong relationship is required between authorities, the private sector, farmers 'organizations in representative pilot areas with the leadership of research teams. This first step should define what kind of subsidies would be efficient for small farms for future extension engaging governmental authorities and the private sector.

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Policy impacts on land-use and agricultural practices in North-West India

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Keywords: stubble burning, water, technology adoption

Introduction

Until the 1960s, agriculture on the Indo-Gangetic Plains of north-west India was characterised by dryland production with very low levels of purchased inputs. While wheat was then the major crop as it is today, there was only occasional opportunistic double-cropping, and cultivation of staples such as coarse grains and pulses far exceeded rice. Just 50 years later, high-input irrigated rice-wheat rotation has become the dominant system in the region. This is especially the case in Punjab where the rice-wheat cropping system now covers more than 2.6 million hectares or 65% of the cropped area, and maize, pulse, oilseed and sugarcane production have declined (Table 1).

Table 1. Trends in Crop Area in Punjab

	1960-61	1980-81	2000-01	2008-09
	'000 ha	'000 ha	'000 ha	'000 ha
Rice	227	1,183	2,611	2,740
Wheat	1,400	2,812	3,408	3,530
Maize	327	382	165	150
Cotton	446	648	474	530
Pulses	903	341	61	40
Oil seeds	185	248	87	60
Sugarcane	133	71	121	80
Total	**3,621**	**5,685**	**6,927**	**7,870**

Source: Milham et al. 2011

This change has been induced through a range of input subsidies (machinery, chemical fertiliser, water, electricity and diesel) and price support mechanisms (minimum support prices and public procurement) that have heavily favoured mechanised, irrigated production of imported varieties of rice and wheat (Milham et al. 2011). While food production, consumer affordability and price stabilisation policy objectives have largely been met, it is now becoming apparent that these benefits have come at some environmental and social cost and there are strong concerns over the sustainability of the farming system:

- productivity is low by world standards;
- water consumption is high and groundwater supplies are being depleted;
- soil fertility is declining and fertiliser rates are excessive and rising;
- energy (electricity and diesel) demand is high;
- at least in Punjab, rice stubbles are largely burned in the field, giving rise to air pollution, greenhouse gas emissions and negative on-farm productivity consequences; and
- the subsidy programs are very costly to government (Milham et al. 2011).

Farmers and government at both State and national levels in India are sensitive to the problems of ground water depletion and stubble burning and are looking for viable alternatives that are both environmentally sustainable and economic. The Australian Centre for International Agricultural Research (ACIAR) has been also supporting the development of more sustainable alternatives, principally through the development of a direct drilling machine known as the Happy Seeder (Sidhu et al. 2008). The Happy Seeder is a small scale, tractor-powered machine that copes with heavy stubble loads. It combines stubble mulching and seed and fertiliser drilling into a single pass, thereby reducing cultivations and leaving stubble for mulching, thus:

- reducing soil moisture loss (reducing water demand, pumping costs and groundwater depletion);
- improving maintenance of soil fertility (reducing fertiliser needs);
- reducing on-farm electricity and diesel demand;
- reducing the cost to government of fertiliser, water, electricity and diesel subsidies; and
- reducing air pollution and greenhouse gas emissions by reducing the need to burn stubbles.

Methods

Through ACIAR, we have investigated policy options to encourage the adoption of alternative stubble management practices (like the Happy Seeder) with the aim of reducing the impacts of agricultural production on communities and the environment. In considering possible future policy options, we first sought an understanding of how existing policy settings have favoured the dominance of the rice-wheat system in the Punjab region and, indirectly, the practice of multiple cultivations and burning rice stubbles. We then used a representative model of a typical rice-wheat farm in Punjab to gauge the importance of these policy settings in influencing land use, the use of inputs and the adoption of more sustainable technologies (Milham et al 2011). The model is of a linear programming form and adheres to the general farm planning maximisation problem, where an objective function (net farm income) is maximised through the choice of an optimal set of activities, subject to a set of physical constraints.

Results and Discussion

Policy scenarios modelled include economic pricing of electricity (mainly used for pumping groundwater) and chemical fertiliser, which are two of the production inputs that are currently subsidised. Under the current subsidy regime, the optimal farm plan had the following characteristics (Table 2):

- the entire cropped area of the farm (4.20 hectare) is sown to winter wheat, with 93% of the area being under irrigated rice - wheat rotation;

- a small are of maize is grown (0.27) hectares being sown;
- the farm consumes around 81 megalitres of water and 1,600 litres of diesel each year; and
- the management system does not include direct drill technology and all rice stubbles (approximately 24 tonnes) are burned.

Table 2. Modelled impact of policy settings on land use and resources

	With Subsidies	Without Subsidies
Happy Seeder used	No	Yes
Rice (ha)	3.93	2.28
Wheat (ha)	4.2	4.2
Maize (ha)	0.27	1.92
Soybean (ha)	0	0
Net farm income (Rps)	152,898	132,999
Rice stubble burned (t)	24	0
Nitrogen (kg)	533	478
Electricity (kw hrs)	1,496	1,557
Diesel (L)	1,644	941
Water (ML)	81.4	60.0
Casual labour (hrs)	279	635

Note: Total farm area 4.40 hectares; total cropped area 4.20 hectares.

These model results were consistent with the findings of a survey of farm households in the Patiala District of Punjab conducted in May 2009 (Kumar and Kumar 2010).

However, when production costs are adjusted to remove the effects of the electricity and fertiliser subsidies, the following model responses are observed:
- the area under wheat is unchanged, however, rice, which is a comparatively high consumer of water and fertiliser, becomes less profitable and the area under this crop drops by over 40%;
- maize takes up the area no longer planted to rice;
- the savings in irrigation and fertiliser associated with stubble retention make direct drill technology like the Happy Seeder a financially attractive option;
- the volume of stubble burned drops to zero, fertiliser and diesel use decline and water consumption is reduced by more than a quarter
- there is a large increase in casual labour demand, thus providing more rural employment; and
- while there is some impact on net farm income (-13%) the farm remains profitable. (Table 2)

It is readily apparent that historical government policy settings have heavily influenced adjustment in the agriculture sector in Punjab. While these policies have for an extended period delivered on objectives relating to expanded production of key food crops and price stabilisation for consumers (eg., Pursell et al 2007), there are strong and increasing concerns about sustainability of the farming system they have spawned. Using representative farm modelling, we have demonstrated the masking effects of electricity and fertiliser subsidies on the potential on-farm, environmental and public health benefits of more sustainable production technologies.

The economic analysis clearly shows that exposure to unsubsidised market prices for electricity and fertiliser, while impacting to some extent on rice production, would increase the attractiveness of technology such as the Happy Seeder and likely encourage adjustment to a farming system that is only marginally less profitable, generates far less air pollution and uses less chemical fertiliser, less fossil fuel and less water.

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Ecological responses to public policy scenarios in farmlands: a bio-economic modelling approach

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Keywords: Biodiversity, Public policy, Bio-economic modelling, Bird, Land-use

Introduction

In recent decades, a biodiversity decline has been reported in Europe, especially for bird populations which have undergone severe and widespread decline. Global changes in European agriculture, including intensification and land abandonment, have significantly modified farmland bird populations (Donald et al., 2006). In this perspective, reconciling agricultural production and biodiversity is of particular interest. Since the early 90's, several public policies have been developed to limit the negative impact and externalities on biodiversity. Our objective is to analyse the impact of such economic policies on bird communities and their sustainability. To address agro-environmental sustainability, both economic and ecological criteria must be considered. As pointed out by Perrings et al. (2006), there is an urgent need for approaches that integrate economic and ecological criteria in conservation problems. Examining forms of farming allowing for the sustainability of biodiversity and agricultural production requires interdisciplinary research. So, in the present paper, we develop a bio-economic model which integrates public policy scenarios, representative regional farmers, farming land-use and bird dynamics. The model allows us to compare the responses to some public policy scenarios of several biodiversity indicators including the Farmland Bird Index (FBI), the Community Specialization Index (CSI) and the Community Trophic Index (CTI).

Materials and Methods

We develop a bio-economic spatialized modelling for the 620 French small agricultural areas, which represents spatial units of homogeneous agro-ecological and economic systems, so are particularly relevant to this study. Our model links three elements: public decision maker, regional economic agent and bird compartments (Figure 1). First the decision maker selects incentives scenarios under budgetary constraints function of the different European Common Agricultural Policy (CAP) perspectives. We present here 5 scenarios: the Statu Quo (SQ) scenario, with no tax and no subsidy to keep the current trend; the Crop (CR) scenario, which promotes Cereal-Oleaginous-Proteaginous crops (COP); the Grassland (GL) scenario with subsidies to extensive grasslands; the High Quality Environmental (HQE) scenario which taxes COP and distributes subsidies to extensive grasslands, and the Double Subsidies (DS) scenario with subsidies to COP and extensive grasslands. For all scenarios, incentives are decreasing with time, which is the current CAP perspective. The second part is composed by the 620 regional economic standard agents, which chose their agricultural land-uses in order to maximize their utility. These choices, made in an uncertainty context, depend on expected gross margins, incentives specified by the decision maker and technical constraints which limit change speed and integrate change costs. Third, to access ecological performance, we chose to focus on farmland common birds (Ormerod et al., 2000). Bird populations are driven by Beverton-Holt dynamics which capture intra-specific competition through the carrying capacity parameter. This parameter depends on the agricultural activities chosen by the farmers. So we analyse the impact of 5 public policies on bird populations through 3 indicators (Farmland Bird Index FBI which is an indicator of trends in abundance, a Community Specialization Index CSI and a Community Trophic Index CTI) from 2008 to 2050. To develop this modelling, multiple databases are articulated: the Farm Accountancy Data Network and the French Agricultural Census for the economic and agricultural parts, and the French Breeding Bird Survey for birds. The budgetary constraint is calibrated with the current French CAP budget. As the farmer choices occur in uncertainty context, we run simulations to estimate means and dispersions of outcomes. We present evolutions of the three ecological indicators function of the scenarios. We normalize all performances by the Statu Quo results to obtain the marginal effects of each scenario compared to the current trend. For the three graphs, yellow represents Cereal scenario, light-green Grassland scenario, dark-green HQE scenario and brown DS scenario. The black parts are the historical data, common for the 5 scenarios.
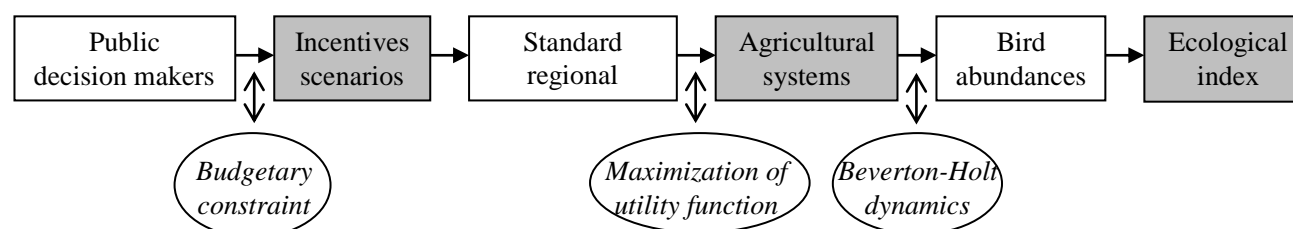
Figure 1: Model coupling: Farmers maximise their utility and adjust their agricultural systems pending on incentives. These choices affect bird community dynamics.

Results and Discussion

As depicted by Figure 2a, FBI exhibits very contrasted patterns under the different scenarios. Promoting extensive grasslands in the policy is the better way to enhance community size. Indeed if cereal specialist species can live in grasslands, many grassland specialist species strongly decrease in the very open landscape of the CR scenario. We complete this information with the two functional indicators. Figure 2b shows that CSI discriminates the scenarios and the better CSI is obtained within the CR scenario. On graph 2c CTI shows a differentiation between the CR scenario and the others, which are promoting the extensive grasslands. These three indicators inform on the response of bird communities to the scenarios. With the CR scenario, we obtain similar trends in population size but lower trophic levels (more granivorous species) than the current situation. When the public scenario is promoting extensive grasslands (GL, HQE and DS scenarios), the population sizes increase, as well as the community trophic level (more insectivorous and carnivorous species). The stronger CSI in spite of very different population sizes indicates that populations with CR scenario are less diversified than those under scenarios promoting grassland. In sustainability terms, communities coming from scenarios promoting grassland are the most stable. From the perspective of ecosystem services, extensive grasslands should be promoted: qualitatively, trophic richness and diversified community ensure more varied and stable ecosystem services, and higher abundances allow stronger ecosystem services (Sekercioglu et al. 2004).

Moreover this is the only point which clearly discriminates the three scenarios promoting grasslands. The scenario the most in favour of grassland (HQE) ensures strongest abundances. This shows that combining many relevant incentives can improve the ecosystem state. The last element of this discussion concerns the non-monotony for all trajectories. We explain these evolutions by the decrease of the incentives in time. When the incentives become too small, farmers adopt the same behaviour than without incentives (Statu Quo scenario), so all

indicators return to 1. This result illustrates that it is necessary to maintain public incentives to drive ecological performances. A short term strategy is not sufficient to a sustainable conciliation between agricultural production and bird biodiversity. We conclude that CAP measures promoting extensive grasslands are appropriate to improve and sustain the bird communities and associated ecosystem services. However to increase their efficiency, the decision maker should choose to couple them to tax on COP and keep them stable at least for medium time.

2a: trends in theFarmland Bird Index

2b: trends in the Community Specialization Index

2c: trends in the Trophic Index
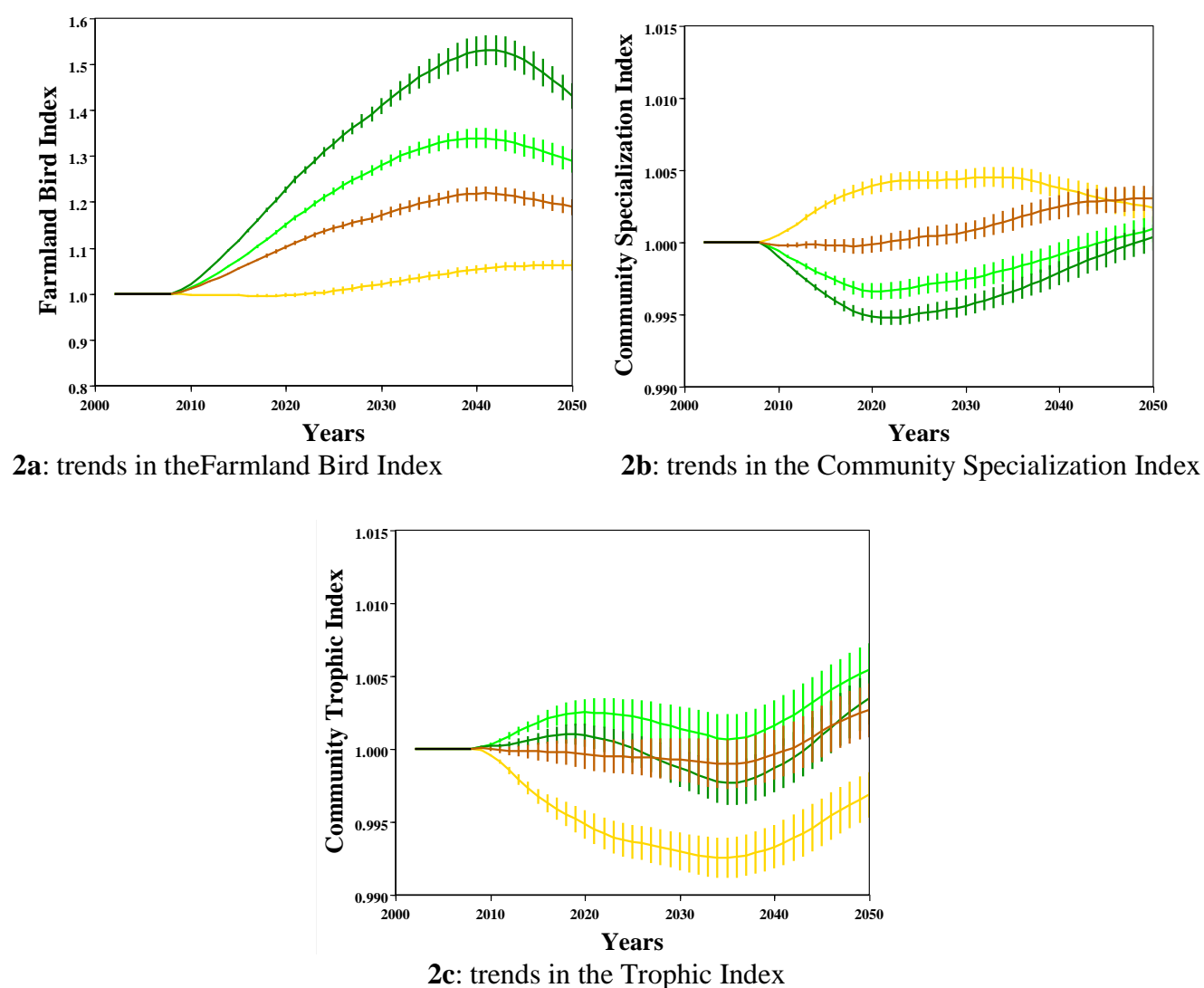
Figure 2: Ecological indicators evolutions with Cereal scenario (yellow), Grassland scenario (light-green), High Quality Environmental (dark-green), Double Subsidy scenario (brown), normalized by the Statu Quo evolutions

From local mini-till experience towards a strategy for development of Conservation Agriculture in the European Union

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Introduction

The adoption of Conservation Agriculture (CA) varies considerably from one country to another. It has been adopted in ecologies as different as tropical and sub-tropical Brazil, dry Western Plains of USA, temperate dry Argentina pampas, and northern cold Finland. This variation indicates that the prevailing soil and climate conditions or the current production systems are not the main drivers of adoption. Human factors may be the key. This paper describes the evolution of tillage systems in France where the level of CA adoption is still low despite many years of promotion effort by several operators. In this paper a hypothesis is proposed about the reasons for the low uptake of CA in France, as well as schemes of relations between farmers and other stakeholders in the society including citizens, businesses, institutions and policy makers seem more favorable towards adoption of CA.

History of Attempts to Limit Soil Tillage in France

From 1970 to 1992: This period was characterized by two main concerns: (i) the increase in grain maize area leading to late seeding of wheat due to late harvest of maize, as well as technical difficulty to seed wheat into the thick layer of maize stalks; and (ii) the objective of reducing the cost of machinery and fuel consumption because of the fuel crisis. The first No-Till trials were made with equipments like Betinson wheat No-Tiller, using paraquat to kill vegetation. Very quickly the limit of such a system appeared: in this opportunistic approach farmers went on using the plough for other reasons, thus alternating ploughing with no-till, and leaving the soil bare for long periods after wheat harvest, as no cover crops were used at that time. In addition, paraquat being a contact herbicide left perennial weeds to infest the land. Farmers and experts who did not want to return to ploughing but still wanted to maintain some level of cost reduction switched to reduced tillage, as well as to combining tillage with seeding. During this period, the change was only an adaptation of conventional systems based on mechanical tools to till and seed, and on adaptation of non-selective herbicides, with large adoption of low rates of glyphosate. The extent of adoption reached by these reduced tillage systems in the late 90's was about 20% of arable cropland, mainly in winter crops rotations, or in wheat-maize rotation with grass or intermediate cover crop. In many cases, the ongoing lack of understanding of principles of good soil and ecosystem management led to lack of consistent results, and to technical traps of which the most widely spread were the questions of weed management, compaction in non-covered loamy and sandy soils, and some diseases, and sometimes run-off and erosion. This made it impossible to make progress.

From 1998 to 2005: Meanwhile, environmental issues began to put more pressure on farmers. The key questions revolved around water quality (nitrates, pesticides), and the consequent threat of limiting fertilizer use and banning pesticides, forcing farmers to find a different way from the conventional, most of them seeking a third way between the conventional and organic. Extension services, technical and scientific institutes at the same time were getting some limited and not well understood information about the non-ploughed systems of so called 'Conservation Tillage' in North America, and also still more limited information about No-Till farming systems in South America. They tested and evaluated some replicas of these systems in France but a lack of understanding of the underlying principles led them to focus only on tillage and seeding equipment, without changing the rest of the production systems. Also, no attention was given to either cover crops or biological life in the soil. The objective was to adapt defensively to political demand, with current know-how and existing technologies. This meant that every time a bad result occurred, they discussed it as reflecting the bad performance of non-ploughed systems, and recommended farmers to continue with ploughing. However, at the same time, some pioneer farmers, private advisors and associations, such as APAD (Association pour la Promotion d'une Agriculture Durable), funded under ECAF (European Conservation Agriculture Federation) leadership, were more convinced of the agronomic and environmental benefits and feasibility of Min-Till and No-Till systems. Observing that some farmers were able to let the systems run with success, APAD began its promotional work, based on the experience of these farmers, and tried to put in place a pedagogy that explained the reasons why in some cases there was success and not in others. The targets had been Farmers Unions/Farmers Organizations/Extension services/Scientists/Experts. Basically, it was now understood that one of the key factors driving success came from continuous soil cover and occupation of the soil by roots. However, the model in place at the time was minimum tillage + cover crops. The area under reduced tillage or Min-Till varied from 30% to 40 %, depending on fuel cost, grain prices, and subsidies. Nevertheless, there was still a lack of consistency in the results to generalize the systems. The technical traps of Min-Till systems remained as before. Most operators still had a poor understanding of the principles of sustainable soil management, and Min-Till was not a real new paradigm or a real alternative to conventional tillage systems. Thus, farmers remained under the political threat of "all ecology" policy.

From 2005 to 2010: By now some farmers having traveled to Brazil did understand the fundamental difference between continuous No-Till with permanent soil cover, and so-called "Conservation Tillage". They began to test No-Till systems on their farms and after some years of variable results they succeeded and improved their soils, and their capacity of getting rid of all types of soil tillage. As a result, the objective and focus of APAD changed to minimum soil disturbance No-Till systems, known also as Conservation Agriculture (www.fao.org/ag/ca), as a basis for sustainable agriculture. At the same time pioneer farmers like Mr. Alfred Gässler began to develop No-Till systems with a Brazilian Equipment Manufacturer by providing farmers a complete system with direct seeding equipment as well as cover crops seeds, and, most important, the whole advice package and training. Another isolated example was Mr. Jean-Claude Quillet who worked with CIRAD staff. There are now around 200,000 hectares of CA in France offering good results in different crop systems. Although, they represent only 1% of arable cropland, these results are enabling APAD to build a success story for future development and spread of CA in France, and in Europe generally (Derpsch, 2008).

Key Lessons

Messages that have been delivered in the EU Commission in May 2008 and 2009, and to Members of the European Parliament through the EU-funded SoCo (Sustainable Agriculture and Soil Conservation) project, are as follows (Sarreau, 2009): CA provides a new farming model, a real breakthrough versus all existing ones; it is an answer to political need of CAP for: macro-economic performance; social needs; and environmental management of territories; and it is the basis for sustainability of farming and food systems, and of agricultural lands. CA enables a permanently high production of biomass, with intensification of ecological processes, emulating high yielding pastures

with zero tillage and in continuous biomass production based on maximum photosynthesis. The performance of farmers who have succeeded and persisted over the years with CA can be summarized by the practical experience in Brittany on the farm of Mr. Bertrand Paumier (Schreiber, 2011): Yields are maintained or improved; soil and ecosystem services are improved including SOM, biodiversity, C sequestration; nitrate pollution is reduced; competitiveness is increased; inputs of energy, fertilizers, pesticides, time and finance are reduced. Overall, intensive CA systems on 50 M ha (50% of arable soils in Europe) would be worth an additional 80 billion Euros annually from extra grain, biomass and carbon credits. This is why CA systems should be attractive to policy makers, farmers and citizens in Europe in the context of the current financial scarcity and the 21st century challenges of high food, energy and input costs, continuing land and biodiversity degradation, water scarcity and climate change.

Strategy for CA Development in Europe

APAD now promotes CA (i.e. No-Till systems) to be an answer to the political need of European Common Agricultural Policy (CAP) for macro-economic performance, social needs and environmental management of agricultural landscapes. APAD has changed its targets, going beyond farmer organization circles, and directly addressing citizens and representatives of citizens, as well as leaders of food industry. This has led to a rapid and growing interest from them, and especially from some of their elected representatives at the European Parliament level. They are now APAD's key partners for policy advocacy. This has generated some potential for jointly building practical examples of the new sustainable farms and to let them spread through the future CAP mechanism. No-Till farms may be seen as a potential CAP project. In light of the lessons learned, and support from international experts, the strategy for CA development in Europe addresses the following elements: (i) what leads to low to average results in terms of influence and thus in development of CA?; (ii) what leads to good results in terms of being listened to and to influence mindsets of farmers, citizens and policy makers?; (iii) the role and strategy of the national CA association which is to enlarge the platform of multi-stakeholder alliances of the project for a new sustainable agriculture for Europe involving industry, farmers, policy makers and others, and for speakers of No-Till Farmers Associations to drive the strategy and be the speakers; (iv) the alliances and supporters from all stakeholders including international groups; (v) the needs at European level to organize and support the European CA project with members of the European Parliament. This strategy is now being implemented by APAD and its multi-stakeholder collaborators through: national associations in key EU countries, driven by No-Till farmers; assisted by the best international CA experts; an organization of advocacy and pedagogy in Brussels, near the MEP and Commission officers, representing No-Till farmers, but also able to bring expertise on their behalf; and establishing a European Conservation Agriculture Advisory Group (ECCAG).

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An index to rate the quality of no-till systems: a conceptual framework

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Introduction

No-till is the prevailing cropping system for grain crops in Brazil and most of South America. Early adoption of no-till system (NTS) was motivated by its effective soil conservation, but later widespread adoption took place because it also saves time and fuel, allowing up to three crops a year in the more humid areas, while maintaining low erosion levels and high yields. A common view is that NTS sustainability rests upon a complementary balance among three key components: absence of field-wide tillage, permanent organic soil cover and adequate crop rotation. In spite of Brazil's early lead in no-till adoption, no-till farmers may not necessarily adhere to best practices conducive to achieving such a balance, resulting in lower than possible soil and water conservation and other environmental services. Main reasons suggested for this non-adherence are farmers' inability to afford cover crops or appropriate herbicides and the perceived need to till occasionally to incorporate lime or alleviate weed and compaction pressures (Bollinger et al., 2006). Thus, a strategy to improve NTS quality must aim at balancing the system´s essential components while also addressing the environmental externalities and potential environmental services. As part of this strategy, there is need to devise a simple, low-cost yet robust quality index to rate the distance a given no-till system is from a benchmark high-quality system. In this paper we present and discuss the conceptual framework of such an index and initial preliminary results.

Key system components and environmental services

An ideal no-till system based on the three key components should have characteristics approaching a forest floor soil condition (Kassam et al., 2009) and hence minimal run-off. But in large parts of Brazil, especially its Southern grain-growing regions where essentially all summer crops are under no-till, stressors such as intensive uncontrolled traffic and poorly designed or no crop rotation impose lower-than-ideal equilibrium infiltration rates (EIR). Assuming yearly return rainfall intensities and EIR ranges similar to ones measured in field trials, run-off events can be as frequent as once a year. On the long rolling slopes of the prevalent Ferralsol surfaces run-off can reach energies high enough to remove and transport crop residues and thence cause channel and gully erosion, and increased flood peaks. Even when or where erosion losses are small, waterborne nutrients and coliform bacteria, where manure was spread, add to the negative off-site effects. While regionally and properly designed rotations and compaction avoidance result in lower frequency of run-off events, this ideal situation is far from commonplace. In order to make off-site effects explicit, run-off management must be recognised as being a key outcome indicator of system quality. Hence, one way to evaluate the quality of NTS is to consider four key system components,

Quality in NTS

Quality in NTS can be defined as the capacity of a given no-till field to maintain or increase crop and livestock productivity while maintaining or enhancing soil, water and air quality and other environmental services. This definition, adapted from that of soil quality (Karlen et al, 1997), explicitly connects the no-till system quality concept to environmental services. NTS quality should reflect the effectiveness of current management and allow an assessment of future management scenarios and options for maintaining or improving system quality. Thus it can be used as a tool, together with any payment for environmental services schemes, to direct farmers towards best practices that lead to a higher quality NTS and environmental services. Such an index should be relatively simple in the early stages of these schemes, but eventually can become more complex as the schemes become better accepted. It should also: (i) be based on a regional benchmark set of best practices to allow for regional differences in crops, crop rotations, soils, terrain and climate; (ii) be constructed from indicators easily recognised by farmers who can self-evaluate; (iii) be sampling-free and non seasonal so it can be determined any time of the year; (iv) be specific to NTS; (v) address directly or indirectly the four key system components described above; and (vi) allow for the recognition of critically low key components so as to guide management decisions.

NTS Quality Index (NTSQI)

This index is built through expert knowledge, using indicators that reflect the four key system components directly or indirectly. Crop rotation and, partially, soil cover permanence are evaluated through rotation intensity (RI), rotation diversity (RD) and crop residue persistence (RP). Soil cover permanence, also partially, and absence of tillage are assessed by tillage frequency (TF). These are determined for a 3-year period, arguably easily remembered by farmers. Run-off is addressed by terrace adequacy (TA), based on run-off over-topping frequency, and conservation evaluation (CE), based on the absence of signs of erosive run-off. Plant nutrition, indirectly linked to soil cover permanence by affecting crop growth, is evaluated through balanced nutrition (BN). Farmer commitment to no-till, an indirect indicator of the combined components, is evaluated through its adoption time (AT). The value of each indicator (Ii) is calculated by

$$Ii = \frac{Ei}{Bi} \quad [1]$$

where Ei is a present or future value of a field parameter and Bi is a regional benchmark value suggested by experimental results or expert opinion (Table 1), except for TA, estimated using 1 event every 5 years as the benchmark ($Ii = 1$), and 4 or more as $Ii = 0$. NTSQI is then calculated as

$$NTSQI = \sum (Ii * fi) \quad [2]$$

where fi is an subjective weighing factor used to emphasise some indicators over others, again set through expert knowledge, and to result in values ranging from zero to 10 (ten). Critical values, designed to help target remedial actions to improve NTS quality, were also set arbitrarily (Table 1).

Initial preliminary results

NTSQI was calculated from questionnaires filled by 24 voluntary farmers over 6 small river basins (Table 2) in Western Parana State, Brazil, located roughly within a 40 km radius of 24.71° S and 53.99° W. The climate in this region is sub-humid sub-tropical with predominantly a maize-soybean rotation, and soils are Ferralsols. Values ranged from just below 6, mostly at Mineira basin, to near 9,

mostly at Toledo basin, and were concentrated around 7, suggesting that many farmers in this sample could still improve their practices towards a higher quality NTS. The farmers achieving the lowest quality ratings were those who had more than one indicator below critical values. The two most critical indicators, based on their frequency, were TA and RP. This indicates that actions aimed at improving NTS quality for those farmers must focus on terrace adequacy and on increasing the number of grass cover crops in the rotation, by using winter cover crops such as black oats. Hence, NTSQI was useful to rank farmers and basins on their distance to an ideal benchmark system, and to diagnose critical parameters. These are then useful to prioritise actions aimed at improving NTS and hence its environmental services. However, the quality index needs further testing and validation and ground truthing to establish its ability to accurately rate differences in real conditions on-farm and identify weaknesses in the NTS being rated that can be ameliorated with specific changes that can be linked to payments for environmental services.

Table 1. Weighing factors (*fi*), evaluation parameters over a period (*Ei*), benchmark values (*Bi*) and critical indicator values.

Indicator	Ei	fi	Bi	Critical
RI	Crops past 3 yrs	1.5	9	0.56
RD	Crop species past 3 yrs	1.5	4	0.50
RP	Grass cover crops past 3 yrs	1.5	6	0.50
TF	Whole field tillage operations past 3 yrs	1.5	6	0.50
TA	run-off over-topping events past 5 yrs	1.0	----	0.50
CE	Cumulative absence of downhill seeding, whole field and edge compaction signs, and visible erosion	1.0	4	0.50
BN	Cumulative presence of manure addition, soil sampling and nutrient balance	1.0	3	0.33
AT	Years of no-till adoption	1.0	22	0.33

Table 2. NTSQI and indicator values; red background indicates critical values.

Farmer	Basin	NTSQI	Indicator							
			RI	RD	RP	TF	TA	CE	BN	AT
1	Ajuricaba	6,15	0,78	1,00	0,50	0,80	0,00	0,50	0,67	0,36
2	Ajuricaba	7,81	0,89	0,75	0,83	1,00	0,50	0,75	0,67	0,68
3	Ajuricaba	6,59	0,78	0,75	0,67	0,80	0,00	0,75	0,67	0,68
4	Buriti	8,19	0,85	0,75	0,78	1,00	1,00	0,75	0,67	0,64
5	Buriti	7,44	0,78	0,75	0,67	1,00	0,50	0,75	0,67	0,73
6	Buriti	6,87	0,95	0,75	0,92	0,80	0,50	0,63	0,67	0,71
7	Facão Torto	7,29	0,74	0,75	0,61	1,00	0,83	0,58	0,67	0,56
8	Facão Torto	6,73	0,67	0,50	0,67	0,80	1,00	0,75	0,67	0,36
9	Facão Torto	7,63	0,89	1,00	0,67	0,80	0,50	0,75	0,67	0,68
10	Facão Torto	5,50	1,00	0,25	1,00	0,00	1,00	0,75	0,33	0,05
11	Mineira	5,80	0,89	1,00	0,17	1,00	0,00	0,50	0,67	0,05
12	Mineira	6,98	0,84	1,00	0,42	1,00	0,50	0,50	0,33	0,68
13	Mineira	5,86	0,67	0,75	0,50	0,80	0,00	0,75	0,67	0,36
14	Pacuri	7,43	0,67	0,75	0,50	1,00	1,00	0,75	0,67	0,64
15	Pacuri	5,92	0,89	0,50	1,00	0,00	0,50	0,25	1,00	0,59
16	Pacuri	7,06	0,67	0,75	0,50	0,80	0,50	1,00	0,67	0,82
17	Pacuri	7,51	0,89	0,75	0,83	0,80	0,50	0,75	0,67	0,68
18	Toledo	7,77	0,73	0,38	0,84	1,00	0,75	0,63	0,67	0,80
19	Toledo	9,04	1,00	0,75	1,00	1,00	1,00	0,75	0,67	1,00
20	Toledo	7,58	0,67	0,50	0,67	1,00	1,00	0,75	0,67	0,91
21	Toledo	7,48	0,78	0,75	0,67	1,00	0,50	0,75	0,67	0,77
22	Toledo	8,03	0,78	0,75	0,67	1,00	1,00	0,75	0,67	0,82
23	Toledo	7,56	0,85	0,45	0,77	1,00	0,70	0,75	0,67	0,68
24	Toledo	7,52	0,67	0,75	0,50	1,00	1,00	0,75	0,67	0,73
	Number of critical farms:		*0*	*6*	*7*	*2*	*13*	*4*	*2*	*2*

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An index to rate the quality of no-till systems: validation

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Introduction

An index to rate the quality of a no-till system (NTSQI) has been proposed on a companion paper (Roloff et al, 2011). NTSQI, even though inspired by the concept of soil quality, is a pioneer index hence requiring testing and validation to assess its trustworthiness with respect to reproducing the phenomena under evaluation and its performance as a tool for decision making. In the context of sustainability, a valid index means it is able to correctly assess factors leading to the sustainability of a given use and management scenario, even though cause and effect relationships are difficult to be established with a high degree of certainty in the usually complex agricultural systems. Indexes such as NTSQI do not aim at forecasting quantities or present impacts, but rather potential impacts of current or future scenarios in a qualitative way indicative of tendencies. For analyses leading to validation, linear or linearizable relationships should not be expected, imposing the use of non-parametric statistical tools that are distribution-independent. Index validation may be approached by analysing its scientific basis, its output validity and its usefulness to the end user (Bockstaller and Girardin, 2003). NTSQI has been proposed based on sound scientific basis, as discussed in the companion paper, with input from farmers and crop consultants, a valid index-building step (Donnelly et al, 2007). Hence it can be judged valid from a scientific point of view. Its usefulness, on the other hand, is difficult to assess at this early stage of testing. Therefore, this paper focuses on its output validity.

Materials and Methods

NTSQI was calculated for 24 farm parcels on five small watersheds in Western Parana State, Brazil, as described on the companion paper. On the same parcels, index-independent parameters were also determined: (i) the average terrace cross-section area (TC); (ii) organic matter (OM), phosphorus (P), potassium (K), cation exchange capacity (CEC) and sum of bases (SB) from composite soil samples (five sub-samples); (iii) average worm population (WP) determined using hand sorting of soil from five 20×20×20 cm pits per parcel. Actual TC was subtracted from the recommended TC to generate DTC, a measure of the degree of adequacy of the terrace system. NTSQI, its component indicators and the independent parameters had their statistical distribution tested for normality by the Shapiro-Wilk method, rejecting the normality hypothesis if $p<0.05$. Correlation strengths among the ranks of NTSQI, its indicators and the independent parameters were determined by Spearman´s $^{\delta\,\text{rank coefficient}}$, calculated from re-sampled values generated by bootstrapping of 1000 samplings of 15 samples. All statistical analysis were performed by the SYSTAT 13 software, whose manuals detail the methods utilised.

Results and Discussion

NTSQI results fell over a relatively narrow amplitude (Table 1), as judged by its low coefficient of variation (CV). In comparison, its indicators had CVs that varied from 13.6 to 57.1 %. While this partially reflect local conditions, it also suggests the indicators were able to clearly differentiate the parcels tested. The lower CV for NTSQI is probably a result of sums of indicators that, for any given parcel, were not all on the low or the high end of possible values. NTSQI results were normally distributed (Table 1). On the other hand all but one of its component indicators and half of the independent parameters were not. Heterogeneity of distributions (not shown) precluded attempts to normalise or linearise the data. Thus, the only option to analyse relationships among the data is the use of non-parametric statistical methods. Soil fertility parameters CEC and SB were not correlated to NTSQI nor to any of its component indicators and were thus excluded from further discussion. NTSQI was strongly and positively correlated with the indicators: tillage frequency (TF) (low frequency results in a high indicator value), terrace adequacy (TA) and adoption time (AT) (Table 2). The only rotation-related indicator moderately correlated with NTSQI was rotation persistence (RP) (presence of grasses on the rotation). Hence, higher NTSQI values were associated mostly with practices unrelated to rotation. The strong correlation between RP and rotation intensity (RI) is because most farmers plant corn following soybeans, as a second summer crop. This, in turn, results in farmers opting for winter fallow instead of a cover crop, justifying the negative correlation between RP and rotation diversity (RD). This leads to the conclusion that any further improvement on NTS quality will depend mostly on improved rotations, more especifically higher species diversity through the use of more winter cover crops. Additionally, the absence of correlation between NTSQI and balanced plant nutrition (BN) indicates that most farmers lack a proper plant nutrition scheme and it should also be improved for a higher quality NTS. Except for WN, the other independent parameters were moderately or strongly correlated with NTSQI. Oddly the strongest and negative correlation was between K and NTSQI. At present there is no reasonable explanation for this nor for the strong correlations of K with other indicators. OM was strongly correlated with NTSQI, and with TA and AT, and moderately so with RD, RP and TF. The correlation with AT is a straight effect of organic matter accumulated over time. The correlation with TA and TF is probably an effect of less organic matter losses over time. The negative correlation between OM and RD needs further analysis to ellicit. While preliminary, these results are encouraging because they show that relatively simple index and indicators are able to assess OM trends as affected by NTS-related practices. The negative moderate correlations of DCT with NTSQI, TA and AT are also encouraging because it indicates that the index and the indicators were able to assess the degree of adequacy of the terrace system present on the parcels. While WN was not correlated to NTSQI, it was positively and moderately so with RI and RP. These may be a straight effect of more grass crops on the rotation period, meaning more decomposition-resistant residues present. The correlation between WN and BN may reflect higher WN associated with manure addition, which increases the value of BN. While preliminary, these results suggest NTSQI is a valid index from an output point of view. It also demonstrates the NTSQI methodology can pinpoint practices that need to be targeted to improve the quality of NTS and hence its environmental services.

Table 1. Descriptive statistics and normality test for NTSQI, its indicators and independent parcel parameters.

	NTSQI	RI[*]	RD	RP	TF	TA	CE	BN	AT
Average	7.17	0.81	0.71	0.67	0.86	0.63	0.68	0.66	0.61
Coef of Var %	11.7	13.6	26.8	29.9	31.4	57.1	22.1	18.2	39.3
Shapiro-Wilk *p*	0.20	*0.03*[♠]	*0.00*	0.19	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*
	P[♣]	**OM**	**K**	**SB**	**CEC**	**DTC**	**WN**	**NWS**	
Average	18.92	3.39	0.52	8.55	13.33	1.00	7.57	2.88	
Coef of Var %	66.3	15.9	28.8	10.6	8.1	258,0	146.0	55.2	
Shapiro-Wilk *p*	*0.00*	0.65	*0.02*	0.79	0.56	0.06	*0.00*	*0.02*	

[*] RI – rotation intensity, RD – rotation diversity, RP – residue persistence, TF – tillage frequency, TA – terrace adequacy, CE – conservation efficacy, BN – balanced nutrition, AT – adoption time.

[♣] P in mg dm^{-3}, OM in percent, K , SB and CEC in cmolc dm^{-3}, DTC in m^2, WN and NWS in numbers.

[♠] Numbers in italics indicate statistically significant ($p < 0.05$) departure from a normal distribution.

Table 2. Spearman´s δ rank coefficient of NTSQI, its component indicators and independent parcel parameters.

	NTSQI	RI	RD	RP	TF	TA	CE	BN	AT	P	OM	K	DCT	WN
NTSQI	1.00													
RI	0.16	1.00												
RD	-0.22	0.27	1.00											
RP	0.46[*]	0.53	-0.54	1.00										
TF	0.56	-0.08	-0.04	-0.10	1.00									
TA	0.62	-0.27	-0.45	0.21	0.49	1.00								
CE	0.44	-0.28	-0.18	0.04	0.05	0.29	1.00							
BN	-0.11	0.12	-0.51	0.53	-0.45	0.00	-0.05	1.00						
AT	0.63	-0.03	-0.25	0.33	0.32	0.36	0.43	-0.14	1.00					
P	0.34	-0.17	-0.34	0.15	0.19	0.32	0.31	0.14	0.24	1.00				
OM	0.55	-0.12	-0.37	0.30	0.43	0.64	0.09	-0.11	0.57	0.13	1.00			
K	-0.78	-0.10	0.23	-0.35	-0.56	-0.44	-0.41	0.05	-0.55	-0.25	-0.48	1.00		
DCT	-0.30	-0.08	0.03	-0.06	-0.38	-0.32	0.14	0.31	-0.38	0.22	-0.44	0.28	1.00	
WN	0.21	0.45	-0.10	0.49	0.03	-0.04	-0.19	0.31	0.04	0.30	-0.02	-0.12	0.10	1.00

[*] Light grey background – moderate correlation ($0.3 < \delta < 0.5$); dark grey – strong correlation ($0.5 \leq \delta$)

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The spatial agglomeration of low-input farming intensity: implications for biodiversity conservation

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Introduction

Many studies have revealed the negative impacts of farming systems with high input use on biodiversity. Less attention has been paid to the distribution of farming intensity on large gradient. Such knowledge is however crucial for the design of more efficient conservation policies. Indeed, the lack of spatial targeting has been identified as an important cause of their low effectiveness (Whittingham, 2007). Zonal policies targeting the protection of agglomerated high nature value areas may be more effective (Kleijn 2003; Feehan, 2005). Conversely, policies may also achieve positive changes when targeting high intensity areas (Primddahl, 2003). The debate on both policies option is still open because farming intensity data are often missing on large gradients. Most studies addressing the spatial distribution of farming intensity focused on organic farming. However, low-input, extensively managed farmlands are also crucial for biodiversity. Biodiversity may also display a non-linear continuous response to the gradient of agricultural intensity. It is thus important to study the spatial distribution of intensity at a fine scale consistent with a fine tuning of public policies. It requires an intensity indicator able to reveal broad gradients, and relevant for the different farming systems. The intensity indicator should also be computable, cost effective and easy to interpret. Most intensity indicators in the literature are relevant for a single production type and focus on a single component of agricultural intensity (*e.g.* N input). They often need specific surveys for their computation at fine scale or they remain at large scales (80-180 km wide entities) when using existing surveys. Objective of this paper was to test the agglomeration of low-input farming intensity at a fine infra regional scale. Relying on national agricultural statistics, we developed a novel method to estimate the value of an intensity indicator relevant for the main French farming systems. Finally we discuss the consequences of its use for the design of efficient conservation policies.

Materials and Methods

The FADN (Farm Accountancy Data Network) was used to develop an aggregated intensity indicator: the *Input Cost / ha* ("*IC/ha*" in *€/ha*). It was defined as the ratio between the main categories of input costs and the total utilized agricultural area (UAA) of the farm:

$$\text{IC/ha} = \frac{(\text{feed} + \text{fertilizers} + \text{fuel} + \text{seed} + \text{vet. prod.} + \text{electricity} + \text{pesticides})\,\text{costs}}{\text{Farm Utilized Agricultural Area}}$$

The use of costs rather than amounts made it possible to aggregate diverse categories of inputs, relevant for five farming systems: industrial crops, cereal crops, mixed farming, bovine dairy and bovine meat. With the FADN dataset, multinomial regression models were developed to predict the *IC/*ha indicator with *simple* variables (land uses, climatic, economic). Two other datasets (common agricultural policy declarations, agricultural social security) were used to compute the mean values of the same *simple* variables at the small agricultural regions ("PRA") scale (mean PRA width = 25 km). The models were then used to estimate the *IC/ha* value at the PRA scale from the *simple* variables. Validation procedure based on leave-one-out cross validation were used. The local Moran index was used to test for spatial agglomeration of PRAs with similar intensities. The local Moran measures spatial auto correlation. Positive values indicate spatial auto correlation *i.e.* clustering of PRAs with close *IC / ha* while negative values indicate more spatial dispersion of *IC/ha*. Significance of the spatial auto-correlation was tested with one-sided bootstrapping method on 1000 samples with replacement.

Results and Discussion

The estimation method provided a continuous value of the intensity indicator – the *IC/ha* – at the fine scale of the PRA (Figure 1a). The *IC/ha* indicator revealed a broad gradient of intensity, PRAs *IC/ha* values ranging from 37 to 1582 €/ha (mean ± sd: 452 ± 194 €/ha). Because the *IC/ha* was a relevant intensity indicator for five important agricultural production types, it could be computed for 84% of the French PRAs. We revealed the precise location of low-input systems, with an *IC/ha* value lower than 300€/ha. They were mainly concentrated in a large area spreading in the centre of France. Other regions contained more isolated low input PRAs, mainly in the eastern part of France. PRAs with high input levels were concentrated in western and northern regions of France while the medium *IC/ha* values filled the remaining territory. Figure 2 shows that within the two intensity extremes, PRAs were agglomerated. There was a significant relationship between the *IC/ha* value of a PRA and its local Moran (p<2e^{-16}, GAM with 5.8 d.f., explained deviance = 43.1%) *i.e.* the similarity with its contiguous neighbours *IC/ha*. The local Moran was positive for PRAs of the two intensity extremes, indicating that low-input PRAs were agglomerated, and PRAs with high *IC/ha* also. Conversely, PRAs with medium intensities showed weak local Moran, indicating more spatial dispersion. Figure 1b highlights the PRAs significantly agglomerated with contiguous neighbours of similar intensity (*IC/ha*). There was significant agglomeration of both low and high intensity PRAs. Most of the PRAs with low *IC/*ha in Figure 1a showed significant value of the local Moran agglomeration index. There was thus a large cluster of low input PRAs spreading across several regions in the centre/eastern France. Three main clusters with PRAs showing high, significantly auto-correlated intensity were found in south western, western and northern France. Both clusters of low and high intensity PRAs did not show consistency with administrative region borders. Therefore, spotting these clusters would not be possible with the regional averages provided by the standard agricultural statistics. Our approach could be helpful to design conservation policies targeted at an infra-regional scale consistent with the clustering of agricultural intensities. In order to improve the cost effectiveness of conservation policies, they may be targeted at the most suitable areas where environmental effects would be provided at lower costs than if conducted elsewhere (Uthes 2010). We suggest that protection policies for preventing extensive areas from intensification or abandonment may be targeted at the low-input clusters we revealed. Conversely, improvement policies for achieving positive changes should be targeted at the high-input clusters. As most of the datasets we used are available in other European countries, our approach could be generalized.
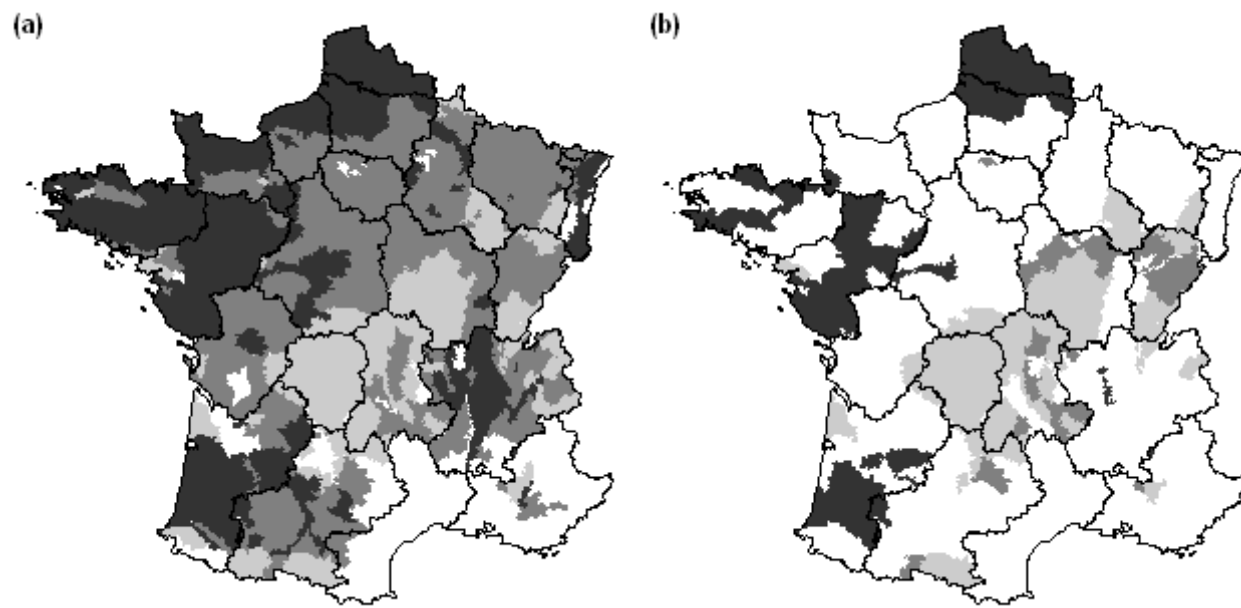
Figure 1. Maps of French PRAs agricultural intensity (*IC/ha*) and agglomeration. Light grey: low *IC/ha* (<300€/ha), medium grey: medium *IC/ha* (300-500€/ha), dark grey: high *IC/ha* (>500€/ha). Administrative regions borders are shown in black. (**a**): data not available for PRAs in white (PRAs dominated by other production types than the five focus types). (**b**): only the PRAs showing significant agglomeration with contiguous neighbours of similar intensity are plotted (PRAs in white means data not available or non significant agglomeration).
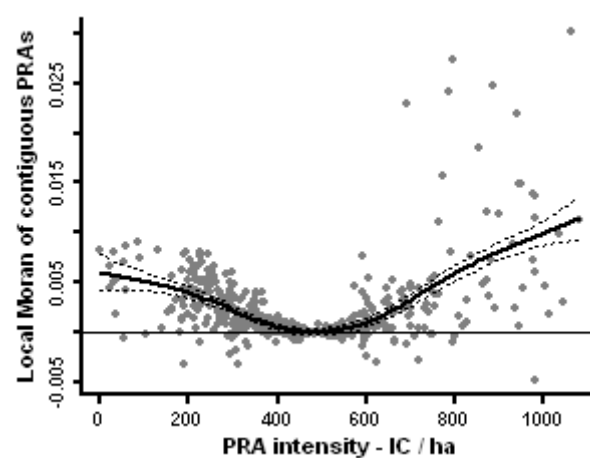
Figure 2. Relationship between the intensity (*IC/ha* value) of each PRAs and their local Moran index. Local Moran index indicates if a PRA is agglomerated with neighbours showing similar intensity (*IC/ha*) values. Each point stands for a PRA. A generalized additive model is used to determine the relation between *IC/ha* and local Moran (black curve), because this relation didn't seemed linear. 95% confidence intervals are shown in dotted lines.

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Conservation agriculture and rainfall variability in Zambia: is CA a promising option for responding to droughts and floods?

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Keywords: rain-fed agriculture, adaptation, climatic risks, food security, crop production

Introduction

Smallholder farmers of Sub-Saharan Africa (SSA) face a lot of risks in their agricultural production. For those in dry-land areas, major risks are related to rainfall and other climatic factors. Water stress in the root zone during critical crop development stages is a fundamental constraining factor contributing to the low yield levels of smallholder farms in such environments. Farmers use a range of approaches, to deal with climatic and other risks, such as choice of crop and crop varieties, use of fertilizer, planting density, water harvesting (Aune and Bationo, 2008). Conservation Agriculture (CA) is one agricultural system being promoted in dry-land areas of SSA as a response option to extreme climatic events such as droughts and floods. CA is a tillage sequence that minimizes or reduces the loss of soil and water and achieves at least 30% soil cover using crop residues (Mazvimavi & Twomlow 2009). It has recently been suggested that the main benefit of the basin variant of CA in water scarce tropical environments may be an in-situ water harvesting effect (Enfors et al, 2010). Since smallholder farming in SSA is mostly rain-fed and susceptible to intra and inter - seasonal droughts, the water harvesting effects of CA basins could prove to be a solution to this problem. With the adoption of CA, yield levels could be stabilized (FAO 2011).

While the benefits of CA in drought-prone regions have been widely documented, performance of CA in high rainfall areas has been more limited. Problems of water-logging from Nkhotakota District of Malawi have been documented (Ngwira et al, 2009). FAO (2011) acknowledged that there were limited benefits of CA in sub-humid environments during years with adequate rainfall as yields could be affected by water-logging. This is one reason why promotion of CA in Zambia has been concentrated on the low rainfall regions. Haggblade and Tembo (2003) noted that the highest adoption rates of basins in Zambia had occurred in the low rainfall regions. While there is literature on performance of basins in low rainfall areas and also for high rainfall areas, there is limited information on the performance of CA basins in drought-prone or low rainfall areas during incidences of high rainfall or flooding. Models of future rainfall trends in Zambia have predicted that low rainfall areas will experience an increase in flooding incidences (GRZ 2007). We report on CA performance during flooding episodes in areas that are normally characterized by low rainfall and droughts.

Materials and Methods

Three provinces were selected as study areas based on variations in agro-ecology and on past and current efforts in the promotion of CA. These were the Southern, Central and Eastern provinces of Zambia. Questionnaires were administered to 640 randomly selected households between June and September 2007. These were households that were under the Conservation Agriculture Programme under the auspices of the Conservation Farming Unit (CFU) of the Zambia National Famers' Union. The same households were interviewed again in 2008 and 2009 although the sample size reduced to 535 in 2008 and 486 in 2009 due to migration due to floods, deaths, and absenteeism. The sampled households were asked questions on their agronomic practices, farming expenditure, and crop yields. The crop yield data obtained from the surveys were correlated with the rainfall data for the areas. Key informants included agriculture extension staff involved in CA and long time residents of the study areas. Two focus group discussions were conducted each consisting of eight CA farmers. Discussions focused on experiences with CA under drought and flooding regimes.

Results

The farming households surveyed over the three year period allocated up to 25% of their cultivated land to CA. The percentage of total land area under CA increased steadily during the three farming seasons although the average area under CA remained the same during the 2007/8 and 2008/9 farming seasons. The percentage increase was as a result of the reduction in the area under conventional agriculture (CV) (Table 1). The average maize yields were 3.4 tons ha^{-1} in the 2006/7 farming season but only 0.77 tons ha^{-1} in the 2007/8 farming season. There were no statistically significant differences in the rainfall received during the 2006/7 and 2007/8 farming seasons (p=0.838). Both seasons had above normal rainfall. The above normal rainfall of 2006/7 did not seem to negatively affect maize yields while that of 2007/8 resulted in significantly lower yields (p=0,003). This finding reaffirms the importance of not only the average amount of rainfall that is received per season but its onset and distribution. ZVAC (2008) observed that the rains experienced in Zambia during the 2007/8 season were atypical not only in their intensity but in their distribution. They covered the usually drought stricken low-lying areas of southeastern Zambia and caused flash floods. FAO (2011) reported that the occurrence of intra-seasonal dry spells that coincide with critical stages of crop growth rather than total seasonal rainfall *per se* may complicate crop establishment and reduce yields. The same may apply to incidences of flooding. The households seemed to have responded to the floods and the lower yields of the 2006/7 farming season by reducing the area under CV and maintaining the area under CA the following season.

Table 1: Land area allocation to CA/CV and Maize yields

	Season		
	2006/7	2007/8	2008/9
Average area under CA (ha)	0.22	0.42	0.42
% of cultivated area under CA	11.5	16.5	24.9
Average area under CV	1.69	2.12	1.27
Total cultivated area (ha) per household	1.91	2.54	1.69
Average Maize yield (tons/ha)	3.39	0.77	1.65
Average rainfall (mm)	1046.3[a]	1086.8[a]	858.6[b]

CV = Conventional agriculture. This includes the use of mould board plough and traditional hand hoe for tillage.
[a]Means followed by the same letter in row are not statistically different at p≤ 0.05 probability level.

Analysis of the area under CA revealed that the households allocated 0.19ha, 0.31 ha and 0.28ha to basins in the 2006/7, 2007/8 and 2008/9 farming seasons respectively. The figures for ripped areas were 0.04ha, 0.11ha and 0.14 ha respectively. The area under basins was slightly reduced while the ripped area continued to increase. Focus group discussions and key informants suggested that problems of water-logging were reported in basins during the years of above normal rainfall. The continued increase in ripped area may be a demonstration of the farmers' confidence in the tillage system under flooding conditions. Farmers reported that they dealt with the problem of water-logging in basins during incidences of above normal rainfall by backfilling the basins completely and/or making ridges. Such sentiments as "we (CA adoptors) were more food secure than our friends who did not use CA…Most of us do harvest quite enough for household consumption either during flood year or drought year while our friends who depend on CV little and mostly nothing…" Other studies have shown that farmers argued that early land preparation and planting associated with conservation agriculture increased chances of survival of the maize crop from floods and increased water retention capacity under CA contributed to higher crop production than under CV during a drought year (Nyanga et al. 2011). We conclude that there is potential for higher production under CA than under CV during incidences of both drought and floods among the Zambian smallholder farming

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A preliminary evaluation of irrigation performance and in season changes under permanent raised beds on Vertosol in Queensland, Australia

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Keywords: efficiency, lateral infiltration, optimisation

Introduction

The irrigation performance of the lengthy Australian raised beds has been largely considered not optimal. Many past studies have suggested changes to current irrigation management and field design for improving irrigation performance. However, the combined impact of variable agronomic management under permanent raised beds (PRB), bed furrow configuration and seasonal changes were rarely considered during past studies. This preliminary study was conducted to identify the current irrigation performance, spatial and temporal variations in soil hydro-physical properties. The key focus was the temporal and spatial variations in lateral infiltration into the centre of permanent raised beds and to identify strategies to improve irrigation performance.

Materials and Methods

Two Vertosol sites, one near Cambooya (site 1) and one near Dalby (site 2) in southern Qld, Australia were assessed during the 2010 summer season. Site 1, was under conservation agriculture (CA) for the last 35 years on 2 m wide beds until the beds and furrows were reorientated by 20^0 before the experiment. After reorientation for improved water harvesting, 8 rows of soya bean, were planted. The blocked end furrows were 460 m long, 48 cm wide and 9 cm deep. The 1 m wide beds (ridges) at site 2 were cultivated annually before cotton sowing to control pests while the furrows (455 m long, 62 cm wide and 9 cm deep) were not relocated season after season.

Field data of furrow dimensions, furrow inflow rate (Q), multiple readings of distance and time of water advance along the furrow and the time to cut-off (T_{co}) were recorded in each furrow and event during four irrigations at all sites. The measured field data was used to calculate the infiltration characteristic for each furrow and irrigation event using IPARM (Gillies and Smith, 2005). IPARM outputs and other field data were then used to parameterise the SIRMODIII model (Walker, 2003) whose calibration was achieved by adjusting the manning's roughness coefficient until the simulated and measured advance times matched. The calibrated model was then used to evaluate the irrigation performance in the form of application efficiency (E_a), ratio of the water stored in the root zone and the water received at the field inlet; requirement efficiency (E_r), ratio of volume of water stored in the root zone to the pre-irrigation root zone soil moisture deficit; and distribution uniformity (DU), average infiltrated depth of water in the lower one quarter of the field divided by the average infiltrated depth of water over the whole field.

Three strategies including optimising: 1. *Tco*; 2. *Tco* and *Q* and 3. Furrow length was tested. The evaluation was based on ensuring $Er \geq 85\%$ (to replenish maximum *SMD* and to utilise in season rainfall effectively) and flow arrival to tail end to avoid dry field sections.

Wetting front penetration into the centre of wide bed at site 1 was recorded at 10 minutes interval at 33, 67 and 100 cm distance from furrow centre across the 2 m wide bed using soil moisture sensors (Sentek®) at 10, 20, 30, 50 and 70 cm depth at four locations, 2 at head (50 m) and 2 at tail (350 m) along furrow. Soil samples using cores 5 cm x 5 cm at 0-10, 10-20 and 20-30 cm depth were collected during the cropping season to determine bulk density using the gravimetric method.

Results and Discussion

Furrow inflow under farmer management was considerably different between the two sites at 1.94 and 2.54 L.s^{-1}. Although furrow lengths were similar, advance times (Ta) and Tco at site 1 were double that of site 2. The difference in *Ta* at site 1 between irrigation events was small at 13% (993 vs. 862 minutes). However *Ta* at site 2 was 34% different between events at 387 minutes (irrigation 1) and 584 minutes (irrigation 2). Consequently, average total inflow was considerable at both sites at 1.4 and 1.1ML/ha respectively due to improper irrigation management (Table 1). As expected degraded soil conditions under conventional tillage with relocated furrow positions increased advance times, whilst large cracks, facilitated by smaller bed sizes and excessively dry soil, on one hand assisted infiltration, but on the other caused considerable soil erosion and furrow blowouts.

Table 1: Impact of irrigation management strategies on current irrigation performance of two sites under black cracking Vertosol soils in southern Queensland, Australia, (values in brackets are +/- standard deviation).

Site	Strategies	Q (L.s^{-1})	Tco (min)	Ea (%)	Er (%)	DU (%)	Inflow (m^3/ha)	Water saving (%)
Cambooya	**Farmer managed**	1.94	1100	72.5	100	90	1393	
		(0.1)	(61)	(6)	(0)	(3)	(113)	
	1. *Tco* optimised	1.94	921	80	92	74	1167	16
		(0.1)	(84)	(8)	(2)	(3)	(137)	
	2. *Tco* and *Q* optimised	3.25	425	98	85	88	879	37
		(0.7)	(88)	(1)	(0)	(3)	(11)	
Dalby	**Farmer managed**	2.54	635	79	97	87	1062.2	
		(0.1)	(64)	(8)	(2)	(1)	(84)	
	1. *Tco* optimised	2.54	473	97	88	77	790.3	26
		(0.1)	(121)	(1)	(3)	(2)	(186)	
	2. *Tco* and *Q* optimised	3.125	370	97	85	82	761.6	28
		(0.2)	(40)	(3)	(0)	(4)	(125)	

Results showed around 32% deep percolation losses during irrigation 1 and around 23% during irrigation 2 for fulfilling *SMD* at *Er*>99% while *DU* ranged 88 to 92% at site 1. At site 2, application losses were around 26% during irrigation 1 (18% deep drainage and 8% tail end runoff losses) and 15% during irrigation 2 (mainly deep drainage) for fulfilling *SMD* at *Er*>96% and *DU*>86%. The reasons were attributed to current in appropriate agronomic management, improper bed furrow configurations and adverse seasonal changes. For instance the loose soil conditions due to deep ripping, smaller furrow dimensions, large furrow surface roughness and more wetted perimeter, as the flow overtopped the bed due to smaller furrow dimensions affected *Ta* and irrigation performance. Consequently, significant erosion and furrow filling was observed at head reaches that compelled the farmer to excavate and enlarge the furrows again before 2nd irrigation.

Irrigation management strategy 1 predicted improved *Ea* that ranged 7-9% at site 1 and 12-23% at site 2, improved water saving that ranged 14-19% at site 1and 18-34% at site 2 at the cost of reduced DU that ranged 14-16% at site 1 and 8-12% at site 2 from existing values. Strategy 2 predicted improved *Ea* that ranged 23-29% at site 1 and 14-21% at site 2, improved water saving that ranged 34-40% at site 1 and 25-30% at site 2 with no significant trade off values at both sites (Table 1). Strategy 3 predicted greater than 90% *Ea* and *DU* at reduced furrow length of 300 m when *Q* was 2 L.s^{-1}. The relationship of optimum *Tco* vs. *Q* (Figure 1) identified can be used as simple decision support aid under comparable field conditions with no cost to labor or machinery.

Results illustrated spatial and temporal variations in lateral infiltration. For instance lateral infiltration was around 33% larger near the furrow (<67 cm from furrow) while the bed middle (67-100 cm range) received 11% less infiltration during irrigation 1 than irrigation 2. Similarly, the bed middle at tail (350 m) end received 37% less infiltration than head (50 m). Maximum lateral infiltration, in 70 cm profile depth, to the centre of 2 m wide bed was achieved during 5 hours of infiltration opportunity time (Figure 2). These variations were attributed to soil subsidence, evidenced by increased bulk density of 10-30 cm profile with time, and reduced flow depth in furrow at tail end. Thus, it can be summarised that irrigation performance can be improved effectively with irrigation management and field design strategies once variable field conditions including soil characteristics, lateral wetting and bed furrow configurations are managed properly.
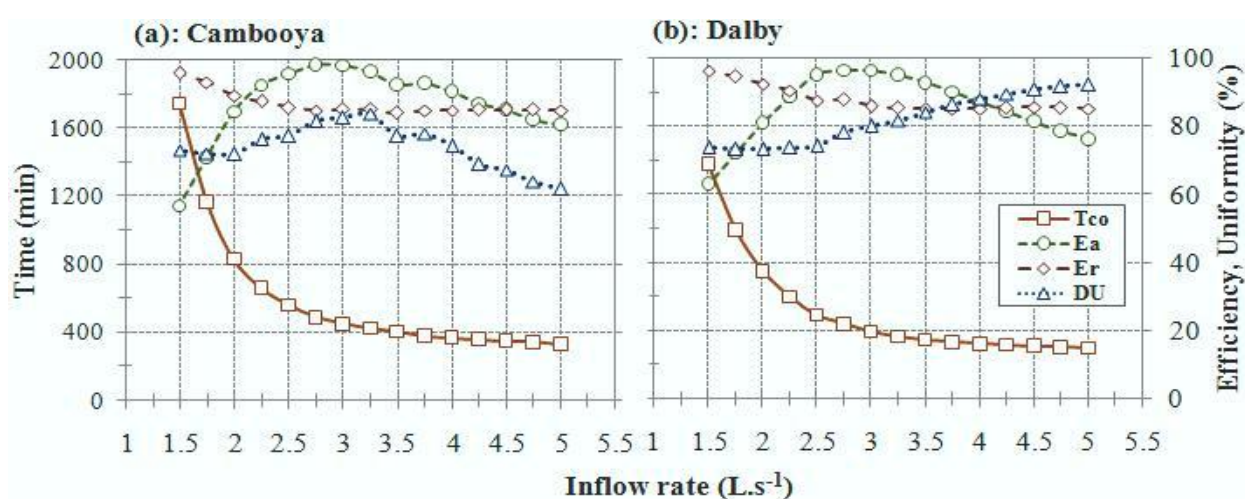
Figure 1: Relationship of optimum *Tco* vs. *Q,* average values of two irrigations, with predicted irrigation performance (*Ea, Er* and *DU*) at two sites.
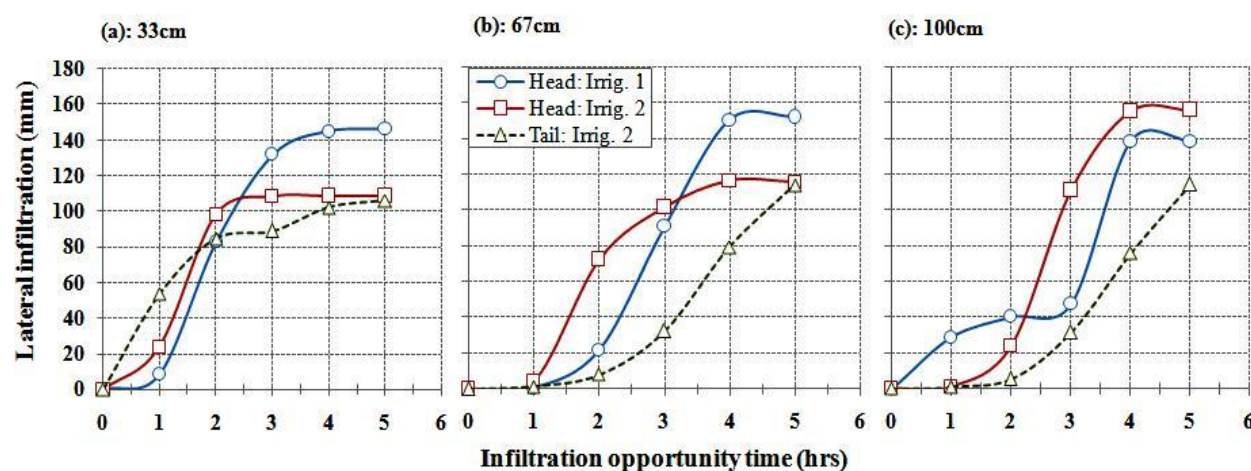
Figure 2: Temporal and spatial variations in water lateral infiltration across 2 m wide bed at (a) 33cm, (b) 67cm and (c) 100cm from furrow centre during summer 2010 (soya bean) at Cambooya, Qld, Australia.

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Reducing nitrate leaching and nitrous oxide emissions using microbial community fermentation technology

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Keywords: integrated nutrient management, enhanced efficiency fertilizer, greenhouse gas

Introduction

Reducing the off-site impacts of fertilizers from agriculture is of world-wide concern, both from an environmental and human health perspective. Nitrogen (N) loss has been addressed more than any other fertilizer nutrient due to the different forms of N and their impact on water quality and the atmosphere. Various approaches have been taken to reduce N loss from soil including the use of slow/controlled release fertilizers, nitrogen stabilizers, and encouraging a greater use of organic or manure-based fertilizers (Trenkel, 2010; Kramer et al., 2006). Integrated nutrient management practices have been developed which draw on multiple factors, including microbial additives, to maximize fertilizer use efficiency and minimize nutrient loss, especially N. Integrating microbial additives into standard or reduced applications of inorganic fertilizers has been shown to improve fertilizer use efficiency (Adesemoye and Kloepper, 2009; Adesemoye et al., 2009). The primary benefits of combining microbial additives to fertilizers is believed to be related to root growth enhancement and increased nutrient uptake, thus the potential for N loss is reduced due to a more efficient nutrient capture by the root system (Adesemoye et al., 2009). Our literature searches did not reveal studies where microbial inoculants were demonstrated to reduce nutrient loss due to non-plant related mechanisms. In this report, we evaluated the microbial-based product, SoilBuilder AF (Advanced Microbial Solutions, Pilot Point, TX USA) for its ability to reduce nitrate leaching and nitrous oxide emissions. This product is derived from a large and complex fermentation microbial community containing several thousand species of bacteria and their by-products (patent pending process). We will demonstrate that this technology can be used to reduce nitrate leaching and N_2O emissions through mechanisms other than root growth enhancement.

Materials and Methods

Nitrate leaching was evaluated in a 3-year field study conducted at Arise Research and Discovery, Martinsville, IL from 2008 – 2010. Field lysimeters were established by partitioning three sides of four plots (4.57 x 9.14 m) to a depth of 1.06 m using heavy gauge plastic sheeting. The fourth side was not partitioned and was bordered by a lysimeter well into which a 10 cm diameter drain tile (buried at 1.06 m) drained leachate from the partitioned plot into the well. Each lysimeter plot was planted with 4 rows of corn spaced at 76 cm x 9.14 m long. At planting, 47 kg N/ha was applied as urea ammonium nitrate (UAN-28) to all plots. Two of the four plots received 9.3 L/ha of the microbial fermentation product, SoilBuilder AF, which was tank mixed with UAN-28. At 2 – 4 weeks after planting, another side-dress of UAN-28, without SoilBuilder AF, was applied at rates of 135 kg N/ha for the full N rate or reduced rates of 115, 125, or 98 kg N/ha for the 2008, 2009 and 2010 growing seasons, respectively. Thus the treatments each year consisted of a full and reduced N application rate with or without SoilBuilder AF. The lysimeter wells were pumped dry at planting and at 5 subsequent times during the growing season to determine water volume leached from the plots, and nitrate concentration in the leachate. Lysimeter tubes (3/row; 12/plot) were used to calculate relative amounts of water leaching under each row of corn within each plot.

In a separate study, N_2O emissions were evaluated from closed, plant-free soil systems in studies conducted at Auburn University, Auburn, AL USA. The non-sterile soil (400 g/0.95 L glass jar) was adjusted to 20% moisture and treated with or without SoilBuilder; SoilBuilder filtered free of microbial cells (microbial by-products only); a mixture of four Bacillus species (1 x 10^5 cfu/mL); or an untreated control. All containers received 25 mL of solution containing the appropriate microbial or control treatment. The fertilizer treatments were applied in equal liquid volumes and consisted of urea ammonium nitrate (UAN-32), calcium ammonium nitrate (CAN-17), ammonium nitrate (AN) or urea, with each fertilizer delivering 75 mg N/kg of soil. Soils were incubated and sampled at 1, 2, 8, 15, 22 and 29 days to determine N_2O concentration in the air headspace. N_2O was measured by gas chromatography in air samples removed by a syringe through a needle septum sealed in the lid of each jar. After withdrawing samples, the jars were opened and allowed to equilibrate at room temperature with the ambient atmosphere prior to re-sealing for the next measuring period.

Results and Discussion

In the field lysimeter studies, there were statistically significant ($P < 0.05$) reductions in nitrate leaching and significant corn yield increases with the addition of SoilBuilder AF compared to the controls (Table 1). The reductions in nitrate leaching ranged from 25% - 37% and occurred at both the high and low N application rates. In these studies, the lysimeter plots received the same SoilBuilder AF or control treatments for each of the three years and, based on the differences in nitrate concentrations at the first sampling of each year, there appears to be a winter carry-over effect on N retention in the soil due to the SoilBuilder AF treatment. Also of interest is that significant reductions in nitrate leaching due to SoilBuilder AF treatment were observed very early in the season and prior to any significant root growth. Root density measurements made in 2010 (data not shown) indicated that there was no significant difference in root density between the SoilBuilder AF and control treatments at the high fertilization rate even though there was a 37% reduction in nitrate leaching over the season. This would suggest that the microbial treatment influenced the retention of soil N by a mechanism(s) other than root growth stimulation as proposed by Adesemoye et al. (2009).

Table 1. Concentration of nitrate (mg/L) in water leached into lysimeter wells and corn yield from fertilized field plots untreated (UT) or treated with SoilBuilder AF (SB).

	2008				2009				2010			
Fertilizer	182 kg N/ha		162 kg N/ha		182 kg N/ha		172 kg N/ha		182 kg N/ha		145 kg N/ha	
Treatment	SB	UT	SB	UT	SB	UT	SB	UT	SB	UT	SB	UT
Pump date 1	9.5	9.8	9.8	9.8	8.0	10.3	**8.0**	11.3	**7.0**	9.0	**5.0**	6.0
Pump date 2	10.0	12.0	9.3	9.3	**8.8**	10.8	**8.5**	10.8	**9.0**	15.0	10.0	12.0
Pump date 3	**9.8**[1]	16.8	**11.3**	17.0	**8.3**	14.3	**9.0**	15.8	**13.0**	19.0	12.0	15.0
Pump date 4	**6.5**	13.0	**7.5**	11.0	**7.5**	14.0	**8.3**	13.3	**8.0**	13.0	12.0	13.0
Pump date 5	**7.3**	10.3	**7.0**	11.0	**7.5**	13.8	**7.0**	14.0	10.0	12.0	**7.0**	12.0
Pump date 6	**6.0**	10.3	**5.0**	8.8	**7.3**	12.3	7.8	10.5	**1.0**	4.0	2.0	4.0
Avg % NO$_3$ reduction	30.4%		36.2%		35.9%		34.5%		37.3%		25.4%	
Yield(Mg/ha)	**11.93**	11.24	**11.94**	11.03	**11.71**	11.08	**11.89**	10.95	**9.31**	8.51	**9.09**	8.06

[1]Boldfaced values comparing SB and UT treatments within the same growing year and fertilizer-N rate are significantly different from non-boldfaced values (P<0.05).

Table 2. Total nitrous oxide emissions (ppm) from non-sterile soils in jars treated with various nitrogen fertilizers and microbial-based inoculants.

	Liquid fertilizer applied at 75 mg N/kg soil			
Treatment	Calcium ammonium nitrate (CAN-17)	Urea ammonium nitrate (UAN-32)	Ammonium nitrate (AN)	Urea
SoilBuilder Filtered	190.99 c[1]	77.87 c	40.30 a	373.34 ab
SoilBuilder (by-products only)	110.91 c	212.72 bc	2.89 b	187.97 bc
Mix of 4 Bacillus sp (1 x 10^5 cfu/mL)	288.87 b	336.73 ab	32.08 a	349.74 a
Control	584.00 a	383.87 a	37.58 a	167.18 c

[1]Values within columns not sharing the same letter are significantly different (P<0.05).

The SoilBuilder product used in the N$_2$O emission study is the non-concentrated formulation of SoilBuilder AF used in the above studies on corn. Our results demonstrated that SoilBuilder significantly reduced N$_2$O emissions from soils treated with CAN-17 and UAN-32 (Table 2). The filtered SoilBuilder (microbial by-products only) significantly reduced N$_2$O emissions from CAN-17, UAN-32 and AN, while the mixture of four Bacillus species significantly reduced N$_2$O emissions over the control in the CAN-17 treatment only. Since there were no plants in these experiments, this reinforces the conclusions from the field corn lysimeter studies described above, that SoilBuilder and SoilBuilder AF are reducing N loss through non-plant related mechanisms.

The above studies demonstrate that microbial community fermentation technology, when combined with inorganic-N fertilizers, can be of significant value in the reduction of nitrate leaching and nitrous oxide emissions, and increase crop yields. Farmer profit at reduced fertilizer-N with SoilBuilder AF compared to the full N control was $US 107.72, 122.92 and 107.29/ha above product cost in 2008, 2009 and 2010, respectively (based on corn prices at $US 0.21/kg and nitrogen at $US 1.21/kg). We believe this is the first report to document the use of a microbial-based technology for inorganic fertilizers which will reduce N loss by mechanisms other than plant root growth enhancement.

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Soil carbon storage under no-tillage practice in northern Tunisia

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Keywords: soil organic carbon, no-tillage, physical fractionation

Introduction

Soil organic carbon (SOC) is considered as one of the keys to soil fertility (Lal, 2007) and is strongly influenced by tillage implementation (Olson et al., 2005). Conventional tillage (CT) for seedbed preparation and weed control may enhance organic matter loss (Cannell et al., 1994). Since 1999, no-tillage (NT) has then been introduced in order to develop sustainable agricultural systems in Tunisia. No-tillage areas increased from 52 ha in 1999 to 12000 ha in 2010. Halvorson et al. (2002) estimated 233 kg C ha^{-1} yr^{-1} was stored under NT *versus* 141 kg C ha-^{1} yr^{-1} under CT. One of mechanisms involved in soil carbon storage is organic carbon localisation in soil fractions. In fact, carbon in macro-aggregates is more labile than carbon in micro-aggregates and tillage can modify this distribution (Sollins et al., 1996). The goal here is to evaluate the effect of no-tillage in SOC storage and to study its distribution in soil physical fractions.

Materials and Methods

Soil samples were collected in March 2010 at 10 cm depth from 6 farmers' fields in northern Tunisia. Conventional tillage, no-tillage over less than 5 years (NT$_{<5 \text{ years}}$) and no-tillage for more than 5 years (NT$_{>5 \text{ years}}$) have been practiced in each farmer's field experiments.
Soil organic carbon (TOC) was determined using the Walkley-Black procedure (1934) on ground soil. Physical fractionation of soil organic matter was used to separate particulate and humified organic carbon according to the protocol proposed by Balesdent et al (2000). The sample was dispersed in deionized water during 24 h. Coarse plant debris (particulate organic carbon: POC) was recuperated by flotation. Humified (HOC) and non-humified (NHOC) organic carbon were isolated by passing the dispersion through 71 μm sieve. Organic carbon content of HOC (<71μm) and NHOC (>71μm) were determined using the Walkley-Black (1934) method.

Results and Discussion

SOC content was significantly greater under no-tillage than in conventional tillage (+ 0.3% and +0,7% in plots NT$_{<5 \text{ years}}$ and NT$_{>5 \text{ years}}$, respectively) (Figure 1). The SOC stored was approximately 1 t C ha^{-1} year^{-1}. This result is in accordance with former studies where the SOC varied from 0.2 to 1 t C.ha^{-1}.year^{-1} (Halvorson et al, 2002; Bayer et al, 2006; Metay et al, 2007). This increase could be due to the carbon restitution which is more important in NT than in CT.

SOC increase was observed in POC, NHOC and HOC fractions in NT$_{>5 \text{years}}$ compared to CT of about 4%, 34% and 6% respectively (Figure 2). The HOC increase shows the contribution of NT practice to aliment soil stable carbon.

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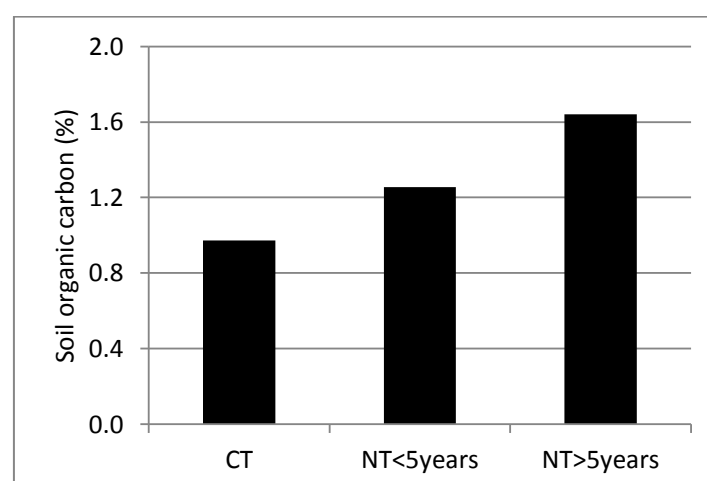
Figure 1. Soil organic carbon (SOC) in 0-10 cm depth of plots with conventional tillage (CT), no-tillage over less than 5 years (NT$_{<5\text{years}}$) and no-tillage for more than 5 years (NT$_{>5\text{years}}$).
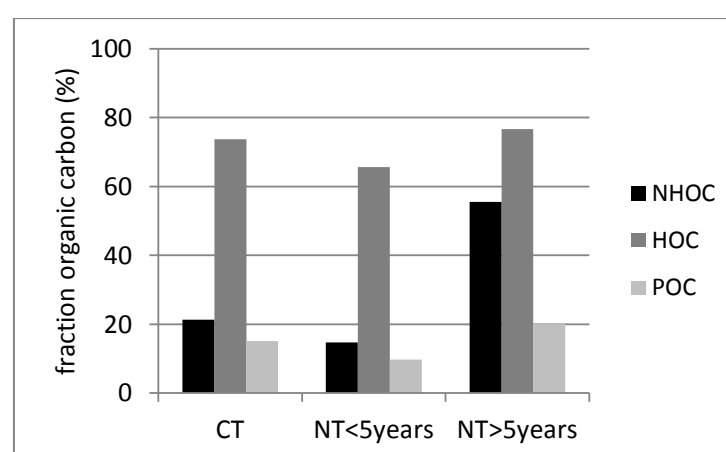
Figure 2. Soil organic carbon distribution in the 0 -10 com depth interval in fractions of particulate organic carbon (POC), humified organic carbon (HOC) and non-humified organic carbon (NHOC) for conventional tillage (CT), no-tillage over less than 5 years (NT$_{<5 \text{years}}$) and no-tillage for more than 5 years (NT$_{>5\text{years}}$).

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Aspects of the use of Conservation Agriculture - as the most sustainable system of farming in arid conditions in Karakalpakstan

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Keywords: water shortage, salinity, moisture, drying, crop residue

Introduction

Karakalpakstan – a Republic located in the southern part of the shrinking Aral Sea – receives only about 100 mm of rainfall, with average annual evaporation of over 1250 mm, and therefore all crop production requires irrigation. The economy is based on agriculture and therefore, the welfare of the population depends on the sustainability and efficiency of farming. However, due to the reduced flow of the Amu Darya River, availability of water for irrigation has been reduced causing marked hardship of the rural population of Karakalpakstan. In "low-flow" years 26.2 to 63.4 per cent of agricultural land remains uncropped, a strong negative impact on the social and economic situation of the Republic as a whole.

Farmers, and the population in general, are well aware that water will become increasingly scarce and that urgent steps must be taken to achieve stability, even in low-flow years. However, at the same time soil fertility is steadily declining as a result of low soil organic matter and widespread salinization, and therefore higher input and labor costs are necessary to attain high yields. Unfortunately, in many cases, farmers are struggling not with the causes of low fertility, but with its consequences.

The current system of agriculture in Karakalpakstan is based on multiple tillage passes that require are expensive and involve considerable energy and labor costs. Although this system assumes the improvement of soil fertility and the attainment of high yields, in reality it is far from achieving sustainable agriculture. However, changing ideas held for centuries and overcoming the belief that "it impossible to harvest without plowing" is exceptionally difficult. Therefore, we carried out experiments on the impact of Conservation Agriculture on some soil parameters of the soil, to begin the gradual shift to the use of water- and resource-conserving farming systems.

Materials and Methods

Implementation of new production methods is always accompanied by problems and difficulties associated with changing established views and opinions. Therefore, in the process of promoting Conservation Agriculture we used approaches aimed at achieving a gradual understanding of the principles and practice of Conservation Agriculture practices among farmers and decision makers. We realized that the demonstration of effects is more effective than talking about the concepts and so we decided to conduct research on the impact of Conservation Agriculture on individual soil parameters.

Demonstration sites were incorporated in the Amudarya district (1,6 ha), Kanlikol district (5 hectares) and Chimbay district (2 hectares). Soils of the site are medium loamy light grey soils. The humus content of soil sites ranged 0,56%-0,71%, which shows a low supply of soil with organic matter. Annually by the end of the growing season the level of soil salinity increases, and therefore before making demonstration sites there conducted leaching of soil salts within 3000-4000 m3 depending on the degree of salinity. Demonstration sites have been prepared beforehand with deep plowing and leveling of field with the laser equipment (Laser land leveling). Then sowing of wheat was performed to create a mulch cover. To measure the flow rate in irrigation water a primitive water meter was installed. To measure the depth of groundwater a piezometer was installed in the Amudarya district.For qualitative soil assessment we used the methods of Visual Soil Assessment developed by G. Shepherd and adapted by J. Benites (1). We determined soil moisture gravimetrically and salt content by the aqueous extract.

Results and Discussion

One of the main components of Conservation Agriculture - the conservation of crop residues on the soil surface - is unusual to farmers and authorities as over centuries they have been accustomed to clean tilled fields. However, research results show that residue retention reduced soil salinity in the upper 10 cm horizon by 75%, and in the top 100 cm depth by nearly 40% compared to areas without residue cover. Soil moisture on fields with winter wheat straw retained on the soil surface varied from 2.5-5.6 % higher at different times of the crop season compared to areas without straw cover.

Survey of fields using the simplest method of Visual Soil Assessment showed that when Conservation Agriculture was applied for two consecutive years, soil quality increased by 7.6 points on the Ranking Visual soil score (Shepherd,2008). Meanwhile, a noticeable improvement in the structure and porosity of the soil was observed. Monitoring studies have shown that using Conservation Agriculture input costs have declined by 68 percent compared to the commonly used agricultural technologies.

Conclusions

- It is difficult to change people's mindset, but by showing positive examples we can gradually change people's minds and in the end achieve widespread use of zero tillage in the region, as the most sustainable (both environmentally and economically) way of farming

- Our research in this aspect is at an early stage. However, initial results are encouraging and they show that under conditions of frequent water shortage, it is necessary to expand and continue research to develop the most comprehensive, science-based recommendations for the use of Conservation Agriculture in the arid conditions of Karakalpakstan.

When using Conservation Agriculture input costs of the farmers in the pilot sites has declined by 68 percent compared to the commonly used agricultural technology. This can be a motivating factor for involvement of farmers to the use of Conservation Agriculture.

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Evaluation of conservation tillage methods in wheat planting in south of Iran

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Keywords: direct drilling, corn residue, reduced tillage.

Introduction

The major objectives of conservation tillage, including principally reduced and no tillage practices, are eliminating mouldboard plowing and burning of the residues. In conservation tillage, the ridges of the previous crop are used, crop residues are retained to cover at least 30% of the soil surface for the next planting, and an appropriate rotation is implemented. In Hamedan, Iran, conventional, reduced, and no till planting methods were compared in a wheat-sugar beet rotation (Saati, 2005). Results showed no significant difference among the tillage methods. Sadegh nejad and Rahmati (2003) compared the effects of different tillage methods on yield of soybean in a wheat-soybean rotation in Gorgan, Iran. Over the three years of the experiment there were no significant differences among conventional, reduced and no tillage methods although reduced tillage (chisel plow) had the highest yield. Smika (1991) compared the effects of different tillage methods on water-holding capacity, soil erosion, nutrients absorption, and wheat yield, and found out that no tillage with residue retention increased grain yield and water-holding capacity as much as 10% and 9% respectively.

Materials and Methods

The current experiment was seeded to wheat on a farm close to Dezful town, Khuzestan Province, in southern Iran. Fourteen treatments in 10 replicates were established in a randomized complete block design on an eight hectare farm in the fall of 2007. Treatments were as follows:

1 - disking (2 times), direct drilling;
2 - disking, fertilizing, planting with combination planting machine
3 - disking (3 times), fertilizing, planting, disking (control plot)
4 - disking, direct drilling
5 - crimper conditioner (2 times), disking, fertilizing, planting, disking
6 - crimper conditioner, disking, fertilizing, planting, disking
7 - crimper conditioner, direct drilling
8 - direct drilling
9 - fertilizing, disking, direct drilling
10 - crimper conditioner, fertilizing, disking, direct drilling
11 - fertilizing, planting, Delta combination tiller
12 - disking, Delta combination tiller, fertilizing, planting, disking
13 - crimper conditioner, Delta combination tiller, fertilizing, planting, disking
14 - Delta combination tiller, fertilizing, planting, disking.

The farm had a silty clay loam soil (clay 30%, silt 46%, sand 24%), and the previous crop was seed corn. After corn harvest, soil preparation was done in each plot according to the treatment. Each plot was 200 m long and 14 m wide and after soil preparation wheat was planted at 180 kg ha^{-1} in all plots on December 20, 2007. Table 1 shows the specifications of the implements used.

At planting, up to 280 kg ha^{-1} of basal fertilizer was applied (up to 100 kg ha^{-1} ammonium nitrate, 80 kg ha^{-1} triple superphosphate and 100 kg ha^{-1} potassium sulphate depending on the site), followed by up to 150 kg ha^{-1} N in two post-emergence applications. Herbicide application and irrigation were conducted following normal farm practices. At maturity, 10 samples of 1m^2 each were taken from all plots to measure yield and yield components and finally, plots were harvested individually by a JD 955 combine harvester.

After measuring biological (total of straw and grain) and grain yield, and yield components (including plant m^{-2}, spikes m^{-2}, and 1000 grain weight) the analysis of variance of the experiment was performed using MSTATC software.

Results and Discussion

Results are shown in Table 2. Different tillage methods showed a significant difference on the wheat yield at 1% level. Treatments 1 (4729 kg ha^{-1}) and 13 (2930 kg ha^{-1}) had the highest and lowest yields respectively. Treatment 1, a direct drilling treatment, yielded 800 kg ha^{-1} more than the control plot (3). The average yield of all direct drilling treatments (1, 4, 7, 8, 9, and 10) was 4361 kg ha^{-1}: 430 kg ha^{-1} (10%) more than both the control plot and the average of all reduced tillage plots (2, 5, 6, 11, 12, 13, and 14).

Treatment 8, which had only one pass of the tractor for land preparation, had a higher yield than the control plot and the average of all reduced tillage treatments. Considering the reduction of passes of tractor and implements, and saving energy and time in this treatment, it can strongly be recommended.

Placing seed and fertilizer beside each other did not show any negative effect on wheat yield (comparison between treatments 8 and 9 in Table 2).

In treatments 11 to 14, in which the Delta combination tiller was used, except for treatment 12, in which a primary disking was performed before using the Delta, other treatments (11, 13, and 14) had the lowest yields among the all treatments.

A combination planting machine is suitable for wheat planting, but in using the machine two main points must be kept in the mind. First, it needs a primary disking prior to seeding and second, it cannot work in wet or dry soils whereas the Gaspardo direct drilling machine does not need a primary operation on the soil before use.

Table 1 Specifications of the Implements

No.	Implement	No. of tillage units	Work width (cm)	Work depth (cm)	Manufacturer	Speed (km/h)	Pulling tractor
1	Offset disk	28	300	8-20	JD, Germany	6	JD 3140
2	Crimper conditioner	24	310	-	Gaspardo, Italy	5-7	New Holland TM155
3	Border maker	2 disks	100	8-10	Local manufacturer	8-10	JD 3140
4	Fertilizer distributor	-	1400	-	Local manufacturer	8-10	JD 3140
5	Delta combination tiller	7 sweeps, 4 disks	300	5-10	Overum, Sweden	10-13	JD 4955
6	Combination planting machine	24	300	8-10	Gaspardo, Italy	6-8	New Holland TM155
7	Grain drill	35	400	3-5	Russia	6-8	JD 4230
8	Direct drill machine	17	306	3-5	Gaspardo, Italy	12-15	JD 4955

Table 2 Comparison among the average values of tested components by Duncan's multiple range test.

Treatments	Grain yield (kg/ha)	Plant/m^2	Biological yield (kg/ha)	Spikes/m^2	Weight 1000 grains (gr)
1	4729 a[#]	280 de	11180 a	448 a	29.9 a
2	4262 abcd	402 a	11130 ab	433 ab	26.5 cd
3	3927 cd	348 b	9806 cde	464 a	28.9 ab
4	4305 abc	242 e	10680 abc	457 a	27.3 bcd
5	4178 abcd	267 de	10470 abcd	475 a	28.7 ab
6	4414 abc	290 cd	10470 abcd	475 a	28.3 abc
7	4248 abcd	254 de	10150 bcd	454 a	28.7 ab
8	4012 bcd	286 cd	9586 de	430 ab	29.5 a
9	4271 abcd	281 de	9783 cde	463 a	30.0 a
10	4604 ab	256 de	10330 abcd	471 a	29.5 a
11	3903 cd	320 bc	10320 abcd	469 a	27.9 abc
12	4178 abcd	275 de	10210 abcd	487 a	27.2 bcd
13	2930 e	279 de	7475 f	378 b	25.4 d
14	3636 d	257 de	9066 e	453 a	26.8 bcd
Prob. F	**		**	*	
CV%	15.1		9.9	14.1	

\# Treatments with same letter have no significant difference
** Significant difference at 1% level
* Significant difference at 5% level

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Feasibility of onservation Agriculture for saline irrigated lands on the Southern Aral Sea, Uzbekistan

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Key words: no tillage, agro-technology, irrigated land, protease activity of the soil, mulching, seasonal salt accumulation, degradation.

Introduction

In recent years the population of Karakalpakstan, Uzbekistan, where irrigated agriculture and livestock production are the main activities, has had problems associated with frequent water deficits. Continuous annual plowing and the lack of organic fertilizer input, removal of crop residues from the fields have caused a substantial reduction of soil organic matter. The majority of irrigated land in Karakalpakstan is affected by salinity. The common agricultural practices, thus, have shown to reduce soil fertility and threaten the ecological balance which, eventually, inevitably leads to the instability of the farming system in this extremely arid region.

Meanwhile, the technology of Conservation Agriculture (CA) has recently become of great interest to agricultural scientists and farmers around the world as a highly sustainable, resource saving, soil fertility sustaining production technology. Plenty of international results show that this technology could be applied in different climatic conditions [House, Parmelee, Mengel, Brennan, Collins, Patabendige.].

In the frame of this study, this technology was tested under the arid conditions of Karakalpakstan (Chimbay district) to explore the feasibility of CA practices and elements of zero tillage management for this region.

Materials and Methods

The Republic of Karakalpakstan is located in the Northwest of Uzbekistan in the arid and semi-arid zone of Central Asia on the southern coast of the Aral Sea. The climate is sharply continental, with dry and high air temperatures in summer (maximum temperature reaches 45 °C) and relatively cold temperatures in winter (minimum temperature reaches -33 °C. Karakalpakstan receives an annual precipitation of about 100 mm, with evaporation rates of 1200-1250 mm. Due to the high evaporation rates, irrigation is required for agricultural production.

The experiments were located in the field sites of K.Awezov farmers association in the Chimbay district of Karakalpakstan. The experimental site was according to their soil type – light, grey and loamy (Russian classification according to Aybergenov). The content of soil organic matter is low (humus is only 0.58 %). Field plot size was 400 m2. Crops planted on the sites were wheat.

Soil samples were collected from different soil profiles and depth and were analyzed for salinity, nutrient content, and texture following the methods of Aleksandrova and Naidenova. Qualitative assessment of the soils was carried out by visual assessment following Shepherd G. (adapted by J. Benites), where a scale of visual soil ranking scores is applied in order to characterize the quality of the soil.

The soils were further analyzed for protease activity by the method of Mishustin and Nikitin. This method is based on the decomposition of gelatin by protease enzymes. Gelatin-coated photo paper was buried in the soil and 4 days later carefully removed and wash it with water. The more gelatin layer of photo paper was corroded, the higher was the protease activity in the soil.

Simple economic calculations for the different treatments were performed.

All data were processed following common statistical procedures.

Results and Discussion

Fertilizers
Embodied in the minds of people for centuries opinions that crop cannot be obtained without plowing is difficult to change. Therefore, in the early years it necessary to show them the different options for increasing crop yields in the fields where zero tillage is used. Studies on the effect of different doses of N and manure showed that the use of zero tillage (N45kg +10 ton/ha manure, N90kg + 10 ton/ha manure or N90kg) increases the yield of wheat at 2.1-2.4 times compared with the option without fertilizers. (Table 1).
Table 1.

Effect of nitrogen and organic fertilizers on the yield of winter wheat under zero tillage

Options	Crop yield Centner/hectare	Net income at the expense of fertilizers in USD
Control (without fertilizer)	16,4	-
N 45 kg/ha	32,6	265
N 45kg/ha+10 ton/ha manure	37,4	331
N 90kg/ha+10 ton/ha manure	39.4	254
N 90kg/ha	35.9	330

Salinity and moisture
The salinity level in the top 0-10 cm soil horizon on the plots with crop residue retention was 0.2-0.5 % of solid remains (Russian classification), and at the plots without crop residues it was higher with 0.8 %. Studies have shown that the preservation of the straw and wheat stubble on the soil surface reduces the seasonal accumulation of salts by 1.6-4 times as compared to the sites without conservation of crop residues. The CA management also contributed to the preservation of soil moisture of 3,5 % compared to the fields without residues.

Soil biological activity
The soil protease activity in the field increased after the use of zero tillage in two years (Figure1, Figure 2).

Figure 1. Protease activity before the use of zero tillage.　　**Figure 2**. Protease activity of the soil after use of zero tillage for 2 years.

Table 2. Soil moisture at the site in June with the use of Conventional Agriculture and Conservation Agriculture

Horizon (depth) cm	Soil moisture in the field of Conventional Agriculture, %	Soil moisture in the field of Conservation Agriculture, %	Difference, ±%
0 - 5	1,9	4,3	+2,4
5 -20	4,6	9,1	+4,5
At an average of 0-20 cm	3,2	6,7	+3,5

Visual soil assessment
Visual assessment of the soil showed that the soil quality of those plots, where no-till has been used for the time of the study, had increased by 8 -9 point of Visual score Ranking compared with baseline.

Economy
When looking at the costs of the traditional and CA treatments, it could be shown that the processing costs for CA practices of farmers for the cultivation of crops declined by 70-75%.

The CA practices and methods of zero tillage gave thus acceptable results for the arid conditions of Karakalpakstan. These positive results are promising and based on them the following conclusions can be made.

Conclusions

- CA practices are quite acceptable for the soil and climatic conditions of Karakalpakstan; Studies on the effect of different doses of N and manure showed that the use of zero tillage (N45kg +10 ton/ha manure, N90kg + 10 ton/ha manure or N90kg) increases the yield of wheat at 2.1-2.4 times compared to the option without fertilizers. Therefore, in order to adapt CA in Karakalpakstan it is necessary to consider this factor as one of the most important, since the soil is poor with organic substance and other nutrients.
- Plant residue reduces the evaporation of moisture from the soil, thus retains more soil moisture by 3.5% and reduces the seasonal accumulation of salts at 1.6-4 times compared with the site where Conventional agriculture is used. Retention of more moisture in the soil and reduction of salinization - both eventually leads to saving of water consumption for irrigation and for flushing of salts. It is very urgent now for the region of Karakalpakstan where in recent years acute shortage of water resources is perceived.
- After two years of the use of zero tillage, protease activity of the soil increased, which allows indicating the activation of the natural processes of restoration of soil fertility.
- It is necessary to continue research on the effects of CA management on soil properties and the environment;

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No-tillage practice effect on soil aggregate stability in northern Tunisia

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Introduction

The soil structure, determined by the kind of aggregates held together by soil-stabilizing agents, is a key factor in soil fertility (Singer and Munns, 2002). The soil structure stability is a function of soil properties such as soil organic matter content and agricultural practices as tillage (Duiker, 2006). Conventional tillage (CT) induces soil modification and often degradation by disrupting soil aggregates and reducing soil organic carbon content (Kay, 1990). In Tunisia, conventional tillage causes fertility loss over 20000 ha per year. No-tillage (NT) increases carbon and nitrogen storage and improves soil physical, chemical, and biological properties (Paustian et al., 1997). Since 1999, no-tillage has been introduced in rain fed cereal areas in order to move towards more sustainable agricultural systems. No-tillage areas increased from 52 ha in 1999 to 12000 ha in 2010. The objectives of this work were (i) to evaluate soil aggregate stability in a no-tillage system and (ii) to identify factors involved in soil aggregate stability.

Materials and Methods

Soil samples were collected in March 2010 at 10 cm of depth from 6 farmers' fields in northern Tunisia. Conventional tillage (CT), no-tillage during less than 5 years (NT$_{<5 years}$) and no-tillage during more than 5 years (NT$_{>5 years}$) have been practiced in each farmers field experiment with wheat as the crop.

Soil aggregate stability was evaluated according to the method described by Le Bissonnais (1996). This method combines three different disruptive tests having various different wetting conditions and energies. These tests are performed on the 3-5 mm size fraction of aggregates. After each test, results were expressed as a mean weight diameter (MWD): the sum of the fraction of soil remaining on each sieves multiplied by the mean inter-sieve sizes. Higher values of MWD indicate higher aggregate stability. Total organic carbon (TOC) was determined using the wet oxidation method of Walkley-Black (1934).

Results and Discussion

A significant increase in SOC content was observed in NT$_{>5years}$ (1.64 %) compared to CT (0.97 %).This result highlights the importance of no-tillage to improve soil fertility.

For aggregate stability, a net increase was observed in NT in comparison to CT. After 5 years of no-tillage the MWD was increased by 16% (MWD=1.8 mm for CT and MWD=2.1 mm for NT$_{<5years}$). No improvement of aggregate stability level was observed after the 5th year of no-tillage conversion (Figure 1). A positive correlation was observed between aggregate stability and total soil organic carbon (r= 0.52, n= 18) (Figure 2a). Chenu et al (2000) have described a similar trend. It is assumed that this correlation could be due to increased microbial activity under NT practice compared to CT (Six et al., 2000). A positive and statistically significant relationship was also noted between aggregate stability and the number of years after the no-till conversion (r= 0.46, n= 18) for all plots (Figure 2b).
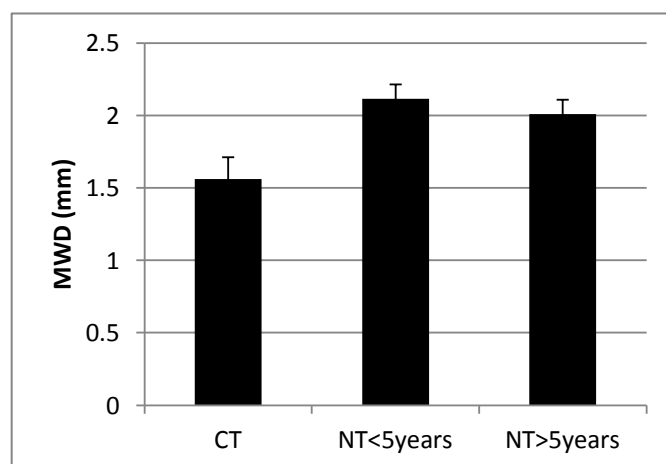
Figure 1. Aggregate stability (MWD in mm) of soil under conventional tillage (CT), no-tillage over less than 5 years (NT$_{<5 years}$) and no-tillage for more than 5 years (NT$_{>5 years}$).
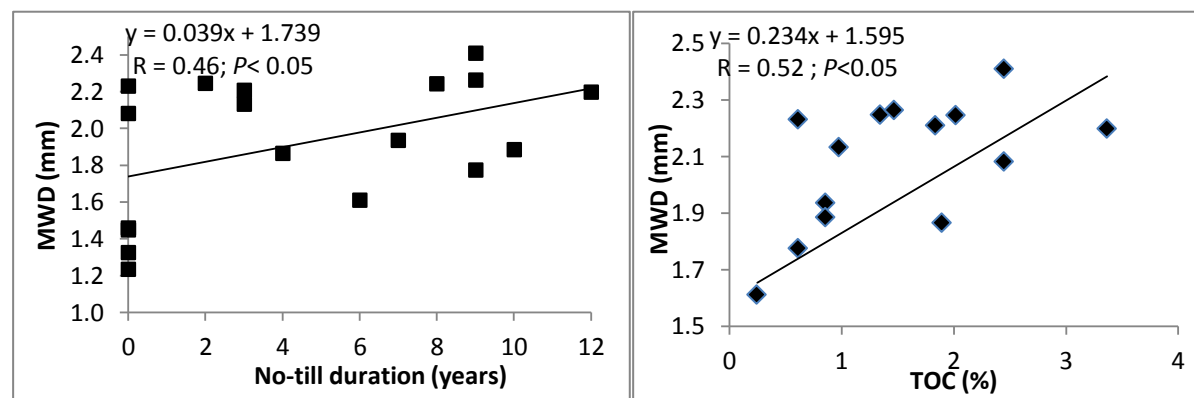
Figure 2. Relationship between aggregate mean weight diameter (MWD) and no-till duration (a) and total organic carbon (TOC; b), respectively.

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Interactions of corn stover incorporation and simulated tillage on emission of CO_2: a laboratory study

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Keywords: soil organic carbon, organic vegetable, weed control, Alfisol, Vertisol

Introduction

Annual horticultural systems commonly rely on frequent and intensive tillage to prepare beds and manage weeds and insects. However, tillage increases the loss of soil organic carbon (SOC) through accelerated CO_2 emission brought about by improvement in soil aeration and soil and crop residue contact (Angers et al., 1993). In contrast, some vegetable farmers use green manures, organic inputs (e.g. compost, mulch) and crop residues to perform various functions including increasing soil organic matter (SOM). Crop residue management systems that maintain organic materials *in situ* can benefit SOM (van Groenigen, et al., 2011). The effects of tillage and crop residue management can have opposing influences and may be difficult to isolate (Dalal et al., 2011). The SOC pool in the soil is the balance of C inputs in the form of crop residue and biomass, and C outputs such as CO_2 emissions and other losses. The CO_2 fixed in plant biomass by photosynthesis is returned to soil that forms SOM, some of which is lost due to tillage (Jarecki and Lal, 2003). Vegetable systems are vulnerable with very little crop residue input and heavy reliance on tillage, reducing SOC. We hypothesised that such systems could be made more resilient by including a high-residue grain crop like sweet corn (*Zea mays* var. *rugosa* L.) in the rotation. The subsequent corn stover input in the soil could balance the expected loss of SOC due to tillage. This laboratory study was conducted to separate the effects of residue incorporation and tillage in an associated field trial where sweet corn stover incorporation in a corn-cabbage (*Brassica oleracea* L.) rotation had a positive effect on SOC, but no differences in SOC for organic and conventional soil management systems. Organic vegetable systems rely on tillage for weed control, whereas conventional systems rely on herbicide. The laboratory study sought to evaluate CO_2 emissions in incubated soil after simulated tillage (weed control in organic) with and without the incorporation of ground corn stover.

Materials and Methods

Soils from 0-10 cm depth were collected from two contrasting cropping sites: a self-mulching black clayey Vertisol and sandy brown Alfisol (Soil Survey Staff, 2010) from the Armidale area of New South Wales, Australia. The concentration of SOC in the Vertisol and Alfisol was 2.47% and 1.28%, respectively.. The soil samples were air-dried, sieved through <2-mm sieve, plant debris removed and homogenised by mixing. Five hundred (Vertisol) and 600 (Alfisol) grams of soil (oven-dried basis) were weighed into 8.6 cm diameter polythene pots to a depth of ~10 cm. A three-way factorial design: (1) ground (<4-mm) stover incorporation (+RES or -RES), (2) simulated tillage (+Till or –Till), and (3) soil type (Vertisol or Alfisol) was used with four replicates in a completely randomised layout. The –RES –Till treatment was considered analogous to a conventional soil management system and the +RES +Till treatment was considered analogous to a organic soil management system. The +RES treatment was amended with 15 tonnes/ha (dry weight basis) of stover with an average C:N ratio of 34:1, and incubated at 25 ºC for four months. During incubation, water was applied once in two weeks for Vertisol and once every six days for Alfisol to bring soil moisture levels from wilting point (-1500 kPa) to field capacity (-33 kPa). When close to wilting point, soils were sieved to simulated tillage (Calderon et al., 2000; Kristensen et al., 2003) through a <4-mm mesh. The sieved soil was then repacked into the pots and the pots were placed in sealed PVC tubes for headspace air sampling. The air samples were drawn through a rubber septum inserted on the cover using a surgical needle mounted on a syringe. The air samples were taken before covering and 30 minutes after covering, and the difference in concentrations was calculated as the flux of CO_2. The air samples were stored in evacuated vials and analysed with a gas chromatograph. Air samples were collected 24 hours (h) before the simulated tillage treatment, and 1 h, 120 h, 240 h and 360 h after the tillage treatment. Analysis of variance was used to assess the effects of residue, simulated tillage, soil type and time of sampling on CO_2-C flux using the statistical package R version 2.9.1. The data were log transformed to stabilise variances. *P*-values ≤ 0.05 were considered significant.

Results and Discussion

The analysis of variance indicated that CO_2-C flux varied significantly over time and residue incorporation (*P* < 0.001) (Figure 1). Tillage treatment and soil type were not significant (*P* ≥ 0.28). The following interactions were significant: soil type × time, soil type × residue incorporation and residue incorporation × tillage (*P* ≤ 0.014). Initial CO_2-C flux levels at -24 h were largely not significant across soil types and treatments (average ~11 mg m^{-2}h^{-1}), with large increases at 1 h to ~ 76 mg m^{-2}h^{-1} on average, followed by a decline to pre-tillage levels (slightly higher in Alfisol) at 120, 240 and 360 h. The +RES+Till treatment was most sensitive to flux of CO_2-C followed +RES-Till treatment in both soil types in first 1 h after the tillage treatment. Soil type × residue interaction was highly significant due to +RES producing 73% and 48% more flux for Alfisol and Vertisol, respectively, in comparison to –RES, indicating a higher rate of residue mineralisation in the Alfisol, presumably due to increased O_2 and CO_2 exchange in the sandier soil (Wuest et al., 2003). Greater fluxes at 120 and 240 h in Alfisol than Vertisol are also likely to be due to greater porosity allowing more gas exchange in the non-swelling sandy soil. The higher flux at 360 h for Vertisol was possibly due to increased porosity (shrinking in response to drying) and/or delayed stimulation of microbial respiration (Wuest et al., 2003). The residue × tillage interaction was based on a lack of tillage effects in –RES, but 40% more CO_2-C flux in +RES for +Till than -Till as soil disturbance facilitates better in soil aeration and soil and crop residue contact for C mineralisation (Angers et al., 1993). Compared with –RES-Till, tillage alone increased flux by 16%, less than the effect of residue alone (52% increase in flux). The -RES-Till treatment (scenario of conventional vegetable) emitted 70% less CO_2-C flux than +RES+Till (organic scenario), indicating that the effects of tillage and residue alone were largely additive. These trends are corroborated by findings for laboratory (Calderon et al, 2000; Wuest, et al., 2003) and field trials (La Scala, et al., 2006) in terms of CO_2-C flux peaking within hours after disturbance and dropping down later, irrespective of residues being applied or not. A portion of the added C is lost as CO_2, especially with tillage, but SOC will still be higher than -RES treatments (van Groenigen, et al., 2011).This trial demonstrated that residue incorporation had a larger effect on CO_2-C flux than tillage for both soil types, suggesting that C availability and form can be more important than disturbance in cropping soils. Residue effects were more pronounced in Alfisol whilst tillage effects were more pronounced in Vertisol. The interactive effect of tillage × residue contributed 40% of CO_2-C flux.
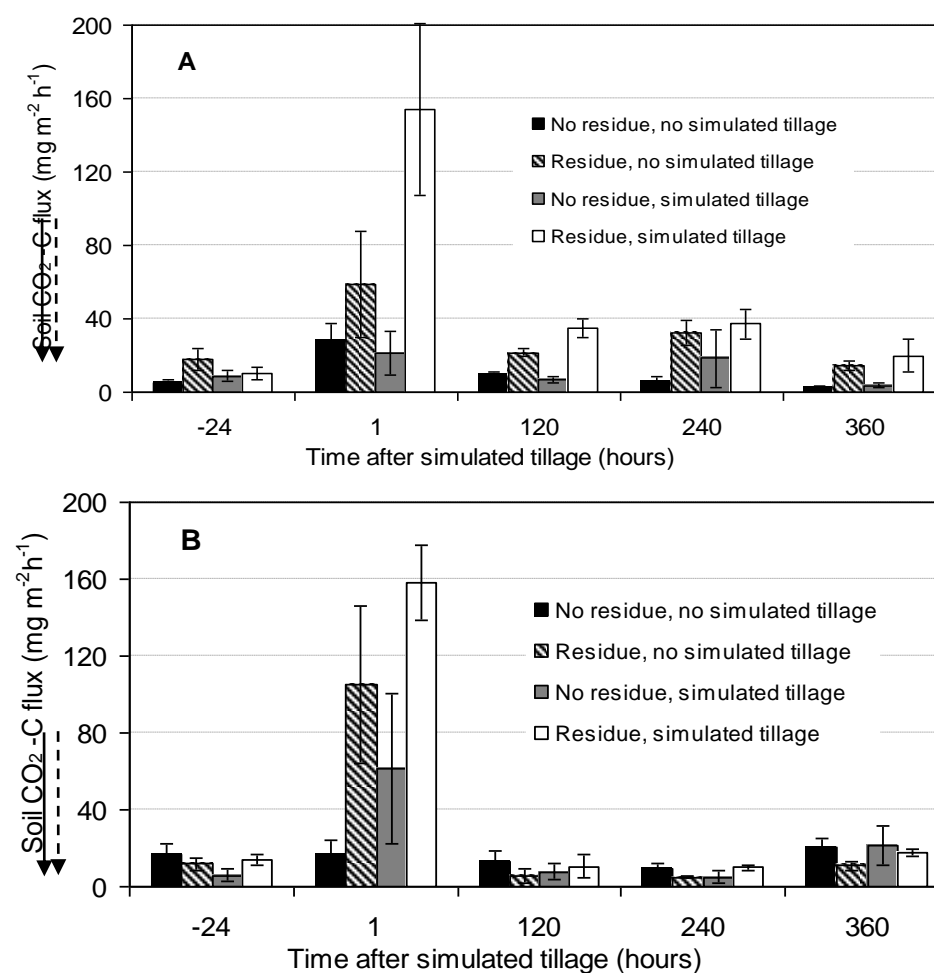
Figure 1. Effect of residue and tillage treatments on soil CO_2–C flux in Alfisol (A) and Vertisol (B) soils. The solid arrow and broken arrows show when simulated tillage and water was applied, respectively, to the soils. In Alfisol, water was also added at 144 and 288 h. Vertical bars are standard errors of the means ($n = 4$).

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Soil nitrogen loss risk decreased and garlic yield increased in no-tillage mulching systems in Yunnan, Southwestern China

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Keywords: no-tillage and mulching; garlic yield; soil nitrogen loss risk

Introduction

A series of environmental problems, such as soil productivity decrease and eutrophication in surface water and ground water due to long-term overuse of nitrogen fertilizer by farmers pursuing higher yields have become more and more serious. This has drawn intensive attention from the public and government agencies. Agricultural practice is a major source of non-point pollution (Liu et al., 2010). Agricultural non-point pollution is the main cause leading to water eutrophication, while soil nitrogen loss is one of the most important factors causing agricultural non-point pollution (Zhu, 2000). Therefore, preventing soil nitrogen loss is the key of protecting water from being polluted. The aim of the study is both to develop a set of fertilization and no-tillage techniques which could prevent soil nitrogen loss and increase soil productivity, by controlling headwaters and pollutant loss, soil fertility improvement, increased economic benefits and prevention of agricultural non-point pollution (Zhang et al., 2009). Supported by Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Conservation Agriculture Network for South-East Asia (CANSEA), and National Major Research Program on Polluted Water Control of Ehai (No.2008ZX07105-002) technically and financially we carried out an experiment of conservation agriculture in a garlic field.

Materials and Methods

The experimental field was a paddy soil which was located in northern Ehai drainage area, Dali County, Yunnan Province (N25°57′55.9″, E100°06′09.7″). The average annual precipitation is 1,117 mm, the average annual temperature is about 15 ℃, and the average annual sunshine is 2,250 h - 2,480 h. The properties of the experimental soil are shown in table 1. The experiment was carried out from October 2009 to April 2010. The experimental crop was garlic. There were 7 treatments: conventional fertilization (CON)[1], optimized fertilization (OPT)[2], nitrogen regulated (NR)[3], no-tillage with straw mulch + cow manure + optimized fertilization (NTC), straw ploughed in, with the following combinations: cow manure + optimized fertilization (BS), cow manure (CM), and non-fertilized (CK). Each treatment had three replications. The experimental layout was randomized block arrangement with block area being 4.8×5 m[2]. The rows were wrapped by plastic film with 30cm row spacing and 20cm row height.

(Note 1: conventional fertilization means the average nitrogen fertilized by farmers, 675(N, kg/ha) in the experiment. Note 2: optimized fertilization means about a half of the conventional fertilization, 375(N, kg/ha) in the experiment. Note 3: nitrogen regulated means fertilizer N recommendation with site-specific management, which was based on the difference between target value of nitrogen supply and soil nitrate N content (0-30cm) and nitrate N applied from irrigation water.)

Table 1: Properties of the experimental soil

Soil depth (cm)	NH_4^+-N/ mg.kg^{-1}	NO_3^--N/ mg.kg^{-1}	OM/ g.kg^{-1}	TN/ g.kg^{-1}	TP/ g.kg^{-1}	TK/ g.kg^{-1}
0-10	4.26	6.64	80.86	4.41	1.28	16.79
10-20	5.25	6.29	80.42	4.42	1.47	18.09
20-30	3.38	5.37	55.28	3.18	1.17	18.47

Results and Discussion

The soil water content in 0-20 cm soil layer was low during the whole garlic growth period due to the dry climate in the experimental area as demonstrated in Figure 1. However, the water content in treatment NTC was the highest and was significantly higher than the other treatments. There were no significant differences among the other treatments. The soil water content of treatment NTC in each of the three layers was the highest among the 7 treatments at harvest. Especially in the 0-10 cm layer and the10-20 cm layer the water content in treatment NTC was significantly higher (about 10%) than that of the other treatments. Therefore, treatment NTC could effectively decrease soil evaporation, conserve soil water, and favour garlic growth.
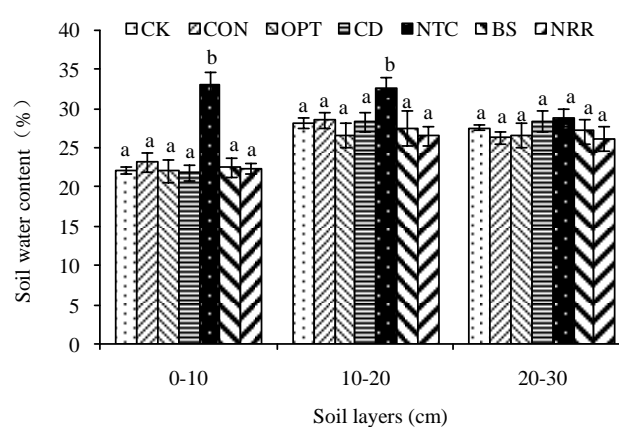
Figure 1: The soil water content (%) of different treatments at harvest （$p<0.05$）

The yield of garlic in treatment NTC was the highest (31.8 t/ha), which was significantly higher than that of treatment CON (7.9%) and OPT (12.4%), respectively (Figure 2). The garlic yield of treatment BS was lower than that of treatment CON (8.5%), OPT (4.6%) and NR (1.5%), respectively, but the differences were not significant. The yield of treatment CM was significantly higher than treatment CK (about 26.5%), but was significantly lower than that of the other treatments. The yield of treatment CM was about 22.8% lower than that of treatment CON.
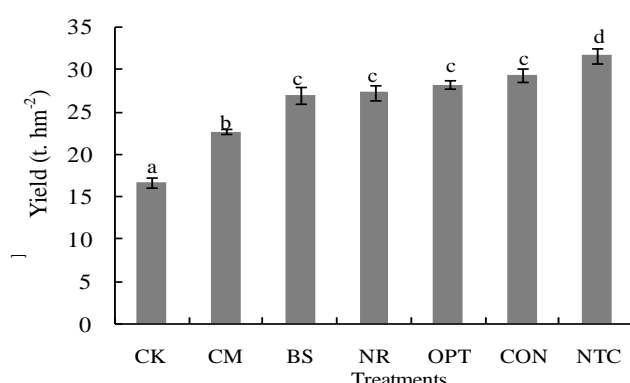
Figure 2: The yield of garlic in different treatments（*p<0.05*）

The residual inorganic N soil content of treatment CON was significantly higher (500 kg/ha) than the other treatments (Figure 3). The residual inorganic N in 0-30cm soil layer in treatment NTC was significantly reduced and was approximately 44.3% lower than treatment CON. The residual mineral N of treatment CM was equivalent to that of treatment CK, and both of them were significantly lower than that of the other treatments.
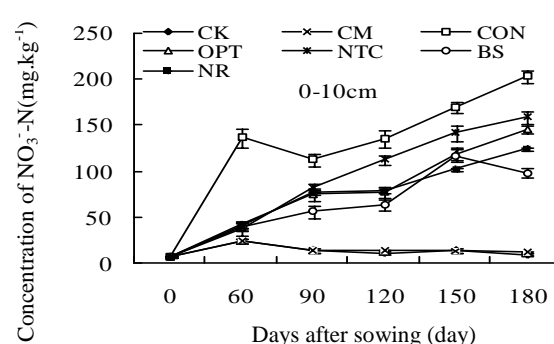
Figure 3: The residual inorganic soil N of different treatments（p<0.05）

The nitrogen loss risk in 0 - 10cm soil layer of treatment CON was the highest during the whole growth period (Figure 4). Straw mulching seems to reduce soil nitrate accumulation and effectively decrease nitrogen loss risk. The soil nitrate accumulation in 0-30cm soil layer could also be decreased by ploughing straw into the soil, which was about 67.1% lower than that of treatment CON.
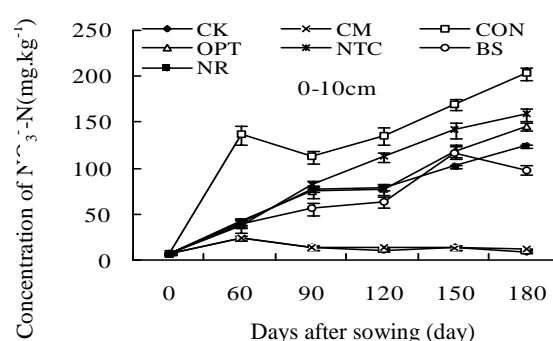
Figure 4. Dynamic of NO_3^--N concentrations in different soil layers under different treatments

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Yield and soil chemical attributes after twelve years of no-tillage with different lime rates in a green harvest sugarcane system

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Keywords: conservation tillage, sugarcane residue, pH, base saturation

Introduction

In Brazil the sugarcane crop is cultivated on almost 9,2 million hectares, with 60% of plantations concentrated in Sao Paulo state. The government of Sao Paulo State has mandated (Act # 47,700 of March 1st, 2003, regulates the law 11,241 of September 19th, 2002) that in flat (less than 12% slope) sugarcane production areas feasible for mechanical harvest, the use of fire to reduce biomass before harvesting must be banned completely by 2021, but recently this deadline was brought forward to 2014. Due to this social pressure the majority of fields are now harvested without burning (around 1,92 million hectares), and a great amount of residue (average 15 Mg of dry matter per hectare each year) is deposited over the soil surface. The sugarcane residue has significant effects on the crop system, by controlling soil erosion (Prove et al., 1995), controlling weeds (Cristoffoleti et al., 2007) and reducing greenhouse gases emissions from the soil (La Scala et al., 2006), in addition to increasing soil organic matter and retaining soil moisture (Bolonhezi et al., 2007, 2010). On the other hand, the great amount of residues increase the cost of tillage by almost 30%, so it is desirable to adopt conservation soil management and use leguminous crops in rotation with sugarcane. Producers now question whether surface application (rather than tillage-incorporated) lime will be as effective in reducing soil acidity, because Brazilian soils require the application of lime to maintain cane yield after 5 or 6 harvests. This was the context of the 1988 start for a long-term field study of the interaction of lime rates and soil management on the agronomic characteristics of sugarcane, and the consequent changes in the soil chemical attributes.

Materials and Methods

The long-term field experiment was laid out on a eutrophic clay Rhodic Hapludox (Oxisol), located at the Experimental Station of Agronomic Institute (Ribeirao Preto city, Brazil). Initially, the trial was set up in a commercial green harvested sugarcane field on 5th ratoon, which has been planted in 1993, when dry biomass on the soil surface was estimated at 13,4 Mg ha^{-1}. A split-plot experimental design with four replications was used, in which the main plots were the conventional tillage (moldboard plowing followed by a two applications of offset disk harrow) and no-tillage (crop residues on its surface after spraying the area with 3.6 kg a.i. ha^{-1} of glyphosate). The subplots were four dolomitic limestone (0; 2,0; 4,0 and 6 Mg ha^{-1}) treatments, applied three times (in 1998, 2003 and 2008), and when planting soybean as a rotation crop, followed by sugarcane crop. Prior to the onset of the trial, soil chemical characteristics were determined (0-20 cm) according to van Raij et al. (2001). This data can be seen Table 1. Ten soil samples were used to obtain one composite from each plot at depths of: 0 to 5, 5 to 10, 10 to 20, 20 to 40 and 40 to 60 cm. Samples were taken 1.5, 2.5, 4.5, 7.5 and 12 years after starting the lime treatments. Soil chemical characteristics were determined at the laboratory of the Soil Research Center of Agronomic Institute of Campinas, using the methodology of Raij et al. (2001). Yield measurements were made every harvest for both soybean and sugarcane. Data were subjected to ANOVA using ESTAT (UNESP, 1992) and the means were examined using regression methods.

Table 1. Chemical properties of surface soil (0-20 cm) at the 1998 start of this experiment

Depth	pH CaCl$_2$	O.M. g dm^{-3}	P (resin.) mg dm^{-3}	K	Ca	Mg	H + Al	Ca+Mg+K	CEC	V %
				--------------------mmol$_c$ dm^{-3}-------------------						
0-20 cm	4.8	31	23	0.8	24	7.2	43.9	31.8	75.8	41

Results and Discussion

The effect of surface liming in comparison with conventional system on acidity-related variables (pH and exchangeable cations saturations-V%) is shown in Figures 1 and 2. The increase of pH and the base saturation in the uppermost layers (0-5 and 5-10 cm) was higher in no-tillage than conventional tillage, but the opposite occurred between 20 and 40 cm depth. In 2005 after the second liming, the effect of liming could be verified up to 10 cm in the no-tillage (Bolonhet et al., 2006). According to Caires et al. (2005), in a trial conducted in southern Brazil, it took between 2,5 to 5 years after liming to verify an increase in exchangeable cations levels below 10 cm depth and this effect was constant for a period of up to 10 years. Our results are consistent with this, probably because the limestone was being re-applied every five years at high rates, so this created an alkalinization front which advanced in depth with time. It is important to emphasize that both conventional and not-till have presented the same trend (linear regression) below 20 cm depth for all soil chemical attributes evaluated. In comparison with control, the high rates of limestone applied under sugarcane residue increased the CEC (cation exchange capacity) by 59, 41, 22, 12 and 17 %, respectively at 0-5, 5-10, 10-20, 20-40 and 40-60 cm depth. Furthermore, the phosphorus, Ca and Mg levels increased as a function of lime rates in the no-tillage below 20 cm. Nevertheless, the non-exchangeable Ca and Mg contents (non-reactive fraction) increased 14 times after three applications in no-tillage (data not shown).

Results to date have found no significant difference between no-till surface applied and incorporated lime treatment on soybean grain yield, but higher stalk sugarcane yield (linear response) was observed in NT compared with CT, for the last four ratoons (from 2004 to 2008). In conclusion, after twelve years monitoring, surface-applied lime in the no-tillage system was effective in reducing soil acidity below the

point of placement. No-tillage associated with green harvest sugarcane and soybean rotation cropping appeared to be the best example of a sustainable energy and food production system.
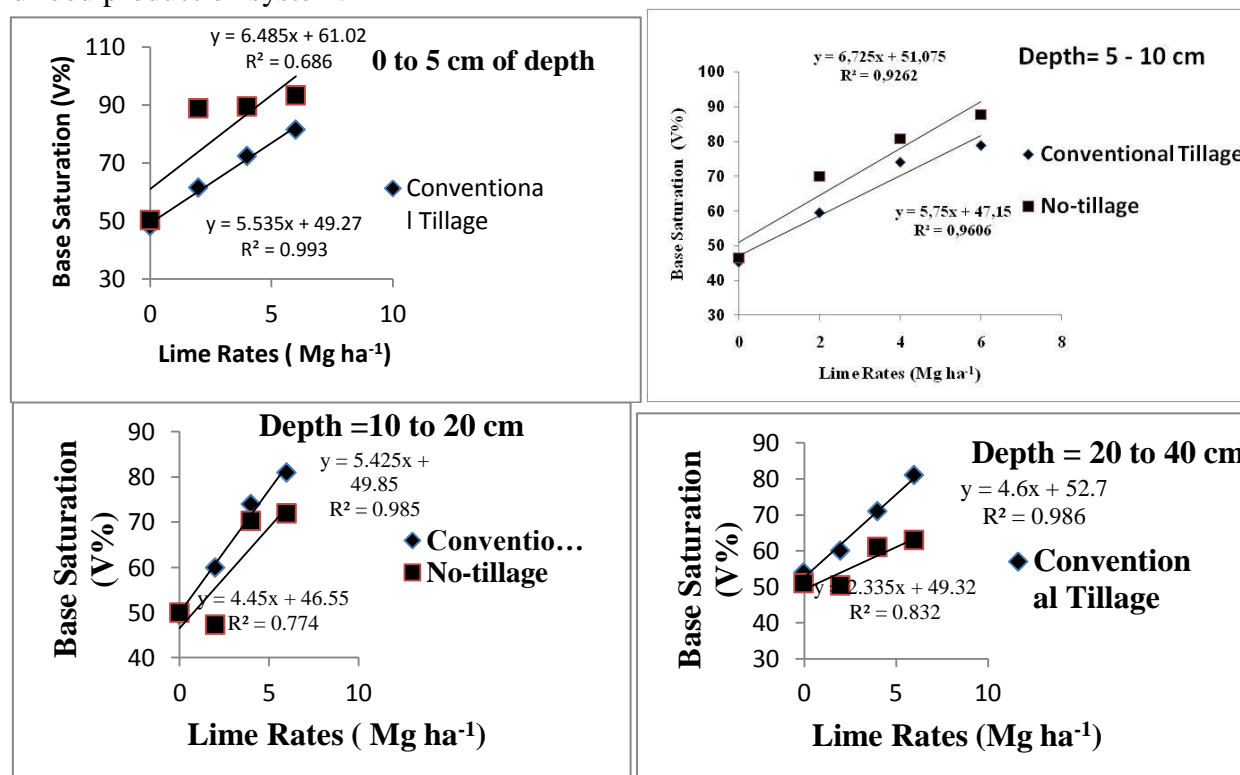
Figure 1. Changes in base saturation (V%) for different depths (0-5, 5-10, 10-20 and 20-40 cm) in function of lime rates and soil managements (conventional and no-tillage) after three limings (1998, 2003 and 2008).
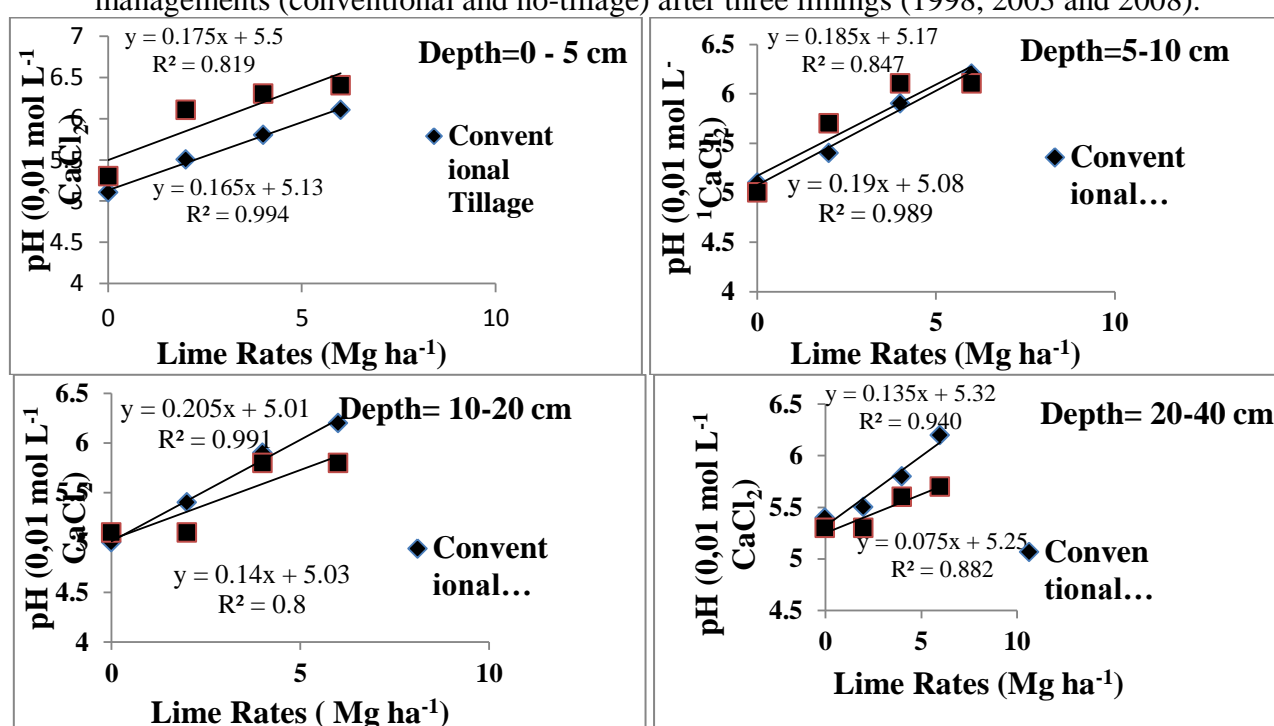
Figure 2. Changes in base saturation (V%) for different depths (0-5, 5-10, 10-20 and 20-40 cm) in function of lime rates and soil managements (conventional and no-tillage) after three limings (1998, 2003 and 2008).

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Soil physical properties affected by soil management and crop rotation in a long term experiment in Southern Brazil

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Keywords: conservation tillage, cover crop, no-till, crop rotation, soil organic matter

Introduction

Soil organic matter (SOM) plays a key role in the formation and stabilization of soil aggregates (Oades 1984); and continual addition of crop residue increases labile SOM near the soil surface, which increases soil aggregation and has a large impact on soil structure (Lu et al., 1998). No-tillage (NT) systems have higher SOM stock and also greater and more diverse biological activity in the upper soil layers, enhancing the soil macroporosity and decreasing soil bulk density compared to conventional tillage (CT). In NT including winter crops into the rotation can enhance the soil aggregate size and stability when compared to winter fallow treatment (Calegari and Pavan, 1995). Castro Filho et al. (2002), in 21 years of work on a clay distrophic red latosol in north Paraná, Brazil, found the best aggregation indices in the 0-20 cm layer in the NT system, mainly due to the increase in the organic carbon content. The main objective of this work is to evaluate such soil physical properties affected by cover crop rotations and soil management after 19 years of applying NT and CT systems with different winter species on a clayey Oxisol in South Brazil.

Materials and Methods

The field experiment was established in 1986 in the IAPAR (Agronomic Institute) Experimental Station at Pato Branco, southwestern Paraná State, Brazil (26°7'S, 52°41'W, and 700 m altitude). Climatologically the area belongs to the sub humid tropical zone (Köeppen's Cfb) with a climate without dry season, fresh summer and an average temperature of the hottest month lower than 22 °C. Annual rainfall ranges from 1200 to 1500 millimeters. The soil at the experimental site is an acidic Oxisol acid with a high clay content (72 percent clay, 14 percent silt, and 14 percent sand), formed from basaltic materials and thus containing kaolinite and iron oxides minerals (Costa 1996). The experimental site was previously cropped for 10 years in a conventionally tilled system mainly with maize and beans. Experimental treatments combined six winter species, and two tillage systems, i.e. CT and NT, in order to obtain a large variety of situations in term of biomass inputs and soil management. Treatments were laid out in a split-plot design in three blocks, with the winter species as the main plots (240 m^2) and the tillage treatments as subplots (120 m^2). The winter crop treatments were blue lupin (*Lupinus angustifolius* L.), hairy vetch (*Vicia villosa* Roth*)*, black oats (*Avena strigosa* Schreb), oilseed radish (*Raphanus sativus* L.), winter wheat (*Triticum aestivum* L.), and fallow. The CT consisted of one disc ploughing and two disc harrowings, both twice a year before summer and winter crop planting. All cover crops, except wheat, were terminated at the flowering stage by cutting with a knife roller (lupin, hairy vetch, black oats and oilseed radish) or killed by herbicide (fallow). In some years the knife-roller was complemented with herbicide in the cover crop plots. Except wheat, all crop residues were left on the soil surface as mulch (NT) or incorporated before planting the summer crop (CT). From winter 1986 until October 2005, the biomass production (winter species) was evaluated at the flowering stage (before termination of growth) and as well as the amount of summer crop residues left on the soil surface after harvesting. The maize and soybean were planted during each year (summer). A total of 9.5 Mg/ha dolomitic lime was applied over 5 applications (1.0, 2.0, 3.0, 1.5 and 2.0 Mg/ha of lime in all plots, in 1989, 1992, 1995, 1999 and 2001, respectively). On the NT system the lime was broadcast on the soil surface and in CT was incorporated by ploughing. The summer crops received chemical fertilizer every year, and the total amount of chemical fertilizer applied during 19 years were: 1300 kg/ha P$_2$O$_5$, 745 kg/ha K$_2$O, and, in corn 425 kg/ha N for corn only. Generally P and K fertilizer was applied at planting and N was split, 1/3 at planting and 2/3 at 45 days after planting of corn. Soil samples were collected in October 2005 from trenches at six depths: 0-5, 5-10, 10-20, 20-30, 30-40, and 40-60 cm.Bulk density measurements were made using 5 cm undisturbed cores (Blake and Hartage, 1986), and soil texture using the pipette method. Soil moisture was determined gravimetrically with samples oven dried at 105 ºC (until constant soil mass weight) to determine water content. For comparison, soil samples were also taken in a forest on the border of the experiment. The experiment statistical analysis considered the soil layers as sub-sub-plots. Results were subjected to analyses of variance and means compared by Least Significant Differences (LSD) when the analysis of variance was significant.

Results and Discussion

The total amount of organic residues (winter crop, maize and soybean residues) added to the soil during the 19 years of this experimental study has been reported in Calegari et al. (2008). The total amount of winter crop residues was higher in the no-tillage treatment than in the conventional tillage plots. Because the fallow treatment is not cultivated during the winter season, it produced fewer residues than other winter treatments in both NT and CT systems. The winter crop treatment was the major factor contributing to differences in the amount of biomass produced.

Soil bulk density in the forest soil was lower than 1.01 kg/dm^3 in the all soil layers sampled (Table 1). In the trial, the bulk density of the arable layer (0-30 cm) increased to, on average, 1.2 kg/dm^{3}whereas in the deeper soil layers, bulk density remained close to the natural (forest) condition, even if the soil has been disturbed intensively (38 times by plough and 76 times by disc harrowing) during 19 years of cultivation. Bulk density of the soil layers was very similar between CT and NT treatments, except in 10-20 cm layer where it was slightly higher under CT. No significant difference was observed in soil bulk density between winter crop treatments. In the NT system the proportion of large aggregates (> 2 mm) was higher than in CT in both surface layers (0-10, 10-20 cm), while the reverse was true below 20cm (Table 2).The winter fallow treatment, with lowest organic residues added during the 19 years (Calegari et al. 2008) had a lower proportion of large aggregates (>2 mm) and a higher proportion of small aggregates (<0.25 mm) than the other treatments. No significant differences were found in aggregate distribution between winter crops. Presumably the lack of soil disturbance and the effects of winter species root during 19 years in NT contributed to promote higher soil aggregation classes (> 2.00 mm) than fallow and CT. From 13 to 24% of the soil organic carbon was considered to be physically protected against biodegradation due to its location in clay or silt sized microaggregates. The crop residues added improved soil aggregation, and no soil compaction occurred at NT, and the winter fallow

showed lowest values for soil aggregate (> 2 mm) than other winter treatments. In the two soil depths (0-10 and 10-20 cm), the aggregation parameters (MWD, GMD and AS) enhanced under the NT system, and the values for MWD and GMD were higher in the upper layer (0-10 cm) than the beneath soil layer (10-20 cm) whereas, the MWD increased with depth in CT system. Values of MWD, GMD and AS were lower in fallow than winter crops but no differences among winter crop species.The NT compared with CT was superior of 78% for MWD, and 238% for GMD. At beneath soil layer (10-20 cm) presented the same trend in upper layer, with 51%, for MWD, and 83%, for GMD, favourable to no-tillage. For the AS %, independent of soil depth, was 7% higher under NT than under CT.

Table 1. The effects of soil management and cropping system on soil bulk density in an Oxisol. Pato Branco, Brazil. 2005.

Soil management	Soil layer (cm)				
	0-10	10-20	20-30	30-40	40-60
	(kg/dm^3)				
NT	1.25aA	1.19bB	1.11bC	1.06aD	1.00aE
CT	1.24aB	1.28aA	1.17aC	1.08aD	1.02aE
* Forest	0.80	0.90	1.00	1.00	1.00

Table 2. The effects of soil management and cropping system on aggregate size distribution in an Oxisol. Pato Branco, Brazil. 2005.

Soil layer (cm)	Soil management	Aggregate size (mm)				
		> 2.00	2.00-1.00	1.00-0.50	0.50-0.25	< 0.25
		(g/100g)				
0-10	No-tillage	39.97 aA	6.65 bB	5.28 bB	3.45 bB	4.92 bB
	Conventional	22.39 bA	12.30 aA	11.38 aA	7.23 aA	9.29 aA
	* Forest	28.37	8.78	8.93	5.24	5.81
10-20	No-tillage	36.08 aB	8.40 bA	7.37 bA	4.34 bA	4.85 bB
	Conventional	23.76 bA	11.73 aA	11.57 aA	6.59 aB	8.63 aA
	* Forest	31.05	9.05	7.77	5.47	6.07
Winter treatment						
	Fallow	27.31 b	10.18ns	9.36ns	5.82ns	8.91 a
	Vetch	31.83 a	9.88	9.03	5.38	6.08 b
	Lupin	31.31 a	9.58	8.59	5.18	6.47 b
	Radish	31.26 a	9.21	8.76	5.27	6.92 b
	Oat	31.14 a	9.98	8.74	5.23	6.41 b
	Wheat	30.45 a	9.80	8.93	5.53	6.74 b

Means followed by the same lower case letters in the same column comparing soil management for each depth into the same aggregate size class, and also winter treatment into each aggregate size class, do not differ at the 5% level of probability by the *F*-test in the analysis of variance. Means followed by the same upper case letters in the same column comparing soil layer into each soil management into the same aggregate size class do not differ at the 5% level of probability by the *F*-test in the analysis of variance. * Forest soil is not included in statistical analysis

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Comparative analysis of the combined effect of sowing machines and cultivars on grain yield and quality of durum wheat (*Triticum durum* **Desf.**)

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Introduction

Conservation Agriculture (CA) techniques are being practised worldwide on more than 117 million hectares (ha) of land (Derpsch and Friedrich, 2009) mainly in North and South America, Australia, with the remainder in Asia and Africa. As opposed to tillage-based systems, CA is a concept for resource-saving agricultural crop production that aims to achieve competitive agricultural yields while helping to reduce degradation of natural resources. Sustainable soil management leads to sustainable crop production and on-farm profits. The combination of minimal soil disturbance, live and dead crop residues and varied crop rotations promote soil life (bacterial and fungal populations) and activity, and thus the overall soil fertility. Since the influence of mechanical openers is determinant for the success of CA systems in general and in dry areas in particular (Choudhary and Baker, 1994), the aim of the present study is to compare different sowing machines for direct seeding of durum wheat in southern Italy, in order assess their influence on crop yield and kernel quality. Possible interactions between the sowing machines and wheat genotypes have also been investigated.

Materials and Methods

The field experiment was carried out in 2009-2010 in Apricena (province of Foggia, Apulia region). The soil in the experimental plots had a loam-silt-clay texture (with 12.5% of sand, 50.5% silt and 36.9% clay), a pH of 8.0 and 0.9% of organic matter. The experiment was laid out as a factorial design with the treatments arranged in a randomized complete block design with 4 replications. The main thesis were the 2 durum wheat cultivars Casanova (Apsovsementi) and Ciccio (Proseme), while the secondary thesis are 5 different seeders, i.e. Gaspardo Directa 300, John Deere 750A, Semeato TDNG 420, Sfoggia Agrometal, Kuhn SDE. The extended total land field experiment area was 22 ha. Two weeks before sowing, 3 l ha^{-1} of Glyphosate at 40.5% were applied.

Wheat seeds were treated with Tebuconazolo (0.45%) + Protioconazolo (3.35%) + Fluoxastrobin (3.35%) and Triticonazolo (11.20%) + Guazatina (11.2%) and sown at 450 germinable seeds m^{-2} (approximately 220 Kg of germinable seeds ha^{-1}). Plots were fertilized with 0.2 t ha^{-1} of D-coder 322 at sowing (30 October 2009) and with 250 Kg ha^{-1} of N PRO (29% of Nitrogen, Timac-Agro, Italia) at the 4th - 6th leaf stage (27 February 2010). To control weeds and pathogens, a protocol from Bayer CropScience was applied: a mixture of 0.5 l ha^{-1} of Mefenpir-Dietile (9%) + Mesosulfuron-Metile (3%) + Iodosulfuron-Metile-Sodio (0,60%) + 1 l ha^{-1} of Sale Sodico Alchiletere Solfato 26.84% + 1 l ha^{-1} of Ciproconazolo (13.80%) + Trifloxistrobina (32.30%) was applied on 6 March 2010; Protioconazolo (12.5%) + Tebuconazolo (12.5%) at 1 l ha^{-1} was applied on 28 April 2010.

Plant density was measured twice, after emergence and at harvesting, by counting the seedlings and the stems on a quadrate of 2 square meters, six times per plots. During the vegetative period plant height was recorded after stem elongation was complete. At harvesting was determined grain yield when grain moisture levels dropped below 13%. Thousand kernel weight (TKW) was determined from subsamples of 200 whole grains from each plots five times. Hectolitre weight was determined using a chondrometer (250 ml). Protein and gluten content were determined on a sample of 500 g of kernels with an Infratec Grain Analyzer 1241 (Foss Electric) instrument. The obtained data were analyzed by a factorial analysis of variance (ANOVA). The Fisher LSD test was applied to the data to evaluate the statistical differences for the effect of each factor in the respective cultivars. Statistical analyses were performed using the statistical environment R (R Development Core Team, 2005).

Results and Discussion

The cropping season was characterized by long periods of intense rainfall, with 141 mm of rain fallen in October 2009 and 420 mm from 1 November 2009 to 30 April 2010. Such circumstances strongly influenced sowing and post-emergence operations. The main statistics, which describes the effect of different sowing machines on the seed emergence, plant height, spike length and yield is given in Table 1. Ciccio showed a higher crop density both at emergence and harvesting, while Casanova was the highest yielding genotype. The higher yield potential of Casanova relies in part in the longer spikes and consequently in a higher number of flowers and seeds per spike. The effect of sowing-machines within the genotypes was statistically significant.

For both genotypes, the highest percentage of emergence and plant at harvesting is associated with the use of the John Deere sowing machine, while Gaspardo the lowest. Good results were achieved also under the Kuhn-Casanova (significant interaction) trial. Data collected at harvesting confirmed the strong importance of the percentage of emergence and hence of the crop density: the John Deere thesis recorded the highest yield for both genotypes and Gaspardo the lowest, confirming that high grain yields are primarily due to the higher number of kernels, directly related to the number of spikes per unit area (Ferrise et al., 2010). The influence of genotype and sowing machines on quality of durum wheat is given in Table 2.

The parameter piedbald grains was only affected by the genotype, with Casanova showing nearly double values than Ciccio. The latter also shows higher grain quality in terms of hectolitre weight, proteins and gluten content (83.17 kg hl^{-1}, 13.3% and 10.9% respectively). The influence of the sowing-machines on grain quality, and probably on yield as well, was significant. For both genotypes, the highest protein and gluten contents were measured in the Gaspardo trial and the lowest in the John Deere trial.

The study highlights that yield and quality of durum wheat mirrors the effect of the sowing-machine on seed emergence and consequently on crop density. Although the crop is partially able to recover with tillering, an adequate crop density is crucial for obtaining high yield and a very important role is played by discs, coulters and blades.

Table 1. Effect of cultivars and sowing machine on plant density, morphology and yield of durum wheat grown in southern Italy
n.s., *, **, not significant, significant at P < 0.05 and 0.001, respectively.

Cultivar	Sowing-machines	Piedbald grains (%)	Protein (%)	Gluten (%)	Hectolitre weight	TKW
Casanova	GASPARDO	16.8	13.1	9.9	80.75	62.6
	JOHN DEERE	19.4	12.3	8.2	80.64	65.1
	KUHN	15.6	12.7	9.2	80.31	64.1
	SEMEATO	16.4	12.7	9.1	81.15	62.6
	SFOGGIA	18.6	12.9	9.1	81.04	63.7
	mean	**17.4**	**12.7**	**9.1**	**80.78**	**63.6**
Ciccio	GASPARDO	7.6	13.6	11.1	83.64	50.2
	JOHN DEERE	8.0	13.1	10.6	82.58	52.9
	KUHN	10.8	13.2	10.8	82.98	52.3
	SEMEATO	10.8	13.2	10.9	83.35	51.9
	SFOGGIA	9	13.4	11.0	83.29	51.3
	mean	**9.2**	**13.3**	**10.9**	**83.17**	**51.7**
s.e.d.		*2.1*	*0.2*	*.04*	*0.5*	*0.9*
F-Test						
Cultivar		**	**	**	**	**
Sow-machines		n.s.	**	**	n.s.	**
Interaction		n.s.	n.s.	n.s.	n.s.	n.s.

Table 2. Effect of cultivars and sowing machine on quality characteristics of durum wheat grown in southern Italy.
n.s.. *. **. not significant. significant at P < 0.05 and 0.001. respectively.

Cultivar	Sowing-machines	Plant at emergence (n m^{-2})	Plant at harvesting (n m^{-2})	Plant height (cm)	Spike length (cm)	Yield[♣] (t ha^{-1})
Casanova	GASPARDO	205	257	79.5	7.6	2.88
	JOHN DEERE	281	308	77.1	7.4	3.78
	KUHN	260	275	76.5	7.1	3.24
	SEMEATO	256	276	78.5	7.3	3.41
	SFOGGIA	212	262	77.8	7.4	3.05
	mean	**242**	**276**	**77.9**	**7.3**	**3.27**
Ciccio	GASPARDO	213	241	66.6	6.5	2.4
	JOHN DEERE	344	362	63.8	6.5	3.5
	KUHN	326	351	64.1	6.3	3.08
	SEMEATO	330	348	65.9	6.5	3.01
	SFOGGIA	247	279	65.4	6.6	2.84
	mean	**292**	**316**	**65.2**	**6.4**	**2.98**
s.e.d.		*13.3*	*9.5*	*0.5*	*0.1*	*0.1*
F-Test						
Cultivar		**	**	**	**	*
Sow-machines		**	**	**	**	**
Interaction		**	**	n.s.	n.s	n.s

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Conservation farming implements for two wheel tractors

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Keywords: Strip tillage, rotary tillage, zero tillage, seed drill

Introduction

Smallholder farmers in many parts of the world have used two wheel tractors (2WT) for over 30 years. They are essentially the first mechanical progression from animal traction systems. At the present time most of the global production is manufactured in Asia. Currently in the order of 500,000 units are made world wide, (Justice 2011) and there are over 300,000 two wheel tractors in use in Bangladesh alone (Islam 2009). Smallholder farmers from South Asia and other parts of the world use two wheel tractors as the main means of land preparation and other farm operations due to small farm and field size combined with an affordable price. Considerable sales are now being made in Africa (AWS 2010).

They are normally powered by single cylinder diesel motors of 8-18 HP and are fitted with multi-speed gearboxes with from 2-6 gears. In normal configuration as sold into the market most are fitted with a rotary tillage unit (rotavator). Rubber pneumatic tyres are fitted for use in upland and rain fed cropping, and steel cage wheels are available as an option for paddy rice production.

Although two wheel tractors are popular with smallholder farmers, the research community has until recently largely neglected them as traction units for conservation agriculture cultural operations. They have limited available power to carry out farming operations. Due to their low mass and limited tractive ability they must of necessity be fitted with simple lightweight and low draft implements.

Early Research into the use of Conservation Farming Implements for 2WT

Early development of conservation farming implements (mainly seed drills) to suit 2WT commenced in Bangladesh in the late 1990s. This was a co-operative venture between the Bangladesh Agricultural Research Institute (BARI) and the International Maize and Wheat Improvement Center (CIMMYT) in Bangladesh. (Haque et al 2004).

A zero till tined seed drill was developed which bolts to the rear of a 2WT instead of the standard rotavator. The machine was tested in farmers fields from 1999-2004. Without prior land preparation, this machine places seed and fertiliser directly into the soil in one operation. (Figure 1). Although performance was reasonable, the seed drill lacked residue clearance and versatility for variable planting conditions.

Figure 1. The original BARI/CIMMYT tined seed drill   **Figure 2**. The improved ACIAR-Rogro tined seed drill

Concurrent with the development of the zero till tined seed drill, a number of small rotary tillage seed drills were imported from China. (Justice et al 2004) A research team comprising BARI, CIMMYT Bangladesh, and AIRC (Agricultural Implements Research Centre) of Nepal evaluated these rotary seed drills for use in conservation farming. This drill bolts to a Chinese 2WT in place of the standard rotavator, and is primarily designed for one pass planting of rain fed crops following rice harvest.

The BARI/CIMMYT/AIRC team investigated the possibility of removing some of the tiller blades, and experimented with retaining only the blades ahead of the planting rows. This creates a system of 'strip tillage' where only strips of the field sufficient for correct placement of the crop seeds, are tilled. Results showed that both drills when used correctly were effective for minimum and zero tillage planting of crops in Bangladesh. However there were difficulties with seed placement, pressing, and the ejection of soil from the planted strips.

Later research with two wheel tractor seed drills

In 2006, with funding from Australian Centre for International Agricultural Research (ACIAR) the BARI/CIMMYT work re-commenced on the development of zero and minimum tillage seed drills for two wheel tractors. Since that time, several main types of seed drills have been developed. (Hossain et al (2009).

Tined type zero tillage drill. (tool bar mounted)
This implement is essentially an improved model of the original tined type zero tillage drill as described by Haque et al (2004). An adjustable three bar tool bar frame that is 1000mm. wide has been made up from 50mm square tube. There are two side rails of flat steel, which have holes at regular intervals. The tool bars can be fitted at various points to allow variable bar spacing. The resultant frame can be set up as a one bar, two bar, or three bar implement. (Figure 2). Various soil engaging options are available including tines, single disc openers, double disc openers and cutting coulters (Figure 3). Other choices include press wheels and levelling harrows.

Further modification to rotary tillage seed drill
The Chinese made seed drill as used in the previous study is normally set up for one pass seeding with 100% rotary tillage. The seed box is set up above the tillage unit, and the seed delivered by tubes and lightweight soil openers to the soil immediately behind the tilled zone. The

standard soil openers and the pressing roller were found to be unsatisfactory. With the modification to the rotary seed drill, an add-on tool bar the width of the tiller (1200 mm.) was made up. This tool bar is also of 50mm square bar with similar tines to the tined unit described earlier. Tines are positioned on the tool bar so that all the seeds can be delivered to the bottom of the tilled layer, and into the untilled subsoil if required. A fertiliser box has also been fitted. This drill can be configured as a strip tillage unit, (Figue 4) or as a one pass seed drill cultivating 100% of the soil

Figure 3. Some optional soil engaging tools to fit the tined seed drill

Figure 4. A Bangladeshi made rotary tillage feed drill set up in strip tillage mode.

Other seed drill types

Md Abdul Wohab of BARI has developed a bed shaper/seed drill based on the standard 70 cm rotavator supplied with Chinese made 2WT. (Wohab et al 2009). This allows the bed planting of crops and is adaptable to other setups.

Another rotary tillage seed drill, the Versatile Multi-crop Planter (VMP) has been designed in Bangladesh with the capability for seed and fertilizer application in rows for: (a) single-pass shallow-tillage; (b) strip tillage for varied width and depth of strips; (c) zero tillage (d) bed planting for single-pass new bed-making or re-shaping of permanent beds with simultaneous planting and fertilizer application, and (e) traditional tillage following broadcast seeding. An important innovation of the VMP has been to replace the round rotary tillage shaft and its fixed-blade positions by a square shaft on which blades can be flexibly attached with brackets for variable row spacing (Haque et al., 2011).

Continuing Research and Development

Research and development is continuing with the prospect of developing other implements for 2WT. These include:
Inter row cultivator, boom spray, lister/furrower, grader blade, laser land leveller, mechanical implement lift system, and angled single disc opener (Thomas 2009).

Commercial production of the tined drill is under way in Cambodia with considerable farmer interest. Prototypes have been made in Bangladesh. A Chinese farm machinery company has completed its first production model tined drill (June 2011). Indicative cost < $US500 each.

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Impact of direct drilling on nascence in a cereal–vetch crop under excessive soil moisture

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Introduction

The Cañamero raña is a broad glacis–piedmont plateau a few hundred square kilometers in area with a longitudinal slope smaller than 1%. Rañas are a common feature in the West of the Iberian peninsula, where they are associated with quartzitic mountains and act as boundaries between river basins. The Cañamero's raña soils are Palehumults and Palexerults (Soil Survey Staff, 1999) dating from the Middle Pliocene, and their morphology and properties were shaped by a subtropical wet pre-Quaternary climate (Espejo, 1987). These soils are highly acidic and weathered, and their exchange complex is dominated by Al, which increases with depth. At present, most of the cultivated soils (Palexerults) are highly degraded by effect of an inappropriate management, which has considerably reduced their organic matter (OM) content with respect to the uncropped soils (Palehumults) and has had a rather unfavorable impact on most of the soil quality-related physical and chemical properties (Mariscal et al., 2007, 2009). Recovering these degraded Palexerults would require the application of liming amendments to suppress Al toxicity and using conservation tillage methods to raise the OM content and improve soil quality. Soils in raña formations, which possess thick Bt horizons accumulating illuvial clay, in a very flat relief, tend to form perched water layers with the upper limit near the surface (10–20 cm), that lead to water saturation or near-saturation conditions in the upper layer of the Ap horizon – the horizon receiving crop seeds and thus being the most adversely affected as regards germination. This is particularly so in the autumn–winter period of especially rainy years. The aim of this work was to assess the impact of direct seeding on the germination rate and early growth stages of a vetch–cereal crop during the 2010–2011 agricultural season, where precipitation in the study area exceeded its mean historical value.

Materials and Methods

The study was conducted in an experimental field set up in 2005 in the Cañamero raña. The design involved split plots and four replications where the primary treatment was tillage (direct seeding, DD versus conventional tillage CT) and the secondary treatment the application of an amendment consisting of sugar foam waste and of red gypsum. Prior to seeding, each tilled plot received a moldboard pass followed by two rotavator passes. All plots were sown by using the same direct sower. The seeded crop was a mixture of forage species consisting of 56.5% of a local oat variety (*Avena sativa*), 17.4% triticale (*Triticoscale*) of the Trimour variety and 26.1% of a local vetch variety (*Vicia sativa*), and applied at a rate of 140 kg/ha. Fine earth in the Ap horizon (0–25 cm) was sandy loam (ISSS) and consisted of 28.5% coarse sand, 52.5% fine sand, 6% silt and 13% clay. This horizon contained up to 55% of coarse altered quartzite pebbles smaller than 4 cm as a rule. Soil samples for gravimetric determination of moisture content after drying at 105 °C were collected (when possible) at three different depths (0–5, 5–20 and 20–40 cm) during the first week of each month from October 2010 to April 2011, except in October which was at the end. The hydraulic conductivity (K) under a constant load was determined in unaltered samples from the 0–5 cm layer of the Ap horizon collected by using steel cylinders 5 cm high × 5 cm wide. These samples were additionally used to determine the water retained at 0.05, 0.1 and 0.33 bar, the former two with a tension table and the latter with Richards' plate. The germination rate was determined in March by counting the number of plants per square meter (3 counts per plot) and the proportion of plant cover by using the software Sigmascan Pro-5 to process digital photographs from the plots.

Results and Discussion

Mean precipitation and temperature (P mm; T ºC) during the study period were: Sept 2010 (9.8; 21.3), Oct (84.2, 14.9), Nov. (58.8; 9.1), Dec. (179.0; 7.9), Jan. 2011 (93.6; 7.3), Feb. (84.4; 8.2), March (60.0; 10.5), April (83.2; 16.4). Figure 1 shows the water content in the fine earth from 0–5 cm layer samples collected during the studied period. As can be seen, the moisture content of DD plots exceeded that of CT throughout; however, visual inspection during the sampling operations revealed a higher water content in the tilled plots. The data for January have been excluded because all tilled plots and 25% of the DD plots were water-saturated in situ. This figure also shows data of the hydraulic conductivity values in undisturbed soil samples from the 0–5 cm layer, which were significantly higher in DD plots. According to Hudson (1994), the differences can be ascribed to the increased OM content in the DD plots (6,6% in DD versus 5,6 % in CT). One other reason for these differences could be the presence in the DD plots of greater amounts of plant residues and root macro and medium -bio-pores filled with root in process of humification. Thus, root pores increased every year in the DD plots but were broken or altered in the tilled plots. These bio-pores presumably increase water retention and facilitate water infiltration and also aeration. It should be noted that application of the Ca amendment had no significant effect on the water–soil relationship (data not shown). Figure 2 shows the amounts of water retained at 0.05, 0.1 and 0.3 bar by fine earth from undisturbed soil samples from the 0–5 cm soil layer. As can be seen, the water contents in the DD plots invariably exceeded those in the tilled plots, which suggests more marked development of large and medium pores resulting from the presence of crop roots and residues. Figure 3 shows the number of germinated plants per square meter and the percent area covered by the crops in March. The number of both cereal and legume plants was much greater in the DD plots than in the tilled plots, and so was the percent covered area. This was a result of the soil–water relationship and aeration conditions in the topmost 5 cm of soil being more favorable in the DD plots. There were no significant differences in the number of germinated plants between the amended and not amended plots. However, vetch plant growth in the unamended plots was very poor relative to the amended plots and they did not progress afterward.
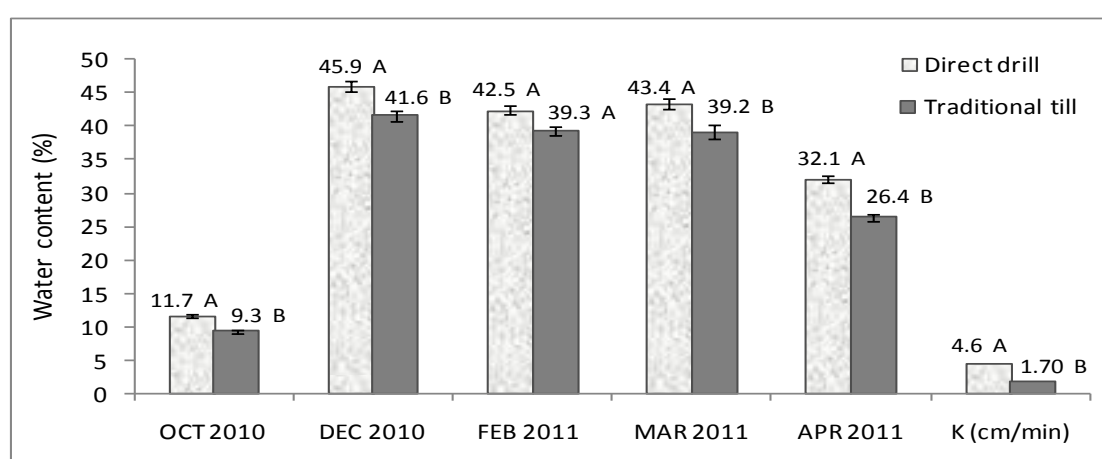
Figure 1. Water content in fine earth and hydraulic conductivity in the 0-5 cm soil layer.
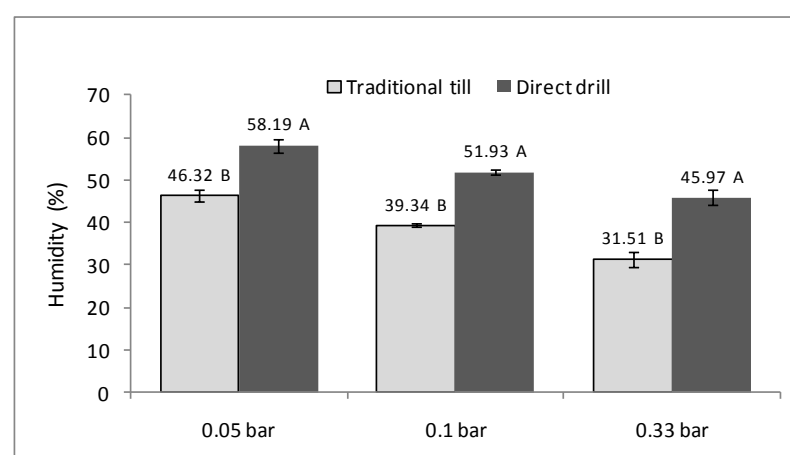
Figure 2. Water retained by fine earth at 0.05, 0.1 and 0.33 bar in the 0-5 cm soil layer.
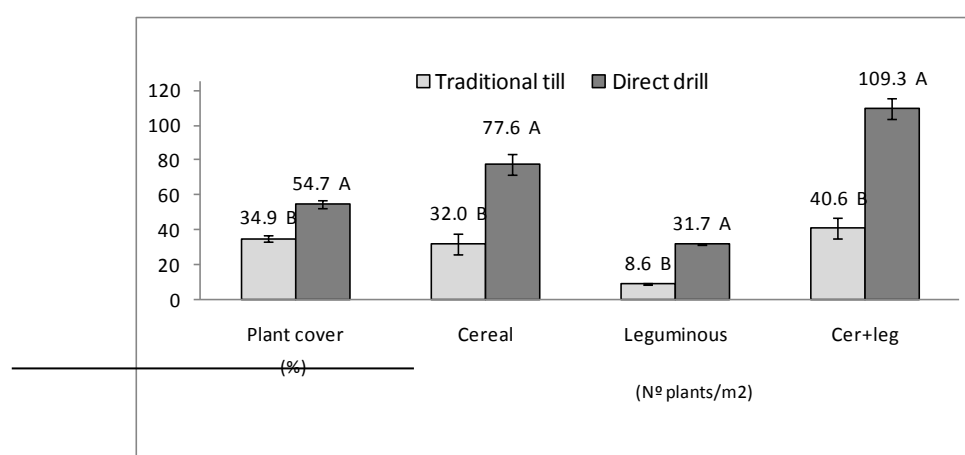
Figure 3. Number of plants per square meter and percentage of soil cover on 5th March 2011.

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Crop – livestock interactions and Conservation Agriculture in Indian Punjab: exploratory village level investigation

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Key words: Resource conserving technologies, Natural resource management, Sustainable agricultural development

Introduction

The crop-livestock systems support the livelihoods of majority of the families in the Indo – Gangetic plains. The system has seen rapid and significant intensification of rice-wheat cultivation in response to the availability of improved inputs and policy/ institutional support in the Indian Punjab, resulting in rapid yield increase from the early 1960s to the 1990s, followed by stagnant or declining grain yields, falling water tables and soil degradation. These threats are being addressed by the Rice-Wheat Consortium and others through research on resource-conserving technologies (RCT's) including zero-tillage, reduced tillage, bed planting and mulching. RCTs typically include aspects of conservation agriculture practices, but may become unsustainable in the long run if they do not combine all the components of conservation agriculture (reduced tillage, ground cover at all times, crop rotation). Applying conservation agriculture practices typically implies the need to retain crop residues on the soil surface, which reduces the availability of residues for livestock production. The present exploratory investigation was made to better understand the croplivestock interactions in the rice-wheat-livestock systems of Punjab in context of the potential adoption of various conservation agriculture practices keeping in view the prevailing crop straw uses and management in Punjab.

Methods

The study was based on informal survey (participatory appraisal), conducted in 6 villages in 2 blocks (Patiala and Rajpura) of Patiala district of Punjab in 2006-07. The objective was to identify key issues at the community level in relation to conservation agriculture, livestock and livelihood issues. The villages were selected according to the expectation of the greatest differences in specific issues such as use of RCTs, proximity to markets, and population. In each village, the people were gathered in a large group with the help of village chief, in a place such as a school or religious premises. To get an overall view of the survey area such as soil types, irrigation practices, RCT activities and livestock population, key informants including the Village chief were initially interviewed. Thereafter the people were divided into three groups of 8-10 persons each: large farmers (> 8 acre), small farmers (< 8 acre) and landless. The team members interviewed each group separately with key informants' information as a check.

Results and Discussion

Table 1: RCT usages by household group, sample villages Patiala, Punjab.

RCT	Crop	Share of hh adopting [%] *		Share of area used [%] **	
		Large farmer (n=6)	Small farmer (n=6)	Large farmer (n=6)	Small farmer (n=6)
Zero-tillage	Wheat	15.50	9.60	21.35	8.65
Direct dry seeded	Rice	-	-	-	-
Direct wet seeded	Rice	-	-	-	-
Reduced tillage	Wheat	43.10	4.6	8 44	5.5
	Rice	14.35	0.24	3.9	0.06
Bed-planting	Wheat	0.48	-	0.12	-
	Rice	0.24	-	0.01	-

* Calculated as (No. of large/small hh adopting) / (Total no. total large/small farm hh)
** Calculated as (Area used) / [(Total village area) * (Wheat or rice area share)]

Crop production
The major crops grown in the surveyed area were paddy in summer and wheat in winter. The next most important were fodder crops like sorghum, oats and berseem. Other crops like vegetables, oilseeds, pulses, gram etc were also grown, though on small areas. In areas where RCTs were being used by some farmers, fine paddy (basmati) constituted 22 % of the total cultivated area, whereas in Non RCT villages it was grown only on 1 % of the cultivated area.

Livestock production
The number of dairy buffalo (adult female) per household was much lower (2.0) in RCT villages than Non RCT villages (5.3). On average, households possessed 3.1 adult female buffaloes, 0.4 adult cross-bred female cows, 0.3 adult male draft bullocks and 0.02 adult goats.

RCTs
Zero tillage and reduced tillage (about half of the normal 4-5 ploughings) were the only RCTs used in the study area, and only for wheat. These RCTs were more prevalent on the large farms, where 15.5 % of households practiced zero tillage for wheat on part or their entire farm, which equated to 21.4 % of wheat area in the village. Only 9.6 % of small farmers were using zero tillage on 8.7 % of the total wheat area. Reduced tillage was more common among the large farmers, with adoption by 43 % on 44 % of the total area under wheat cultivation, while only 4.7 % of small farmers used reduced tillage on 5.5 % of the total wheat area. RCT practices were being adopted more strongly in villages farther from the market, with 17.5 and 34.1 % of households adopting zero and reduced tillage, respectively. In contrast, only 4.2 and 11.2 % of households in villages near markets had adopted zero and reduced tillage, respectively. About 50 % of the area under wheat in far villages was subject to RCTs in the form of zero or reduced tillage, whereas only 20 % was under the RCTs in near villages. Owing to their proximity to market; near villages feel more prompted towards the alternative uses of wheat straw restricting adoption of conservation practices.

Crop residue management

During the survey year, 75% and 56% of the wheat was harvested with combines on large and small farms while 75% and 70% of the paddy was harvested with combines on these farms respectively. Of the total wheat straw harvested manually 86 and 95 % was used for fodder for owned animals by large and small farms, respectively, and the rest was sold. The wheat straw produced by combine harvesting was partly fed to their owned animals and partly sold in the market. A large amount of such wheat straw (36 and 13% for large and small farmers, respectively) was also left on the fields and then incorporated during tillage for rice. The large and small farmers mainly used the manually harvested paddy straw as fodder for owned animals i.e. 35 % and 67 %, respectively. These farmers sold about 10-13 % of the paddy straw in the market. Other uses of the manually harvested paddy straw included roofing etc. The paddy straw in combine harvested fields was mostly burnt in the field. About 98 % was burnt by small farmers (< 8 acre) whereas 36 % of large farmers (> 8 acre) left the straw in the field for incorporation during tillage for the subsequent rice crop. The large farmers were of the view that leaving more wheat straw on the field would adversely affect establishment and thus yield of the subsequent rice crop, and that leaving more paddy straw in the fields would require more ploughings for land preparation for the subsequent wheat crop. The large farmers also considered that there would be no effect of residue retention on water requirements for the subsequent crop. On the other hand, small farmers perceived no effect of leaving wheat straw in the fields on the subsequent rice crop, but considered that it would increase the tillage cost and labour requirement for land preparation for rice. Farmers were unanimous that leaving paddy straw in the fields would lead to lower fertilizer requirements and yield enhancement of the following crops. More straw (wheat and paddy) was fed to animals in villages situated further from markets, and these were also the villages where RCTs were being adopted more strongly. None the less, the study showed that Patiala farmers are adopting zero tillage at a slow pace. To accelerate the adoption of this technology, there is a need to identify the constraints inhibiting its adoption, and solutions for overcoming these constraints. Managing zero tillage will be highly demanding in terms of knowledge, and thus there will be a great need of extension services to promote the technology.

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Acknowledgements

Testing the SODICS model: Does it provide useful estimates of deep drainage in clay soils?

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Keywords: Soil chloride, deep drainage, modelling, irrigation

Introduction

Deep drainage (DD) may cause salinity *via* rising saline water tables. This paper is presenting the testing of a unique, rapid methodology of determining possible salinity problems both within agriculture fields and from these fields to groundwater. Although there are means of reducing DD such as rapid water on/off fields and changing crop and pasture types (Robinson et al. 2010), it is necessary to first know its cause and amount. In terms of hazard reduction, a method of estimating DD must be able to discriminate low rates (1 to 10 mm/year) from medium (20 to 50 mm/year) and high rates (>100 mm/year). It should also be effective in terms of cost and labour.

The SODICS (Solute Dynamics In Clay Soils) model, developed by Rose et al (1979), estimates soil water movement from changes in soil solute concentration over time. Changes in salt concentrations are equated to inputs (infiltrating rain plus irrigation) and outputs (the translocation of salt from the soil profile). Because many clay soils in northern Australia contain large amounts of salts that are slowly leached by rainfall or irrigation, the SODICS model has many potential applications in estimating long-term deep drainage and identifying salinity hazards. SODICS has been used extensively to provide information about the "leakiness" of cultivated fields in rainfed agriculture (Tolmie et al. 2003) and has been used in a few studies of irrigated agriculture (e.g. Thorburn et al. 1990).

Our aim is to apply the model in two contrasting cases and review its strengths and weaknesses. The applications were: (i) over a short time period in a rainfed field and (ii) over a long period in an irrigated field.

Methods

The model was implemented in a user-friendly Excel spreadsheet, where a macro applies goal-seeking tools to soils' data and the non-linear SODICS equations. In this version of SODICS, equations are used twice: (i) using the shape parameter of the solute concentration profile (λ) at t_1, and (ii) using a second value, calculated at t_2 (λ_2). If the shape of the solute profile has changed between t_1 and t_2, the estimates of DD will be different. The earlier applications of SODICS used λ_2 and assumed a negligible change in λ.

Soil chloride profile data were available from two fields - one over a short period (SHORT, 3 months) and the other over a long period (LONG, 12 years). Both sites were clay soils (Black Vertosols, Isbell 1996) and were located in the Lockyer Valley, Queensland. For SHORT, the field had been irrigated with water of 6 dS/m for 15 years at the time of initial soil sampling; data of Talbot and Bruce 1974 (Figure 1). Measurements at that time showed that the field had either accumulated or maintained a significant amount of salt in the profile. Deep drainage was estimated for a later, non-irrigated period of 3 months during which the only water input was 748 mm of rainfall. We speculate that DD during this period was substantial: probably >300 mm (40% of rainfall) but <600mm (80% of rainfall), as there was ~100 mm of evaporation in that period and the soil had a storage capacity of <200 mm (data not shown). For LONG, the field had been irrigated for 12 years (t_1 to t_2) (Figure 2). The estimated solute input was 600 mm/year at 100 mg/L Cl⁻ from irrigation and 600 mm/year at 1.5 mg/L from infiltrating rainfall. SHORT was assumed to have the same chloride concentration in rainfall.

Results

SHORT. The SODICS estimates of DD were 373 to 744 mm over the 3 month period at 1.2 m depth (for λ_1 and λ_2, respectively); a two-fold difference. Deep drainage reduced the initial chloride concentration by 28% (from 18 to 12.9 t/ha of Cl⁻).
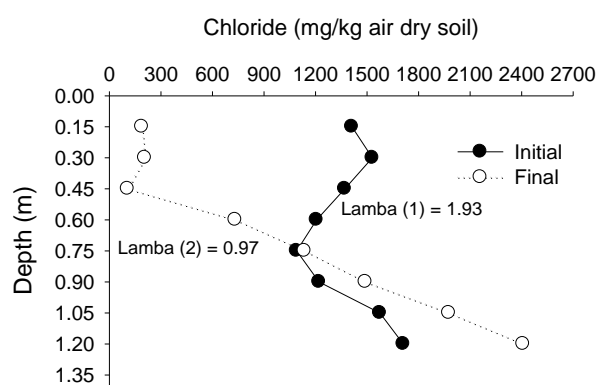
Figure 1. Initial and final soil chloride concentrations for SHORT (data from Talbot and Bruce 1974)
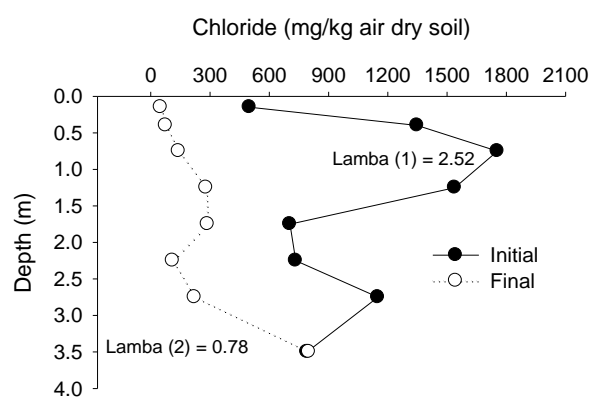
Figure 2. Initial and final soil chloride concentrations for LONG. Data from Ellis (unpublished report to Qld Govt) and Foley (pers. comm.).

LONG. The SODICS estimates of DD were 102 and 224 mm/year at 1.75 m depth (for λ_1 and λ_2, respectively), more than a two-fold difference. At this site Cl⁻ between t_1 and t_2 at 1.75 m decreased from 24.0 to 4.1 t/ha (almost a 83% decrease, Figure 2). Given the large proportion of salt lost it was not surprising that the shape parameters (λ) were quite different for the initial and final conditions and the DD estimates varied two-fold.

Discussion

Thorburn et al. (1990) used SODICS to analyse data from 19 Black Vertosol soils in the Lockyer Valley and found an average rate of DD of 219 mm/year (range 13-554 mm/year). These data are mostly from climates, soils and farming systems similar to LONG. Our estimates for LONG fall well within the range of their values. Independent estimates of DD at the LONG site have also been made using daily water

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balance modelling (Robinson et al., these proceedings) and their results further reinforce the validity of our estimates from SODICS. We note, however the importance of calculating DD for both λ_1 and λ_2 rather than assuming $\lambda_1 \approx \lambda_2$, which was not true in these cases.

Although SODICS had not been tested for periods of a year or less, the results for the SHORT data matched the range of results likely from consideration of the water balance during the period. From this and previous analyses, and theoretical considerations, we suggest that the following conditions are necessary to obtain accurate estimates of DD from SODICS: (i) soil solute concentrations are known, (ii) solute inputs are known (rainfall, irrigation, fertilisers), (iii) t_1 and t_2 must be more than 3 months apart, (iv) water movement (both downward and upward) must be the main cause of changes in the solute profile, (v) the shape of the solute profile must not have changed excessively (ideally $0.5<\lambda_1/\lambda_2<2$), and (vi) the soil profile is spatially homogenous and there is no lateral flow.

Soil chloride loss and drainage were greater where zero till had been practised for longer periods compared with traditional tillage (Tolmie 2004). The change in soil chloride since clearing indicates a large mass of salt has been added to the groundwater. Drainage in the Queensland environment is episodic and depends on rainfall sequence. This is reflected in the above results in that drainage determined from time sequence data is specific for the given time and rainfall period.

Results showed that the improved water infiltration associated with the improved soil structure, from increased organic matter and earthworm numbers, with conservation agriculture may well lead to dramatically increased through-water dynamics in both rainfed and irrigated situations. The model being tested here may provide a rapid, first-cut assessment of the soil water dynamics in conservation agriculture fields and associated on- and off-site salinity risks."

The SODICS model provided considerably greater resolution of DD rates than would usually be required to categorize the rate as low, medium or high, and provide an assessment of the contribution that DD makes to the salinity risk in a given situation. Although the cost and labour requirements of soil sampling and chloride analyses for SODICS are significant, they are low when compared with alternative methods of estimating DD (such as lysimetry). Therefore, SODICS is a useful tool for estimating DD because it has favourable technical and economic characteristics.

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Effect of tillage and residue retention on maize productivity

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Keywords: fuel consumption, labour requirement, emergence, rice straw

Introduction

In Bangladesh, maize is generally sown after extensive tilth and minimum residue retention. Conservation agriculture (CA) systems reduce the input costs, machinery use, CO_2 emissions; and improve soil health (Raper et al., 1994). Crop residues are known to affect soil physical properties (Hulugalle et al., 1986), availability of nutrients (Wade and Sanchez, 1983; Asghar et al., 2006) and soil biological activity (Tian et al., 1993). Crop residue retention has been suggested to improve overall soil fertility and to support sustainable crop production. Crop residue retention under no tillage system reduce soil erosion, increase soil organic matter (SOM), and reduce requirement of labour and fuel under cereal grain and row crop culture (Salinas-Garcia et al., 1997). Kumar and Goh (2000) reported that incorporation of crop residues is essential for sustaining soil productivity through replenishing SOM that not only a key indicator of soil quality, but it also supplies essential nutrients upon mineralization (N, P, and S) and improves soil physical, chemical, and biological properties (Kumar et al., 2001). In our country, the crop residue is used mostly for cattle feed (Saadullah et al., 1991), fuel for stove and some cases burning. It is essential to estimate the amount of crop residue that should be retained in field to get the benefits. Therefore, the present research investigated to find out the minimum tillage with residue retention could be an effective element for maize production.

Materials and Methods

The experiment was set up at the Bangladesh Rice Research Institute (BRRI), Regional station, Rajshahi (24°69´latitude N, 88°30 longitude E) in the cool dry *Rabi* season of 2009. Land preparation was done with the Versatile Multi-crop planter (VMP). The main plot treatments were - conventional full tillage with four passes by the 2-wheel tractor (T_1); zero tillage by using hand tool 'naigla' (T_2); bed formed by VMP (T_3), and strip tillage by VMP (T_4) and planted maize seed manually by hand. The subplot treatments were 100 % residue retention (C_1); 50% residue retention (C_2) and 0% residue retention (C_3) from the previous monsoon season rice. The maize seed of variety NK 40 was used. All recommended agronomic practices were maintained in the trial. Maize seed was sown with 20 cm distance from seed to seed on 19 December 2009. Recommended basal fertilizers were applied in the furrows. Rice straw was spread on the surface as per treatments. In 100 % straw retention plots, 4,582 kg ha^{-1} (on an oven-dry weight basis) rice straw was spread; and half that amount of straw was spread for the 50 % straw retention plots. The trial was laid out in a strip plot arrangement with three replications with tillage types in main plots and residue retention in sub-plots.

Results and Discussion

Fuel consumption was significantly higher (49.3 l ha^{-1}) in T_1 than other treatments (Table 1). Fuel consumption in T_3 and T_4 were 27.8 and 16.6 l ha^{-1}, respectively. Labour requirement in t T_2 was 500 % higher than for the treatments T_3 and T_4. There was no significant difference in labour requirements for land preparation between the treatments of T_3 and T_4. The greatest time was required for maize seed sowing in T_2 (161.3 person-hr ha^{-1}) and that was almost 300 % higher than the treatments, T_3 and T_4 (Table 1) for the placement of seed and fertilizer in untilled soil. Lowest time (49.4 person-hr ha^{-1}) requirement was recorded in T_3 due to broadcasting the basal fertilizers before bed formation and seeds were sown in tilled soil. The highest cost for land preparation was incurred in T_1 (Taka 3,774 ha^{-1}) and lowest (Taka 1,055 ha^{-1}) in T_3 because of minimal fuel and labour requirement. The maize seed sowing cost was highest in T_2 because of the need to place and cover the fertilizers in the furrow, then sow and cover the seed in the furrow (Table 2). The maize plant emergence rate was highest in bed planting and lowest in zero tillage plots. Rodent's damage was observed higher in zero tillage, strip tillage and conventional tillage plots than bed planting. Among the species, the weeds - *Chenopodium album* and *Cynodon dactylon* were dominant. Severe weed infestation was found in the zero tillage plots (T_2) followed by strip tillage plots (T_4) (Table 3). The highest time and maximum cost for weeding was incurred in the 0 % residue retention plots (Table 4). Tillage treatment had no significant effect on maize grain yield. Conventional tillage, zero tillage by *naigla,* bed formed by VMP, and the strip tillage by VMP plots yielded maize grain outputs of 7.75, 7.00, 8.48 and 7.19 t ha^{-1}, respectively. Residue retention did not significantly affect maize grain yield either. The 100 %, 50 % and 0 % residue retention plots yielded 7.31, 8.05 and 7.45 t ha^{-1}, respectively. The benefit cost ratio of conventional tillage, zero tillage by *naigla*, bed formed by VMP, and strip tillage by VMP was 2.95, 1.73, 3.26 and 2.10, respectively.

Table 1: Effect of tillage on fuel consumption, and on labour requirements for land preparation, basal fertilizer application and maize seed sowing.

Treatment	Fuel consumption (l ha^{-1})	Labour requirement (person-hr ha^{-1})	
		Land preparation	**Seed sowing and basal fertilizer application**
Conventional tillage (T_1)	49.3a	51.8a	73.0b
Zero tillage by 'naigla' (T_2)	0.0c	40.6b	161.3a
Bed formed by VMP (T_3)	27.8b	11.8c	49.4c
Strip tillage by VMP (T_4)	16.6b	10.3c	59.7c

In a column, means followed by a common letter are not significantly different at 1 % level by Duncan's Multiple Range Test.

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Table 2: Cost of land preparation and maize seed sowing under different tillage systems.

Parameter	Tillage treatment (Taka ha^{-1})			
	Conventional tillage (T$_1$)	Zero tillage by 'naigla' (T$_2$)	Bed formed by VMP (T$_3$)	Strip tillage by VMP (T$_4$)
Land preparation	3,774a	1,219b	1,602b	1,055b
Seed sowing + basal fertilizer application	1,461b	3,226a	989d	1,194c
Total	**5,235a**	**4,445b**	**2,591c**	**2,249d**

In a row, means followed by a common letter(s) are not significantly different at 1% level by Duncan's Multiple Range Test.
Note: 70 Taka = 1 USD

Table 3: Effect of tillage on weed control

Parameter	Tillage treatment				Level of significance
	Conventional tillage (T$_1$)	Zero tillage by 'naigla' (T$_2$)	Bed formed by VMP (T$_3$)	Strip tillage by VMP (T$_4$)	
Weeding (person-hr ha^{-1})	653b	1,903a	836b	1,444ab	*
Weeding cost (Taka ha^{-1})	13,050b	38,050a	16,740b	28,888ab	**

*, $P < 0.05$; **, $P < 0.01$

Table 4: Effect of residue retention on weed control

Parameter	Residue retention			Level of significance
	100 % residue retention (C$_1$)	50 % residue retention (C$_2$)	0 % residue retention (C$_3$)	
Weeding (person-hr ha^{-1})	884c	1,060b	1,682a	**
Weeding cost (Taka ha^{-1})	17,690c	21,210b	33,650a	**

** Significance at 1% level, * Significance at 5% level

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Evaluation of the versatile multi-crop planter for establishing sprouted direct-seeded rice

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Introduction

Wetland rice seeding is an increasingly common practice for irrigated and favourable rainfed lowlands. Most developed countries sow rice seed in saturated water to minimize cost and labour requirements (Smith and Show, 1996). Farmers in developing countries increasingly are adopting wet seeding because of the migration of farm labour to non-farm jobs and the consequent labour shortage and high costs for manual transplanting (Ho, 1995; Pandey, 1995; Pingali, 1994). Wet seeding in irrigated areas occurs into aerobic, anaerobic, and wet soils based on the level of oxygen in the vicinity of the germinating seed or the depth of flood water at seeding. Direct seeded rice either broadcasted or line sown gave significantly higher grain yield than transplanting under proper management (Elahi et al., 1997; Hussain et al., 2000). Santhi (1999) reported that the establishment of sprouted rice seed under broadcasted systems flowered 7.2 days earlier than transplanted rice seedling. The sprouted rice manually sown in lines had 7 days earlier flowering than transplanted rice in both dry and wet seasons. The delayed flowering in transplanted rice might be due to transplanting shock of the rice seedling. Islam (2008) observed that the radicle and plumule length was increased with the increase of incubation duration. Islam (2008) also reported that significantly higher grain yield was attained after 96 hours of rice seed incubation; however, using a drum seeder, no difference was observed among 24, 48 and 72 hours incubation. Very recently, CIMMYT has developed a 2-WT tractor-operated Versatile Multi-crop Planter (VMP) with the provision to use adjustable row spacing of crops for zero tillage, strip tillage, single pass shallow tillage, bed planting, and even conventional tillage (Islam et al 2010). The VMP has facilities to sow seed and place basal fertilizer simultaneously in a single pass operation under different tillage systems. To obtain the direct-seeded rice establishment benefits, the VMP was evaluated to assess the performance of sprouted rice seed sowing. A field study was undertaken to determine the establishment of sprouted rice seed and estimate the damage of radicle and plumule during mechanized sowing; and to determine the optimum time of rice seed incubation for grain yield.

Materials and Methods

The experiment was conducted in a farmer's field, Digram, Godagari, Rajshahi (24°31′57.54″N and 88°22′40.22″E) during the hot and dry *Kharif 1* season. A popular high-yielding rice variety - BRRI dhan42 was sown on 29th April, 2010. The seed treatments were: Dry seed (T_1); soaking overnight (T_2); soaking overnight and 24 hours incubation (T_3); soaking overnight and 48 hours incubation (T_4); and soaking overnight and 72 hours incubation (T_5). Equal dry weight of uniform seeds were put into fresh water and removed after 24 hours of soaking. The soaked rice seeds were kept in jute bags at ambient air temperate for incubation. Before sowing, seeds were removed from the jute bag and air dried in the shade for two hours. The length of plumule and radicle was measured from 15 randomly selected rice seeds in each treatment. Slide callipers were used to measure the length of plumule and radicle from their junction with the rice seed. Land preparation, seed sowing and application of recommended basal fertilizers were done simultaneously by using VMP in a single pass strip tillage operation. Seeds were sown in dry land followed by application of irrigation. A fluted-type seed meter with eight flutes was used in the VMP. In each treatment, rice seed samples were collected from the seed dispensing tube into polythene bags to measure the damage in whole rice seeds, plumule, and radicle. The clearance between flute and concave of seed meter was adjusted to maintain the actual seed rate as well as minimize the damage of whole seed, radicle and plumule. The spacing between rows was 20 cm. Soil samples were collected randomly from 0-7.5 cm and 7.5-15 cm depth. Core sampler was used to measure the bulk density and moisture content. Rice grain yield was recorded from each pre-selected 10 m^2 area per plot and adjusted to moisture content of 14 %. Data were analysed by using MSTAT-C software. Means were compared by the least significant difference (LSD) test.

Results and Discussion

The soil in experimental field was silty clay. Initial bulk density in 0-7.5 cm depth was 1.12 (g cm^{-3}) at 21.2 % gravimetric water content and bulk density in 7.5-15 cm depth was 1.36 (g cm^{-3}) at 22.4 % gravimetric water content. Longest radicles (11.14 mm) were observed after 72 hours of incubation and the shortest (3.0 mm) were observed after 24 hours of incubation. Plumule length was not much increased with the incubation period. No breakage was observed in plumule, radicle or whole rice seed due to rotation of the fluted type seed meters. Seeds were safely dispensed into the opened furrow of strip tillage. Emergence rate of incubated rice seed is given in Table 1. Irrespective of the length of incubation, 7 days were required for emergence of the rice seedling. The highest rate of emergence was found with 48 hrs incubation. The rice seed incubation time did not significantly affect the crop maturity date or number of tillers produced (Table 2). Numerically, dry rice seed produced higher numbers of tillers (381 m^{-2}) followed by 24 hours soaking with 48 hours incubation of seed. Lowest numbers of tillers (198 m^{-2}) were produced from 24 hours incubation of rice seed. However, percent of effective tillers was highest from sowing rice seed after 48 hours incubation. No statistical difference was found on panicle number m^{-2} among the treatments. Lowest panicle number was obtained for the 24 hours-incubated rice seed. Irrespective of incubation period, the rice crops matured within 100 days. Highest rice grain yield was obtained from sowing seed after 72 hrs incubation. There was no statistical difference in yield between dry rice seed and seed incubated for 72 hours. Similarly, there was no statistical difference between 24 hours soaking of rice seed; and 24 hours soaking followed by 48 hours incubation of seed. Incubate seed required more days to sprout but matured the rice crops in the same duration. Sprouted rice seed did not reduce the field duration. It can be concluded that sprouted rice seeds can be dispensed safely through the seed meters of VMP.

Table 1. Effect of incubation time on rice seedling emergence after 7-11 days (no. m^{-2}). Values are means of three replicates.

Treatment	Days after seeding				
	7	8	9	10	11
Dry seed (T$_1$)	62a	76a	78a	80ab	78ab
Soaking overnight (T$_2$)	35b	38b	39b	38b	35b
Soaking overnight and 24 hours incubation (T$_3$)	28b	33b	36b	34b	33b
Soaking overnight and 48 hours incubation (T$_4$)	75a	85a	93a	97a	98a
Soaking overnight and 72 hours incubation (T$_5$)	61a	74a	82a	84ab	84a
Level of significance	*	*	*	**	**
CV(%)	25.1	30.01	26.7	27.5	26.9
LSD	24.6	34.47	32.9	50.2	48.5

** Significance at 1% level, * Significance at 5% level.

Table 2. Effect of seed treatments on grain yield and yield contributing characters of *Kharif 1* season rice. Values are means of three replicates

Treatment	Tiller (no. m^{-2})	Non-bearing tiller (no. m^{-2})	Panicle (no. m^{-2})	Grain yield (t ha^{-1})
Dry seed (T$_1$)	381	63	318	3.5ab
Soaking overnight (T$_2$)	319	43	277	2.5c
Soaking overnight and 24 hours incubation (T$_3$)	198	18	180	2.3c
Soaking overnight and 48 hours incubation (T$_4$)	319	17	303	2.9bc
Soaking overnight and 72 hours incubation (T$_5$)	263	38	224	3.8a
Level of significance	NS	NS	NS	*
CV(%)	24.91	53.56	22.74	9.98

* Significance at 5% level; NS non significant.

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Energy utilization in unpuddled transplanting of wet season rice

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Introduction

Energy is the key input in modern agriculture. Productivity of agriculture depends on adequate inputs such as power, improved seeds, fertilizers and irrigation water. One way to optimize energy consumption in agriculture is to use efficient crop production methods (Kitani, 1999). Crop yield is directly linked with energy input (Srivastava, 1982). In a conventional cropping system, the greatest energy consumer is soil tillage. In comparison to conventional cultivation fuel consumption can be reduced by 3 to 4 fold with the no-till system (Moitzi, 2005). Sayre (2000) summarized the potential advantages of reduced tillage planting systems as reduced fossil fuel use; reduced production cost; increased profit; reduced crop turn-around time; increased land-use efficiency; reduced drudgery in planting, especially suitable for female household members; more efficient crop water use (for both rainfed and irrigated conditions); improved soil physical, chemical and biological activities; enhanced carbon sequestration; and enhanced flora and fauna biodiversity. A change in soil tillage method also causes a slow, but substantial modification to the soil physico-chemical characteristics (bulk density, porosity, infiltration, moisture content and temperature), which becomes apparent in the medium to long term. Rice establishment under unpuddle transplanting system is the new phenomenon which was first time evaluated under the project *"Addressing constraints to pulses in cereals-based cropping systems, with particular reference to poverty alleviation in north-western Bangladesh"* during the dry cool boro rice season in 2009 in 8 farmers filed of Rajshahi district. These trials had provided some exciting results on irrigation water saving and reduction of tillage and cost without grain yield penalty. Therefore, the present study was undertaken to compare the operating energy involved in wet season transplanted rice culture under conventional puddling and a range of non-puddled ("unpuddled") systems.

Materials and Methods

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) Regional Station, Rajshahi, in the wet season of 2009. The 2-wheel tractor (2-WT) operated Versatile Multi-Crop Planter –VMP (Islam, 2010) was used for land preparation of all tillage types except the puddled treatments, which involved 2 dry tillage passes followed by additional 2 wet tillage passes using the 2-WT rotary tiller. Tillage treatments were conventional tillage and puddling (CT); puddling and then beds formed manually (BP_1); 58 cm dry bed formed by the VMP in a single pass (BP_2); and dry strip tillage by the VMP in a single pass (ST). Rice seedlings were transplanted under puddle condition in CT and BP_1 and unpuddled condition for BP_2 and ST. A randomized complete block design with three replications was used for this experiment. Thirty five-day-old rice seedlings of BR 11 were transplanted in all treatments by hand. Both direct and indirect energy inputs were estimated (Table 1). The chemical and biological energy inputs were considered as indirect energy inputs, whereas physical energy inputs were allocated across both indirect and direct energy inputs (Singh et al., 1994). The amounts of labor, fuel, fertilizer and pesticides (herbicide, insecticide and fungicide) were recorded and used in the determination of the fertilizer and chemical energy inputs in the crop production process. These amounts were converted to energy input using energy conversion factors from Gopalan et al. 1978; Bala and Hussain,1992; Mandal et al., 2002; Singh, 2002; Canakci et al., 2005; Yilmaz et al., 2005; Erdal et al., 2007; Esengun et al., 2007. Grain and straw yields were converted to energy output using a conversion factor of 14.57 MJ kg^{-1} for grain and 12.5 MJ kg^{-1} for straw (Bala and Hussain, 1992; Ozkan et al., 2004). The energy use was calculated for all operations in the crop production process, namely, (i) seedling raising; (ii) land preparation; (iii) transplanting; (iv) weeding; (v) fertilizer and pesticide application; and (vi) harvesting and threshing.

Results and Discussion

Direct energy consumption accounted for only a small proportion of the total energy consumption, ranging from around 9 % in CT, BP_1 and BP_2 to 4 % in ST (Table 1). Direct energy use was highest in CT and BP_1 (2.35 and 2.41 GJ ha^{-1}) and least in ST (0.78 GJ ha^{-1}). Fuel was the main direct energy input. Human input was low, even with manual bed formation. Indirect energy accounted for 91.2 % of total energy use in CT, 90.8 % in BP_1, 91.3 % in BP_2 and 95.9 % in ST. The largest source of indirect energy consumption was from fertilizer (37 to 52 % of the total energy consumption). The other major forms of energy consumption were in irrigation, machinery (in conventionally tilled systems), and plant protection.

Reduced tillage decreased energy consumption as fuel use by machine. Avoidance of puddling almost halved irrigation energy use in rice production. The operational energy input was highest for the treatments of CT and BP_1 (26 -27 GJ ha^{-1}) and least for BP_2 and ST (19-20 GJ ha^{-1}). Energy savings in BP_2 and ST were 19 and 24 %, respectively, compared to CT, mainly due to low fuel consumption in tillage operation, lesser machinery use and reduced irrigation. Grain yields were statistically similar i.e. 4.43, 4.56, 4.55 and 4.30 t ha^{-1} which was equivalent to energy outputs of 64.52, 66.50, 66.23 and 62.73 GJ ha^{-1} for CT, BP_1, BP_2 and ST, respectively. Table 2 showed that the energy output/input ratio was least in CT and BP_1 (4.6- 4.8) and 40 % higher in BP_2 and ST (6.0-6.5). The results showed that the reduced number of tillage operations resulted in about a 25 % energy saving and a 40 % increase in energy use efficiency, and that the energy consumption for mechanization accounts for less than one fifth of the total balance.

Table 1: Energy consumption (GJ ha^{-1}) based on energy sources under different tillage options

	Conventional tillage and puddling (CT)	Puddling and then beds formed manually (BP$_1$)	58 cm dry bed formed by the VMP in a single pass (BP$_2$)	Dry strip tillage by the VMP in a single pass (ST)
Direct energy				
Fuel	2.20 (8.2)	2.24 (8.5)	1.51 (7.5)	0.54 (2.8)
Human	0.16 (0.6)	0.17 (0.6)	0.25 (1.2)	0.25 (1.3)
Subtotal	**2.35 (8.8)**	**2.41 (9.2)**	**1.76 (8.7)**	**0.78 (4.1)**
Indirect energy				
Seed	0.44 (1.6)	0.44 (1.7)	0.44 (2.2)	0.58 (3.0)
Machinery	4.39 (16.4)	3.89 (14.8)	1.01 (5.0)	0.60 (3.1)
Fertilizing	9.93 (37.1)	9.93 (37.8)	9.93 (49.0)	9.93 (52.0)
Plant protection	3.93 (14.7)	3.93 (14.9)	3.93 (19.4)	3.93 (20.6)
Irrigation	5.71 (21.3)	5.71 (21.7)	3.21 (15.8)	3.28 (17.2)
Subtotal	**24.40 (91.2)**	**23.88 (90.8)**	**18.51 (91.3)**	**18.31 (95.9)**
Total	**26.75a (100)**	**26.30a (100)**	**20.27b (100)**	**19.10c (100)**

Figures in the parenthesis indicate the percentage. In a row, means followed by a common letter(s) are not significantly different at 5 % level by LSD test. LSD$_{0.05}$ = 0.73, CV (%) = 1.57

Table 2: Energy input-output relationship under different tillage options

Parameter	Conventional tillage and puddling (CT) GJ ha^{-1}	Puddling and then beds formed manually (BP$_1$) GJ ha^{-1}	58 cm dry bed formed by the VMP in a single pass (BP$_2$) GJ ha^{-1}	Dry strip tillage by the VMP in a single pass (ST) GJ ha^{-1}	CV, %	LSD$_{0.05}$
Output (grain + straw)	123.08	125.92	121.80	122.79	8.88	NS
Energy output/input ratio	4.6b	4.8b	6.0a	6.5 a	8.70	0.95

In a row, means followed by a common letter(s) are not significantly different at 5 % level by LSD test.

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A new approach to manage prostrate cover crops on permanent beds

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Keywords: Stubble, Vertisol, Crop rotation, Herbicide, Toolbar

Introduction

Cover crops are frequently sown in rotation with high value crops in many annual cropping systems. In minimum or no-tilled systems, the cover crop is usually killed by applying one or more herbicides, significantly increasing the cost of cover cropping (Snapp et al., 2005). Consequently, several researchers have experimented with combinations of herbicides (at lower rates) with selected mechanical interventions which do not disturb or bury the cover crop. (Creamer and Dabney, 2002).

The objective of this study was to develop a management system which reduced trafficking and the amounts of expensive and toxic herbicides used to kill a cover crop in furrow-irrigated permanent beds while retaining the killed crop residues as *in situ* mulch into which the next crop could be sown (Figure 1). The cropping system tested was one in which vetch (*Vicia villosa* L. Roth, *Vicia benghalensis* L.), a prostrate leguminous cover crop, was followed by cotton (*Gossypium hirsutum* L.). Vetch is currently managed with a slasher mower at 50% flowering, followed by either incorporation or applicationof a knockdown herbicide such as Sprayseed® (11.5% Paraquat + 9.8% Diquat). This report summarises the development of an implement to manage vetch cover crops in rotation with cotton in northern New South Wales, Australia (Hulugalle et al. 2009).

Figure 1. Killed vetch residues retained as *in situ* mulch in a bed-furrow system

Figure 2. Final design ("Stage 3") of mulching implement

Materials and Methods

The site, design and management details for the field experiment for which the new implement and technique were developed are reported in Hulugalle et al. (2009). The initial strategy for cover crop management (Stage one) involved mowing followed by several passes of an 8-row boom sprayer and occasional follow-up sprays with Round-up. We developed an implement in two stages to improve upon this approach.

Implement design

The implement was designed to kill and retain vetch residues as an *in situ* mulch and reduce the use of the expensive, toxic herbicide Sprayseed®. The initial design (Stage 2) consisted of a toolbar to which paired sets of parallel coulter discs were attached. The pairs of discs were located such that they ran on either side of the vetch plant line to a depth of ~2-4 cm, thus cutting of any lateral stems . It was assumed that the discs would follow the bed contours, thus ensuring a uniform cutting depth. A set of nozzles that applied herbicide (Sprayseed®) to the vetch plant line on the bed surfaces was located between individual disc pairs . The nozzles were attached to a tank that contained the herbicide. The discs also minimised herbicide drift. While this design was successful in reducing Sprayseed® application amounts and killing the vetch, it also resulted in annual winter weeds such as milk thistle (*Sonchus oleraceus* L.) proliferating in the furrows, and additional applications of Roundup® were required.

In Stage 3, the implement was subsequently modified to include a second tank and a second set of nozzles that directed Roundup® to the furrows to control winter weeds. In addition, the rigid coulters discs were replaced with a toolbar with spring-loaded coulter discs as cutting depth by coulters were found to be variable. This final design (Stage 3) consisted of a toolbar to which sets of spring-loaded parallel coulter discs were attached, one set of nozzles that applied Sprayseed® to the bed surfaces and was located between individual discs, and a second set located on the toolbar directed Roundup® to the furrow (Figure. 2). The two groups of nozzles were attached to two tanks which contained the different herbicides. Limiting Sprayseed® application to a narrow band between two coulter discs ensures that herbicide drift is greatly reduced, thus minimising non-target crop damage, and reducing exposure of farm workers to Sprayseed®.

Assessing the implement evolution – experimental data

Detailed records were maintained of labour requirements associated with both setting up and in-field operation of the new implement in its two stages. Detailed records were also kept of fuel use, herbicide application rates and costs. Fuel use and greenhouse gas emissions (as carbon dioxide equivalents, CO_2-e) associated with vetch control, herbicide and fuel production and transport were estimated from available sources (West and Marland, 2002; Chen and Baillie, 2007; Audsley et al., 2009; F. Scott, personal comm., 2009). The data was used to assess labour requirements, and greenhouse gas emissions associated with herbicide and fuel production for three developmental stages of the vetch management system. In summary these were:

- Stage 1 – Mowing followed by applying Sprayseed® with 2 passes of an 8-row boom sprayer ("No implement"). Occasionally, an additional application of Roundup® with a single pass of a boom sprayer was required.
- Stage 2 - Mowing followed by applying Sprayseed® with an intermediate stage of the implement and Roundup® with a single pass of an 8-row boom sprayer ("Later stage");
- Stage 3 - Mowing followed by applying Sprayseed® and Roundup® with the final version of the implement in a single pass (Figure 2) ("Final design")

Results and Discussion

In-field fuel (diesel) use and greenhouse gas emissions, and emissions associated with fuel production and transport were in the order of Stage 2 > Stage 1 > Stage 3 (Table 1). In comparison with the Stage 1, herbicide production and transport resulted in Stages 2 and 3 emitting 21% less CO_2-e. This was because Stages 2 and 3 used less herbicides. A significant proportion of emissions (32-37%) in all three stages was accounted for by the mowing. It is likely that major improvements in terms of fuel and emission reduction may be achieved by seeking alternatives to the slasher. Flail mowers, undercutters, cutter bars and band mowers are possible alternatives (Creamer and Dabney, 2002). Stage 3 required 36% less labour than Stage 1, and 26% less labour than Stage 2. This is a significant cost saving as the hourly cost to an employer for a farm worker is $A 31.55/hour, then estimated labour costs would be of the order of $A 347 for Stage 1, $A 300 for Stage 2 and $A 221 for Stage 3. Other benefits would include reduced herbicide exposure and fatigue to workers due to reduced working hours and lower Sprayseed® application rates.

Table 1. Estimated emissions and labour requirements (including setting-up time). Emissions estimated for herbicide and fuel production includes those associated with transport

Options	Operation	Implement	Diesel used (L/ha)	In-field emissions	Herbicide production emissions	Fuel production emissions	Total	Labour (man h/ha)	Total costs ($A/ha)
					CO_2-e (kg/ha)				
Stage 1 (No implement)	Mowing	4-row Slasher	10.7	31.0		4.5	35.5	3.5	
	Applying Spray.Seed® (3 L/ha) x 2	8-row boom sprayer	4.4	12.8	20.0	1.9	34.7	5.0	
	Applying Roundup® (3 L/ha)	8-row boom sprayer	2.2	6.4	28.8	0.9	36.1	2.5	
Total			17.3	50.1	48.8	7.4	106.3	11.0	423
Stage 2 (Later stage)	Mowing	4-row Slasher	10.7	31.0		4.5	35.5	3.5	
	Applying Spray.Seed® (3 L/ha)	4-row coulter/ band sprayer	6.2	17.8	10.0	2.6	30.4	3.5	
	Roundup® (3 L/ha)	8-row boom sprayer	2.2	6.4	28.8	0.9	36.1	2.5	
Total			19.1	55.1	38.8	8.1	102.0	9.5	344
Stage 3 (Final design)	Mowing	4-row Slasher	10.7	31.0		4.5	35.5	3.5	
	Applying Spray.Seed® (3 L/ha) + Roundup® (3 L/ha)	4-row coulter / band sprayer	6.2	17.8	38.8	2.6	59.2	3.5	
Total			16.9	48.8	38.8	7.2	94.7	7.0	265

Conclusions

An integrated mechanical and chemical management system was developed that could (1) kill bulky prostrate cover crops such as vetch with fewer machine passes, (2) reduce use of more toxic herbicides such as Sprayseed®, and (3) decrease labour, risk to operators and the carbon footprint.

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Overcoming problems associated with retaining crop stubble on permanent beds in furrow-irrigated cotton farming systems

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Keywords: Vertisol, Crop rotation, Minimum tillage, Soil management

Introduction

"Permanent" beds are raised beds which preserve the same wheel tracks and remain in place for several seasons before renovation or realignment requires them to be ploughed down and reconstructed. They have been used successfully in the Australian Cotton Industry since the 1980s (McGarry, 1995). The resultant benefits, particularly when integrated with suitable rotation crops, such as wheat (*Triticum aestivum* L.) include better soil physical and chemical quality, improved carbon management and water conservation, and lower fuel use and costs than full tillage each year (Hulugalle and Daniels, 2005; Hulugalle and Scott, 2008). Yields are not necessarily higher, but reduced costs give greater returns. Problems associated with managing permanent beds in cotton production systems include beds shifting over compacted furrows with time, managing rotation crop stubble to optimise water flow during irrigation, applying anhydrous ammonia through crop stubble and excessive tillage during compulsory post-harvest bed cultivation for heliothis (*Helicoverpa* spp.) pupae control. These problems can, however, be overcome by using appropriate machinery (Hulugalle et al., 2006) and agronomic management practices (Hulugalle and Daniells, 2005). This paper summarises solutions developed to overcome problems associated with *in situ* stubble retention in irrigated cotton farming systems.

Overcoming disadvantages of retaining crop stubble as *in situ* mulc*h*

In the past, managing rotation and cotton crop stubble in permanent bed systems usually involved either slashing and incorporating stubble into the beds with shallow cultivation equipment such as disc-hillers or burning (Schoenfisch, 1999). Retaining rotation crop stubble *in situ* and sowing cotton into it (Figures 1 and 2) can, however, result in benefits over those noted previously, *viz.*

- lower erosion, runoff, off-field movement of pesticide residues and nutrients (Waters and Sequira, 2000; Waters et al., 2000; Hulugalle and Daniels. 2005)
- less extreme fluctuations in early season soil temperatures in beds (Hulugalle, unpublished data);
- higher water infiltration, rainfall harvesting during fallow, soil organic C and exchangeable K in beds (Hulugalle and Daniells, 2005; Hulugalle et al., 2005);
- lower rate of heliothis moth infestation in young cotton (Waters and Sequira, 2000);
- lower fuel use and greenhouse gas emissions (Hulugalle, 2010).

Disadvantages include blocking of "gas knives" by crop stubble during application of anhydrous ammonia as fertiliser, increased waterlogging during irrigation and inability to incorporate residual herbicides (Hulugalle and Daniells, 2005). Anecdotal evidence also suggests that where cotton is sown into wheat sprayed out with herbicides ("green wheat") stubble, transient N immobilisation may occur.

Blocking of "gas knives" by crop stubble during anhydrous ammonia application into the beds can be avoided by attaching coulter discs to the front bar of the gas rig, in front of the gas tines, to cut through the stubble (Weaver et al., 2000; Figure 3). A press wheel, which follows the tine, seals the soil and leaves a rolled surface ready for planting. The gas tines and press wheels are fastened onto the back bar of the gas rig. During the pass of the rig, the only residue disturbed is that on the top of the bed. After anhydrous ammonia has been injected, a residue-free strip approximately 10-cm wide, remains on the top of the beds. As an alternative to anhydrous ammonia, granular fertilisers such as urea can be either broadcast or applied in irrigation water.

Waterlogging during irrigation events is avoided by retaining the stubble in the furrows only until the start of the irrigation season (Hulugalle et al., 2004). At this point, except for a 2 m long buffer strip in the furrows at the tail drain end of the field, the point of a sweep (V-shaped tillage implement which performs shallow tillage over broad widths) is run through the furrow to a depth of 10-cm to clean out the stubble from the furrow bottom (Figure 4). This facilitates water flow through the field. The retained 2-m strip slows water flow just enough to sediment out dispersed clay (Figure 5). Excess salts and nutrients adsorbed onto clay particles are deposited in the furrow and do not move off field with runoff.

Residual herbicides and their incorporation can be avoided in stubble-retained systems by using Roundup-Ready® crops in combination with judicious applications of the herbicide, Roundup®. Where Roundup-Ready® crops are unavailable, herbicides can be applied using shielded sprayers.

Figure 1.Vetch stubble retained as *in situ* mulch in a bed-furrow system

Figure 2. Cotton and sorghum growing in wheat and vetch stubble in a bed-furrow system

Figure 3. Modified gas (anhydrous ammonia) rig with coulter discs in front of gas knives
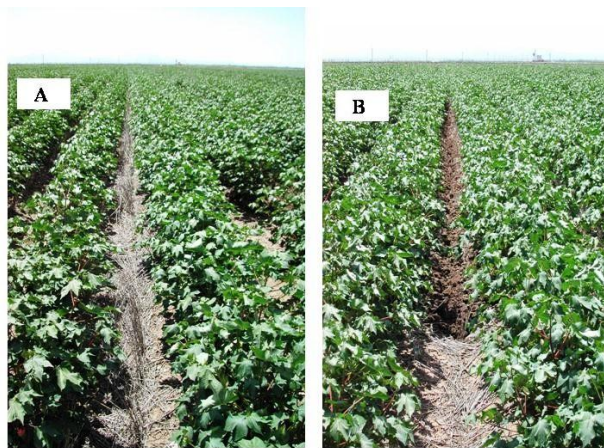
Figure 4. Clearing standing wheat stubble from furrows with sweeps. (A) Uncleared furrow with wheat stubble; (B) Cleared furrow with 2-m stubble buffer
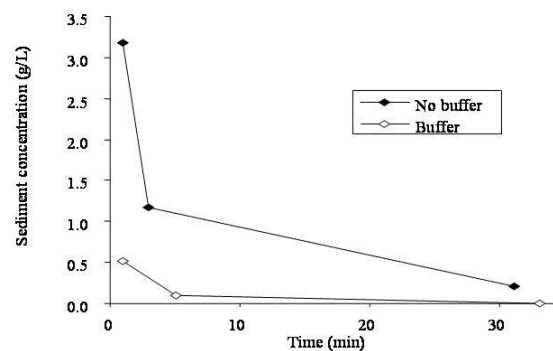
Figure 5. Effect of 2-m vetch buffer on sediment concentration in runoff from 1st irrigation in October 2003 at Australian Cotton Research Institute, near Narrabri, NSW, Australia.

Conclusions

Efficacy of permanent beds can be improved by retaining rotation crop stubble undisturbed *in situ*. Disadvantages include blocking of "gas knives" by crop stubble during application of anhydrous ammonia as fertiliser, increased waterlogging during irrigation and inability to incorporate residual herbicides. These problems can, however, be overcome by using appropriate machinery and agronomic management practices

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Do livestock reduce crop yields in conservation farming systems?

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Keywords: mixed farming, grazing, stubble retention, controlled traffic

Introduction

A livestock enterprise, particularly sheep, in conjunction with a wheat-based cropping enterprise has long formed the basis of mixed farming systems throughout south eastern Australia. This enterprise mix is fundamentally symbiotic, with sheep able to consume and give value to otherwise wasted by-products from the cropping enterprise (e.g. crop residues, weather damaged and spilt grain, early vegetative crop growth) whilst the legume-based pasture phases used for sheep production allow fields to be spelled from crop production, increasing soil nitrogen fertility and reducing levels of crop weeds and diseases. The presence of both livestock and crops also diversifies farm business, offsetting production and price risk and increasing resilience (Kirkegaard et al. 2010). In recent times much credence has been given to the potential for conservation farming practices such as no-till seeding with complete stubble retention and controlled traffic to increase crop productivity in the face of rising global food demand and declining resources. Some proponents argue that the full potential of conservation farming systems may not be realised if sheep are grazed on cropping country, removing residue cover and trampling soils, but there is little contemporary research evidence to support this view (Bell et al. 2011). We report the first two years of a study specifically designed to test this assertion.

Materials and Methods

This experiment is located on a red chromosol soil 5 km SSE of the township of Temora in SE NSW (S 34° 29.430', E 147° 30.395', 298 m ASL, 523 mm average annual rainfall with equi-seasonal distribution) and consists of six treatments in a split-block randomised design with four replicates;

1. Nil graze, stubble retention
2. Nil graze, stubble burn
3. Stubble graze, stubble retention
4. Stubble graze, stubble burn
5. Winter graze, stubble graze, stubble retention
6. Winter graze, stubble graze, stubble burn

A four year old lucerne pasture in a farmer's field was sprayed out in late spring 2008 and large plots (7 x 16 m) established which allowed all operations to be conducted using controlled traffic. All plots were fenced so they could be individually grazed by sheep. Wheat cv. EGA Gregory was planted on 30 April 2009 and the winter graze treatments (5, 6) were applied to this crop using three weaner ewes per plot to graze the wheat crop whilst it was in the vegetative stage on 18-19 June and again on 7-9 July 2009 (~517 DSE/ha days). Following harvest of the wheat crop in November 2009 the stubble graze treatments (3,4,5,6) were applied by grazing four weaner ewes in the nil winter graze treatments (3,4) and three in the winter graze treatments (5,6) from 30 November-7 December 2009 (~2414 and ~1810 DSE/ha days respectively). This left an average 0.8 t/ha of stubble in the stubble grazed plots compared to an average of 5.4 t/ha of stubble in the un-grazed plots. Soil water was monitored during the summer fallow period using time-domain reflectometry (TDR) soil water probes (Campbell Scientific CS615) at the soil surface (7.5 and 15 cm depth) and a neutron moisture meter (NMM) for the subsoil (10 to 180 cm depth). Summer weeds that emerged at the site were controlled with herbicide and a total of 313 mm rain fell during the summer fallow period, including five significant individual events (Figure 2). At the end of the summer fallow period, all residues were removed from a 1 m² area in each plot and infiltration rates measured using a drip infiltrometer (McCallum et al. 2004). The stubble burn treatments were applied on 17 and 18 March 2010 and thus had no bearing on soil water accumulation during the summer fallow period. The whole site sown to canola cv. Tawriffic TT on 15 April 2010 and the winter graze treatment was re-applied using six weaner ewes per plot from 30 June to 1 July 2010 (~517 DSE/ha days). In-crop rainfall was 460 mm and grain yield and soil water were measured at crop maturity.

Results and Discussion

The nil graze treatment accumulated more water during the summer fallow period following large and intense rain in mid-February and early March (Table 1). The extra water accumulated was stored deep in the profile (Figure 1) indicating that the difference in accumulation was due to improved infiltration in the presence of stubble rather than reduced evaporation. This hypothesis is supported by measurements of soil water at the surface which showed no difference between the nil graze or winter and stubble grazed treatments (Figure 2). Grazing significantly reduced infiltration rates measured at the end of the summer fallow period. We hypothesise that this was due to the removal of stubble by grazing and subsequent rain drop impact damage rather than soil physical effects due to grazing, as infiltration rates in the surrounding un-grazed farmer's field (low stubble cover ~1.6 t/ha of a drought-affected canola crop) were as low as those in the grazed treatments (Table 2). The amount of stubble remaining in the grazed treatment (0.8 t/ha) was below the 2.0 t/ha or 70% cover level commonly recommended for the prevention of run-off and soil erosion on clay soils (Felton et al. 1987). Despite the differences in plant-available water prior to sowing in 2010, in-crop rain was sufficient to sustain crop growth and there were no significant differences in crop yield between the grazing treatments (Table 3) or stubble burn treatments (data not shown). Differences in plant-available water persisted at maturity (Table 3) and may subsequently affect grain yield in 2011. Our data support the conclusions of a recent review (Bell et al. 2011) reporting that soil physical effects from grazing sheep trampling tend to be shallow and transient and reductions in subsequent crop yield are rare. However, loss of cover associated with overgrazing is clearly a risk. These findings give confidence that provided a critical level of soil cover is maintained (>70% or 2.0 t/ha of cereal stubble), livestock can be retained within modern conservation cropping systems without compromising crop performance, and may continue to provide production and business risk benefits in the future.

Table 1. Mean plant available water from 10 to 180 cm depth as measured by the neutron moisture meter in the different stubble treatments during the summer fallow period of 2009/2010.

Treatment	Plant available water (mm)			
	16 Dec 2009	13 Jan 2010	23 Feb 2010	16 Mar 2010
Nil graze	13	14	105[a]	155[a]
Stubble graze	14	14	77[b]	110[b]
Stubble and winter graze	15	16	66[b]	99[b]
LSD (p=0.05)	NS	NS	13	19
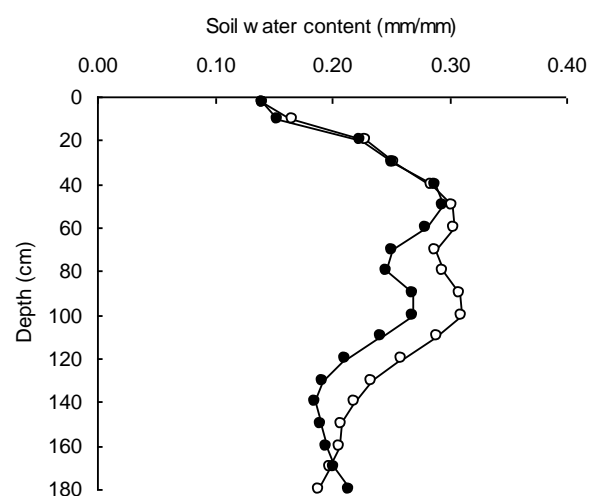
Figure 1. Volumetric soil water content down the soil profile of the nil graze (○) and combined grazed treatments (●) on 16 March 2010.
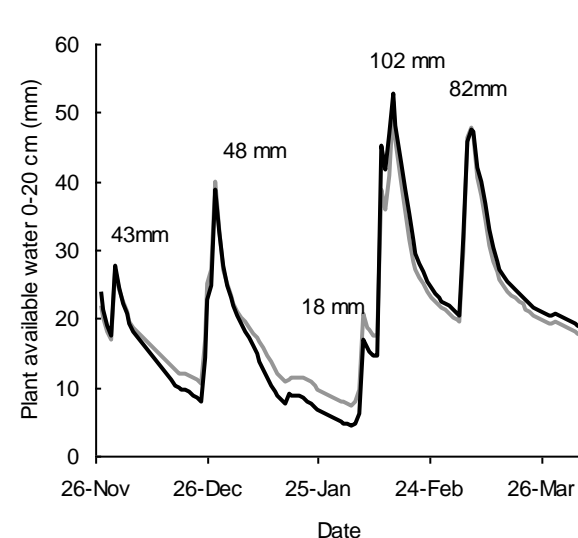
Figure 2. Plant available water from 0 to 20 cm depth as measured by FDR probes in the nil graze (━) and stubble and winter graze treatments (━). The numbers next to curve peaks are amounts of rainfall in corresponding events.

Table 2. Drip infiltrometer measurements under different grazing treatments and in the surrounding un-grazed canola stubble on 11 March 2010.

Treatment	Amount of water to ponding (mm)	Steady-state infiltration rate (mm/h)
Nil graze (5.4 t/ha wheat stubble)	19[a]	36[a]
Stubble graze (0.8 t/ha wheat stubble)	8[ab]	20[b]
Stubble and winter graze (0.8 t/ha wheat stubble)	6[ab]	16[b]
Un-grazed canola stubble (~1.6 t/ha)	5[b]	11[b]
LSD (P=0.05)	14	11

Table 3. Mean grain yield of the canola crop sown over grazing treatments in 2010, and mean plant available water at canola maturity on 12 November 2010. Stubble retain and burn treatments have been bulked according to grazing treatment.

Treatment	Canola grain yield (t/ha)	Plant available water at canola maturity (mm)
Nil graze	4.1	116[a]
Stubble graze	4.2	86[b]
Stubble and winter graze	4.0	78[b]
LSD (p=0.05)	NS	25

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Double no-till in a rice-wheat rotation under eastern Gangetic plains of South Asia: medium-term effects on productivity and profitability

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Introduction

Rice-wheat cropping systems occupy 13.5 million hectares in the Indo-Gangetic Plains (IGP) of South Asia (Gupta and Seth, 2007) and supports food and livelihood security for millions. In India alone, rice-wheat rotation (10.5 m ha) contributes about 40% of the country's total food grains. Multiple challenges associated with plow based conventional production practices in rice-wheat rotation including declining factor productivity, shrinking farm profits due to increasing energy and labour costs, an emerging irrigation water crisis and recent challenges of climate change are leading to a major threat to food security of South Asia.

Traditional practice of manual transplanting of rice seedlings in random geometry after intensive dry and wet tillage and conventionally tilled broadcast seeding of wheat contributes significantly to these challenges, making this system unsustainable. The contrasting adaphic requirements of rice and wheat under conventional practices leads to sub-soil compaction and destroys soil structure in surface soil, resulting in restricted root penetration and poor soil nutrient-moisture-crop root interactions of succeeding upland crop (wheat) leading to low productivity (Jat et al., 2009). In eastern Gangetic Plains (EGP), late harvest of rice and 7-10 days additional window for planting after conventional tillage leads to delayed planting of wheat. Therefore, the wheat growth window is relatively shorter in EGP than North-Western Indo-Gangetic plains due to late planting and terminal heat effects at maturity. Therefore, this study was planned as a long-term trial to address the challenges in rice-wheat rotation of EGP as discussed above. This paper highlights the medium term effects of different Conservation Agriculture based practices including double no-till as a strategy to address the challenges.

Methods

A long-term trial was established during monsoon 2006 at the research farm of Rajendra Agricultural University, Samastipur, Bihar, India (25.58510 N, 85.40313 E). The soil of the experimental site is clay loam with medium organic matter content (0.68 %). The site has hot and humid summers and to cold winters with average rainfall of 1344 mm, 70 % (941mm) of which received during July-Sept. Frequent droughts and floods are common in the region.

Eight combinations of tillage and crop establishment methods for a rice-wheat cropping systems were established in large plots (1400 m^2 each). The treatment combinations were; Puddled transplanted rice (PuPTR)- Conventional till wheat (CTW), PuTTR-Zero till wheat (ZTW), Direct seeded rice on permanent beds (PBDSR)-Direct drilling of wheat on permanent beds (PBDDW), Zero-till direct seeded rice (ZTDSR)-CTW, ZTDSR-ZTW without residue (ZTW-R), ZTDSR-ZTW with residue retention (ZTW+R), Unpuddled transplanted rice (UPTR)– ZTW, and Wet DSR (WDSR)- ZTW.

For PuTPR, 23 days old seedlings were transplanted after 3 passes of dry tillage followed by 2 passes of wet tillage and planking. In CTW, 3 passes of dry tillage (harrow and cultivator), broadcasting of 150 kg seed/ha followed by 1 pass of tillage and planking was practiced. For ZTDSR, 25 kg seed ha^{-1} was drilled using a multi-crop Zero till seed-cum-fertilizer planter without any tillage. Same was used for direct drilling of wheat (ZTW) using 100 kg seed ha^{-1}. On permanent beds (67cm centre of furrow to furrow) both rice and wheat were planted using a raised bed planter keeping two rows on each bed and seed rate for rice and wheat were used @ 20 and 75 kg ha^{-1}, respectively. In UPTR, the 23 days rice seedlings were transplanted after dry tillage but eliminating wet tillage (puddling). The WDSR was established using broadcasting of sprouted seeds of rice after both dry and wet tillage (puddling). All the treatments received similar fertilizer nutrients @ N-150 kg, P$_2$O$_5$ 60 kg and K$_2$O 60 kg both for rice and wheat. The yields were recorded using the standard protocols. The profitability (net returns) was calculated as the values of the inputs and outputs over the years in Indian rupees and were expressed as the value in US$ over the years.

Results and Discussion

The data on productivity of rice, wheat and rice-wheat system, cost of production and net returns as presented in Table 1 is the average of 04 years. Results revealed that the highest average productivity of rice was realized with PuTPR followed by ZTDSR and WDSR. However, the average productivity under ZTDSR was significantly higher over UPTR and PBDSR. But, the net returns under ZTDSR and PBDSR were significantly higher over rest of the tillage and crop establishment options mainly due to difference in cost of production (US$ 200-250 ha^{-1}). The wheat productivity was significantly higher under ZTW+R (double no-till) over rest of the treatments. Further, the wheat productivity was substantially reduced when it followed PuTPR, rather than other tillage and establishment practices. It was attributed mainly to sub soil compaction due to intensive wet tillage (puddling) that restricts root penetration of the post rice crop (Aggarwal et al, 1995). Under double no-till and permanent beds, the improved soil porosity and infiltration rate provides more favourable conditions for the upland crops, leading to higher productivity (Jat et al, 2009). Further, the yield advantage of residue retention under double no till system was noticed only in wheat and not in rice.

The total cost of production of the system (rice and wheat) was much lower under permanent beds (PBDSR-PBW) and double no-till on flat soil (ZTDSR-ZTW- +/-R) by US$ 323 and 252, respectively, compared with conventional practice (PuTPR-CTW), and system profitability was significantly (US$ 398 and 281 ha^{-1}) improved over conventional practice (Table 1).

Yield trends over 4 years among the double no-till and conventional till practice as presented in figure 1 revealed that double no-till had stable and higher rice crop yield compared to conventional transplanting. Further, the continuous no-till practices led to steadily increased grain yield both rice and wheat over the years. Therefore, double no-till is most promising option for improving productivity and profitability while sustaining the natural resources and addressing the emerging challenges in rice-wheat systems of eastern Gangetic plains.
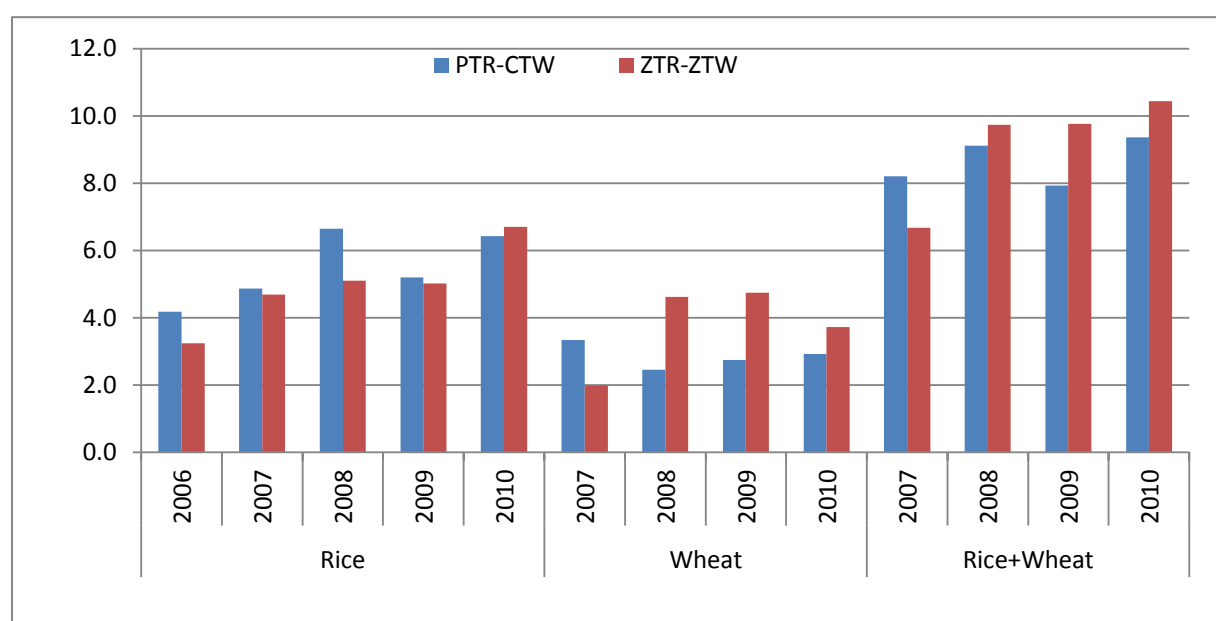
Figure 1. Productivity(t/ha) trends of rice and wheat under double no-till and conventional till practices in the rice-wheat rotation

Table 1. Productivity and economics of long-term conservation agricultural practices in rice-wheat system (Average of 04 years).

Tillage and crop establishment methods	Rice			Wheat			Rice-wheat System		
	Grain yield (t/ha)	Total cost of prodn (US$/ha)	Net Return (US$/ ha)	Grain yield (t/ha)	Total cost of prodn (US$/ ha)	Net Return (US $/ha)	Grain yield (t/ha)	Total cost of prodn (US$/ ha)	Net Return (US$/ha)
PuTPR-CTW	5.80a	680	522c	2.85e	432	327e	8.65b	1112	849e
PuTPR-ZTW	5.78a	679	514c	2.93e	343	447d	8.70b	1022	961d
PBDSR-PBDDW	5.18c	449	639a	3.13d	340	491d	8.30c	789	1130b
ZTDSR-CTW	5.23c	479	631a	3.68b	448	543c	8.90b	926	1174b
ZTDSR-ZTW-R	5.38b	486	631a	3.75b	381	630a	9.13a	867	1261a
ZTDSR-ZTW+R	5.03c	473	591b	3.93a	387	656a	8.95b	860	1247a
UPTR-ZTW	4.70d	581	424e	3.60b	374	595b	8.30c	955	1018c
WDSR-ZTW	5.35b	632	481d	3.53c	369	577b	8.88b	1002	1058c
Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by the Duncan's multiple range test (DMRT)									

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Increasing crop yields through conservation tillage in dryland areas of China

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Keywords: conservation tillage, North China, yield

Introduction

Conservation tillage (CT) has been globally recognized as an advanced agricultural technology that may reduce the effect of drought and improve the physical condition of soils. In China, CT research started with support from the Ministry of Agriculture (MOA), China and the Australian Centre for International Agricultural Research in 1992 (He et al. 2010). This work has demonstrated significant improvements in productivity over this period, especially in the arid and semi-arid region of China. This paper reports the impacts of CT on crop yields in dryland areas of China including the loess plateau of China, North China plain, Northeast China, Northwest China and the farming–pastoral ecotone of Inner Mongolia.

Materials and Methods

The long-term experiments were conducted at Linfen (1993-2006) on the Loess Plateau one crop/year region, Beijing (2000-2007) and Hebei (1998-2009) of North China Plain (NCP) two crops/year regions, Liaoning and Heilongjiang (2005-2007) of Northeast China one crop/year regions, Gansu (2005-2007) of Northwest China one crop/year region, and Farming pastoral ecotone at Inner Mongolia (1998-2008). In all these experimental sites, two tillage treatments were evaluated: CT and Traditional tillage (TT). Residue was removed from TT before mouldboard ploughing to a depth of 10-18cm, followed by harrowing, hoeing, rolling and levelling.

Results and Discussion

Long-term CT has shown the positive results in terms of providing higher crop yields as compared to TT in the five different areas (Table 1) of the dryland cropping regions of China. The NCP and the Northeast of China has the greatest yield under either treatment, but the largest improvement due to CT occurred in the Loess Plateau region.

At Linfen (1994-2006) on the Loess Plateau, Li et al. (2007) showed that mean yield for CT management (3.6 t/ha) was 19.2% higher than TT treatment, and yield differences between treatments were significant in 6 out of 12 years (P<0.05). It is interesting to note that the mean yield advantage of CT was relatively small (8.4%) in the first 3 years of the experiment, but this increased to a mean value of 22.3% in the subsequent 9 years, and yield improvements were greater in drier years. At Beijing (2000-2007) of NCP, Zhang et al. (2009) showed that tillage treatments had little effect on winter wheat yields during the first 3 years or on summer maize yields during the first 2 years, but yields of both crops were significantly ($P < 0.05$) higher under CT in subsequent years. As indicated in Table 1, average winter wheat yields in 2004–07 under CT was 423 kg/ha (7.46%) higher than TT; In summer maize, CT was 138 kg/ha (3.24%) higher. In Hebei, winter wheat and summer maize yields in CT and TT treatments fluctuated widely from year to year. Mean 11 years' winter wheat yield for CT was 3.5% greater than that for TT, and yield differences between treatments were significant in 4 out of 11 years (P<0.05). Again, the mean yield advantage of CT was minimal in the first 5 years of the experiment, but improved to 6.2% in the subsequent 6 years, and similar effects in maize. Mean (1999-2009) yield for CT plots was 1.4% higher than that for TT plots, and the yield differences were significant (P<0.05) in the years of 2004 and 2009. Again, these significant yield advantages produced by CT were only observed in the last 6 years of the experiment. At both Liaoning and Heilongjiang in Northeast China, He et al. (2010) found a mean yield improvement from CT of 88.3 kg/ha (Liaoning) and 225 kg/ha (Heilongjiang), compared with TT. At Gansu in Northwest China, He et al. (2008) found the mean wheat yields for CT and TT treatments were 6128 kg/ha and 5981 kg/ha, indicating a significant ($P < 0.05$) yield improvement of 0.8% for CT compared with TT treatment. In Inner Mongolia, He et al. (2009) indicated that the yields on CT treatments were greater than those on the TT plot, with significant differences ($P < 0.05$) in 6 of 10 years on average. The mean yield advantage of CT was relatively small (6%) in the first 4 years, but this increased to a mean value of 13% in the subsequent 6 years.

Statistically significant results have not been achieved in all years, or in all trials, but some clear patterns can be seen in the accumulated data and publications from this work. The most important is the substantial improvement in crop yield generally associated with conservation tillage. This yield benefit is much greater in dry years, but often not seen for some years after adoption. Conservation tillage also makes a positive contribution to soil structure and economics. It is clearly an appropriate technology for improving the yields and sustainability of dryland crop production in China.

Table 1. Crop yields (t/ha) under conservation tillage (CT) and traditional tillage (TT) in Linfen of Loess Plateau (1993-2006), Li et al. (2007); in Beijing (2000-2007) and Hebei (1998-2009) of North China Plain, Zhang et al. (2009); in Liaoning and Heilongjiang (2005-2007) of Northeast China, He et al. (2010); in Gansu (2005-2007) of Northwest China, He et al. 2008; and in Farming pastoral ecotone of Inner Mongolia (1998-2008), He et al. (2009).

Site	Crop			1994	1995	1996	1997	1998	1999	2000	2001
Loess Plateau	Linfen	Winter wheat	CT	3.2[a]	2.5[a]	3.9[a]	4.1[a]	3.1[a]	2.6[a]	2.6[a]	3.8[a]
			TT	3.0[a]	2.3[a]	3.5[a]	3.9[a]	2.5[b]	2.1[b]	1.7[b]	2.9[b]
North China Plain	Hebei	Winter wheat	CT	–	–	–	–	–	6.1[a]	6.3[a]	5.8[a]
			TT	–	–	–	–	–	6.2[a]	6.2[a]	5.6[a]
		Summer maize	CT	–	–	–	–	–	10.4[a]	9.9[a]	9.5[a]
			TT	–	–	–	–	–	10.2[a]	10.1[a]	9.4[a]
	Beijing	Winter wheat	CT	–	–	–	–	–	–	6.3[a]	5.8[a]
			TT	–	–	–	–	–	–	6.2[a]	5.6[a]
		Summer maize	CT	–	–	–	–	–	–	9.9[a]	9.5[a]
			TT	–	–	–	–	–	–	10.1[a]	9.4[a]
Northeast China	Liaoning	Spring maize	CT	–	–	–	–	–	–	–	–
			TT	–	–	–	–	–	–	–	–
	Heilong-jiang		CT	–	–	–	–	–	–	–	–
			TT	–	–	–	–	–	–	–	–
Northwest China	Gansu	Spring wheat	CT	–	–	–	–	–	–	–	–
			TT	–	–	–	–	–	–	–	–
Farming pastoral ecotone	Inner Mongolia	Spring wheat	CT	–	–	–	–	1.2[a]	1.3[a]	1.4[a]	1.3[a]
			TT	–	–	–	–	1.1[a]	1.1[b]	1.4[a]	1.2[a]

Site	Crop			2002	2003	2004	2005	2006	2007	2008	2009
Loess Plateau	Linfen	Winter wheat	CT	4.2[a]	4.0[a]	5.2[a]	3.8[a]	4.7[a]	–	–	–
			TT	3.0[b]	3.4[a]	4.6[a]	2.7[a]	4.4[a]	–	–	–
North China Plain	Hebei	Winter wheat	CT	6.4[a]	6.5[a]	5.6[a]	6.4[a]	6.1[a]	6.3[a]	6.5[a]	5.7[a]
			TT	6.6[a]	6.4[a]	5.3[b]	6.2[a]	5.8[b]	5.3[b]	6.4[a]	5.4[b]
		Summer maize	CT	10.0[a]	10.7[a]	9.2[a]	9.9[a]	9.5[a]	10.4[a]	10.3[a]	9.6[a]
			TT	10.1[a]	10.5[a]	8.8[b]	9.8[a]	9.2[a]	10.5[a]	10.1[a]	9.2[b]
	Beijing	Winter wheat	CT	6.4[a]	6.5[a]	5.6[a]	6.4[a]	6.1[a]	6.3[a]	–	–
			TT	6.6[a]	6.4[a]	5.3[b]	6.2[a]	5.8[b]	5.3[b]	–	–
		Summer maize	CT	10.0[a]	10.7[a]	9.2[a]	9.9[a]	9.5[a]	10.4[a]	–	–
			TT	10.1[a]	10.5[a]	8.8[b]	9.8[a]	9.2[a]	10.5[a]	–	–
Northeast China	Liaoning	Spring maize	CT	–	–	–	9.4	9.1	10.6	–	–
			TT	–	–	–	9.3	9.0	10.6	–	–
	Heilong-jiang		CT	–	–	–	9.5	9.5	10.9	–	–
			TT	–	–	–	9.6	9.4	10.3	–	–
Northwest China	Gansu	Spring wheat	CT	–	–	–	5.4[a]	6.1[ab]	6.4[a]	–	–
			TT	–	–	–	5.6[a]	6.0[a]	6.2[a]	–	–
Farming pastoral ecotone	Inner Mongolia	Spring wheat	CT	1.5[a]	1.3[a]	1.5[a]	1.5[a]	1.4[a]	1.4[a]	–	–
			TT	1.3[b]	1.1[b]	1.5[a]	1.3[b]	1.1[b]	1.1[b]	–	–

Values within a column in each experimental site followed by the same letters are not significantly different (P>0.05).

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Sowing performance of a spatially modified no-till drill in chopped and spread paddy straw

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Introduction

No-tillage with residue retention is a major step for enhancing sustainability of the rice-wheat cropping system, causing less damage to soil structure and requiring less energy, time and cost than the traditional cultivation method. In no-tillage systems, crops are planted either entirely without tillage or with just sufficient tillage for placement and seed coverage for germination. Zero till seed drill technology has shown saving in fuel up to 37-70 litres per hectares, advancing sowing dates for wheat by 2-4 weeks, saving up to 25-30% water, reducing major invasive weed incidence up to 40-50% in wheat and increasing yield by 5-15% over conventional systems (Yaduraju, 2006). The major problem in no-tillage sowing is the high amount of residues of previous crop, which hinder operation of no-till machine (Shukla et al., 1984). The standing stubbles of height up to 30-40 cm do not affect the sowing performance of seed drill, but rows of long loose straw left after combine harvesting cause frequent choking between furrow openers and the frame of the drill (Singh et al., 1995). Straw in the field often builds up in front of the tines of drill, and eventually blocks the tine and frame, causing long delays, uneven seeding rate and depth and a patchy stand of plants (Graham et al., 1986). When no-till drill and strip-till drills are operated in chopped and spread paddy straw conditions, there is only marginal increase in straw accumulation compared with a clean field (Bansal, 2002). Effective residue management requires both straw and chaff to be finely chopped and evenly spread over the entire width of the cut. This study was undertaken to check the sowing performance of a spatially modified no-till drill in paddy straw that had been chopped and spread.

Materials and Methods

Experiments to determine the sowing performance of the spatially modified no-till drill in combine harvested fields were conducted during 2010-11 at the PAU Ludhiana campus departmental farm. Paddy crop of PR-118 variety was harvested with combine harvester, then one operation of PAU's straw chopper-cum-spreader was carried out to reduce the straw length to 50- 100 mm. Sowing of the wheat crop, variety PBW-502, was done with spatially modified no-till drill. The average height of cut was 371 mm, average length of chopped paddy straw was 90 mm and average weight of loose straw in the field was 4469.9 kg/ha at a moisture content of 23.9 % wb. All wheat crop production practices, such as seed and fertilizer rates, followed the standard recommendations of Punjab Agricultural University, Ludhiana. The spatially modified no-till drill (Singh, 2004) has three rows of furrow openers as compared to two rows in the conventional no-till drills, allowing furrow openers to be staggered, and provide up to 800 mm lateral clearance between adjacent openers.

For the present study three furrow openers were fitted in each row, providing a lateral clearance of 600 mm between adjacent openers, and the vertical clearance between the frame and ground was increased from 300 mm to 600 mm, using longer shanks for the furrow openers. Other components of the machine –inverted T-type furrow opener, seed and fertilizer boxes etc – were same as those used in Pantnagar type no-till drill. Sowing performance parameters were assessed, including furrow geometry, seed placement, germination count, effective tiller count, and then plant height, ear length, number of grains per ear head, thousand grain mass and grain yield were sampled at harvest. The control treatment was a crop sown in the same combine harvested field, before the use of a stubble shaver and straw removal. Sowing was then done with conventional no-till drill. Experimental data was statistically analyzed to test the difference between treatments at the 5% level of significance, using software CPCS1 developed by Punjab Agricultural University, Ludhiana.

Results and Discussion

Increased spacing between furrow openers and increased ground clearance of main frame was effective in eliminating clogging with rice straw surface density of 8 ton/ha. The modified machine successfully planted wheat seed under rice straw mulch with thickness ranging from 70 to 92 mm, achieving all the advantages of zero-till-drilling through a thick layer of mulch. Furrow width varied between 34 and 37 mm for the modified no-till drill, compared with 35 and 40 mm for the control treatment. Furrow depth varied between 59 and 64 mm for modified drill, compared with 54 - 59mm for the control of treatment, but this was not necessarily the seed placement depth. Seed bandwidth varied from 30.0 to 42.0 mm, with a mean value of 35.3 mm and coefficient of variability of 11.19% for the modified no-till drill as compared with 30 to 39 mm range, mean 33.9 mm and CV of 7.03% for the control treatment (Table 1). The modified drill put 56.65% seed on the centreline, compared with 63.15% seed for the control treatment. This smaller percentage of seed on the central line of the modified no-till drill, (compared with control treatments) could be due to vibrations and distortion of the machine in this residue condition. The average plant count plants in 10 cm intervals of a 1 m longitudinal length was 4.14 for residue conditions, and 3.91 for control treatment. Seed to seed spacing interval and their probability mass function (PMF) for both the treatments is given in Table 2. Maximum PMF was 0.180 and 0.225 for residue conditions and for control treatments respectively, for seed spacing interval of 2.0 - 2.5 cm.

A germination count was done 10, 17, 24 and 31 days after sowing (DAS) the wheat crop. The germination count at 10 days after sowing varied from 15 to 19 for the modified no-till drill whereas it varied from 21 to 26 for the control treatment. Analysis of variance for germination count showed that after 10 days of sowing, the average germination count for modified no-till drill was 17.1 which is significantly lower compared to 23.2 for control treatment. But after 31 days of sowing there was no significant difference between the germination counts of these two treatments. This may be a function of the bruised paddy residue which formed a substantial matt over the soil surface. This mat covered the seed row and delayed initial germination of seedlings. Once irrigation was applied to the field, the thicknesss of the straw mat reduced significantly, allowing the germinated seedlings to emerge out of straw mat. Effective tiller count per meter length of row varied between 90 and 98 for the modified no-till drill operated in residue condition and between 90 to 96 for the control. Difference in effective tiller count was non-significant for both the treatments. Plant height varied between 894 to 941 mm for modified no-till drill and between 877 to 919 mm for control, but plant height was found to be non-significantly different at 5% level of significance. The ear length varied between 98 to 102 mm for modified no-till drill and between 97 to 101 mm for control. Difference in ear length was non-significant for both treatments. The number of grains per ear head varied from 41 to 45 for modified no-till drill and from 40 to 44 for the control. Differences in number of grains per ear head were non-significant for both treatments, but the average thousand grains mass was 44.1 gm for wheat crop sown with the modified no-till drill under residue condition and it was 43.5 gm for control treatment. The thousand grain mass was found to be non-significantly different at 5% level of significance. The crop was harvested at five random places, each having an area of one square meter each. Harvested crop was threshed manually to find grain yield. In case of

modified no-till drill average grain yield was 5204 kg/ha whereas for control treatment the average grain yield was 5110.5 kg/ha. Average grain yield was found to be non-significantly greater than control treatment yield, perhaps because of better moisture and temperature conditions in case of straw residue on the field. Nutrient availability from decomposed straw might also have been a factor in the improved wheat crop yield.

Table 1. Bandwidth (mm), number of plants per meter row length and percentage of seeds as plants on the central line for machines

Replication	Modified no-till drill under residue condition			Control		
	Bandwidth (mm)	No. of plants/m	% of seed on central line	Bandwidth (mm)	No. of plants/m	% of seed on central line
1.	36.0	52	64.9	33.0	41	64.6
2.	35.0	49	50.4	35.0	38	57.6
3.	32.0	41	51.9	31.0	36	61.8
4.	42.0	38	55.5	35.0	41	62.7
5.	31.0	40	57.4	39.0	34	62.8
6.	33.0	29	52.5	35.0	40	61.5
7.	39.0	46	56.5	30.0	43	63.2
8.	34.0	44	65.8	33.0	42	68.2
9.	41.0	37	49.4	33.0	41	64.8
10.	30.0	38	62.2	35.0	35	64.3
Avg.	35.3	41.4	56.65	33.9	39.1	63.15
Range	12	23	16.4	8	9	10.6
Standard Deviation	4.16	6.64	5.92	2.51	3.14	2.73

Table 2. Seed spacing interval and probability mass function (PMF)

Seed spacing (cm)	Modified no-till drill under residue condition		Control	
	Seeds	PMF	Seeds	PMF
0-0.5	0.8	0.020	1.0	0.025
0.5-1.0	2.7	0.065	2.3	0.060
1.0-1.5	5.4	0.130	4.5	0.115
1.5-2.0	6.6	0.160	6.4	0.165
2.0-2.5	7.5	0.180	8.8	0.225
2.5-3.0	6.4	0.155	6.3	0.160
3.0-3.5	5.6	0.135	4.3	0.110
3.5-4.0	3.7	0.090	3.1	0.080
4.0-4.5	2.1	0.050	1.6	0.040
≥4.5	0.6	0.015	0.8	0.020
Total	41.4	1.000	39.1	1.000

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Initial results on the response of maize and pigeonpeas to conservation agriculture at Karatu-Tanzania

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Keywords: climate change, conservation agriculture, soil fertility

Introduction

Tanzania employs 84% of the rural population in small-scale agriculture with very low levels of productivity. Drought and low soil fertility rank high among the factors limiting production. Yields are not only low (1-2 t/ha-maize) but decreasing. Many interventions have attempted to address these problems with nil or marginal impacts on productivity, but a new approach-- conservation agriculture (CA) -- has recently been emphasised for Sub-Saharan Africa (SSA). CA is a set of land management principles that aim to sustainably increase crop yields and farm profits with balanced economic and resource base benefits (Dumanski et al., 2006). In CA, organic matter is expected to build up over time as soil tillage is limited, crop residues retained on the soil surface, and crops rotated. In other environments CA has proved effective at conserving soil water, and reducing labour requirement, but it has also required expensive (and often unavailable) inputs. In the Karatu district, for instance, CA cropping systems increased maize yields from 1,250 kg/ha to 3,750 kg/ha, but this required the use of fertilisers, timely weeding, improved plant densities and seed quality (Shetto and Owenya, 2007). Despite the promise of CA, adoption has been low in SSA, because small scale farmers lack access to the necessary knowledge, equipment and inputs needed to reduce farmer's reliance upon hand tillage and weed control. Adoption is complicated further by household dependence upon crop residues to feed livestock, and for heating, construction, and sale, (Shetto and Owenya, 2007), because, crop residues can often be sold for up to US$43/ha. In this paper we report on the results from a number of exploratory trials established in the Karatu district during 2010 for the purpose of testing and developing productive, resilient and sustainable small-holder maize-legume cropping systems.

Materials and Methods

Eleven on-farm exploratory trials were established in the Karatu district in 2010. Each trial consisted of three treatments namely conservation agriculture (CA), conventional agriculture (Conv.) and farmers practice (FP). The eleven trials were established on similar soils and environments within a 2km radius, and considered as replicates. Each treatment was approximately 1,000 m^2. Conv. and FP plots were tilled, while in the CA treatment weeds were controlled by using glyphosate prior to seeding. Maize (cv. SC 627) was manually seeded in all treatments in 0.90m rows at 0.60m spacing (two seeds per hole). Pigeonpea (cv. ICEAP 00040) was seeded between maize rows at 50 cm spacing from plant to plant in CA and Conv. treatments but in FP the spacing was one meter from plant to plant. Basal fertilizer DAP (18:46:0) was banded about 5 cm beside the maize seed at 125kg DAP/ha in CA and Conv. but none was applied in FP treatment. Urea fertilizer (46%N) was also side dressed on maize plants at 125kg Urea/ha (57.5 kg N/ha) about a month after crop emergence in all the treatments.

Data recorded included initial soil chemical and physical properties (Table 1). Labour for each operation was recorded on one of the demonstration plots per village. Prices of all inputs used on each of the plots were also collected and partial budgets calculated. Crop biomass at tasseling and maturity and final crop yields were recorded. Ten samples per treatment, each consisting of 5m x 2 rows were harvested in each trial (for both maize and pigeonpea). Yields per hectare were calculated after adjusting grain weights to 12.5% moisture content. The adjusted yield data for each trial were then subjected to statistical analysis using the statistical package GENSTAT. A two way analysis of variance was run (Randomized Complete Block Design) where farmers were considered as blocks (11) each consisting three treatments (CA, Conv. and FP), i.e. eleven replicates. Partial budgets and marginal rate of returns (MRR) were calculated for maize and pigeonpea, this included grain yields, and the sale of the maize stubble in the Conv. treatment.

Table 1: Initial Soil condition-Rhotia, Karatu, 2010 (Means for 11 farms)

Soil depth (m)	pH water	Organic matter (%)	Total nitrogen (%)	Available P (ppm)
0-0.15	6.86	3.77	0.18	63.91
0.15-0.30	6.84	3.46	0.16	50.37

Available P was determined by Bray-1 method

Results and Discussion

In maize, FP yielded significantly less (P ≤ 0.05) than CA and Conv. treatments in grain and biomass yield (Table 2). No statistically significant differences were observed between CA and Conv. treatments. This was expected as the benefits of CA over Conv. are expected to emerge after a few years of continuous and correct practice. Derpsch (2008) indicated that about five years (or growing seasons) of no-till conservation practices are required before soil properties improvements are reflected on crop yields. The observed differences between FP and CA and Conv could be explained by the use of P fertilizer in those treatments. In terms of pigeonpeas, FP treatment had slightly higher grain yield compared to the other two treatments though it was not significant. Likewise, treatments did not differ significantly in biomass production (Table 2).

In spite of moderate rainfall 630 mm during the growing period (Jan-Aug) and provision of all agronomic recommendations in CA and Conv. treatments, grain yields were lower than the achievable yield of 5,500 kg/ha for maize and 1,250 kg/ha for pigeonpeas for the region. The lower than expected yields for the season could be attributed to poor rainfall distribution (not shown). In addition, late seeding caused grain filling to coincide with cold weather, hence maize crops did not receive enough heat units to develop properly.

Table 2. Mean biomass and grain yield of maize and pigeonpeas in Rhotia-Karatu District, 2010.

Treatment	Maize biomass production (t/ha)	Maize grain yield (t/ha)	Pigeonpeas biomass production (t/ha)	Pigeonpeas grain yield (t/ha)
Conservation agriculture	7.6b	3.4b	0.65	0.21
Conventional agriculture	7.1ab	3.5b	0.69	0.18
Farmer's practice	5.7a	2.7a	0.67	0.23
Mean	6.8	3.2	0.67	0.21
C.V.%	27	20.5	ns	ns
LSD(0.05)	1.7	0.62		

LSD means Least squares difference; ns means not significant

Table 3. Partial budget per hectare basis

Variable costs	Conv	CA	FP
Cultivation (U$S)	23.8	0	23.8
Cost of fertilizer (DAP, U$S)	30	30	0
Cost of fertilizer application (U$S)	1.9	1.9	0
Cost of herbicide (U$S)	0	19	0
Cost of herbicide application (U$S)	0	4.7	0
Cost of weeding (U$S)	26	28.6	26
Total variable costs (U$S)	*81.7*	*84.2*	*49.8*
Gross yield of maize (kg/ha)	3,533	3,446	2,723
Adjusted yield (10%)	3,179.7	3,101.4	2,450.7
Gross benefit-maize (U$S)	*485.4*	*473.5*	*374.1*
Gross yield of stover (kg/ha)	7,108	7,575	5,674
Adjusted stover yield (10%)	6,397.2	6,817.5	5,106.6
Gross benefit-stover (U$S)	*36.5*	*0*	*31.8*
Gross yield of pigeonpeas (kg/ha)	182.0	205.6	231.5
Adjusted yield (10%)	163.8	185.04	208.35
Gross benefit-pigeonpeas (U$S)	*83.3*	*94.16*	*106.0*
Total gross benefit (US$)	*605.2*	*567.6*	*511.9*
Net benefit (U$S)	**523.5**	**483.46**	**462.1**

The partial budget analysis showed that Conv. had the highest net benefits (NB), followed by CA, and both were better than the FP treatment (Table 3). Although the CA treatment had higher maize yield compared to FP, CA had a much lower rate of return (Table 3). This was due to the revenue accrued by selling or feeding maize residues to livestock in the Conv. and FP treatments.

The evolution of yields and profits over the next four years will continue to be monitored to determine potential long term benefits of the different treatments. Agronomic activities including seeding will be timed properly to make efficient use of rainfall.

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Impact of dry seeding with alternate wetting and drying on rice productivity and profitability in Punjab, Pakistan

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Keywords: conventional farmers' practice**,** direct seeding**,** water saving, tillers, grain yield

Introduction

In Pakistan, rice is the second largest staple food crop after wheat. It is planted on an area of over 2.88 Mha with total production of 6.87 Mt. Rice in Punjab province is grown by manual transplanting of 30-35 day old rice seedlings (raised somewhere else) into puddled soil and the fields remain flooded for most of the season. The present rice cultivation system is not very productive, resource-efficient or sustainable. Continuous puddling over the decades has led to deterioration in physical properties of the soil through structural break down of soil aggregates and capillary pores and clay dispersion. Low nitrogen-use efficiency in paddy rice (≤ 40 %), and low plant population are significant causes of low paddy yield of the traditional production method. The rice crop consumes over 30 % of the available water resources in the country. There is a deficit of 20985 Mm^3 water in agriculture which is likely to be doubled in the 2nd decade of this century. Thus, complete reliance on labour- and water-intensive rice cultivation is not going to be economic in the present scenario. In order to grow more quality food from scarce resources (labour, water, inputs) on marginal/degraded lands, the current rice crop production system must be improved to make it more viable and eco-friendly.

Dry seeding with alternate wetting and drying (AWD) water management reduce irrigation water input and labour requirement, and improve the soil for non-rice crops grown in rotation with rice. It entails dry seeding of rice in non-puddled soil, aiming at high yields. Even though transplanting is a popular method among the farming community for rice planting, the cost of labour is high, and it often results in delayed planting, and sub-optimal plant density. Therefore, substitution of transplanting with dry seeding could be advantageous (Johnkutty et al., 2002). Dry seeding with AWD can greatly reduce water losses and labour requirement (Mann et al., 2007). Hence, dry seeding with AWD was tested and demonstrated at several farmers' fields during the 2009 and 2010 rice seasons to evaluate effects on crop yield and irrigation input in Punjab, Pakistan.

Materials and Methods

The demo plots were conducted at 25 locations of three main rice-growing areas viz. Sadhoke (district Gujranwala), Chunian (district Kasur) and Chiniot of Punjab province. The soil of this belt is heavy-textured, poorly drained and saline-sodic. Shortage of canal water is prevalent, and large numbers of tube wells have been installed to supplement the irrigation water for rice crop production. The sites for demo plots were selected along the main route and appropriate branch roads for maximum visibility to have maximum multiplier effect among the farming community. At each site, dry seeded rice with AWD was compared with conventional farmers' practice (puddled, transplanted and continuously flooded rice). A total 135 plots (one acre each) were established. For the dry seeded rice, 15 kg pre-soaked seeds (soaked for 30-35 h in water), were broadcast onto the surface of the cultivated soil when soil moisture was at field capacity, and then planking was done. At the same time, the rice nursery was sown for transplanting. A basmati rice variety was used at all sites. At some sites, light irrigation was applied 5-6 days after seeding to facilitate germination and plant establishment, depending upon soil moisture and ambient temperature. Otherwise, the first irrigation was applied 12-15 days after sowing. Subsequent irrigations were applied at 3-5 days interval for one month to promote plant growth and tillering, then the irrigation interval was increased to 7-9 days. Weeds are a major threat to high productivity of dry direct seeded rice crops. A pre-emergence herbicides (e.g. *Pendimethalin*) was applied immediately after seeding. Then, at 30-40 days after sowing, when maximum weeds appear the post-emergence herbicide *Clover* @ 2.5 liter/ha (*Ethoxy sulfuron*) was applied. In some fields, one hand weeding (a normal requirement for dry seeded rice with AWD in farmers' fields) was done. Recommended agronomic and crop protection practices were applied uniformly to all the plots. Irrigation water to each field was measured through "Cut-Throat"flumes installed in the main water course to each field. Data on productive tillers, plant height, panicle length, thousand-grain weight and grain yield were recorded and analyzed statistically using STATISTIX software and differences among the treatment means were compared by the least significant differences (LSD) test at the 5% probability level.

Results and Discussion

Irrigation water saving
The dry seeded rice crops used an average of 1410 mm irrigation water against 1850 mm with conventional farmers' practice (Table 1), a 25% irrigation water saving. The maximum water saving was recorded at Sadhoke site, on clay soil (with high water-holding capacity and low percolation rate), while the lowest saving was recorded at Chunnian site, on light textured soil.

Table 1. Average irrigation water use and saving of dry seeded rice (DSR) compared with farmer practice at 3 sites.

Project sites	Irrigation water input (mm)		% water saving of DSR over farmers' practice
	Farmers' practice (puddled, transplanted and flooded)	Dry seeded rice	
Sadhoke (n=52)	2160 a	1450 c	33
Chunian (n=43)	1730 b	1300 d	25
Chiniot (n=40)	1680 b	1470 c	12
Mean	1850	1410	25

Productive tillers and grain yield
At all the three sites, dry seeding resulted in more productive tillers, with site averages of 388-451/m^2 and an average increase of 48.6% over puddled transplanted rice (Table 2). These results are consistent with those of Wiangsamut et al. (2006) and Ullah et al. (2007), who found more productive tillers in dry seeded than transplanted rice. Average yield of dry seeded rice was 5.35 t ha^{-1}, compared to 4.20 t ha^{-1} with conventional farmers' practice, a 27.3% increase (Table 3). These results are also consistent with those of Ullah et al. (2007),

Wiangsamut et al. (2006) and Gangwar et al. (2008) who recorded maximum rice yield from dry seeding. The partial budget analysis showed that dry seeding of rice generated Rs. 32,550/ha (US$ 383/ha) more than the conventional rice production practice. Thus dry seeding with AWD can help overcome the problems of low plant density leading to low yield, and scarcity of water and labour, in the current rice farming system, leading to enhanced land and water productivity and farmers' income.

Table 2: Average productive tillers of dry seeded rice (DSR) compared with farmer practice at 3 sites.

Project sites	Productive tillers/m^2		% increase of DSR over farmers' practice
	Farmers' practice (puddled, transplanted and flooded)	Dry seeded rice	
Sadhoke (n=52)	287 b	452 a	57
Chunian (n=43)	235 c	397 a	69
Chiniot (n=40)	310 b	388 a	25
Mean	277	412	49

Table 3: Average grain yield of dry seeded rice (DSR) compared with farmer practice at 3 Sites.

Project sites	Rice yield (t/ha)		% increase in DS over farmers' practice
	Farmers' practice (puddled, transplanted and flooded)	Direct dry seeded rice crop (DS)	
Sadhoke (n=52)	4.0 b	6.0 a	48
Chunian (n=43)	3.5 b	4.6 b	31
Chiniot (n=40)	5.1 a	5.5 a	8
Mean	4.2	5.4	27

Figure 1: Dry seeded rice crops at farmers' fields in Sadhoke and Chiniot during 2009.

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Conservation Agriculture-based rice-wheat-jute cropping systems in Bangladesh

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Key words: Double reduced tillage dry direct seeded rice and wheat, line sown jute, production costs, net profit

Introduction

Farmers in Bangladesh make inefficienct use of many agricultural inputs, including seed with broadcast establishment methods employed for many crops like rice,wheat and jute. Coupled with the prevalent use of old varieties that limit yield potential, the net profitability of field crop production in Bangladesh is generally low. Late planting of winter crops such as wheat, together with high costs of land preparation, compounds the issue of lower profitability (Mazid et.al, 2009 and 2006). On-farm validation and refinement of conservation agriculture-based (CA) management systems in Bangladesh offers scope to reduce production costs and raise profitability. To that end, experiments were conducted in the Dinajpur region in NW Bangladesh to evaluate the performance of dry direct-seeded rice (DSR) in the Aman (monsoon) season followed by line sowing wheat using single-pass roto-tiller/seeder in the winter season, and then zero-tillage sowing of jute.

Materials and Methods

Experiments were conducted in farmer's fields on a light textured soil at Moktarpara, Mominpur, Rangpur District starting with the Aman season in 2009 followed by wheat in winter season in 2009-10 and then jute in Kharif-1 (spring) 2010. Land preparation and sowing for rice and wheat were combined in a single operation with a line seeder mounted on the Chinese two-wheel tractor locally called PTOS (power-tiller operated seeder). Jute was sown with a 'mini' zero-till multi crop drill for the four-wheel tractor (4WT). The rice variety (BRRI dhan 33) was early maturing and short duration (115-118d for transplanted rice (TPR) and 103-105 days in DSR condition). For rice, triple super phosphate (TSP) and muriate of potash (MoP) were applied as a basal dose each at 71 kg/ha and gypsum was applied at 81 kg/ha. Urea was top dressed based on leaf color chart (LCC) readings with 165 kg/ha applied in 3 equal split applications during 2009-10. Prodip variety of wheat was established after rice harvest on 26 November, 2009. TSP and MoP were applied as a basal dose for wheat at the rate of 143 and 71 kg/ha, respectively. Gypsum (71 kg/ha) and zinc sulfate (10 kg/ha) were also applied as a basal dose. A total rate of 214 kg/ ha of urea was applied with 2/3rd at planting and remaining 1/3rd top dressed after the 1st irrigation at 20 days after sowing (DAS). Weed control for wheat was done by application of Affinity (carfentrazone) at 1.630 kg/ha at 23 DAS. The crop received three irrigations at 20, 52 and 74 DAS. Jute (Tossa jute - *Corchorus olitorius*) was established with zero-tillage on 9 April 2010 after harvest of wheat. No herbicides were applied, but the crop was manually weeded as needed. The seed rate of jute was 4.94.kg/ha using a mini 4WT-powered seed drill as line sowing facilitates weed control. Excess plants were thinned out when the crop was 15–20 cm tall plants**.** Approximately 50-70 plants germinated per linear meter and were subsequently thinned at the time of 1st hand weeding to 10-12 plants per meter. TSP and MoP were applied as a basal dose to jute at the rate of 50 and 62 kg/ha, respectively. Gypsum (37 kg/ha) was also applied as a basal dose. A total rate of 124 kg/ ha of urea was applied with one third at 25 days after sowing (DAS) and the remaining two thirds top-dressed at 50 DAS.

Results and Discussion

CA-based double reduced till dry-seeded rice, reduced till wheat and zero tillage line sown jute
Includesion of double reduced till dry DSR followed by wheat sown with the 2WTOS (PTOS) and this followed by line sown zero tillage jute reduced the turnaround time and allowed the introduction of a third crop. The dry DSR-wheat-jute cropping system not only increased land productivity but also increased the net income (Table 1)

Early maturing short duration rice varieties such as BRRI dhan33 matured in mid October that created employment of agricultural labor, improved food security during crises period that is locally name as "Monga" and increased crop intensity. Moreover, the short duration varieties combined with CA-based reduced till dry DSR matured about 40 days earlier than long duration MV rice and so escaped terminal drought in September and gave good yield.

Farmers broadcast wheat with a high seed rate (150 kg/ha) in full tilled condition (minimum 4 ploughings by country plough) and the crop establishment costs Taka (BDT) 9696 (USD 131) per hectare whereas line sowing of wheat with single pass of the 2WTOS (PTOS) and a lower seed rate (120kg/ha) cost only BDT 6423 (USD 87). Thus farmers saved BDT 3273 (USD 44) per hectare due to CA based reduced till and use of a lower seed rate

Line sowing of jute used a newly devised seeder with a cup seed metering system with a seed rate of 4.94 kg/ha which was 1.24 kg/ha lower than the usual farmer practice of broadcasting seed. Jute was infested with large numbers of weeds, and required at least 2-3 manual weddings within 45 DAS. Manual weeding comprised about 50% of the total cost of production in the broadcast method. However, machine sowing of jute in rows facilitated weeding and saved 35 labour days/ha: a cost saving of USD 76/ha.

Table 1: Net income in double reduced till dry DSR-wheat and ZT Jute in Mominpur, Rangpur, CSISA Dinajpur Hub 2009-10

Tech./Method	Crop	Variety	Yield (t/ha)	Rice Equivalent Yield (t/ha)	Total Income (Taka/ha)	Production Cost (Taka/ha)	Net Income* (Taka/ha)
Dry DSR by 2WTOS (PTOS)	Rice	BRRI dhan33	2.666	2.666	35657	22533	13124
Wheat sown by 2WTOS (PTOS)	Wheat	Prodip	4.347	5.260	78899	36951	41948
ZT by Mini 4WTO ZTMCP (6-tines)	Tossa Jute	O-72	2.195	5.622	84334	50662	33672
Total			9.208	13.548	198890	110146	88744

* USD1= Tk 74.00

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Initial findings show benefits of controlled traffic for intensive vegetable production

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Keywords: porosity, infiltration, tillage, farming systems

Introduction

Controlled traffic farming (CTF) keeps all paddock traffic in the same wheel tracks, thereby separating compacted traffic zones from soil used for growing crops, and providing a wide range of benefits for crop production. Benefits observed in research and commercial practice in the grain and sugar industries include reduced soil erosion, more efficient energy, water and fertiliser use, improved soil structure, organic matter and timeliness, and increased productivity (Bowman 2008; Lamers et al. 1986; McPhee et al. 1995; Stewart et al. 1997; Vermeulen et al. 2007).

Use of CTF in the Australian grain and sugar industries has increased in recent years as the benefits have become more widely recognized. The uptake of CTF in the intensive vegetable industry is almost non-existent for a number of reasons, including diversity and incompatibility of current equipment, and often, a diversity of ownership arrangements (e.g. private, contractor and company-based machines) requiring industry-wide involvement for effective change.

Recent research in vegetables in Tasmania has provided evidence of improved soil conditions through the use of controlled traffic, while on-farm demonstrations have identified a number of factors that need to be addressed for practical adoption of the technique. Issues to be resolved for successful adoption of CTF in vegetable production include tracking stability on compacted wheel tracks, and implement working and track width compatibility.

Materials and Methods

A 2 ha experimental site near Devonport, Tasmania, has red ferrosol soils, and is representative of the prime vegetable production areas in Tasmania. The site has undulating topography and a winter dominant rainfall of 1000 mm/y. Irrigated summer vegetable cropping is the main enterprise of the region, although rain-fed winter crops are also grown.

The site has two treatments – controlled traffic based on a 2 m wheel track, and conventional practices using random traffic. Both treatments are cultivated as required, although the type, number and intensity of tillage operations varies with the treatment and seedbed requirements. Measurements taken at various times each season include soil bulk density, and related derived parameters, and soil resistance. Bulk density cores are taken at depths 0 – 50, 125 – 175 and 275 – 325 mm and provide data on bulk density, porosity, gravimetric and volumetric water content, water filled pore space and the ratio of soil:water:air in the sample. Soil resistance data are collected at 100 mm intervals across a 3 m transect, to a depth of 600 mm at 15 mm intervals.

Demonstration sites have been established on two farms with similar soil types, and on a third site with duplex soils. Less intensive monitoring occurs on these sites, which are used for testing and demonstrating controlled traffic within the constraints of existing farming operations.

Results and Discussion

Results are presented for porosity, water filled pore space, infiltration and tillage operations on the main research site. Although soil cores were taken at three depths, only data from 150 mm is presented. This is often the approximate depth of final seedbed tillage operations. Data for other depths reflect similar trends, although the magnitude of differences varies.

Porosity
Porosity is derived from bulk density samples. Figure 1 shows porosity under controlled traffic is consistently higher than under conventional management. The increase in porosity under controlled traffic has implications for water holding capacity, drainage, aeration and root growth, all of which can be beneficial for plant growth.
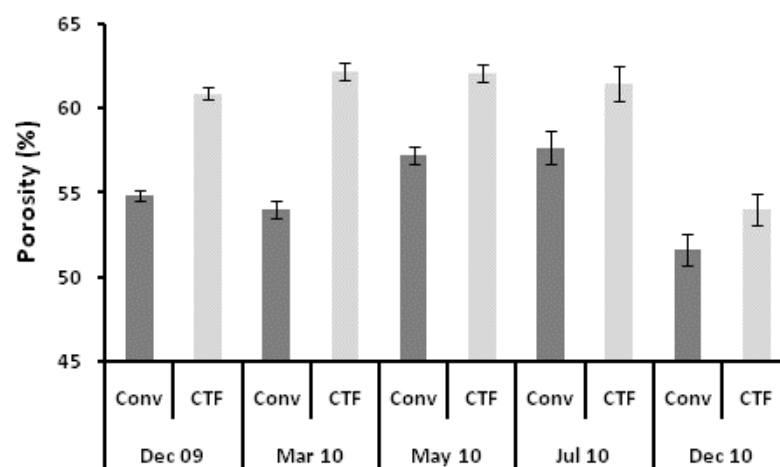
Figure 1. Soil porosity at 150 mm depth from areas managed with conventional tillage and controlled traffic. Error bars indicate S.E. of means. All differences between treatments are significant (p<0.05) with the exception of the data for Jul 10.

Soil-water-air ratio
Figure 2 shows that, as well as higher porosity, soil under controlled traffic also has a more balanced ratio of water:air in the pore spaces. Very high percentages of water filled pore space indicate conditions approaching anaerobic, which can significantly influence the incidence of root disease and the generation of nitrous oxide emissions from nitrogenous fertilisers. Nitrous oxide is a high impact greenhouse gas, and the soil conditions under controlled traffic have the potential to reduce the level of emissions.
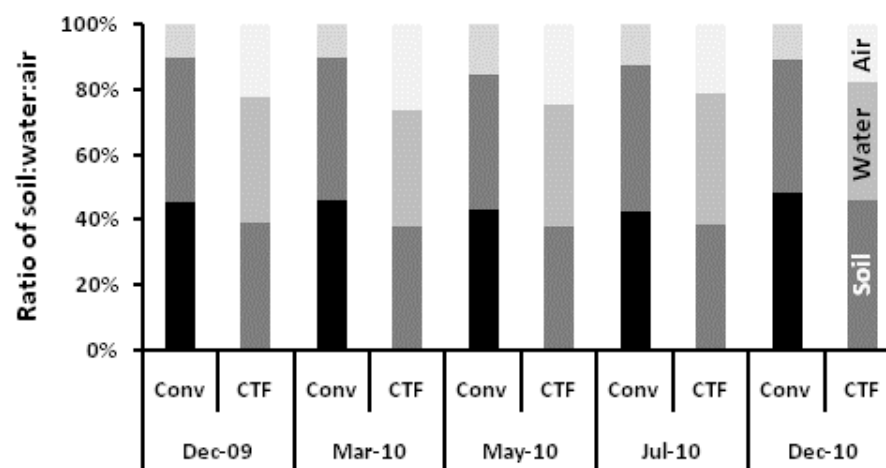
Figure 2. Ratio of soil:water:air in soil cores taken at 150 mm depth from areas managed with conventional tillage and controlled traffic.

Infiltration

Only one set of infiltration tests has been conducted so far on the trial site. A Cornell Infiltrometer was used and the data showed a substantial difference in infiltration capacity between the two treatments (Table 1). This change will reduce run off and erosion from the crop beds, and has implications for capture and storage of rainfall and irrigation water.

Table 1. Infiltration test data from conventional and controlled traffic treatments (July 2010).

	Conventional	Controlled traffic
Duration of test (min)	30	90
Average time to run-off (min)	4	Not reached
Average run-off rate (mm/h)	202	0

Tillageoperations

Controlled traffic eliminates compaction removal as a primary reason for tillage in vegetable production. Consequently, tillage operations under controlled traffic are largely directed towards residue management and seedbed preparation. This reduces the number and energy intensity of tillage operations required (Table 2).

Table 2. Number of tillage operations to transition between crops managed under conventional and controlled traffic systems.

Crop transition	Conventional	CTF
potato - onion	4	2
onion - broccoli	3	1
broccoli - beans	4	3

The changes in soil condition that occur through the use of controlled traffic will have impacts across all aspects of vegetable production. Soil that is not impacted by traffic compaction provides a more robust growing environment under variable climatic conditions and requires significantly less effort for seedbed preparation. The initial findings show clear benefits from controlled traffic for soil management in intensive vegetable cropping. These benefits will be further monitored over the remainder of the project, and findings used to assist development and uptake of controlled traffic in the vegetable industry.

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Characterization of soil nutrient levels in smallholder Ffarms in Eastern Kenya

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Keywords: Soil fertility; Total Nitrogen; Soil Carbon; Extractable phosphorus

Introduction

Declining soil fertility and crop yields are major problems experienced by smallholder farmers in eastern Kenya where maize and legumes are grown in complex and risky farming systems. Even though the natural fertility of the soils is moderate to high, over time soil fertility declined due to inappropriate soil management practices and nutrient depletion. Climate variability and the socio-economic environment add up to the uncertainties farmers face making the use of inorganic fertilisers extremely low due to the high risk of the practice. The region has a highly variable bi-modal annual rainfall that ranges between 800-1400mm accumulated over two well defined rainy seasons. The short rains (SR) run between March and July, and the long rains (LR) between October and January (Jaetzold, R. and Schmidt, H. 1983).

Maize and beans are the most common crop enterprises and grain yields are generally low, at 1.3 and 0.6 t ha^{-1} season^{-1}, respectively. Low grain yields are attributed to reduced soil fertility caused by nutrients removal through residues and crop harvests. Under similar environmental and land management conditions in the Kilimanjaro region of Tanzania, modest maize and bean crops removed 57.6, 12.5 and 55.5 kg ha^{-1} year^{-1} of N, P, and K, respectively (Kaihura, et al., 2001). Legumes are expected to contribute to the N economy of the system, but since harvesting involves pulling out the whole plants with their roots, the benefit of additional N is probably negligible. In this paper we present a characterization of the present situation on soil nutrient levels of croplands across eastern Kenya.

Materials and Methods

The study was conducted during May to July 2010 at 24 farms within four sites (6 farms per site) in the upper midlands (UM$_3$) and lower midlands(LM$_4$) agro-ecological zones (AEZs) of the eastern slopes of Mt. Kenya ($\approx$1200m asl). Mean annual temperature is 20°C (Jaetzold, R. and Schmidt, H. 1983). Soils are deep ($\approx$2.0m) well weathered Humic Nitisols, but due to intensive unsustainable cultivation methods and inadequate use of fertilisers, soil fertility has declined leading to very low levels of productivity. The farming system is dominated by medium maturity ($\approx$140 days to physiological maturity) maize (*Zea mays* L.) varieties that are intercropped with beans (*Phaseolus vulgaris* L.) and pigeon-peas (*Cajanus cajan* L.) in UM$_3$ and LM$_4$, respectively (Waithaka, et al., 2006).

Soil samples were taken at each site from the top 0-15cm for the determination of soil pH, organic carbon (OC, %), and total N (%). The same samples were used for the determination of extractable P (mg kg^{-1} of soil), using Olsen-P (Olsen, et al., 1954). Soil profiles (0 – 210cm) were dug at each of the four sites and metal ring-cores were used to take soil samples for the determination of soil bulk density (BD) at 0-30, 30-60, 60-90, 90-120, 120-150, 150-180 and 180-210cm depth intervals.

Results and Discussion

Over 70% of the farmers in the upper humid zones (UM$_3$) used organic and inorganic fertilizers on the maize crops. However, the amounts applied were low (<20 kg N ha^{-1}) to meet optimal crop nutritional requirements (60 kg N ha^{-1}, for a maize grain yield of 6 t ha^{-1} season^{-1}). In the midlands zone sites (LM$_4$) the amounts were much less (5-10 kg N ha^{-1} season^{-1}). No manure or fertilisers were used on legume crops. Over 82% of the manure produced in LM$_4$ (semi-arid zone) was sold out to the upper midland zones to be applied in coffee and other cash crops. All contacted farmers used conventional tillage practices to grow maize and legumes. No farmer practiced sustainable conservation agriculture practices or incorporated crop residues into the soil to improve soil fertility. Based on farmers' reports, grain yields were low, averaging 1.1 and 0.5 t ha^{-1} for maize and legumes, respectively (Table 1).

Table 1: Farmers' reported main crop yields (t ha^{-1}) during short and long rains in eastern Kenya region.

Site	AEZ	Soil texture	Farmer Reported Crop Yields (t ha^{-1})	
			Maize	Legume(s)
Kyeni	UM$_3$	Loamy clay	1.63 a	0.70 a
Mariani	LM$_4$	Sandy clay loam	1.28 a	0.57 a
Mweru	UM$_3$	Loamy clay	0.85 ab	0.35 a
Mworoga	LM$_4$	Sandy clay loam	0.68 b	0.30 b
Mean	-	-	**1.11**	**0.48**
CV	-	-	**62.60**	**61.67**
LSD	-	-	**0.86**	**0.36**

Means with the same letter are not significantly different (p ≤ 0.05)

At all four sites, soil pH was low with a mean soil pH of 5.44 (water), which significantly (p ≤ 0.05) differed between farms and sites. The relatively low pH level was attributed to over 50 years of continuous cultivation without inadequate application of soil amendments. Mean soil extractable P was significantly low at 13.9 mg kg^{-1} (Table 2). This was associated to soil P mining via farming activities. Soil P levels were also observed to vary from farm-farm and site-site due variable farm tillage methods, presence of livestock, and the amount of fertility inputs applied (Tittonell, et al., 2007). This makes difficult to apply blanket recommendations of soil fertility within farms, across farms and regions. Total soil nitrogen averaged 0.2%, with no differences between sites, in both zones. Soil OC varied between 0.84 and 1.4% across sites.

We observed statistically significant differences (p ≤ 0.05) in bulk density across sites (Table 2). The sites in LM$_4$ had a higher BD values compared to those in the upper zones, 1.2g/cm^3 and 1.1g/cm^3, respectively. This could be attributed to the higher clay contents of the soils of the lower semi arid zones. In the Mworoga and Kyeni sites the values of BD were slightly higher in the upper than in the lower soil horizons. This could be attributed to compaction in the top soil layer during the various land operations (e.g. ploughing, seeding and

weeding). Thus, BD measurements can greatly aid in making decisions on the tillage techniques to apply, particularly under long-term cultivation studies (Ekwue, 1990).

Table 2: Soil characterization parameters (pH, total N, OC, extractable P and bulk density) at four sites in eastern Kenya

Site Name	Zone	Soil Characterization				
		pH (water)	Nitrogen (%N)	Organic Carbon (% OC)	Extractable P (mg kg^{-1} soil)	Bulk Density (gm/cm^3)
Kyeni	UM$_3$	5.60 a	0.14 a	1.39 a	10.87 b	1.14 b
Mariani	LM$_4$	5.80 a	0.15 a	1.19 a	14.78 ab	1.12 ab
Mweru	UM$_3$	5.00 b	0.13 a	1.29 a	12.16 b	1.09 a
Mworoga	LM$_4$	5.43 a	0.15 a	0.84 a	18.00 a	1.38 c
Mean	**-**	**5.44**	**0.14**	**1.18**	**13.95**	**1.18**
CV	**-**	**6.10**	**29.25**	**41.23**	**25.13**	**17.18**
LSD	**-**	**0.41**	**0.05**	**0.60**	**4.31**	**0.22**

Means with the same letter are not significantly different ($p \leq 05$)

Conclusions

Low soil fertility is one of the major challenges faced by smallholder farmers across eastern Kenya where maize and legumes are grown under complex and risky farming systems for food and cash generation. Results from soil sampling and analysis indicate widespread nitrogen and phosphorus deficiencies in most soils and regions. As also observed by Tittonell et al., (2007). These results also indicated a high variability in soil fertility across sites and regions. It is clear from these results that a pathway to the sustainable intensification of maize-legume cropping systems across eastern Kenya will require particular emphasis at providing economic levels of inorganic nitrogen and phosphorus fertilisation.

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Conservation tillage practices and weed management options on productivity and weed population of soybean

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Key words: Conventional tillage, Zero tillage, Grain yield

Introduction

The adoption of soybean [*Glycine max* (L.) Merr.] has brought about a perceptible change in the economy of the farmers in south-east Rajasthan. Being a rainy season crop, its growth and yield are, however, reduced by 25-77 per cent (Kurchanina et al., 2001). Weeds are a major problem in this cropping system and their control is essential for successful crop production. Reducing tillage and herbicide use are two means of improving weed management (Swanton et al., 2006). Mostly farmers use pre-plant incorporated and pre-emergence herbicides for weed control in soybean, but their efficacy is reduced by various climatic and edaphic factors. Hand-weeding is a traditional and effective method of weed control, but untimely and continuous rains as well as unavailability of labour at peak time are main limitations of manual weeding. The only alternative that needs to be explored is the use of post-emergence herbicides, which requires screening in soybean for efficiency against either monocotyledonous or dicotyledonous weeds. Their mixtures may broaden the window of weed management by broad-spectrum weed control (Bineet et al., 2001). Crop nutrition is an important factor, but weeds can exploit the habitat more efficiently and reduce the availability of nutrients to the crop.

Materials and Methods

A field experiment was conducted during *kharif* season 2008 at the research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi on sandy loam soil, slightly alkaline (pH 7.6), low in organic C (0.38%), and available N (145 kg/ha), medium in available P (9.01 kg/ha) and high in available K (259.4 kg/ha). The treatments included four tillage and crop establishment practices, viz. conventional tillage flat-bed, conventional tillage raised-bed, zero tillage flat-bed and zero tillage raised-bed, and six weed management options, viz. control, weed free, pendimethalin @ 0.75 kg/ha as pre-emergence (PE), chlorimuron ethyl @ 6 g/ha as post-emergence (POE), pendimethalin @ 0.75 kg/ha as (PE) + 1 hand weeding (HW), pendimethalin @ 0.75 kg/ha as PE + chlorimuron ethyl @ 6.0 g/ha as (POE). Thus, 24 treatment combinations were laid out in a thrice replicated split plot design, keeping tillage and crop establishment in main plots and weed management options in sub-plots. The net plot size was 15 m^2. After the harvest of *rabi* crop wheat in April, land preparation and sowing was completed on 10 July with a zero-till seed drill and bed planter, at 35 cm row spacing using 80 kg/ha seed (DS 9814) variety, and 20 kg N, 60 kg P$_2$O$_5$ and 40 kg K$_2$O /ha, at sowing. The crop was harvested on 23rd October, 2008.

Results and Discussion

The total weed population was significantly influenced by crop establishment practices and weed management options at 30, 60 and 90 DAS. At 30 DAS, the maximum total weeds were recorded on zero tillage flat-bed planting system closely followed by zero tillage raised-bed planting and weed population was recorded for chlorimuron ethyl (POE), significantly higher than other treatments. Weed dry matter accumulation was significantly influenced by crop establishment and weed management at all the 3 stages of crop growth. Weed dry matter was maximum for zero tillage flat-bed which was significantly higher than all other treatments. Zero tillage raised-bed planting technique also produced significantly higher dry matter production than conventional tillage raised-bed and conventional tillage flat-bed system of planting and also control was produced significantly higher than all other treatment followed by chlorimuron ethyl (POE) along (Table1), The superiority of pendimethalin in reducing the weed intensity has also been reported by Pandey et al, (1996) and Chauhan et al. (2002). The integrated weed control treatment method of pre-emergence application of pendimethalin + 1 HW was found effective in controlling both grassy and broadleaf weed population. Sharma and Deepeshr (2002) observed a significant effect on grain yield due to application of chlorimuron ethyl at 6, 9 and 12 g/ha. However, application of 12 g/ha was found to be the optimum dose for getting maximum soybean yield. Behera et al. (2005) found that chlorimuron ethyl at 6 and 9 g/ha was effective as pre-emergence application under clay loam soil (Vertisoils) in central India. Grain yield of soybean was significantly influenced due to tillage and crop establishment practices. The highest grain yield of 2.32 t/ha was recorded in conventional tillage raised-bed treatment, which was statistically similar conventional tillage flat-bed and zero tillage flat-bed, and zero tillage raised-bed treatment. All these treatments had significantly higher grain yield than zero tillage flat-bed system of planting. Even zero tillage raised-bed had marginally higher grain yield (1.7%) than conventional tillage flat-bed treatments. Conventional tillage raised-bed had 5% higher grain yield than zero tillage raised-bed planting system. The highest grain yield (2.5 t/ha) of soybean was recorded in weed free treatment, a 34% yield improvement on the lowest (1.8 t/ha), recorded in the control treatment. Among other treatments, the maximum grain yield of 2.18 t/ha was recorded with treatment constituting of pendimethalin + 1 HW. This treatment performed similarly with application of only pendimethalin but was significantly superior to control, chlorimuron ethyl alone as post-emergence application and pendimethalin as PE and chlorimuron ethyl as POE (Table2), Rajput and Kushwa (2004); Mallik et al. (2006), Idapuganti et al. (2006) also found a similar response with the application of 1.0 kg/ha of pendimethalin + 1 hand weeding either at 30 DAS or 20 DAS. Sing et al. (1994) also reported that 0.5 kg pendimethalin + 1 HW at 40 DAS was quite effective to control the weeds and provide significantly higher soybean grain yield. The performance of soybean was better in conventional and Zero tillage raised-bed than flat-bed conventional and zero tillage system of planting. Pendimethalin @ 0.75 kg/ha as PE + 1 HW at 25 DAS was very effective method of weed management in soybean. Pendimethalin application @ 0.75 kg/ha as PE was quite effective to control the weeds in soybean. The chlorimuron ethyl @ 6 g/ha as post-emergence was not very effective to control the weeds.

Table 1. Tillage, crop establishment, and weed management effects on weed population and weed dry matter

Treatment	Weed population (No/m^2)			Dry matter (g/m^2)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Tillage and crop establishment						
Conventional tillage flat-bed	6.98 (50.56)	6.13 (39.11)	4.97 (25.66)	8.23 (75.40)	5.93 (44.54)	4.36 (20.88)
Conventional tillage raised-bed	6.27 (41.55)	5.49 (31.88)	4.72 (22.88)	8.32 (77.32)	5.62 (39.61)	4.11 (17.06)
Zero tillage flat-bed	7.13 (54.44)	6.11 (38.88)	5.04 (26.66)	11.8 (155.7)	9.23 (104.0)	9.05 (92.05)
Zero tillage raised-bed	7.06 (54.11)	5.83 (35.88)	4.64 (22.44)	10.4 (121.0)	7.41 (69.21)	5.96 (40.35)
CD (P=0.05)	0.244	0.265	0.302	0.280	0.374	0.128
Weed management options						
Control	9.91 (98.50)	8.02 (64.00)	6.50 (42.00)	13.0 (172.1)	12.2 (151.9)	8.44 (80.13)
Weed free	3.83 (14.33)	3.44 (11.50)	3.10 (9.333)	2.90 (8.117)	2.56 (6.583)	3.12 (9.883)
Pendimethalin @ 0.75 kg/ha PE	6.64 (43.83)	6.09 (37.00)	5.07 (25.33)	10.3 (110.2)	7.30 (58.83)	5.96 (43.41)
Chlorimuron ethyl @ 6 g/ha POE	7.45 (55.50)	6.73 (45.00)	5.54 (30.33)	11.5 (136.5)	9.69 (97.80)	7.41 (60.43)
Pendimethalin @ 0.75 kg/ha PE + 1HW	6.54 (42.66)	5.03 (25.00)	3.72 (13.50)	10.4 (112.4)	3.12 (9.450)	3.77 (14.30)
Pendimethalin @ 0.75 kg/ha as PE + Chlorimuron ethyl @ 6 g/ha as POE	6.79 (46.16)	6.04 (36.16)	5.13 (26.00)	10.0 (104.8)	7.35 (61.51)	6.52 (47.38)
CD (P=0.05)	0.312	0.271	0.296	0.275	0.257	0.149

*Square root transformed values √(X+0.05), original values are in parentheses

Table 2. Tillage, crop establishment, and weed management effects on yield and yield attributes of soybean

Treatment	Grain yield (t/ha)	Pods/Plant	1000-Seed weight	Seed/pod
Tillage and crop establishment				
Conventional tillage flat-bed	2.17	67.00	137.61	2.09
Conventional tillage raised-bed	2.31	72.55	140.65	2.17
Zero tillage flat-bed	1.72	59.33	124.34	1.75
Zero tillage raised-bed	2.20	65.94	128.66	2.23
CD (P=0.05)	0.200	3.163	11.84	0.066
Weed management options				
Control	1.84	57.83	122.59	1.77
Weed free	2.47	77.16	145.04	2.55
Pendimethalin @ 0.75 kg/ha as PE	2.15	66.58	132.23	2.07
Chlorimuron ethyl @ 6 g/ha as POE	1.97	61.33	127.97	1.89
Pendimethalin @ 0.75 kg/ha as PE + 1HW	2.18	70.25	137.71	2.17
Pendimethalin @ 0.75 kg/ha as PE + Chlorimuron ethyl @ 6 g/ha as POE	2.00	64.08	131.19	1.90
CD (P=0.05)	0.148	2.746	7.275	0.154

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Can conservation agriculture improve soil quality and sequester carbon in the short term for dryland smallholders in the developing world?

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Keywords: conservation agriculture, soil quality, soil fertility, carbon sequestration, smallholder

Introduction

The Sustainable Agriculture and Natural Resource Management (SANREM) Collaborative Research Support Program (CRSP) implements multidisciplinary and multi-institutional applied research that mobilizes science and technology, fosters innovation and improvement in the social, economic, and environmental sustainability of agriculture and natural resource management, and leads to improved food production, secure livelihoods, and expanded trade opportunities and capacities for stakeholders. Phase IV research activities are focused on increasing smallholder food security through the introduction of conservation agriculture production systems (CAPS). In October 2009, SANREM CRSP began its Phase IV research on conservation agriculture in Haiti, Bolivia, Ecuador, Ghana, Mali, Lesotho, Mozambique, Uganda, Kenya, India, Nepal, Cambodia and the Philippines. This phase will continue through September 2014. The research is implemented through seven US-based universities, who share $15 million in funding from USAID. The global research program is managed by Virginia Tech, where four cross-cutting research activities (CCRAs) facilitate data quality control so that results across project sites can be compared at the end of the project. The CCRAs are Soil Quality and Carbon Sequestration, Economic and Impact Analysis, Gendered Knowledge, and Technology Networks for Conservation Agriculture. Phase IV research and capacity building activities will develop and demonstrate locally sustainable CAPS for smallholder rain -fed crop production systems that improve food security and the productive capacity and ecosystem services of degraded and productive agricultural lands.

The overarching goal of the Soils CCRA is to determine if dryland smallholders in the developing world can increase soil organic carbon (SOC), and hence soil fertility, by adoption of conservation agriculture (CA). We know that CA increases SOC under mechanized agriculture in the developed world, but it is unclear if such increases are feasible in the developing world for dryland smallholders growing staple crops. There is also an interest to determine the potential for carbon sequestration in these systems, which may potentially lead to payments under carbon trading schemes. Coordination of soil and agronomic investigations among all 13 developing countries before and after CAPS are implemented is critical to measuring soil fertility and carbon sequestration changes due to CAPS. We are coordinating all long term research activities' (LTRA) data collection so that we can make meaningful and scientifically verifiable comparisons across all project sites. Our specific objectives are to:
1. Quantify SOC in host country project sites before and after CAPS implementation.
2. Identify CAPS cropping systems or biophysical elements that improve soil fertility.
3. Relate increased soil fertility to site-specific socioeconomic environments.

We will also facilitate LTRAs and host-country partners to build capacity regarding biophysical data collection from CA plots vs. current practice controls, in order to determine effects on production and the ability to produce sufficient biomass to protect the soil and increase SOC.

Material and Methods

We will collect bulk density and SOC data at the 0-5 and 5-10 cm depths from selected researcher managed plots, and will include current practice control plots. Since sampling and shipping of soil samples from each and every researcher-managed plot will be cost- and laborprohibitive, selection of specific plots for sampling will be determined at each site according to those "best-bet" CAPS trials which will have shown the most promising success as a technology that can 1. Incorporate as many of the CA principles as possible, 2. Have a good chance to improve soil quality over time, 3. Improve production capacity over current practices, and 4. Have the greatest potential for adoption. Samples from the 0-5 and 5-10 cm depths will be sent to Virginia Tech, where we will build a Time Zero soil library, so that analyses can be conducted under one laboratory for comparative purposes. The library will also serve as an archive for LTRAs or other researchers that may require Time 0 soil samples from our project areas. To the extent possible, GPS data will be recorded from all field sites in order to provide accurate maps and GIS data relevant to crop production in the region.

Soil samples will be composited from at least 16 cores, sieved to pass through a 2 mm sieve, and air-dried prior to shipping. The requirement for at least 16 composite cores represents the number of cores needed to reach a diminishing return between the labor expended and the number of samples needed to determine a minimum detectable difference (MDD) in SOC. Grain yield will be measured by weighing subsamples after harvest. Above-ground biomass will be measured using quarter-meter quadrats, and percent ground cover will be determined using line transects. Total carbon and nitrogen contents will be determined using dry combustion. Fields with a history of liming or those on calcareous soils will be treated with acid to account for carbonates. Particulate organic matter (POM) is a size-based fractionation and will be determined at Time 0 and again at the end of the experiment using procedures described by Gregorich & Beare (2008). This may be combined with density-based fractionation procedures to determine labile and recalcitrant SOC pools. Fractionation procedures may be altered if an alteration will offer better opportunities to determine treatment differences in accordance with the timeframe remaining in this phase of the program.

Anticipated Results and Discussion

Although this will be an expensive soil library to build, it will provide data quality control across global project areas by analysing samples under one lab. We will quantify changes to soil fertility and carbon sequestration due to CA treatments over time. It will also serve as an invaluable asset for those LTRAs who continue research beyond the timeline of Phase IV, as well as for those researchers who may require reference samples for future comparisons. One challenge with determination of carbon sequestration rates is that SOC may not significantly increase over the timeframe of this program. A global data analysis from 276 paired treatments indicated that an average of 0.57 ± 0.14 Mg C ha^{-1} yr^{-1} was sequestered after changing from conventional tillage to no-till, except in wheat-fallow rotations where no change was found (West & Post, 2002). The study noted that an additional $0.20 \pm$

0.12 Mg C ha^{-1} yr^{-1} can be sequestered by including rotations (except changing from continuous corn to a corn-soybean rotation, which resulted in non-significant treatment differences in SOC accumulation). In our CAPS systems, which employ both minimum tillage and crop rotations, we might therefore reasonably expect to sequester approximately 0.77 Mg C ha^{-1} yr^{-1}, such that after three years we may accumulate approximately 2.3 Mg C ha^{-1} yr^{-1}. However, the authors note that C sequestration rates reach a maximum in about 5-10 years after conversion from conventional agricultural practices, so after three years of our CAPS trials, we may reach C sequestration rates that are approaching their maxima, thereby increasing our chances of finding significant differences in SOC between treatments. Rather than rely on total SOC changes alone, we will quantify labile and recalcitrant SOC fractions, which can be more sensitive indicators of short - term management changes and their effects on soil fertility (Conant *et al.*, 2004). We collaborate with other CCRAs to implement transdisciplinary research, specifically quantification of soil fertility parameters in relation to gendered knowledge of soil fertility in host-country areas, and also investigations of SOC for carbon credits in conjunction with the Economic and Impact Analysis CCRA.

One of the main goals of the Soils CCRA is to provide support to LTRA and host -country institutions to assist in biophysical data collection. Support may include building the capacity of host-country soils labs, in-field training on determining bulk density, or supporting LTRAs to implement components of CA, such as minimum tillage, as part of their research plans. We are currently evaluating methodology to determine the differences in greenhouse gas (GHG) and other gas (i.e., NH_3) emissions from CA and traditional practices at two sites (with three replications each) in Ecuador. Additionally, we are involved in the assessment of soil fertility under minimum tillage and crop rotations as part of an on-farm experiment in Thumka, Nepal. This experiment will, among other things, determine the land use ratios under the differing systems.

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Evaluation and promotion of integrated crop and resource management technologies in rice-wheat systems in Pakistan

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Introduction

The Indo-Gangetic Plains (IGP), being one of the most agriculturally productive areas in South Asia has diversity in natural resources, socio-economic conditions, and farming systems. Rice-wheat (RW) is major cropping system occupying about 1.7 million ha in Pakistan out of the total 13.5 million ha in South Asia (Hobbs and Morris, 1996) and contributing around 80% of the total cereal production (Timsina and Conner, 2001). The continuous rice-wheat system has depleted the natural resources of the country, especially water and soil fertility, thereby reducing the food security and livelihoods of the rural population. The steeply increasing cost of production and mismanagement of resources has resulted in the production of rice and wheat lagging behind the growth in demand. In order to enhance the productivity of cereal cropping, accelerating the adoption of innovative resource-conserving technologies (RCTs) by the farmers remains the only option. RCTs, being the key components of conservation agriculture (CA), are the best option to utilize all the resources effectively for food production. Elements of CA, *inter-alias*, include organic soil cover, improved on-farm water management, minimum tillage, direct seeding, retention of crop residues, and appropriate crop rotations, leading to sustained high yields with less risk of diseases and pest attack. It contributes to enhanced productivity and environmental conservation on a sustainable basis in the long run. RCTs such as improved irrigation through lined canals, laser-assisted land levelling, zero tillage in wheat, bed planting in wheat and use of the leaf colour chart (LCC) for N management in rice were evaluated in farmers' fields under an Asian Development Bank (ADB) funded project during 2005-08. The experiences gained during the introduction and promotion of RCTs and the resultant impact on crop productivity and farmers' income are also summarized.

Materials and Methods

The ADB-funded project (ReTA-6208) was launched in Pakistan in collaboration with the International Rice Research Institute (IRRI), Philippines, the International Maize and Wheat Improvement Center (CIMMYT) and the Rice-Wheat Consortium (RWC) during 2005-2008. The project aimed at reducing rural poverty and improving farmers' incomes and livelihoods by enhancing agricultural productivity and profitability through the adoption of resource conservation in the rice-wheat cropping system. Partners in Pakistan were the Pakistan Agriculture Research Council (PARC), On Farm Water Management of Punjab (OFWM), and local NGOs. The project area included a cluster of six villages of Tehsil Depalpur, Okara District, Punjab, with an extension of 1943 ha in total. Several interventions such as laser-assisted precision land levelling, zero-till drill seeded wheat (ZT-DSW), zero-till drill-seeding under surface mulch (ZT-DSW-Residue), double zero-till wheat and rice (DZT-DSW; DZT-DSR), bed planted wheat (BED-DSW), permanent bed planting (DBED-DSW), bed-planted wheat with intercropped sugarcane (BED-DSW-Sugar), conventional-till (puddled) transplanted rice (CT-TPR), conventional-till (puddled) transplanted rice with the use of the LCC for N management (CT-TPR-LCC), reduced-till drill seeded rice (RT-DSR), reduced-till drill seeded rice plus sesbania (RT-DSR-S), zero-till transplanted rice (ZT-TPR), zero-till drill seeded rice (ZT-DSR), bed planting—transplanted rice (BED-TPR), and bed planting—direct drill seeded rice (BED-DSR) were introduced and promoted among the farming community (Table 1). For technology diffusion, farmer-support services like soil/water testing, precision land levelling; establishment of a machinery pool and a village seed bank; water canal improvement; establishment of farmer-participatory research trials, farmer training and educational material were also provided.

Results and Discussion

The project activities over the three years resulted in the lining of all the 16 water canals in the project area (4362 m) which improved irrigation efficiency of 1210 ha by 40% and gave labor savings of 30%. Use of pure and quality seed supplied through the village seed bank increased wheat yield by 297 kg ha^{-1} during 2007. A total of 571 farmers benefited from laser-assisted precision land leveling (1943ha or 100% coverage), that improved seed germination (85-90% in levelled fields as compared to 65-70% in non-levelled fields); reduced irrigation water consumption by 20-30% and labor use by 30%; and increased grain yields of both rice and wheat crops. Zero-till technology in wheat was adopted on 1738 ha, leading to savings of 60 liters of diesel ha^{-1} and an increase in wheat yield of 300 kg ha^{-1} over the conventional practice. Zero-till technology also decreased the cost of cultivation by 30% and increased net income of farmers by US$115 ha^{-1} (Table 2). At the same time, soil quality, soil health and soil biological activity was increased. Bed planting of wheat saved energy and water use and increased wheat yield by 755 kg ha^{-1}. However, mean rice yield over three years (2005-2007) was highest in the traditional transplanted rice crop (3.9 Mg ha^{-1}); followed by transplanted rice on raised beds (3.6 Mg ha^{-1}), and reduced-till direct drill seeded rice (3.0 Mg ha^{-1}). Use of the LCC for need-based N management in rice improved the utilization of N fertilizer in transplanted rice crops; reducing the use of N by 15 to 20% and increased rice yields by 104 to 166 kg ha^{-1} (Table 3). As a consequence, farmers' net income increased due to use of LCC in rice. The educational campaign for technology awareness for farmer groups, extension personnel, policymakers, and national scientists was also carried out through field visits, farmers' field days, workshops, and traveling seminars during 2005-2007. Detailed accounts of these activities can be obtained from the ADB project web-site (www.rwc.cgiar.org/PROMIS/ADB). Promotion materials such as information brochures, calendars and posters on laser levelling, zero tillage, bed planting, crop residue management (turbo seeder and other seed drills), and LCC were distributed to farmers, and television programs and a documentary video were also prepared to spread the message of new technologies in place of conventional management practices for rice and wheat. The project implementation has generated an estimated additional income of 2.832 million US$ for the farming community of the project area over the period of 2005-2008. The impact of RCTs has been summarized in Table 4. The new RCTs increased the productivity of the R-W system and enhanced farmers' income and livelihood. It is therefore, recommended that the project activities may be extended to other areas of the country for transferring the benefits of the proven technologies to deprived farming communities.

Table 1. The number of participating farmers and area covered for each Resource Conservation Technology (RCT) in 2005-2008.

RCTs	No. of Farmers	Total area (ha)	Area of adoption (%)
Water canals lining 4362 m in 6 villages	-	1210	62.27
Laser land levelling	571	1943	100
Zero tillage of wheat	208	1738	89.44
Residue management wheat planted with turbo seeder	67	466	23.98
Double zero till of wheat	11	19	0.97
Bed planting of wheat	265	878	45.18
Leaf Colour Chart (LCC) for rice	279	396	20.38
Direct seeding of rice	36	74	3.80
Bed planting of rice	17	26	1.3
Permanent raised bed planting (rice-wheat)	6	11	0.57

Table 2. Impact of zero tillage on energy saving, yield increase and reduction of cultivation cost.

	Energy Saving			Yield		Cost Saving	Total Benefits
Area (ha)	Fuel saving (l ha^{-1})	Total fuel saving (l)	Value of fuel saving (US$)	Wheat yield increase (Mg ha^{-1})	Value of total increased yield (US$)	Saving in cost of cultivation ($)	(US $ million)
1738	60	104280	69,520	141	38,556	46,346	**0.154**

Note: 1 US$ = 75 Pak Rs.

Table 3. Impact of the use of Leaf Color Chart on saving of nitrogen and fertilizer cost in the project area.

Year	No. of farmers	Area (ha)	Farmers' applied N/ ha		Saving on fertilizer cost (US$)	Yield increase (Kg/ha)
			Without LCC (Kg)*	With LCC (Kg)		
2005-06	85	104	12,896	10317	449	104
2006-07	121	166	20,916	16732	728	128
2007-08	158	230	28,980	23,184	1008	166

*Standard practice (N 126 kg/ ha)

Table 4. Farmers' cumulative monetary gains (in US $) as a result of adoption of resource conservation technologies (RCTs) during 2005-2008.

Laser Land levelling (1943 ha)	Water canal lining (4362 m)	Bed planting (878 ha)	Leaf Colour Chart (LCC) (396 ha)	Zero tillage (1738 ha)	Crop residue management wheat planter with turbo Seeder (466 ha)
$1.999	$0.2623	$0.09257	$0.3916	$0.1544	$0.008

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Integrating economics, technology networks, soils and gender to remove constraints to Conservation Agriculture in the developing world

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Introduction

The Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP) is sponsored by the U.S. Agency for International Development's Bureau of Food Security, participating U.S. universities, and host country institutions around the world. Our research engages stakeholders at all levels to develop sustainable, localized farming practices. The multi-country program is comparative, with research identifying common elements that affect conservation agriculture adoption. The research theme of SANREM CRSP's current phase is to develop conservation agriculture production systems (CAPS) aimed at increasing smallholders' agricultural productivity and food security through improved cropping systems. In addition to increasing food security, CAPS will contribute to and take advantage of improved soil quality and fertility. Farming systems with CAPS will maintain a year-round soil cover, minimize soil disturbance from tillage, and utilize crop rotation systems. The majority of SANREM CRSP research is conducted through long-term research award (LTRA) activities. Currently, there are seven projects developing CAPS in 13 countries across Africa, Asia, and Latin America. Each LTRA collaborates with and contributes to four cross-cutting research activities (CCRAs): economic and impact analysis; gendered knowledge; technology networks; and soil quality and carbon sequestration. In contrast to the in-depth, locally adapted LTRA research, the purpose of the CCRAs is to collect and analyze findings across LTRA sites for global application. The CCRAs are designed to elicit and organize common elements that will help generalize and expand findings to a wider range of sites and circumstances. To obtain reliable and valid comparability across LTRA sites, a balance is required between standardization of methodology and the flexibility to adjust for site and activity specifics. A standardized research protocol developed by the each CCRA in collaboration with the LTRAs is integrated with LTRA activities. To the extent possible, data needs for the various CCRAs are met through LTRA data collection activities.

Economic and Impact Analysis

This project is developing an economic model that will serve as a template for economic impact analyses of SANREM CRSP Phase IV regional projects as well as future SANREM CRSP regional programs. The economic challenges to CAPS adoption are among the most formidable obstacles that will confront LTRAs and their collaborating host country partners. While the benefits to participating smallholder farmers are short-term time savings and long-term increases in crop yields, income, and food security, there are also substantial short-term costs of adoption such as: applications of herbicides, soil amendments, specialized equipment, and risk and uncertainty associated with new, intensified management systems. Additional benefits, such as ecosystem services, accrue over time to the broader society. However, the CAPS farmers who produce these benefits may not be compensated for their efforts. The relative importance, magnitude, and distribution of benefits and costs will likely vary widely over the geographical distribution of production systems covered by the LTRAs. However, in order for wide-scale adoption and impact to occur in any region, the fundamental economic research problem remains the same. This CCRA collaborates and assists the LTRAs in developing a common baseline and methodology for addressing this general question. Later, as relevant LTRA data become available, plans call for the analysis to be expanded to the higher level landscapes and a more comprehensive economic impact assessment of CAPS. It is expected that the resulting comparative analysis across LTRAs will provide significant insight into general strategies that promote wide-scale adoption of CAPS. The main objectives of this project are to: 1. Identify the costs and benefits of CAPS in cropping systems/practices and related animal and forestry sub-systems, 2. Identify optimal CAPS and the sequencing of CAPS elements for each cropping system being researched, 3. Identify broader economic and social impacts of wide-scale CAPS adoption, and 4. Identify any policy changes required to enhance CAPS adoption in each crop system.

Gendered Perspectives

The Gendered Perspectives for Conservation Agriculture CCRA is a participatory research effort that addresses gender-related factors contributing to the success or failure of CAPS. Understanding local knowledge, beliefs, and perceptions of soils—both women and men's—is one of several essential components for potential adoption of CAPS. Socio-economic factors such as increased labor requirements—especially for women—are among the critical constraints to adoption of CAPS. Women possess specialized agricultural knowledge in areas such as soil quality and crop-livestock management which may differ from that of men's based on their practices, access to and control of assets, and other factors; this may provide incentives (or disincentives) for women's participation in CAPS. Women's participation in the development and evaluation of proposed CAPS is necessary because this will involve a reallocation of their resources including time and labor. Interactions among households, livestock, and soils in terms of biomass allocation present competition and integration opportunities for CAPS. For example, dung may be used for fertilizer, but also as fuel for cooking. Crop residue may be left to improve soil quality, but may also be used as feed. The decision over resource allocation may have significant gender dimensions given that animals are often among women's few agricultural assets. Leaving crop residue on the field may limit animal feed and fattening – adversely affecting women's interests and wellbeing – and put livestock needs in conflict with conservation practices. Such possible gender-based constraints may also provide opportunities for increasing gender equity, such as engaging women to plant cover crops, or supplying animal dung to increase soil fertility. Research will draw comparisons between local knowledge and participatory techniques on the one hand and scientific and technical methodologies on the other. This CCRA explores three questions: 1. What are men and women's local soil knowledge, beliefs, and perceptions; soil management practices; and access to agricultural resources, including land, information, and soil inputs? 2. What are the gendered landscapes linked to knowledge, beliefs, and perceptions of soil quality and soil management practices? 3. What is the gendered nature of access to and control over animals and animal by-products in context of crop-livestock interaction? The Gender CCRA employs a series of qualitative research techniques: community level focus group discussions and activities to map community soils; household visits to carry out the same activities at the farm level; transect walks, and participant observation of farming practices. Farmers will identify and describe different soils, including their "best" and "worst" soils, at the community and farm level; soil samples will be collected and analyzed in collaboration with the Soils CCRA. Descriptors of soils will be compared with lab results and examined for gender differences. It is expected that women will more often use descriptors related to soil fertility while men will describe soil more in terms of physical properties. In addition, after farmers identify soil types on their land through hand-drawn maps;

plots will be mapped using GPS. Sources of knowledge, beliefs and perceptions of soil quality will be explored and analyzed in conjunction with the Technology Networks CCRA. From 2009 to 2010, focus group activities, including soil interpretation were conducted in Mali, Ghana, Uganda, Ecuador, Kenya, and Philippines. Fieldwork begins in Bolivia and the Philippines in 2011, and Nepal in 2012.

Technology Networks

The goal of the SANREM CRSP Technology Networks cross-cutting research activity is to determine factors facilitating innovation and scaling out of conservation agriculture production systems (CAPS) for smallholders. Comparing technology network findings across LTRA research sites will reveal characteristics of the structure and functioning of agricultural networks that enable system level problem solving for successful smallholder CAPS development. We argue that technological change leading to sustained adoption of smallholder CAPS involves more than just the introduction of CA practices by a transforming agent (extension/NGO) but also the building of shared understandings and supportive relationships with other partners in the community and agricultural service sector. Critical to these shared understandings is a shift toward conservation agriculture knowledge and attitudes and away from conventional and risk-averse agricultural production perspectives. Our study focuses on three objectives: 1. Identifying the knowledge and attitudes (technological frames) concerning agricultural production practices held by actors in the network; 2. Describing the structure of information and physical resources flows between these actors; and 3. Determining critical network pathways and opinion leaders facilitating technological change among farmers and their service sector partners. This cross-cutting research is designed to piggyback on LTRA baseline and follow-up surveys planned for years 1 and 4. Two target groups (farm households; and agriculture service sector and community actors) need to be surveyed to obtain a minimum network analysis dataset at each site. While this research applies standard quantitative data collection and analysis techniques, the overall design involves a comparison of network case studies from each of the LTRA sites. Within site comparisons of network parameters before and after the initiation of LTRA field research will provide the foundation for site level hypothesis testing. Cross site comparisons of network case studies will allow for assessing the differential impact of each site's network structure and functioning. Two sets of hypotheses will be explored in order to achieve study objectives. The first set tests the relationship between technological frames and agricultural practices. The second set addresses network relationships directly, testing them from the perspective of service sector actors, farmers, and the network as a whole.

Soil Quality and Carbon Sequestration

The overarching goal of this CCRA is to determine if dryland smallholders in the developing world can increase soil organic carbon (SOC), and hence soil fertility, by adoption of conservation agriculture (CA). We know that CA increases SOC under mechanized agriculture in the developed world, but it is unclear if such increases are feasible in the developing world for smallholders growing staple crops. There is also an interest to determine the potential for carbon sequestration in these systems, which may potentially lead to payments under carbon trading schemes.

Coordination of soil and agronomic investigations among all 13 developing countries before and after conservation agricultural production systems (CAPS) are implemented is critical to measuring soil fertility and carbon sequestration changes due to CAPS. We are coordinating all long term research activities' (LTRA) data collection so that we can make meaningful and scientifically verifiable comparisons across all project sites. Our specific objectives are to: 1. Quantify SOC in host country project sites before and after CAPS implementation, 2. Identify CAPS cropping systems or biophysical elements that improve soil fertility, and 3. Relate increased soil fertility to site-specific socioeconomic environments. We are building a soils library from all project countries at 0-5 and 5-10 cm depths from researcher-managed sites. These samples will be analyzed for include pH, CEC, total organic C (TOC), total N, extractable P, K, Ca, Mg, Zn, Cu, B, Mn, and Fe. Since we may not find differences in TOC over the short term (<5 yrs), we will fractional TOC into labile and recalcitrant fractions using size-based and density-based fractionation procedures.

We also facilitate LTRAs and host-country partners to build capacity regarding biophysical data collection from CA plots vs. current practice controls.

Candidate plants to help soil pest control in Conservation Agriculture: potential effects of 21 species used as cover crops in Madagascar

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Keywords: upland rice, cropping systems, nematode

Introduction

Cover crops are one of the pillars of conservation agriculture (CA). Used in association or rotation with the main crops, they contribute to insure functions such as : reduced runoff, erosion, and weed pressure; soil structure and fertility improvement; forage production [32]. Alongside these beneficial effects, cover crops may also contribute to crop pest and disease control [27]. In Madagascar 21 cover crop species are used in upland rice based CA cropping systems (Table 1). These cover crops were selected mainly according to their capacity to fulfil the functions cited above. The reduction of pest impact was not considered, although pests such as "white grubs" and "black beetles" (Col., *Scarabaeidae*) are major constraints in conventional and CA upland cropping systems in the Madagascan highlands [26, 28]. A literature review was therefore conducted to assess the potential use of these 21 cover crops to reduce the impact of pests on cropping systems.

Materials and Methods

The review analysed 38 scientific sources from the ScienceDirect®database and CIRAD library. The mechanisms of action of the plants were reported following the typology of effects proposed by Ratnadass et al [27], namely: (A) temporal pest/pathogen cycle disruption via non-host effects; (B) resource concentration/dilution and spatial disruption of pest dynamics/pathogen epidemics; (C) pest deterrence or repellence; (D) pest stimulation or attraction; (E) below-ground allelopathic effects; (F) stimulation of soil pest-pathogen antagonists; (G) crop physiological resistance via improved nutrition; (H) effects via provision of alternative food to natural enemies of crop pests; (I) effects via provision of refuges/shelters for predators due to vegetative structural/architectural characteristics; (J) effects via microclimate alteration; (K) physical barrier effects.

Results and Discussion

Only one article reports effects of a plant on a black beetle: *Trifolium repens* on *Heteronychus arator* [17]. Some articles report effects on various insects [4, 8, 9, 11, 14-16, 19, 21 , 30, 36] while most of the references document effects of plants on nematodes (Table 1). It was therefore concluded that in view of the high endemism in Madagascar and the lack of references on the potential effects of plants on pests in the Malagasy context, these effects should be tested locally. The selection of plants can focus on plants reported elsewhere as the most effective against nematodes, which may be indicative of the production of biocide molecules with a broader spectrum. Very few studies have been conducted on nematodes in Madagascar[37]. Studies require specific knowledge and thus, the effects of plants on nematodes are largely underestimated when evaluating the cropping systems. Thus, much remains to be done to precisely assess the effects of cover crops on soil macrofauna in general, and more specifically on pests. Such work is needed for better design and evaluation of new CA cropping systems. Up to now, the effects of cover crops on pests have been underestimated as compared to more visible effects such as weeds and erosion control [32], and the ability of cover crops to reduce pest incidence is still underused.

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Table 1. Inventory of actions of 21cover crops used in Madagascar on crops pests, references from literature**.** Effective part of plant : R : roots; S : shoot/stem; L : leaves; MD: missing data, i.e. unknown. Mechanisms : A, B, C, D, E, F ,G, H, J, K (see Materials and Methods)

Cover crop Familly -Specie	Pest targeted Type	Name	Effective part of the plant	Mechanisms	References
Fabaceae					
Arachis pintoï, A. repens	Nematoda	*Pratylenchus loosi, Meloidogyne incognita, Meloidogyne paranaensis, Roylenchus reniformis*	MD	Unknown	[20]
	Insecta	*Diaprepes abbreviatus*	S, L	K	[19]
	Insecta	*Cyrtomenus bergi*	S, L	A	[30]
Cajanus cajan	Nematoda	*M. incognita , Meloidogyne javanica, R. reniformis, Heterodera cajani, Pratylenchus zeae, Pratylenchus sudanensis.*	R	A	[20 , 29, 33 , 34 , 36]
	Insecta	*Spodoptera exigua*	MD	Unknown	[36]
Crotalaria grahamiana, C. spectabilis, C. juncea	Nematoda	*M. incognita, Meloidogyne arenaria, Meloidogyne javanica, R. reniformis, Pratylenchus brachyurus, P. zeae, Pratylenchus. coffeae, Radopholus similis*	R, L	A, E, F, G	[20, 22, 29, 38]
Desmodium uncinatum	Nematoda	*Hoplolaiminae genera, Meloidogyne spp.*	MD	Unknown	[20]
	Insecta	*Busseola fusca, Chilo partellus*	S, L	C, G,	[14-16]
Mucuna pruriens	Nematoda	*Belonolaimus longicaudatus, Paratrichodorus minor, Criconemella ssp., Scutellonema ssp., Heterodera glycines, Tylenchorhynchus claytoni, M. incognita, M. javanica, P. brachyurus, Ditylenchus sp, Aphelenchoides sp, Aphelenchus avena, Tylenchus sp , R. reniformis*	R, L	E, F, J	[3 , 25]
V. unguiculata	Nematoda	*M. incognita, M. javanica, M. arenaria*	R	A, E	[22 , 29]
	Insecta	*C. partellus, Chilo orichalcociliellus, Sesamia calamistis*	S, L	A, G, K	[35]
Vicia villosa	Insecta	*Delia radicum, Plutella xylostella*	S, L	Unknown	[8, 21]
	Nematoda	*M. arenaria, Meloidogyne artiellia*	R	A	[10, 24]
Stylosanthes guianensis	Nematoda	*M. incognita, M. javanica, P. brachyurus*	R	A	[20 , 29]
Trifolium semipilosum, T. repens	Nematoda	*Meloidogyne trifoliophila*	R	A	[2 , 23]
	Insecta	*Heteronychus arator*	R	C	[17]
Graminae					
Avena sativa	Nematoda	*Meloidogyne spp.*	R, S, L	B	[29]
	Insecta	*Tetanops myopaeformis*	S, L	H, K	[9]
	Acarina	*Oligonychus punicae, Scirtothrips citri*	S, L	D	[4]
Brachiaria ruziziensis, B. brizantha, B. humidicola.	Nematoda	*M. incognita, M. javanica*	MD	Unknown	[7 , 29]
Cynodon dactylon	Nematoda	*M. incognita*	MD	A	[12]
	Insecta	*Spodoptera frugiperda*	MD	Unknown	[11]
Eleusine coracana	Nematoda	*R. reniformis*	R	A	[1]
Lolium multiflorum	Nematoda	*R. reniformis*	MD	Unknown	[13]
	Insecta	*L. phyllopus*	MD	Unknown	[4]
Brassicaceae					
Raphanus sativus	Nematoda	*Heterodera schachtii, M. incognita, Meloidogyne halpa, R. reniformis, Trichodorus sp., Pratylenchus sp.*	R	A, E	[5 , 6, 18 , 29 , 31]

No-till practices in the drought and salt-affected region of Uzbekistan

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Key words: conservation agriculture, mulching, crop residue

Introduction

On achieving independence, Uzbekistan laid major emphasis on agricultural growth and efforts towards developing its own market economy. During this transition, large inefficient shirkat farms were dissolved and a number of small private farms established. For development of these new farms there are constraints associated with limited potential and abilities in crop, soil fertility and on-farm water management. During this period, new challenges of crop diversification, salinity, land privatization, etc. have emerged. There is an urgent need to pilot changes in irrigation and agricultural practices in the region in order to address the issue of declining water availability - this is a high priority for the Governments of Uzbekistan and the Autonomous Republic of Karakalpakistan. Climatically, Uzbekistan and the Karakalpakstan are part of the dry mid-latitude desert characterized by hot summers and cold winters. Conservation Agriculture is particularly useful in dry areas, where low rainfall is the main constraint to growing crops, and it may help farmers to switch to more productive methods. The use of CA enables the soil to store more of the precipitation that falls during the fallow period, so farmers can consider more intensive crop rotations.

Materials and Methods

This experiment was conducted at the two demonstrations farms of Chimbay district, Autonomus Republic of Karakalpakistan, Uzbekistan. High-sensitivity GPS receiver eTrex Vista®HCx used to obtain GPS coordinates of the research site and the coordinates are 42058`19.71`` N and 59050`38.30``. The irrigated areas of the experimental site are considered to be of slightly saline soil and the value of soil salinity fluctuates from 0.199% to 0.637%. The content of Cl ranges from 0.03 to 0,065%, which is close to the maximum allowable concentration (0.04%) for these conditions. Biological activity of the soil is one of the main characteristics to be assessed for soil fertility. The method of Mishustin, Nikitin, and Vostrovs (1969) was used to assess soil fertility and to determine the soil biological activity. Fresh cleared soil profile was pressed against the flat emulsified side of photo paper and backfilled with the cleared soil to reflect its normal position. The extracted photo paper was then washed to remove any potential contaminants and dried in the shade. The experiment was laid out in a randomized complete block design. Field observations were recorded on plant height, spike length, grains per spike, and. The data was statistically analyzed and means were compared using LSD test.

Results and Discussion

The increased soil organic matter levels improve the availability of water to plants. One/percent of organic matter in the soil profile can potentially water at a rate of 150 m3 ha^{-1}. Permanent soil cover and the avoidance of mechanical soil tillage reduce water evaporation. As a direct result, water use efficiency is increased and the water requirements for a crop can be reduced by 30%, regardless of whether a crop is grown under irrigation or rainfed conditions (Bot and Benites 2005).

The influence of crop residue on soil humidity and density in the upper layer of the ground were studied (Table 1). Results indicated that the crop residue increased soil moisture by 3.2% and decreased bulk density by 0.1 g/cm3 in the soil upper layer. Obviously, bulk density decreased due to better development of secondary roots which are located in the upper layer of the soil.

Table 1. Influence of crop residue on soil moisture and bulk density 2005-2007

Field number	Soil depth (cm)	Moisture, %		Bulk density, g/cm^3	
		Residue	No residue	Residue	No residue
7	0-10	12,2	9,7	1,49	1,60
8	0-10	10,6	6,8	1,56	1,60
Average	0-10	11,4	8,2	1,50	1,60

The protease activity of the soil was found higher in the soil with crop residue than without crop residue (Photos 1 and 2). Plant residue positively influences the soil quality, decreases soil density; increases soil moisture (Andrew S.S., 2004; Wilhelm, W.W.,2004; Nurbekov et al 2009) and increases biological (protease) activity of the soil (Nurbekov et al 2008). That is why, preservation of crop residues, straw chopping and tossing the straw on the surface of the field with appropriate machines such as harvester combines can improve physiological and biological properties of the soil, which significantly increases the soil fertility (Nurbekov 2008).

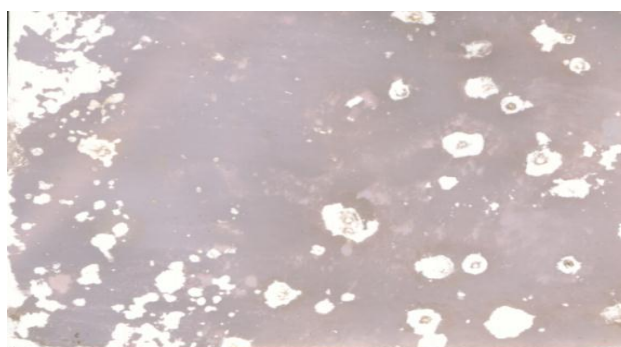Photo 1 Protease activity of soil   without crop residue

Photo 2 Protease activity of soil   with plant residue

Soil mulching is a technique where the soil surface is covered with materials in order to conserve water, prevent soil salinity, smother weeds, etc. In this experiment, different rates of manure as mulching materials (10 t/ha, 15 t/ha, 20 t/ha), also mungbean and sorghum straw were applied. Wheat yield in treatments with manure application was 0.6-0.7 t/ha higher than in control plots, which was 1.63 t/ha.

Studies have shown that the application of manure results in significant increases in grain and straw yield of wheat. The significant effect was also noticed on such yield contributing characters like spike length and number of grains per spike. The increase of manure level from 10 t/ha to 20 t/ha also brought a significant increase in yield and yield contributing characters (Table 2). The application of mulch or mungbean and sorghum resulted in significantly higher content of soil moisture in 0–15 cm soil depth as compared to the control which was simultaneously reflected in yield and yield contributing characters.

Table 2. Organic manure, humus content, agronomic traits and winter wheat yield (2005-2007)

Treatment	Plant height, cm	Spike length, cm	Grains per spike	Yield, t/ha	Yield increase, t/ha
Manure, 10 t/ha	52,1	7.15	32,5	2,24	0,61
Manure, 15 t/ha	56,8	7,4	33,2	2,31	0,68
Manure, 20 t/ha	62,6	9,2	35,5	2,49	0,86
Residue of mungbean, 10 t/ha	52,5	6,8	27,4	1,85	0,22
Residue of sorghum, 10 t/ha	48,8	6,4	24,0	1,59	-
Control	47,1	6,2	24,6	1,63	-

LSD_{05}-0.36 t/ha; Sx%-6.6

As indicated before, one the main principles inherent in CA practices is maintenance of crop residue in the field with stubble stems and chopped straw. Consequently, the salts will not be accumulated in upper layer of the soil due to decreased evaporation. Mulching with sorghum, mungbean crop residues or with organic manure decreased the dry salt contents in 0-10 cm soil layer (Table 3). Soil mulching with plant residue and manure decreased the salt content in 0-10 cm soil layer by between 1.6 and 4 times.

Table 3. Dry salt content as affected by mulching

Treatment	% from air-dry mass of the soil
Control (no mulching)	0.80
Manure	0.25
Mung bean crop residue	0.50
Sorghum crop residue	0.20

Conclusions

The soil densities for both tillage systems were very similar and were suitable for good crop growth. The soil strength measurements were all low enough and within range for excellent crop growth.

A study on the protease activity of the soil has shown that activity of the soil with crop residue was higher than in without crop residues

Taking into account the slow decomposition of organic manure and crop residue it is too early to make general conclusions but nevertheless the results obtained are encouraging. The humus content increased significantly but the effect of organic manure and crop residue on soil fertility requires further investigations.

This is the first step towards Conservation Agriculture adoption and successful implementation. There are many efforts ahead needed to ensure further success of Conservation Agriculture, including training of farmers and specialist, and providing supports to improve the supply of necessary equipment and resources.

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Adapting Conservation Agriculture for smallholder farmers: potential of cassava (*Manihot esculenta*) in Zambia

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Introduction

Crop productivity among smallholder Zambian farmers is said to be low due to poor and unsustainable farming systems (Kabamba and Muimba-Kankolongo 2009). The low productivity has contributed to chronic household food insecurity as most households run out of food before the next harvest. Conservation Agriculture (CA) is therefore being promoted in order to address this problem. Although CA is premised on the three general principles of minimum mechanical soil disturbance, organic mulch cover from residues and cover crops, and crop species diversification through rotations and associations (Kassam and Friedrich 2010), variability in production environments leads to the need for a corresponding diversity of CA practices (FAO 2011). CA has to contribute to the improvement of both livelihoods of smallholder farmers and environmental regeneration. The CA model in Zambia combines annual cropping systems with agro-forestry and perennial crops. Cassava (*Manihot esculenta*) is a perennial drought resistant crop that performs well on low fertility soils (Fasinmirin and Reichert 2011), is self propagating, and an available food source during the annual hunger period that characterizes most smallholder households in Zambia (CFU 2006). Cassava has been included in the CA package by the Conservation Farming Unit (CFU), a Non-Governmental Organization (NGO) that has been promoting CA in Zambia since its establishment in 1995. As part of its Conservation Agriculture Programme (CAP) which has been implemented in 12 districts, CFU has been distributing cassava cuttings to all its group farmers through a lead farmer extension model. Each household is given 400 cassava cuttings, enough to plant 0.04 hectares at a density of 1 m x 1m.

We analyzed data from a sample of 640 households collected annually over a period of four farming seasons (2006/7-2009/10). We examined the adoption trends of cassava and associated challenges. We tested the hypothesis that the practice of CA was contributing to household food security by increasing the growing of cassava in areas where it was hitherto not traditionally grown. The assertion that integration of cassava in CA helps to mitigate household food insecurity during extreme climate change events (floods in our case) was also examined.

Materials and Methods

The study was carried out between August 2007 and September 2010. The households interviewed were randomly selected from adopters list kept by CFU. Data were collected through questionnaire survey, and focus group discussions. Area under cassava was used both as an indicator of adoption and indicator of intensity of adoption. Three provinces, Southern, Central and Eastern Provinces, were selected as study areas based on current efforts in the promotion of CA. The population is comprised mainly of smallholder farmers who grow crops for home consumption and for sale. Most important crop grown is maize (*Zea mays*), the country's main staple crop. Other crops grown are cotton (*Gossypium hirsutum*), soybeans (*Glycine max*), cowpeas (*Vigna unguiculata*), groundnuts (*Arachis hypogaea*), sorghum (*Sorghum bicolor*), sweet potatoes (*Ipomoea batatas*), and cassava (*Manihot esculenta).*

Results and Discussion

Results show a significant increase from baseline (2006/7) to 2009/10 season in the proportion of farmers adopting cassava. The percentage of households that had planted cassava increased from 3.9% during the 2006/7 farming season (commencement of CAP implementation) to 30% during the 2009/10 farming season. Percentage of households that harvested cassava was only 2.7% in 2006/7 but increased to 11% over a period of three seasons (Table 1). The amount of cassava harvested followed a similar trend with the average of 166.7kg per household in 2006/7 increasing to 463.3 kg during the 2009/10 farming season. Average area planted to cassava per household rose from 0.01 ha in 2006/7 season to 0.05 ha during the 2009/10 season. These increases were attributed to CA promotion and the distribution of cassava cuttings by CFU and other NGOs and attendance of training sessions on CA by members of the sampled households. The slight reduction in the percentage of households that planted cassava and in the average area that each household planted during the 2008/9 season was attributed to failure to access the cuttings. Farmers also pointed out challenges of termite attack and low survival rates of the cassava cuttings. These problems were commonly found in the so called "Elite" or new varieties of cassava. Although cassava has been promoted as a drought resistant crop, its performance did not seem to be adversely affected during seasons of above normal rainfall (Table 2). The floods experienced during the 2006/7 season did not affect yields. Flooding incidences of 2007/8 season significantly reduced maize yields while cassava yields increased despite the floods. With the predicted increase in climatic variability in the study areas, with expected increases in both drought and flooding incidences, cassava will become an increasingly important safety net crop in instances of poor maize yields. The increased production of cassava by CA farmers could go a long way in helping households during the traditional hunger period when their food stocks are low as they wait for the following season's harvest (Figure 1). It could also enable households to store their maize harvests to be sold during the rainy season when cereal prices are at their peak. There is need to increase farmers' access to cassava cuttings to boost their production even further. One option could be the development of local supply chains so that farmers could have timely access to locally adapted varieties.

Table 3. Cassava adoption and production

Season	2006/7	2007/8	2008/9	2009/10
Farmers area under cassava (%)	3.9*	8.4	5.4	30.4*
Farmers that harvested (%)	2.7	2.3	2.1	11.0
Amount harvested (Kg)	169.4*	390.9	698.9	460.9*
Average area (ha)	0.01*	0.03	0.02	0.05*
Sample size (n)	639	535	484	424

*Significantly different at 0.001 level, *

Table 4. Comparison of crop production during a normal season and season with floods

Season	2006/7	2007/8	2008/9
Crop Yield (kg)			
Cassava	169.4	390.9	698.9
Maize	3838.4	1827.0	2413
Rainfall (mm)	1046	1087	859
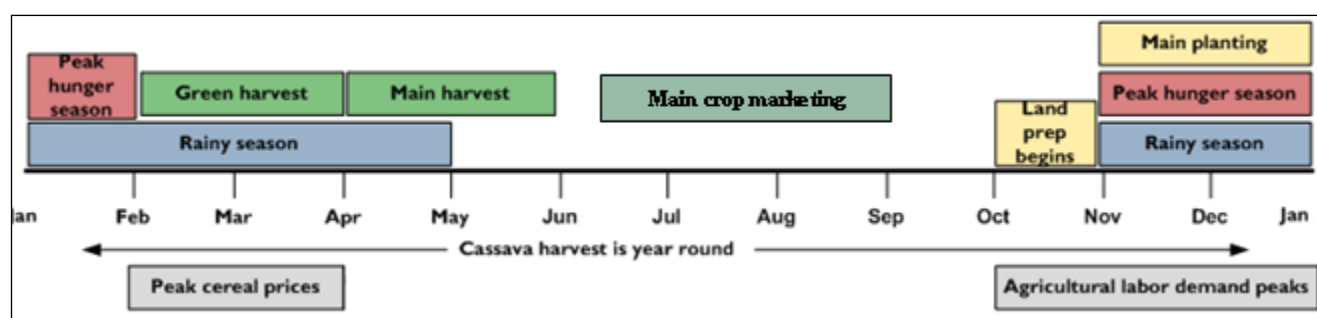
Figure 15: Potential of cassava in food security adapted from FEWS NET 2011

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Conservation Agriculture in the Russian Federation

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Keywords Russia, resource saving technologies, cereal production, cereal export, precision agriculture.

Present level of Grain Production in Russia

Under good weather conditions of 2008, Russia produced 108 million tonnes cereals from 44 million hectares with an average yield of 2.4 t/ha. Under extreme droughts of 2009 and 2010, it produced 90 and 62 million tonnes cereals, respectively. The average yield of cereals in the Russian Federation is 2.0 t/ha compared to an average of only 1.35 t/ha at the end of Soviet Union. With lot of unused fertile land and better scope of improved management, the Russian Federation can become a leading grain producer in the world. Agriculture is facing the problems associated with poor market infrastructure, lack of adequate storage facilities, inefficient transport system, persistent decline in rural population, limited export facilities and lack of credit or financial mechanisms. Lack of technical manpower including the agricultural labour force, lack of policies to reduce risk or support technologies against droughts, erosion and degradation of agricultural lands caused by conventional production technologies like fallow land etc, and lack of policies for good quality seed and genetically modified crops are some of the technical constraints that need to be overcome to enhance productivity.

Successful transition towards above technologies would also need policy intervention towards modern seed, glyphosate-resistant crops, marketing and making Russian produce more competitive in the world market.

Forecast of middle term level of grain production in Russia (2020)

In order to achieve the productivity growth rate of 2% per year, the role of farm management practices (like precision farming, field monitoring for input use and soil quality, monitoring of quality of inputs and the use of new information technologies) is necessary. Appropriate machinery to adopt resources (labour, energy and cost-saving technologies) and technologies that help increase organic matter in the soil should also be promoted.

Estimation of long term level of grain production in Russia (2050)

Assuming a modest annual productivity growth of 1.25 % over the following 40 years, the average yield of cereals could amount to 3.8 t/ha in 2050. If the abandoned land is brought under cultivation, Russia could produce 150 million tons of cereals from 60 million hectare by 2020, and 300 million tons from 80 million hectare by 2050. If the Russian population remains stable, the demand for cereals as food will be around 35 million tons. The demand for feed could increase from 50 million tons in 2020 to 80 million tons in 2050. Under the above assumptions, 65 million tons of grain would be available for export or biofuels in 2020 and 185 million tons in 2050. It should be noted, however that under favourable condition these production level could well be reached in 2030.

Present and future use of CA in Russia

According to 2010 estimates of the Ministry of Agriculture, the Russian Federation at present has 15.0 million hectare under conservation agriculture (CA). Based on the sale figures of seeders from 2005 to 2009, the National Movement for Conservation Agriculture (NMCA, www.nmoca.ru) also confirms this area under CA. Out of this area, no-till based seeding accounts for 4.5 million hectare while precision farming technologies are covering 2.0 million hectares. NMCA further estimated that in the year 2020, resource saving technologies will cover an area of 40 million hectares out of an estimated area of 60 million hectares under cereal crops. The corresponding figures for no-till and precision farming technology are estimated to cover 10 and 20 million hectares, respectively. Further estimates indicate that out of an estimated area of 80 million hectares by 2050, the area under CA will be 60 million hectares and under no-till technologies it will be 40 million hectares

Activities of the National Movement for Conservation Agriculture (NMCA)

The NMCA provides the information and educational activities for facilitating the adoption of resource saving technologies under ecological and climatic conditions of Russia. We are also working with Russian research centres and universities and the leading foreign public and scientific organizations. The movement at its own expense publishes scientific papers, brochures, monographs and popular science books of leading Russian and foreign experts on conservation technologies in agriculture.

With a view to sharing knowledge about the latest innovative technologies, the movement has conducted over 15 seminars and conferences on precision farming. It helps bringing together both experienced professionals and experts in the field of precision agriculture and those who are going to apply these technologies on their farms. NMCA publishes one magazine "Resource Saving Agriculture", which is devoted to resource saving technologies and technologies for precision farming. With circulation of 5000 copies in every three months, it plays an important role in the spread of

Creating Innovation Centres for Conservation Agriculture

In order to intensify research in resource saving technologies, precision farming and irrigation efficiency, NMCA created a knowledge base of all such technologies. The work on best CA-based foreign and domestic agriculture contains publications of scientists from Europe and America including various presentations in FAO and UN sponsored activities/ reports. NMCA has also introduced important projects aiming at modernization of agribusiness. The Innovative Centres of Resource Saving Technologies have also been created on the initiative of NMCA.

These centres will help increasing the productivity growth in agriculture by means of sustainable agricultural practices on CA. These practices will further help check the soil degradation and improve the soil fertility. Other components of agriculture growth like competitiveness of agriculture products and economic efficiency will also be covered by such centres. On the whole, these centres will promote CA based on the local soil and climatic conditions. The work will involve scientific investigation, testing of technologies, generating information and conducting demonstrations.

At the moment, at our initiative, three Innovation centres on Conservation Agriculture have been established. They are based on the Orenburg State University, RGAU-MSHA Timiryazev and VGOU VPO Samara State Agricultural Academy. Today, the Innovation Centres have become a scientific and practical agricultural institution for CA in Russia.
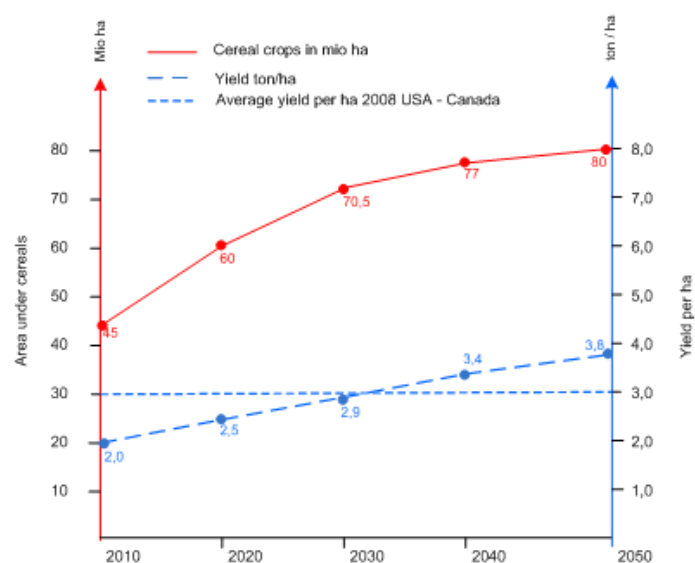
Figure 1. Estimation of the Development of Cereals Production in the Russian Federation 2010 - 2050
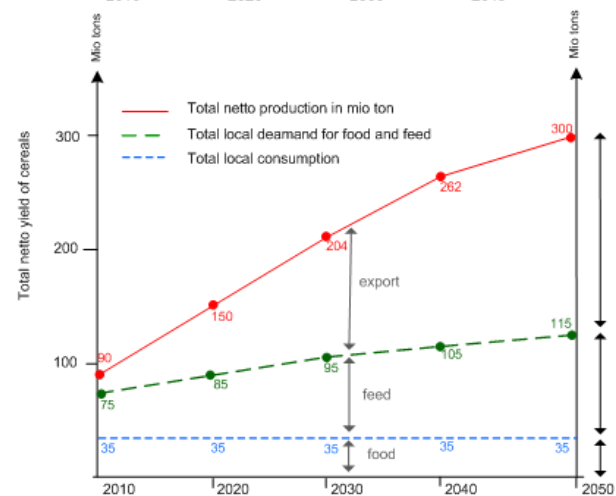
Figure 2. Export Potential of Cereals of the Russian Federation 2010 – 2050
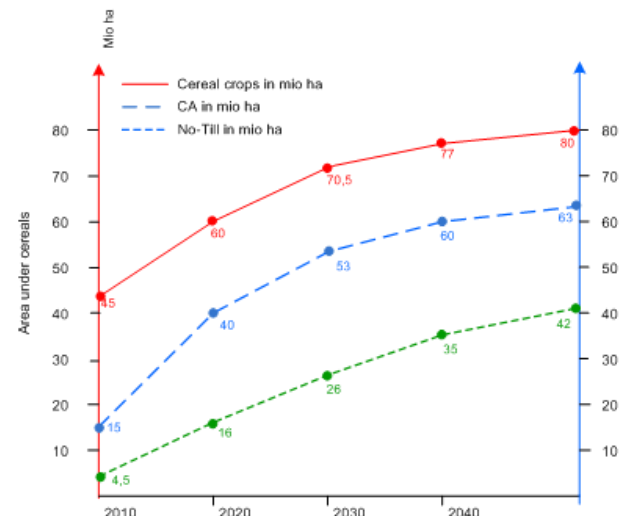
Figure 3. Estimation of the Area under CA and No-Till in the Russian Federation 2010 - 2050

Table 1: Seeders sold in Russia 2005 - 2009

Year	Total	CA technology	% of total
2005	13109	2309	17
2006	11022	2758	25
2007	11712	2954	25
2008	12707	3727	29
2009	5184	2443	47
	53734	**14187**	**26**

Conservation tillage, residues management and cropping systems effects on carbon sequestration and soil biodiversity in a semi-arid environment of India

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Key words: Conservation tillage, carbon sequestration, microbial biomass, diversity, soil enzymes, metabolic functionality

Introduction

Conservation agriculture is a major focus in the Indian agriculture in order to sustain the quality of natural resources and to meet the challenges of ever increasing demands for food, fodder and fuel of the country. One of the most important principles of conservation agriculture is minimal soil disturbance. Several workers (Gupta et al 2002, 2005) have reported positive effects on soil health and environmental quality of no-till system in India. It is also documented that conservation agriculture has potential to sequester C in the soils because it enhances *in-situ* recycling of crop residues, which not only reduces the loss of N, P, K and S but also reduces emission of green house gases and destruction of beneficial micro-flora and fauna of soil. Along with conservation agriculture, crop diversification proved to be of paramount importance in mitigating the environmental problems arising on account of monoculture. Inclusion of certain crops in the sequence has been found to reduce weeds; reducing nitrate leaching and increased fertilizer use efficiency. But what role the crop species play under the conservation tillage, particularly on biological properties of soil is largely unknown. Therefore, to establish the benefits and develop recommendations, there is a need of research at the field/ecosystem scales. The objective of this study was to assess the pattern of C and N sequestrations, and different biochemical and biodiversity indicators in soils under maize-based cropping systems under conservation agriculture.

Materials and Methods

Four different maize–(wheat/chickpea/mustard/linseed)–greengram rotations under conventional or no-tillage with or without residues treatments at the Indian Agricultural Research Institute Research farm, New Delhi (longitude 77°12'E, latitude 28°38'N, and altitude 239 m above mean sea level) were selected (*see* Plates 1 to 4 in the next page). Soil samples of these systems were studied in the winter season of 3rd year of the experiment (2007-2008). The climate of the region is subtropical, semi-arid and the annual rainfall is 750 mm; about 80 % of which occurs from June to September. The experiment was laid out following randomized block design with three replications. Composite soil samples from each replication were obtained and analyzed for total soil organic C (SOC), microbial biomass C, dehydrogenase activity, and abundance of bacteria, fungi and actinomycetes following standard protocols (Chhonkar et al*., 2007; Patra et al*. 2005).
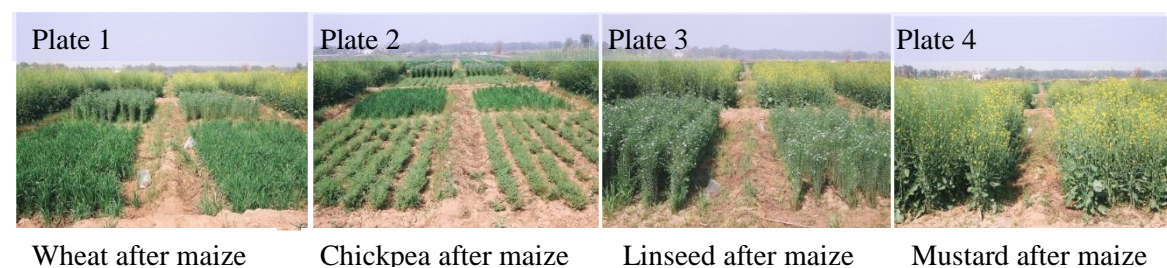
Results and Discussion

The results have revealed a range (0.39-0.54%) of soil organic C (SOC) in the samples (Figure 1a)**.**

Residues incorporation with conventional tillage (CT + R) or retention on the surface under zero tillage (ZT + R) were at par but had higher SOC than conventional tillage (CT) or zero tillage (ZT) systems (Figure 1b)**.** Growing linseed crop showed better C sequestration potential in soil than wheat, mustard or chickpea; and linseed under ZT + R had the highest SOC (0.54%) among the treatments (Figure 1c) in this experiment**.** Average potential N mineralization (PNM) rate, which is considered an indicator of the quality of soil organic matter, narrowly ranged from 1.4 mg kg^{-1} day^{-1} in ZT to 2.5 mg kg^{-1} soil day^{-1} in CT + R. Highest PNM (2.6 mg kg^{-1} soil day^{-1}) was exhibited in the system of chickpea under CT + R treatment. The interaction effect of residue management and tillage practices has also strongly affected the microbial biomass C (MBC), microbial quotient (ratio of MBC to SOC) and metabolic functionality of microbial community (i.e., ratio of deydrogenase activity to MBC). These parameters invariably followed the order: ZT + R> CT+R> ZT> CT, and, as in case of SOC, ZT + R under linseed had highest MBC, dehydrogenase and MQ. Relationship between SOC, MBC, and dehydrogenase activity has indicated that MBC is strongly associated (R^2 = 0.68**) with SOC, where as deydrogenase with MBC (R^2 = 0.60**) (Figure 2a), indicating that metabolic functionality of the microbial communities is more strongly influenced by the pool of microbial biomass or metabolic quotient (R^2 = 0.45**) than the SOC (R^2 = 0.30*) (Figure 2b).

Regarding the microbial population, the average density of bacteria has followed the order: CT + R> ZT + R> CT> ZT (Figure 1d, e, f). Whereas, in case of fungi the order was ZT + R > CT + R > ZT > CT. From the ratio of bacteria to fungi it can be inferred that CT was dominant with bacteria followed by CT + R treatment. Proportionately higher fungi in ZT or ZT + R than CT has been revealed, indicating higher importance of fungi to residues decomposition and nutrient mineralization in these two systems. Among the crops, the ratio of bacteria to fungi was highest in linseed (1.7) followed by wheat (1.6), mustard (1.2) and chickpea (0.9).

Conclusions

It can be concluded from this study that soil organic C or potential N mineralization in CT + R or ZT + R were almost at par but higher than only CT or only ZT systems. Among the crops, growing of linseed showed highest potential in C sequestration in the soils. Metabolic functionality of the microbial communities found to be more strongly associated with the pool of microbial biomass or metabolic quotient than the total soil organic C. Higher proportion of bacteria to fungi in CT than ZT systems indicated the significant role of fungi in decomposing crop residues and nutrient mineralization in these soils.
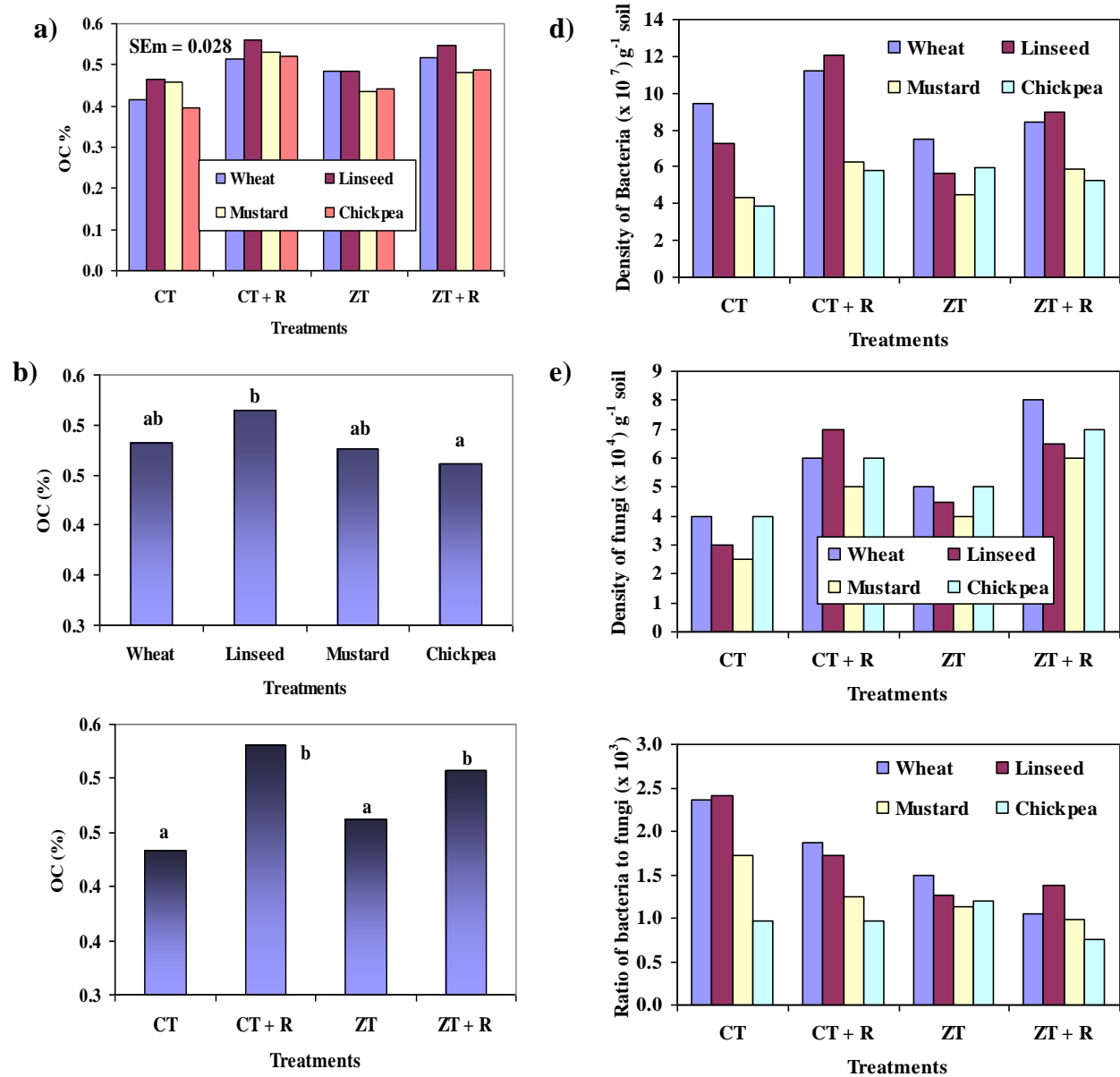
Plate 1	Plate 2	Plate 3	Plate 4
Wheat after maize	Chickpea after maize	Linseed after maize	Mustard after maize

Figure1. a, b, c. Effect of tillage practices and crop rotations on organic C sequestration.
d, e, f. Density of bacteria and fungi and their ratios in soils as influenced by tillage and residues management practices in different maize-based cropping systems.
CT, R, and ZT indicate conventional tillage, residues and zero tillage respectively. Bars with similar alphabets are not significant according to Duncan Multiple Range Test (DMRT) at p<0.05.
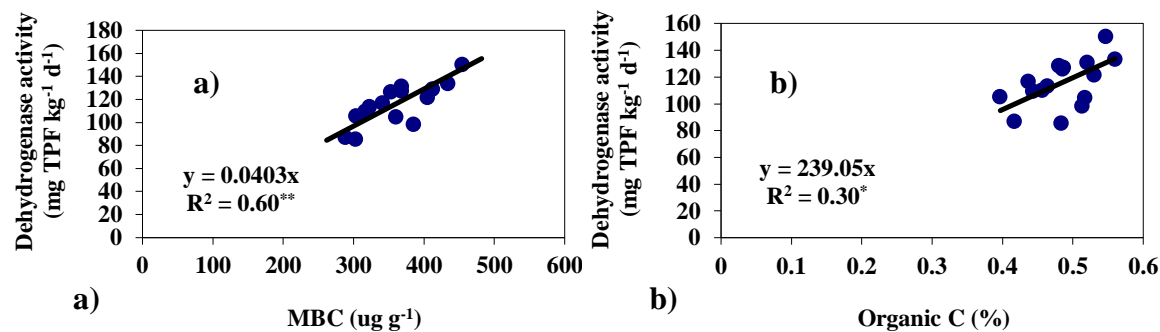

Figure 2 (a). Relationship of dehydrogenase activity with microbial biomass C (MBC) and, (b) organic C in soils under conservation tillage and residues management under maize based cropping systems

Acknowledgements

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Farming system modelling and Conservation Agriculture (CA) adoption: intensification, risks, resilience and strategies: an example in the Lake Alaotra in Madagascar

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Introduction

The understanding of farmers' strategies is an absolute prerequisite to explore constraints, as well as, opportunities for a better development. Livelihood analysis integrate a farm and an household where farming and non farming activities are taken into account, as well as, livelihood requirements and expenses in order to understand the real "strategies" behind decisions on production factors allocation. The concept of "strategy" is here understood as a means to implement a "project" with a view to the future, i.e., the definition of a range of production targets and the mobilization of the means necessary for their implementation (Mollard, 1993). CA adoption is a real change of paradigm: i) a move to new agricultural practices based on sustainability and ii) what may be far more important, a move to a mid or long term strategy. Therefore, we consider CA adoption as a move from a short term "annual crop based" traditional combination to a mid-term "perennial strategy of new annual crop combination". Besides the traditional "short term" vs "long term" strategies, we would like to emphasize two other concepts. The first one, suggested by Yung and Zaslavsky (1992), with "defensive" and "offensive" strategies is based on farmers' reactivity to constraints and opportunities. Adopting CA is clearly "offensive", either to move from "mining" agriculture to sustainable agriculture (with focus on stability and resilience) or to boost agricultural production (securing intensification with fertilizers, for instance). It is based on technical changes, access to services and risks assessment. Some farmers will profoundly change the initial structure of the farm and production factors allocation as observed, for instance, in Madagascar (Domas et al., 2008). Therefore, farming system modeling is used to measure impact of CA adoption or in a prospective analysis to forecast impact of various scenarios. Both are currently being developed within the BV-Lac development project in the Lake Alaotra region (Penot, 2010). A model performs two main roles: a figurative role, representing the systems (the functioning of the system) and a demonstrative role (identifying possibilities and strategies). A good model for development is a "useful" model. The "functional" characteristic, that we define, is linked to its operating and operational characteristics, to its adaptability to different analytical situations encountered, and to its potential in generating useful results in the perspective of an action-study for the various stakeholders (producers, associations, decision makers, etc.). The current results have been widely used by local development projects in Lake Alaotra (BVlac) and Vakinankaratra areas (BVPI-SEHP.

Materials and Methods

The tool presented in this paper, Olympe (INRA/CIRAD/IAMM) (Attonaty et al., 1999), is based on a "step by step" simulation approach and scenario building, in order to test technical changes, innovation and impact on farm income, organization of labour, and general strategy on production factors allocation. Priority is given for modelling results within their contexts. The simulation model needs to be dynamic to take into account the impact of the socio-economical context. The modelling and the simulation in particular, can only really work, firstly, if the researcher modeller fully understands the concept of the project, and secondly, if he is engaged in the participative research, as well as, in the development and use of the tool with local development operators. The software Olympe is used to manage the Farming System Reference Monitoring Network (FSRMN), currently developed in Madagascar (Penot, 2008). The "step by step" approach has no defined automatic "rules" as the decision is based on a "manual" choice of technologies or strategies by local participants, in local sessions. The FSRMN, which was originally composed of 48 farms from 2007 to 2009, now has 15 farms in 2010/2011. Each farm is representative of each type, according to the typology, established in 2007, and area (three main areas around the lake). Only one scenario, from 2010/2011, is presented in this short paper, although more than 50 scenarios have been prepared, by local development teams, between 2008 and 2011.

Results and Discussion

The farm "M901" is a traditional agricultural system of the Lake Alaotra area, based on groundnut and cassava with fallow. Land is on lease for 3 years. The farmer is interested in any cropping system that eliminates fallow. Several possible trajectories are tested. In the first trajectory, the farmer replaces one hectare of its traditional low input upland crops with one hectare of CA "classical" maize-cowpea/rice system (in red). The second trajectory is based on a maize-cowpea /rice rotation system (in green). This system was considered as "optimal" in the context of the lake until 2008. The change in cropping system (in red) allows the farmer to have a more stable cash balance over time. The accumulated balance significantly increased which ultimately allows him to capitalize and invest. The second trajectory stabilizes the cash balance then increases it. It appears to be a more interesting strategy to the operator than the previous one (Figure 1).

The first hazard to be tested is the impact of fertilizers price increase on intensification strategies. In 2008, fertilizer prices doubled, leading farmers to eliminate the use of fertilizers. It is questionable if this choice is effectively justified and simulation may help to identify the economic threshold of the use of chemical fertilizers. Figure 2 shows the impact of such trend due to higher fertilizer prices on cash balance at the end of the year (after family expenses). Despite 50% price increase, the "intensive" trajectory remains the most interesting, with a certain level of intensification. In reality, farmers have clearly opted for "zero fertilizer" option in 2010 (22 plots out of the 2700 monitored by the local Bv-Lac development project have been chemically fertilized). The "optimal" CA pattern remains a more resilient system than the "classic" CA pattern, with a better accumulated cash balance (Figure 3). The results of these scenarios challenge the abandonment of intensification techniques by farmers. The current choice of farmers, however, can be justified by the fear of unpredictable rising fertilizer costs introducing a clear economic risk if climatic risk is important (case of the 2010/2011 year, for example). To limit risk, the farmer is moving towards systems with low input, using organic manure only. The second scenario in based on both fertilizer price increase and rice price decrease (according to local price possible trends effectively recorded in the past) (Figure 3).

Where shocks are cumulative (higher fertilizer prices and a decline in rice prices), once again the second trajectory seems to provide the best results. Global farm resilience and cash flow are increased due to production stability. This reduces farm vulnerability to shocks and improves accumulated balance providing a better "cash safety net" against more shocks as long as yields are not affected by strong climatic events. The fact that most farmers have not adopted this system for low intensification systems must be explained in the risk analysis. It seems clear that climatic risk is high in this area and might jeopardize intensification effort, however, CA systems have proven in the past

to have a certain level of "buffer effect" to overcome climatic constraints. The 2010/2011 agricultural campaign has been characterized by very erratic rainfall.
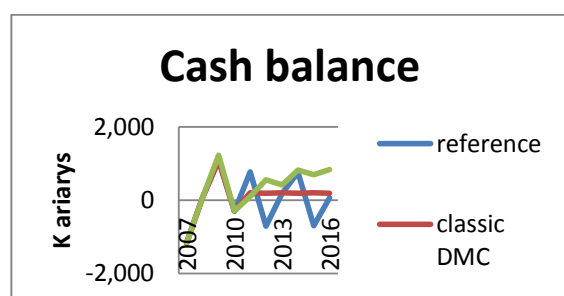

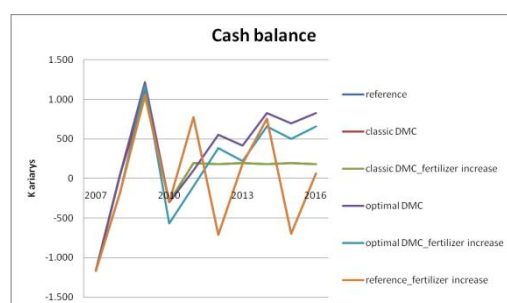**Figure 16:** Cash balance of the farmer before the shock

Figure 2: Cash balance of the farmer after an increase in fertilizer prices by 50%
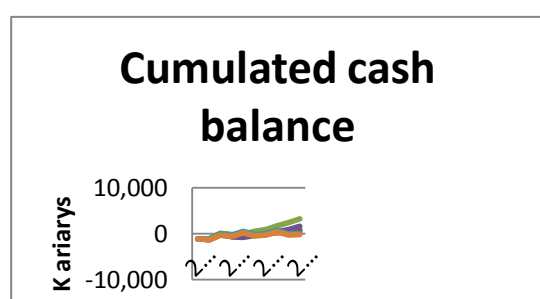

Figure 3: Cumulated cash balance and rising fertilizer prices

Poor cash availability, volatility of sale price and fear of non-reimbursement of any credit, drives farmers to a non intensification policy, or a low level of input cropping patterns, to decrease economic risks. As farmers achieve food security they tend not to jeopardize the situation with a step forward into intensification. They do favor yield stability with CA practices and eventually better production levels after 10 years as fallow has disappeared. The combination of both climatic risk and economic risk mainly due to price volatility restrains them from securing more production with combined CA and intensification. However, after 7 years of adoption, many farmers recognize that CA practices do stabilize production as a whole (as recorded by project databases, Domas, 2010), despite this risk is still considered too high (or is it too early in the adoption process?) to use both CA and intensification in such a volatile economic context.

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Evolution of Conservation Agriculture (CA) cropping systems on uplands in the Lake Alaotra area since 2003

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Introduction

A study in 2010 (CIRAD/ESSA/ANR pépites project/EU, Harisoa, 2010) has been implemented on CA cropping systems evolution in the Lake Alaotra region since the beginning of the local development project in 2003 (BV-lac). This paper focuses on CA systems evolution on upland (*Tanety*). Farmers move from original dead cover based systems (introduced in 2003) to cover crop based systems in 2006. Since 2009 and the doubling of fertilizers prices, low input systems have emerged.

Methodology

The study area is the basin of Lake Alaotra. The north-east and south-east zones of the lake are those with current CA adoption at a significant level. The oldest fields under CA (since 2003) have been selected to monitor rotations, practices and yield. There are 225 plots with CA: 7 years of CA: 1; 6 years: 4; 5 years: 19; 4 years 62; and 3 years: 200 - we sampled 139 plots belonging to 86 farmers.

Results

Table 1 and Figures 1 and 2 represent the evolution of adoption of the main CA systems (with percentage of surveyed area by crop and by year). In 2002-2003, all CA crops on *tanety* were systems under imported dead cover of *bozaka (Aristida)* or rice straw. In 2003-2004, 34% of plots already had "Cassava + *Brachiaria*" covercrops. Farmers gradually gave up the dead cover based systems (only 7% plots in 2005-2006) due to additional work required for collecting and mowing of the biomass. The systems with cover crops thus started to develop in 2005-2006: 42% of the plots had corn associated with climbing leguminous plants (corn + *Dolichos* and corn + cowpea), 7% were pure climbing leguminous plant culture (cowpea) and 29% with cassava + *Brachiaria*. From 2005 to 2010, the "corn + legume // rainfed rice" rotation started in CA systems. In the meantime, farmers adopted a certain level of intensification with, on average, 80 kg/ha of NPK and 50 kg/ha of urea on main crops (rice and corn) and discovered that mulching in CA does protect the soil and increase the efficiency of fertilizers (by diminishing the risk of fertilizer loss). Ecological intensification was on its way. Since 2007-2008, farmers started to adopt systems including *Stylosanthes* (considered as perennial leguminous plant), on an extensive basis (1% of the plots in 2005-2006 to 12% in 2008-2009) with systems based on corn, rice and groundnut. *Stylosanthes* is very much appreciated by farmers on poor upland soils (tanety) because of its large biomass production and easy control: without chemical herbicides but with 100 man/days/ha of labour in the dry season when labor is cheap and plentiful.

Table 1 : Evolution of CA areas on uplands (*tanety)*in the eastern zone of the lake Alaotra.

Year	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
Total area Northeast	0,0	0,0	4,5	18	18	18	18	18
Total area Southeast	0,54	0,90	2,26	9,59	9,59	9,59	9,59	9,59
Total number of plots	2	5	33	119	119	119	119	119
Total number of farmers	1	3	20	56	56	56	56	56
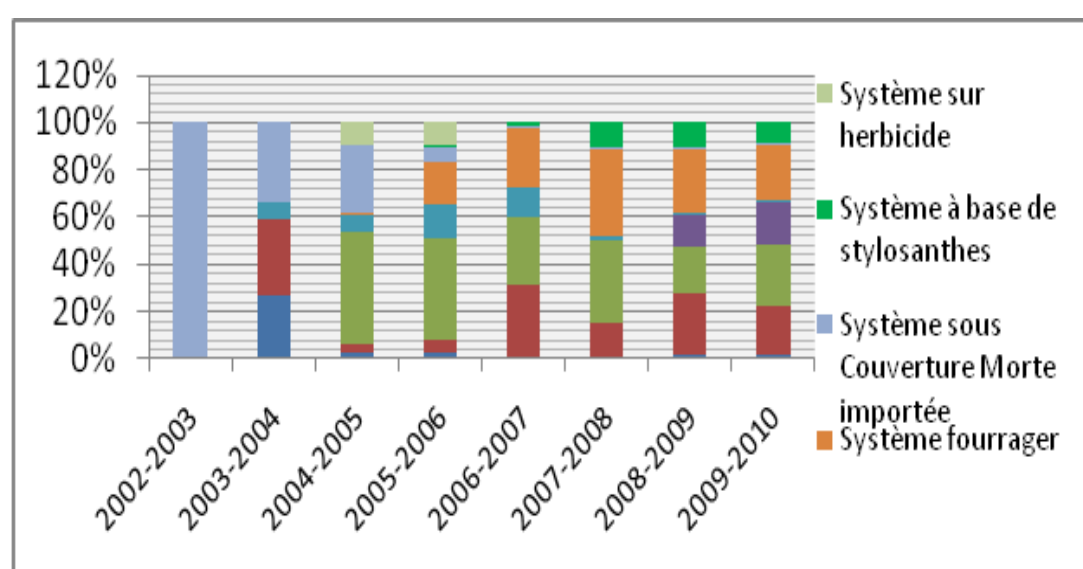
Figure 1 : Main trend of CA cropping systems evolution from 2002 on upland (*tanety)* in the eastern zone of the Lake Alaotra, Madagascar.

The "corn + cowpea (*Vigna unguiculata*)" association has been widely adopted by local farmers when the market was very favorable in 2004-2005 (37% of the plot). The protein contribution and income from cowpea are also among the important components which encourage farmers to develop such systems. Cowpeas mature in the dry season when prices are good on the local market, but it has been gradually replaced by "corn + *Dolichos*" (45% of the plots in 2007-2008). Cowpea has been attacked by several diseases and thus eventually produces less annual biomass than that of *Dolichos*, which leads to increase weeding requirement. *Dolichos* is appreciated for its

qualities: i) high volume of biomass which retains much more soil moisture, ii) long cycle which protects the ground in the dry season, iii) tolerance to drought. The "corn + *Vigna (umbellata)*" and "corn + *mucuna*" associations are also adopted for diversification but at a slower rate. In 2006-2007, the 2-year rotation "corn + various legumes // rice" has been widely adopted as the high biomass production in the first year gives good rice yields the following year. The importance and role of biomass in CA is today widely recognized but farmers' prioritize upland rice grain production .
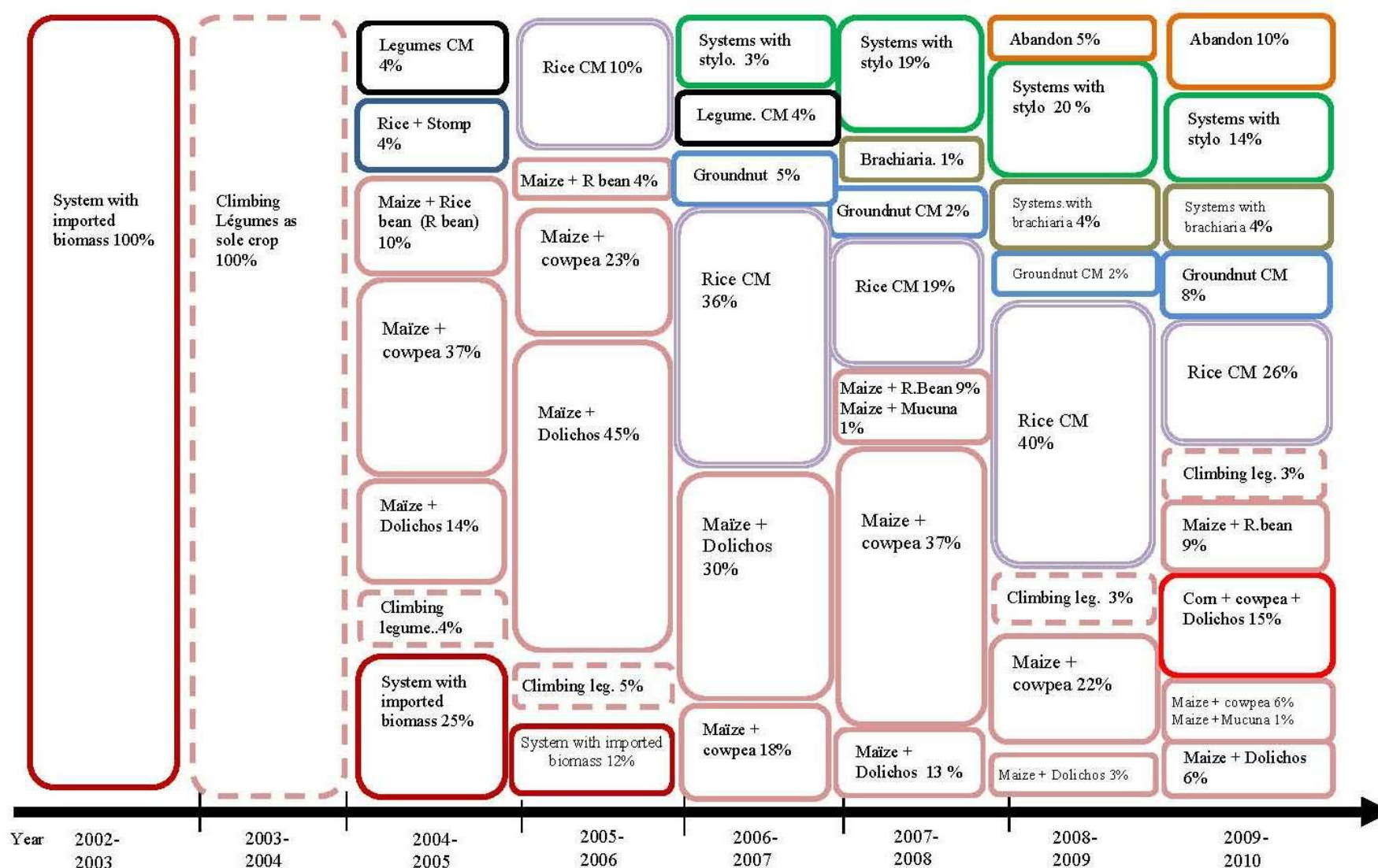
Figure 2: Evolution of CA systems with planted cover crops on upland (*tanety)*, Lake Alaotra.

Conclusion

The BVlac project began in 2003. CA extension on upland zones with systems based on dead mulch changing in 2006 to planted cover crops (mainly *Dolichos, Mucuna, Stylosanthes and Bracharia)*. Farmers have adopted these systems to overcome risk and unsustainability of the traditional "mining" agriculture (Penot and Scopel, 2010). So far, the monitoring of the CA system evolution displays the capacity of farmers to adapt to various types of situation showing that CA practices may well be effectively adopted on a long term basis (Penot and Andriatsitohaina, 2010).

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Increasing rainfall-use efficiency for dryland crops on duplex soils

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Keywords: Subsoil manuring, plant available water capacity, Sodosol

Introduction

Plant available water in soil is a key driver for crop production in water-limited environments. This is particularly apparent for large grain-growing areas of southern Australia where rainfall-use efficiency is restricted by subsoil constraints. Many of these soils have texture-contrast profiles, where lighter-textured topsoil, from sandy-loam to loamy-clays, overlies dense clay subsoil. These are the duplex soils that are classified in the Australian soil classification system as Sodosols, Chromosols or Kurosols (Isbell 2002). These soils in general, and Sodosols in particular with sodic subsoils, have low plant available water capacity (PAWC) because the clay subsoil has a low proportion of meso-pores and low hydraulic conductivity, so little rainfall can infiltrate into the B horizon. Furthermore the low macro-porosity and high soil strength of the clay, mean that root penetration and exploration into the clay subsoil, and water extraction from the clay, are restricted. Such soil problems are not limited to southern Australia as there are large areas of alfisol soils, where dense clay subsoils can occur (Kalpage 1974) and constrain crop yields.

This paper reports on a field experiment on a Sodosol soil in the high rainfall zone of south west Victoria in Australia, that set out to improve the physical properties of the dense, clay subsoil at the site. We postulated that an improvement in the physical properties of the clay subsoil would enable roots to penetrate and extract water and nutrients from the subsoil, and this would then enable more rainfall to infiltrate and be stored in the clay subsoil. The approach taken was to incorporate different organic and inorganic amendments into the top of the clay B horizon; such interventions have previously been rejected because of the cost associated with such deep intervention. The practice involving the incorporation of high rates of organic amendments in the subsoil with deep ripping, has now been termed 'subsoil manuring' (Gill et al., 2009)

Materials and Methods

This study involved 2 consecutive wheat crops grown in 2005 and 2006 at a field site at Ballan in south west Victoria. The site was a paddock under permanent raised beds that had been under continuous cropping (canola-wheat-barley-wheat-canola) for the last 8 years. The 2005 year received normal rainfall with 170 mm of spring rainfall, whereas 2006 was a drought year with only 74 mm falling during the spring months. The experimental design was a randomized block with 9 treatments in 4 replicated blocks. We report on 4 treatments: a control, deep ripping (to 40 cm), and the deep incorporation of gypsum at 10 t/ha, and lucerne pellets (2.8 %N, 0.9 %P, 1.4%K) at 20t/ha, at a depth of 30-40 cm in the subsoil. The amendments were applied manually through a pipe attached behind a deep ripper. There were two rip lines, 80 cm apart, on each 1.7-m bed (centre to centre). Soil properties, crop management details and site information are described in Gill et al., (2008). These data show an increasing clay content, bulk density, and sodicity and decreasing hydraulic conductivity and macro-porosity, with depth. The treatments were applied one week before wheat (*Triticum aestivum* var. Amarok) was sown in early May 2005. The same crop was sown in late May in 2006. Grain yields were determined from plants harvested in 0.5 m^2 quadrats taken on the top of the bed. Grain protein percent was determined by analyzing the grain for N using an Elementar Vario analyzer, and multiplying by 6.25. The volumetric water content (θv, v/v %), in 20-cm soil layers from the depth of 20 to 80 cm, was determined when the wheat crop was sown in 2005 and 2006, and at crop maturity in December 2005 and 2006, using a calibrated Neutron Probe. The soil water in layers was expressed in mm using the calculation [θv (%) x depth (mm)]/100.

Results and Discussion

There were marked improvements in grain yields with the subsoil manuring treatment (lucerne pellets), in comparison to the control for the first 2 crops following the subsoil intervention (Table 1). An additional 5.3 t/ha of wheat grain was produced in 2005, representing a 70% yield increase, while an extra 1.9 t/ha yield increase represented a 53% gain in the 2006 drought year. In both years the lucerne amendment resulted in grain protein concentrations in excess of 13%, and these are attributed to the high N status of the subsoil-manured plots due to the added N in the amendment. There was no benefit from deep ripping or added gypsum on grain yield or grain protein concentration compared to the control plants.

The increased grain productivity with subsoil manuring can be explained by the improved water supply to the wheat crops, and to improved supply of nutrients from the organic amendment. More water was extracted from the 40-60 and 60-80 cm subsoil layers in 2005 and 2006 by wheat plants in the subsoil manured treatments, compared to the controls (Table 2). The increases amounted to 2-3 fold increase in the 40-60 cm layer, and a 3-4 fold increase in the deeper 60-80 cm layer. Deep ripping resulted in close to a 60% increase in crop extraction in 2005 compared to the control, but this difference had disappeared in 2006. It is likely that additional water was extracted below 80 cm but this was not measured.

The subsoil manuring treatment also increased the water accumulation in the 40-60 and 60-80 cm subsoil layers during the summer-autumn fallow period in 2006. The effect was most marked in the deeper layer where there was a more than 12-fold increased in storage and capture of summer rainfall into this 60-80 cm layer, compared to the control treatment. This marked improvement in the capacity of subsoil layers to accumulate and store rainfall can be attributed to the improvement of soil structure and the increase in hydraulic conductivity in the upper layers of the clay subsoil with subsoil manuring (Gill et al., 2009). In addition, the 2005 wheat crop had extracted an extra 90 mm of water from the 40-80 cm layer, thereby 'creating space' for storing the extra water in the subsoil. Thus the subsoil manuring intervention increased the PAWC of this sodosol profile, and greatly increased the rainfall use efficiency in both favorable growing seasons and drought years. The outcome is a trade-off between the energy required to undertake the subsoil intervention, and the carbon and nutrient inputs in the organic amendment, in return for improved water use.

Table 1. Treatment effects on grain yield (t/ha), harvest index, and grain protein (%) for two successive wheat crops in 2005 and 2006.

Treatment	2005			2006		
	Grain yield (t/ha)	Harvest Index	Grain Prot. (%)	Grain yield (t/ha)	Harvest Index	Grain prot. (%)
Control	7.6	0.54	9.1	3.6	0.50	10.8
Deep-ripped	8.0	0.63	9.2	4.2	0.58	11.1
Gypsum	8.5	0.53	8.5	3.8	0.51	10.6
Lucerne pellets	12.9	0.64	13.4	6.5	0.50	13.9
LSD (P=0.05)	1.8	0.09	0.9	1.6	ns	1.8

ns, not signifiant

Table 2. Treatment effects on changes in soil water (mm) in subsoil layers during the cropping cycle in 2005 and 2006, due to crop extraction and fallow accumulation.

Period of the crop cycle	Soil layer (cm)	Soil water (mm)				LSD (P=0.05)	P-value
		Control	Deep-ripped	Gypsum	Lucerne		
2005	20-40	33.0	40.8	22.2	32.6	12.6	0.03
Crop extraction from	40-60	11.8	25.1	13.9	40.0	11.4	0.008
sowing to harvest	60-80	12.6	27.2	14.8	50.6	8.6	<0.001
	TOTAL	57.4	93.0	50.9	123.2	26.3	<0.001
2006	20-40	30.6	41.8	41.5	36.8	-	>0.05
Fallow accumulation	40-60	10.9	10.4	16.7	43.4	15.1	0.04
- harvest to sowing	60-80	3.5	15.2	16.5	44.8	15.7	<0.001
	TOTAL	45.0	67.4	74.7	125.0	27.8	<0.001
2006	20-40	22.3	28.8	29.4	34.9	11.2	0.03
Crop extraction from	40-60	24.3	20.2	32.5	46.7	12.8	0.005
sowing to harvest	60-80	17.5	18.2	33.2	54.0	10.5	<0.001
	TOTAL	64.0	67.8	95.1	135.6	28.7	<0.001

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Nutrient use and dynamics in Conservation Agriculture including legumes in the Midwest of the Malagasy highlands

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Introduction

Soil degradation in tropical agro-ecosystems results in increased food insecurity and environmental degradation. This process is mainly related to soil erosion and Soil Organic Matter (SOM) depletion under agricultural management (Séguy et al., 2006) and often increased by the reduction of aggradation fallow duration (Drechsel, 2001). In many regions of Sub Saharan Africa, where crops are produced continuously and with little or no nutrient inputs, soil degradation is threatening agricultural productivity (Vitousek et al., 2009). Such a situation calls for integrated approaches to improve nutrient availability and soil fertility (Vanlauwe et al., 2006).

Conservation Agriculture (CA) has been proposed to sustainably improve agricultural production in the tropics (FAO, 2008). This approach combines direct-seeding, permanent soil cover by organic mulch and a diverse crop rotation. CA almost eliminates erosion and increases soil organic carbon (C) content (Bernoux et al., 2006). The increase in soil organic C content is usually followed by an increase in total N content, enhancing soil N mineralization potential and the N supply for the crop (Maltas et al., 2007). If legumes are introduced in the system, they additionally fix N_2 (Ojiem et al., 2007) and are in some cases able to access forms of phosphorus (P) that are not accessible to cereal crops (Hocking, 2001). Furthermore, in some cases no-tillage has been shown to preserve mycorrhizal hyphae and maintain a higher diversity of arbuscular mycorrhizal fungi (Jansa et al., 2003). This is particularly important for acidic Ferralsols with usually low SOM and very low available P.

Whereas the effects of soil preparation on the one side, and of residue management on the other, have been studied, little work has been done on nitrogen (N) and phosphate (P) dynamics in CA as practiced by smallholders in the tropics, especially when legumes are introduced in the system as additional cover crops. However the capacity of CA including legumes to improve nutrient use efficiency might become a key issue for its adoption by smallholders. In this context the MOETH project has been implemented in Madagascar to understand how CA affects the fluxes and dynamics of N and P in the presence of a legume, and to identify, together with the farmers, strategies that will allow them using these resources in the most sustainable way.

Materials and Methods

The MOETH project is being realized by the Group of Plant Nutrition of the ETH Zurich, the Laboratory of Radio-Isotopes (LRI) of the University of Antananarivo and the International Research Unit on Cropping Systems and Sustainable rainfed Rice production (SCRiD, involving both FOFIFA and CIRAD scientists) since the end of 2009. It focuses on the Midwest zone of Madagascar at mid altitude (between 800 and 1200 masl) tropical sub-humid region (annual rainfall around 1200 mm), mainly cultivated by small scale farmers (between 1 and 10 ha). Most of the soils are nutrient depleted acidic Ferralsols, which are very difficult to put under cultivation given the limited access of local smallholders to inputs and financial assets. Thus, innovative approaches have to be developed with farmers to sustainably cultivate the infertile hill slopes called 'tanety'.

The project is organized in 4 work packages (WP1-4, Figure 1). In WP1, we conduct on-farm studies in reference areas of the Midwest where conservation agriculture has been adopted. A survey is conducted to evaluate how farmers manage nutrient sources (plant residues, manure, mineral fertilizers) at the farm level and how and why they implement CA. In WP 1 we will also assess crop performance and nutrient budgets in farmers' fields under conservation and conventional agriculture. In WP2, we work in a researcher-managed field experiment to study the effect of soil preparation (direct seeding vs. ploughing) and *Stylosanthes guianensis* (a legume, thereafter called stylo) residues management (removal/mulch) on upland rice yields, root growth, and N and P dynamics. In this experiment, we will measure N_2 fixation by stylo using the natural ^{15}N abundance method and N use by rice from different sources using both direct and indirect ^{15}N labeling techniques. In WP3, using appropriate ^{33}P labeling techniques, we will study the uptake of P derived from different sources by stylo and upland rice and the effect of legume residue application on the dynamics of microbial and organic P in soils. In WP4, we will evaluate the validity and relevance of the results beyond the reference areas studied in WP1. This work will be conducted in the Midwest region by undergraduate student surveys' and by workshops with farmers, farmers' organizations and NGOs and subsequently by expanding our up-scaling activities in two other ecological zones of Madagascar.

Results will be shared with stakeholders during field visits and workshops each year. The project will be accompanied by a reflection group representing the stakeholders who may give recommendations to the project members.

Results and Discussion

This project will allow to separate tillage effects from cover crop effects on N and P cycling and the main crop production under CA, trying to unravel the different causes and effects as suggested by Giller et al. (2011). The application of the foreseen isotopic methods to the Ferralsols under investigation will be challenging, but will bring robust information on how CA modifies N and P nutrient dynamics. The association of scientists from the LRI, the SCRID and the ETH, holds the complementary expertise to conduct and successfully complete the project.

The scientific information acquired in the project will contribute to evaluate the relevance of CA for improving agricultural production in smallholders' farms of Madagascar and in other regions of the tropics (Giller et al., 2011; Oberson et al., 2010). All the results will be shared and discussed with Malagasy stakeholders (farmers, local NGOs, national structures promoting CA and politicians) in order to

identify the most efficient CA practices for optimizing N and P availability and uptake by the crop. Lastly, the results will be relevant for the training and dissemination of agro-ecological techniques on Madagascar as requested in the strategy paper of the Madagascar direct seeding group (GSDM, 2007).
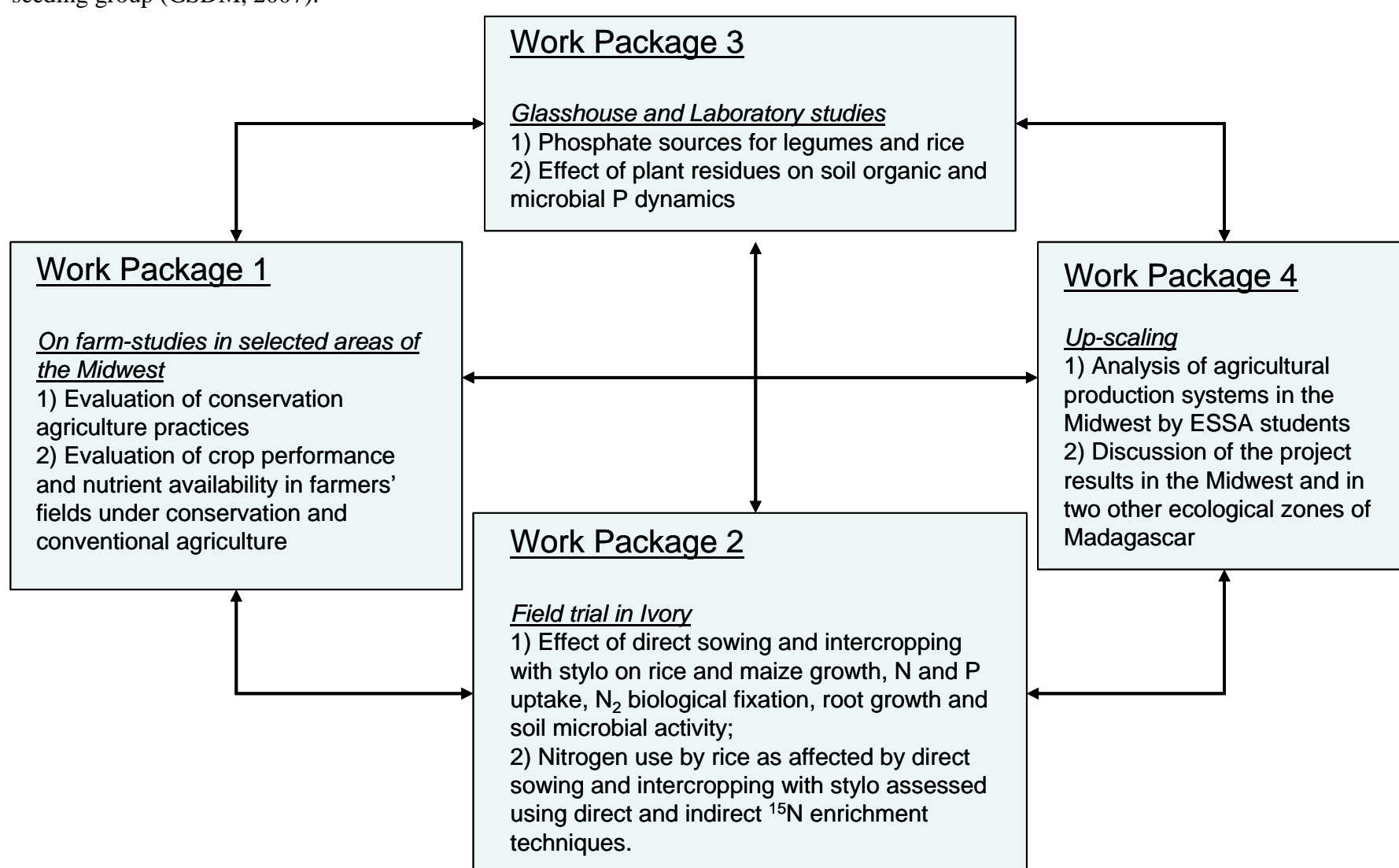

Work Package 3

Glasshouse and Laboratory studies
1) Phosphate sources for legumes and rice
2) Effect of plant residues on soil organic and microbial P dynamics

Work Package 1

On farm-studies in selected areas of the Midwest
1) Evaluation of conservation agriculture practices
2) Evaluation of crop performance and nutrient availability in farmers' fields under conservation and conventional agriculture

Work Package 4

Up-scaling
1) Analysis of agricultural production systems in the Midwest by ESSA students
2) Discussion of the project results in the Midwest and in two other ecological zones of Madagascar

Work Package 2

Field trial in Ivory
1) Effect of direct sowing and intercropping with stylo on rice and maize growth, N and P uptake, N_2 biological fixation, root growth and soil microbial activity;
2) Nitrogen use by rice as affected by direct sowing and intercropping with stylo assessed using direct and indirect ^{15}N enrichment techniques.

Figure 1. Conceptual framework of the MOETH project: Work packages and flux of information between the work packages

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Designing low input-high value integrated and resilient farming systems to face future challenges

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Introduction

The north-eastern region of India, with an area of 255090 km^2 is endowed with rich natural resources but their indiscriminate use and mismanagement have resulted in soil erosion from the hill slopes and silting of river beds and floods in the plains. The social sanctions and belief system maintained a balance between resource potential and their utilization for a long time but due to the increase in the demographic pressure, imbalance has been created. To feed the fast growing population in the region and to satisfy their other needs, the people have mismanaged and misused soil and water resources (Sharma, 2003). Prevalence of shifting cultivation, has caused land and environmental degradation as it involves deforestation. The shifting cultivation system was alright when the population was low and the shifting cycle was 25 to 30 years, allowing sufficient time for rejuvenation of vegetation for incorporating in the soil. But with increase in population, the shifting cycle has reduced to 3 to 7 years, making it unsustainable. Shifting cultivation is practised in 3869 km^2; however the total affected area is 14660 km^2. Deforestation as part of shifting cultivation has depleted the biodiversity of the region. The important issue is to promote the conservation and sustainable use of natural resources which allow long term economic growth and enhancement of productive capacity, along with being equitable and environmentally acceptable. A long-term-multidisciplinary study is in progress since 1983 to evolve sustainable new farming systems which may be productive, eco-friendly and resilient, to replace shifting cultivation..

Materials and Methods

The north-eastern region of India comprising seven states is predominantly hilly. By and large, the farmers have no permanent land ownership and so they take little interest in its judicious management. The land is allotted to them by the village chief, as per tribal laws, for few years to cultivate. For the impact of land use on sediment yield a long- term- multidisciplinary study, having livestock based, forestry, agro-forestry, agriculture, agri-horti-silvi-pastoral, horticulture and shifting cultivation land use systems, to monitor their comparative efficacy with regard to productivity, *in-situ* retention of rain water, sediment and water yield, from different watersheds. The details of the farming systems are shown in Table 1. The scientists from the disciplines of soil and water conservation, soil science, plant protection and social sciences are engaged in the project. Soil and nutrient losses were monitored through monitoring gauges fixed at the exit point of each watershed. Meteorological data were collected in the observatory located near the project site. The chemical analysis of soil and water samples collected from each land use was done as per procedures outlined by Jackson (1973). The sediment yield was calculated on km^2 basis. The population of the region and food deficit was taken from the available records. Integrated management of the land uses was done by following soil and water conservation measures, recycling of animal manure / farm wastes and application of nutrients as per soil tests and crop requirement. The benefit/cost ratio (B/C) was calculated as the ratio of total value of the produce from a land use divided by the cost of inputs, including labour. In case of tree farming (Forestry and Agro-forestry), the wood mass accumulated per annum was considered as produce. It was calculated on annual basis and then mean values were considered.

Table 1. Vegetation cover and soil and water conservation measures in different land use systems

Land use	Slope (%)	Crops/trees	Livestock	Soil and water conservation measure
Livestock (grasses and fodders)	32.0	Maize, rice-bean, oats, pea, guinea grass, tapioca, broom grass	Cows, pigs, rabbits	Contour bunds, grassed water-ways, trenches
Forestry	38.0	*Alder nepalensis, Albziia lebbeck, Acacia auriculiformis*	None	None
Agro-forestry	32.2	*Ficus hookerii,* Eucalyptus, guava, pine, pineapple, french bean, pulse crops.	Goats, rabbits	Contour bunds
Agriculture	32.4	Beans, radish, maize, paddy, ginger, turmeric, ground-nut, oats, grasses on risers.	Cows	Bench terraces, contour bunds, grassed water-ways
Agri-horti-silvi-pastoral	41.8	Beans, vegetables, guava, Citrus, ginger, *Alder nepalensis, Ficus hookeri, grasses*	Pigs, goats	Bench terraces, contour bunds, grassed water-ways
Horticulture	53.2	Peach, pear, citrus, guava, lemon, vegetables.	None	Same as above
Shifting cultivation	45.0	Mixture of crops	None	None

Results and Discussion

Population and food deficit
The population of north eastern region is increasing at an annual compound growth rate (ACGR) of 2.43% as against 1.69% in the country. The population in the region has increased almost four folds between 1951(10.1 million) and 2001(39.3 million), within a span of 50 years. The region has a food grains deficit of about 2.5 million tonnes and the gap is widening year after year. With present rate of population

increase, the situation may become alarming. The food security cannot be ensured unless suitable measures are undertaken to evolve alternate land uses.

Effect of land use on sediment yield, water yield and resource degradation

The average sediment yield was only 0.44%, 2.68%, 1.47%, 0.31%, 0.73% and 2.27% in fodder, forestry, agro-forestry, agriculture, agri-horti-silvi-pastoral and horticulture land use systems of that of shifting cultivation (Table 2). Highest average sediment yield in new land use systems was 71.7 t km^{-2} when the annual rainfall was 2770 mm and minimum 28.1 t km^{-2} when the annual rainfall was 1992 mm as against 4499.7 km^{-2} and 2669.4 km^{-2} in shifting cultivation, respectively. The sediment yield varied according to the rainfall received during a particular year and the nature of vegetation in a particular land use. By and large more than 90% of rainwater was retained *in-situ* in new land use systems compared to below 65.9% in the shifting cultivation (Table 2). More *in-situ* retention of rainwater helped in the availability of adequate moisture from the soil to the succeeding crops when the rainy season receded. It was interesting to note that while in shifting cultivation 34.1% of rain water escaped as runoff, it varied from 0.6% to 17.7% in the new land use systems. Maximum of 99.4% of rain water was retained in livestock based land use system, followed by agriculture (99.1%). More runoff generation from shifting cultivation areas has encouraged flood events in the region, resulting in resource degradation and poor crop productivity. It was estimated that annual loss of N, P, K, Mn, Zn, Ca and Mg is 26.9, 3.9, 21.3, 0.88, 0.54, 2.23 and 1.69 kg ha^{-2}, respectively (Sharma and Sharma, 2004). Shifting cultivation is not only a set of agricultural practices but implies the whole nexus of people's religious belief, attitude, self image and tribal identity. So, they are not willing to leave shifting cultivation unless some sustainable land uses are available as an option. The livestock based land use system can be adopted where demand for milk is there or market is near for selling of the animal produce. The runoff water is collected in a pond down the slope and used for irrigation during winter as well as for rearing of fish. The soil load per litre of runoff from watersheds varied from1250 to 20,300 mg soil. There has been sufficient fertility build-up due to the application animal manure and farm wastes and the new land uses have become more resilient ensuring optimum productivity.

Table 2. Effect of land use on the soil loss and water yield

Parameter	Land use						
	Livestock based	Forestry	Agro-forestry	Agricul-ture	Agri-horti-silvi-pastoral	Horticulture	Shifting cultivation
Soil loss (t km^{-2})	16.2	97.2	43.4	11.3	26.6	86.2	3621.3
Water yield (mm)	14 (0.6)	433 (17.7)	237 (9.6)	21 (0.9)	77 (3.1)	401 (16.5)	835 (34.1)

Values in the parenthesis are per cent of rainfall

Influence of land use on soil characteristics and productivity

The organic carbon, humus, exchangeable calcium, magnesium, potassium and available phosphorus increased significantly in the new land use systems compared to shifting cultivation, however, the DTPA extractable zinc, copper, iron and exchangeable aluminium decreased over the initial soil status. The decrease in iron and aluminium content in the soil was also favourably good as their initial soil content was toxic to the plants. The decrease in exchangeable aluminium was favourable for plant growth. The B/C ratio due to increased productivity was highest (2.1) in livestock based farming system, followed by horticulture (1.9) and agriculture (1.8) as against 0.6 of that of shifting cultivation. The B/C ratio was low in forestry as wood has not been sold, however annual accumulation of wood mass gave a mean ratio of 2.0 at the prevailing price. With these farming systems in place, the future challenges of hunger and environmental degradation can be met. The farmers have started adopting the new farming system as per their requirement and situation. The concerned state governments are giving incentives to farmers to adopt new systems.

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Integrated management of inputs to maximize crop yields in humid highlands for food security

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Keywords: nutrients, food deficit, shifting cultivation, cropping systems, north-eastern region of India

Introduction

The crop production research has been reoriented as cropping systems research in the recent years. Assessment of fertilizer schedule for a system is a complex problem because of so many factors affecting availability of nutrients, their fixation and loss and residual affects (Palaniappan, 1985). The cropping systems for an area must suit the local agro-climatic and soil conditions and be superior in terms of their biological productivity with least disturbance to ecosystem. The north-eastern region of India, with an area of 255,090 sq km, is predominantly hilly. The population in the region has increased almost four folds between 1951(10.1 million) and 2001(39.3 million), within a span of 50 years, while food production has not kept pace with this increase. The region has still a food grains deficit of about 2.1 million tonnes (Sharma, 1999). Shifting cultivation, the major land use system of the region, is practised in 3869 km^2 area, annually; however the total affected area is 14660 km^2. It has resulted in large scale deforestation, soil erosion and degradation of natural resources. The practice was acceptable when shifting cycle used to be 25-30 years. Due to increase in population at an annual compound growth rate of 2.43%, the shifting cycle has come down to 5-7 years. The practice results in annual loss of 88.3 and 0.218 million tonnes of soil and crop nutrients, respectively, from the region. The region receives average annual rainfall of 2450 mm. The results reported in this paper are from a study undertaken to evaluate four potato-based cropping systems in terms of their productivity, nutrient uptake and recovery and, economic return.

Materials and Methods

Field experiments were conducted for three consecutive years on a sandy loam soil (*Typic hapludalf*) for integrated management of nutrients and water as ell as economics of four potato-based cropping systems. The crop rotations were, potato–cauliflower, maize-potato, rice-potato and potato-radish. The available N, P and K content of the experimental soil at initial stage was 186, 6.8 and 201 kg ha-1, respectively, with pH 5.2 and EC 0.156 dS m^{-1}. The maize, rice and summer potato were the first crops in a sequence while cauliflower, radish and spring potato were second crops. There were ten treatments as given in Table 1. The treatments were replicated four times in a randomized block design. Full dose of P, K, and FYM (farmyard manure) and half of N were applied at sowing time while rest half of N was applied one month after sowing/planting of a crop. The FYM contained 0.40, 0.12 and 0.38 % of N, P and K, respectively, on fresh basis. The crop yields were recorded at harvest. The benefit/cost or economics of a cropping sequence was calculated as per prevailing market prices of different commodities. The soil and plant analysis was done as per procedures underlined by Jackson (1973) and Piper (1950). The tillage practices were that the potato, cauliflower and radish were grown by ridge and furrow methods, maize on flat beds and rice as wetland cultivation.

Table 1. Fertilizer schedule for N, P, K (kg ha^{-1}) and FYM (t ha^{-1})

Treat-ments	Maize, rice	summer	potato	Cauliflower	spring	potato,	radish
	N	P	K	N	P	K	FYM
F0	0	0	0	0	0	0	0
F1	50	22	25	100	0	0	15
F2	50	22	25	100	22	42	0
F3	50	22	25	100	0	0	0
F4	100	44	50	100	0	0	15
F5	100	44	50	100	22	42	0
F6	100	44	50	100	0	0	0
F7	150	66	75	100	0	0	15
F8	150	66	75	100	22	42	0
F9	150	66	75	100	0	0	0

Results and Discussion

Crop yield
Summer potato responded significantly up to the application of 100, 44 and 50 kg ha^{-1} of N. P and K, respectively. The application of FYM @ 15 t ha^{-1}, however, enhanced the response of the crop to 150, 66 and 75 kg ha^{-1} and highest tuber yield of potato was 23.23 and 22.31 t ha^{-1} in potato-cauliflower and potato-radish rotations, respectively. In the absence of P and K or FYM, the curd formation in cauliflower was delayed and markedly small and loose curds were formed. The application of P, K and FYM to cauliflower improved the ratio of curd to foliage from 24.3% to 34.6%. Significantly highest grain yield of maize was obtained with the F4 treatment and no further increase was found with higher level of applied nutrients (Table 2). In maize-potato crop rotation, the tuber yield of potato increased by 11.0% with the application of FYM and N over N applied alone. The increase in tuber yield may be attributed to additional supply of nutrients through FYM as well as improved soil physical condition for proper development of tubers. The residual effect of nutrients applied to potato was observed on the subsequent maize crop during the second and third year of experimentation. The response of rice to nutrients in rice-potato rotation was similar to maize. Maximum significant yield of radish was obtained with the highest level of applied nutrients that is 150, 66 and 75 kg ha^{-1} of N, P and K, respectively. The response of summer potato, cauliflower and radish to nutrients at highest level of applied nutrients was due to the reason that these crops are heavy feeders.

Nutrient uptake
Potato haulms (foliage) had higher concentration of N compared to tubers; however, in case of cauliflower, curd had higher concentration of N than foliage. In maize, more N and K concentration was found in stalks than grains while reverse was true for P concentration. Highest uptake of N, P and K was found in potato-cauliflower rotation followed by potato-radish, rice-potato and maize-potato rotations,

respectively (Table 3). Similar trend was found in nutrient recovery also. In the nutrient balance sheet approach, it was found that N and P had positive while K had negative balance in the soil. Removal of K was more than applied in all the cropping systems except maize. The highest depletion of K was found in potato-cauliflower rotation followed by potato-radish, rice-potato and maize-potato. The addition of nutrients to soil for a particular crop would depend on loss due to leaching, volatilization, fixation and residual effect of nutrients applied to the preceding crops. On an average, of the total nutrients removed, summer potato accounted for 57.7% N, 53.4% P and 65.6% K while spring potato removed only 41.9% N, 43.1% P and 47.0 % K.

Table 2. Mean (average of 3 years) yield of different crops (t ha^{-1})

Treat -ment	System I		System II		System III		System IV	
	Summer potato	Caulif lower	Maize	Spring potato	Rice	Spring potato	Summer potato	Radish
F0	7.80	1.12	0.68	5.79	1.29	5.23	6.15	6.98
F1	16.81	8.90	1.21	10.88	2.25	9.72	14.75	10.25
F2	15.65	3.25	1.06	9.76	2.12	9.17	13.66	10.45
F3	14.71	0.99	0.95	8.45	1.92	8.27	12.25	9.56
F4	20.66	9.51	1.75	13.91	2.76	12.19	18.23	21.98
F5	19.72	4.02	1.50	11.95	2.54	12.00	18.06	20.08
F6	18.41	1.63	1.43	10.06	2.04	10.99	16.23	19.02
F7	23.23	10.24	1.71	14.81	2.75	12.75	22.31	26.86
F8	21.75	5.80	1.68	14.43	2.55	12.75	21.05	25.18
F9	20.31	2.04	1.55	12.87	2. 23	11.25	19.02	23.04
CD, p= 0.05	1.59	1.26	0.19	1.37	0.31	1.12	1.69	1.73

Table 3. Nutrient uptake, % recovery and benefit/cost ratio of different cropping systems

	Nutrient uptake			% recovery			Benefit/
Cropping system	N	P	K	N	P	K	cost ratio
Potato-cauliflower	185.1	17.6	175.8	89.0	20.2	140.6	1.79
Maize-potato	129.2	9.5	122.0	58.7	15.4	113.2	1.36
Rice-potato	163.1	14.6	149.9	74.3	17.4	125.5	1.59
Potato-radish	172.4	15.7	159.5	85.6	18.2	132.4	1.76

Residual effect and economic return

Analysis of the soil samples after the completion of the experiments showed that there was a build-up of nutrients in all the cropping systems over their initial status in the soil. The available N and K content in potato-cauliflower system was significantly lower than other systems while available P varied non-significantly. This may be due to more depletion of these nutrients in this rotation. The beneficial effect of FYM on the available nutrient build-up in the soil was observed. Potato-cauliflower system was the most profitable followed by potato-radish, rice-potato and maize-potato in that order. Maize proved to be non- profitable mainly because of high precipitation and low summer temperature (15 to 27 ^{O}C), which affected grain filling at maturity. Summer potato gave the highest net profit followed by cauliflower, radish, rice and spring potato. The crop yields obtained in these four cropping systems was 2.5 to 3.5 times higher than that of shifting cultivation.

Adopting these sustainable and eco-friendly cropping systems by the cultivators has ensured enduring food security in the region. This would not only bridge the gap of food deficit but make the region a food surplus zone. This will be possible only when a balanced use of inputs is made to properly selected cropping sequences according to the local agro-climatic situation.

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Cover crops and nitrogen fertilisation for maize crop grown in cerrado Oxisol

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Keywords: *Zea mays* mineralization urea legume grass

Introduction

In the tropical and subtropical regions intensively cultivated with crops, the decrease in productive potential has often been attributed to the erosion and decomposition of the soil organic matter (SOM). The non-plowing of the soil allied to the addition of organic carbon through the cultivation of green manures and or "commercial" crops, that add great amounts of residues to the soil, are fundamental measures for maintaining the balance of the SOM which is an important N source for crops (Amado et al., 2002; Scivittaro et al., 2003). Maize is one of the main no-tillage crops in Brazil, which is grown mainly in the savannah area in rotation and/or succession with soy bean and cotton crops. As nitrogen (N) is required in large amounts for corn production, it is of great importance to know the capacity of green manures to supply N requirements for crop production. The objective of this work was to therefore evaluate the effects of cover crops and different nitrogen rates on maize productivity, grown under no-tillage in cerrado (savannah) Oxisol.

Material and Methods

The research was carried in the Experimental Farm of Faculty of Engineering, Sao Paulo State University, located in Selvíria-MS, Brazil (51º 22' W and 20º 22' S, 335 m of altitude). The soil is classified as Dystroferric Red Latosol, cerrado (savannah) phase (Embrapa, 2006). The experimental area has a history of 19 years under conventional tillage and the last eleven years in no-tillage. The chemical characteristics of the soil, in the layers of 0-0.10 and 0.10-0.20 m, are respectively: pH (CaCl$_2$) 4.9 and 4.7; total N 1.0 and 0.8 g kg^{-1}; O.M. 26.0 and 22.0 g dm^{-3}; P (resin extractable) 30 and 25 mg dm^{-3}; Ca 32 and 20 mmol$_c$ dm^{-3}; Mg 18 and 12 mmol$_c$ dm^{-3}; K 2,0 and 2,6 mmol$_c$ dm^{-3}; H+Al 31 and 38 mmol$_c$ dm^{-3}; S 4,0 and 3,5 mg dm^{-3}. The experimental design was randomized blocks with 20 treatments and four replications in a 5x4 factorial outline. The treatments were four cover crop species, sunnhemp (*Crotalaria juncea* L.), pigeon pea (*Cajanus cajan* L.), green velvet bean (*Mucuna prurens*), millet (*Pennisetum glaucum* L.) + spontaneous vegetation (fallow) combined with four N rates (0, 30, 90 and 150 kg ha^{-1}), applied as urea fertiliser to maize grown in succession. The cover crops were sown on 01/09/2010, using 0.40 m between rows for legumes and 0.25 m for millet, and harvested at 72 days after sowing (DAS). The maize (Pioneer hybrid simple 30F80) was mechanically sown on 17/11/2010. The basal fertilisation at sowing was 90 kg ha^{-1} of P$_2$O$_5$ and 60 kg K$_2$O ha^{-1}, as single superphosphate and potassium chloride. Except for the control (without mineral N), N was applied at 30 kg N ha^{-1} at seeding and the remainder (60, 90 and 120 kg ha^{-1}) as topdressing, at the four leaf stage. The plant and ear height were measured before harvest. The number of rows per ear, grain per row and grain per ear, were evaluated in 20 ears from each plot. Grain yield was determined after harvesting manually 5 rows of 4 m of each plot, and the weight of a thousand grains and grain yield in kg ha^{-1} determined. The data were analysed statistically by *F*-test, with comparison of means by Tukey test at the 0.05 probability level and regression analysis.

Results and Discussion

At 72 days after sowing (DAS), the dry matter yield of cover crops followed the order: millet (13,650 kg ha^{-1}) > sunnhemp (8,420 kg ha^{-1}) > green velvet bean (5,872 kg ha^{-1}) > pigeon pea (5,623 kg ha^{-1}) > spontaneous vegetation (2,955 kg ha^{-1}). There was also significant interaction between N and cover crops for the grain yield of maize. Final stand (57,310 plants/ hectare) and prolificacy (1.10 ears per plant) were not affected by treatments. The plant height and ear height were higher for the maize in succession to legumes crops than in succession to millet or fallow (Table 1). In relation to mineral N rates, there was a quadratic response for plant height and a linear response for ear height (Figure 1a), with the lowest heights observed where no N had been applied. This phenomenon is due to the important requirement for N in the process of photosynthesis and cell division and expansion (Marschner, 1995). Regarding the number of rows per ear, grains per row and the number of grains per ear, the highest values were in the treatments in succession to legumes or fallow (Table 1). The largest thousand grains weight was also obtained in the treatments preceded by legumes, with in comparison, no significant difference where maize succeeded fallow or millet. As N increased the number of rows per ear increased following a quadratic model, whereas the number of grains per row (Figure 1b), as well as the number of grains per ear and thousand grain weight (Figure 1c), increased linearly with N rate. The highest maize grain yields in treatments without mineral N were obtained where legume was grown previously; with the lowest yields observed where millet or fallow soil was previously practiced (Table 2). Except for the fallow treatment that received 150 kg N ha^{-1}, regardless of the nitrogen rate, the highest grain yield was obtained where maize preceded a legume cover crop. Furthermore, yield did not significantly differ between rates of N where a legume cover crop was used. The presence of legume residues associated with the application of 30 kg N ha^{-1} at sowing provided grain yield higher than that with application of 90 kg N ha^{-1} where millet or fallow was used in the sequence. Based on the maize productivity in the legume treatments without mineral N application, the response in grain yield would be equivalent to applying 80 kg N ha^{-1} for maize grown in the fallow soil, and 108 kg N ha^{-1} for the maize in succession to millet (Figure 1d). In general, the greatest grain yield response to N was obtained by applying 30 kg ha^{-1}, decreasing with the other rates, suggesting the importance of implementing the nutrient at sowing. It is noteworthy that although there was a linear response for grain yield with increasing N rates with the use of legumes (Figure 1d), the application of only 30 kg ha^{-1} at sowing proportioned yield grains above 7 t ha^{-1} grain. The difference in yield between the treatments receiving 90 or 150 kg N ha^{-1} is not feasible economically, considering the share cost of fertiliser and its application. It is concluded that nitrogen fertiliser must be applied to maize crop at sowing, even using legume, with N applied as a topdressing when proceeding millet or fallow ground. Millet resulted in the lowest grain maize yield compared to legumes, regardless of the N rate. The results indicate that there is an opportunity to both reduce N fertiliser inputs and increase maize yields by growing in succession with a legume cover crop, which are both important considerations in Brazil where resources are limited and there is a need to improve both productivity and environmental sustainability.

Table 1. Plant height, ear height, grain per rows, rows of grain per ear, grains per ear and weight of thousand grains, as affected by cover crops and nitrogen rates, Selvíria, MS, 2010/2011.

Species	Plant height	Ear height	Grain per row	Row per ear	Grain per ear	Weight 1000 grains
	m					g
Sunnhemp	2,32 ab	1,29 a	38,72 a	14,50 b	558,25 a	345,45 a
Pigeon pea	2,28 b	1,27 a	37,68 ab	14,92 a	554,99 a	346,96 a
Velvet bean	2,35 a	1,30 a	37,81 ab	14,96 a	562,50 a	347,77 a
Millet	2,20 c	1,19 b	37,54 ab	14,33 b	509,70 b	305,40 b
Fallow	2,17 c	1,13 c	35,99 b	14,62 ab	544,54 a	322,52 b
MSD	0,055	0,05	2,02	0,37	34,65	17,72
CV (%)	2,43	4,03	5,43	2,57	6,38	6,40

Values followed by same letters, in columns, do not differ ($p < 0.05$) amongst themselves by the Tukey test.

Table 2. Maize grain yield as affected by nitrogen rates and cover crops, Selvíria, MS, 2010/2011.

N rate kg ha^{-1}	Grain yield maize				
	Sunnhemp	Pigeon pea	Green velvet bean	Millet	Fallow
	kg ha^{-1}				
0	6,164 a	6,230 a	6,069 a	3,267 b	3,985 b
30	7,034 a	7,020 a	7,132 a	4,243 b	4,967 b
90	7,709 a	7,917 a	7,885 a	5,827 b	6,443 b
150	7,853 ab	8,391 a	8,037 ab	7,112 b	7,869 ab

Values followed by same letters, in row, do not differ ($p < 0.05$) amongst themselves by the Tukey test.
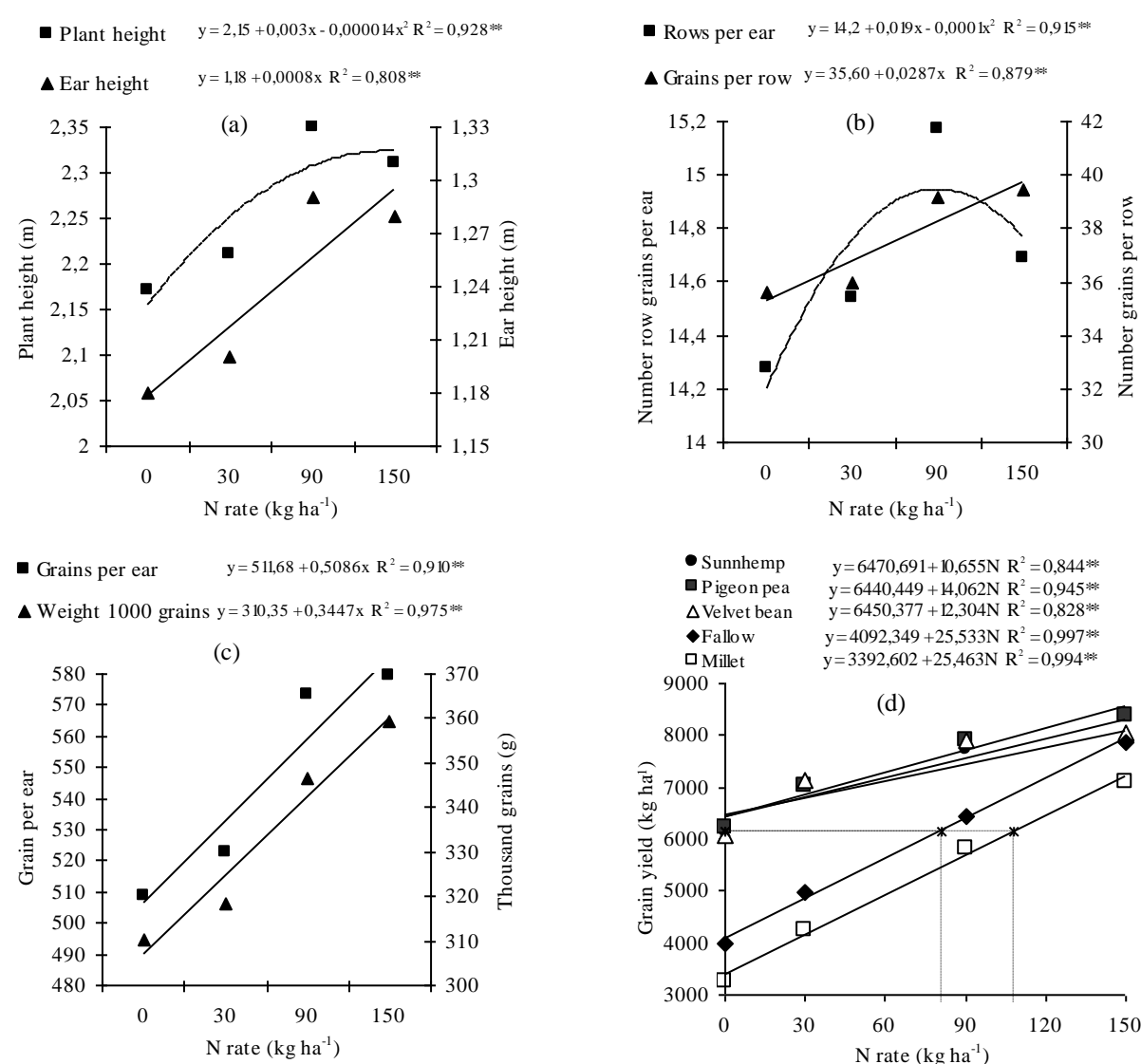

Figure 1. Plant and ear height (a), grain per rows and row per ear (b), grains per ear and weight of thousand grains (c) and grain yield (d), as affected by nitrogen rates and cover crops, Selvíria, MS, 2010/2011.

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Performance of permanent raised bed planting in rice-wheat system in Eastern Uttar Pradesh, India

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Introduction

The rice-wheat system of the Indo-Gangetic Plains (IGP) is important for food security, employment, and livelihoods for millions of rural and urban poor in the region. Recently, evidences suggest that sustainability of RW system is at risk as the productivity of the system is static for past several years and total factor productivity is declining because due to fatigued natural resource base, changing climate, increasing water scarcity, labor shortage, escalating fuel prices, and adverse effects of puddling on soil health. The system, therefore, needs infusion of new technologies to increase productivity, income, and sustainability. In recent years, the major emphasis in RW system has been on practicing conservation agriculture to reduce the production costs energy consumption, sustain productivity, and increase the profit margin of the farmers (Gupta et al., 2002.). In raised bed planting systems, crops are grown on the raised beds and irrigated by furrows.. Dimensions of furrows and raised beds are best dictated by the tractor width and type size. It is best to use narrow tyres for crop planting in raised bed systems to avoid compaction of raised beds with wide tyres. This system can also be used to plant intercrops in different configurations. Raised bed planting system promotes crop intensification and diversification besides saving irrigation water. In raised bed system, saves 30-40% water as compared to conventional flood irrigation practice (RWC, 2002, Mann and Meisner, 2003). Benefits of Raised bed system also include (i) fewer weeds, (ii) facilitates seeding into relatively dry soils (iii) vigorous and better crop stands, (iv) savings of costly seed (v) reduced crop-lodging and seed and fertilizer contact (vi) better drainage, improved rainwater conservation; and crop productivity and (vii) minimizes wilt infestation in crops like pigeon pea and avoids temporary water logging problems.. The raised bed planting system is gradually becoming popular amongst the R-W farmers as it allows light and frequent watering, needed to address terminal heat stresses due to climate change. The performance of raised bed system further improves when the system is coupled with precision laser land leveling.

Materials and Methods

A farmer participatory experiment in village Pindahara, distt. Ballia in eastern U.P. was conducted for six years (2002- 2008) to evaluate the performance of permanent raised bed planting system in terms of water and fertilizer use efficiencies, profitability, and opportunities for intensification and diversification of rice-wheat cropping system. The raised bed planting system was compared with the conventional tilled planting practice. The bed planting system was initiated with freshly prepared raised beds used to transplant young rice seedlings during the monsoon season. Winter and summer season crops (wheat and mungbean etc.) were planted on the beds used for rice after reshaping. Rice was established either by transplanting of 30 -35 days old young seedlings or by direct dry seeding as per farmer's preference. Wheat and other crops were established by direct seeding on the beds reshaped only once in the dry (winter/Rabi) season. During the wet season (Kharif) rice was established without tillage, except in 2005-06 when pigeon pea (PP) replaced rice and the crop was established by reshaping of beds. It may also be mentioned that the all crops were established in presence of residues of the previous season crops in permanent bed system in all the seasons during the six years. On the same beds 3-direct seeded rice, 2- transplanted rice 1- summer mungbean, 1- pigeon pea and six crops of wheat were grown in the six year period.

Results and Discussion

Results showed that permanent bed planting system increased the rice yield by 33 % and 60% in wheat along with reduction in the cultivation cost by 26 % for rice and 24 % for wheat. Compared with conventional farmer's practice, permanent raised bed system improved water and fertilizer use efficiency by 20-25 percent and reduced the total production cost of RW system by nearly 30 percent (table1). The average yield of rice and wheat was 3.94 Mg ha^{-1} and 4.82 Mg ha^{-1} in permanent bed planting as compared to 2.97 Mg ha^{-1} and 3.02 Mg ha^{-1} with farmer's practice. Compared with the conventional till system the net returns from R-W system were up by US$ 206 and 249 ha^{-1} in permanent bed planting system. This system also saves an expenditure of US$ 174 ha^{-1} of total cost. It was observed that net return of the farmers can be significantly enhanced through substitution of rice with less water requiring extra short duration pigeon pea and also by changing the rice establishment method (from transplanted rice to direct dry seeded rice). Results indicated that RW system can be further intensified and diversified by growing mungbean and early pigeon pea on raised beds during summer and wet season. When these crops are planted on the raised beds they escape crop losses due to temporary water logging. Thus, the raised bed planting system also offers significant opportunities for intensification and diversification.

Table 1: Performance of tillage and crop establishment options on yield and return of crops under permanent furrow irrigated raised bed planting system

Year	Technology	Wet Session					Dry Session					
		Crop/ Varity	Yield (Mg ha-1)	Total cost (US $ ha-1)	Total Return (US $ ha-1)	Net Return (US $ ha-1)	Technology	Crop/ Verity	Yield ((Mg ha-1)	Total cost (US $ ha-1)	Total Return (US $ ha-1)	Net Return (US $ ha-1)
2002-03	FBTPR	Rice BPT-5204	3.75	289	461	173	PEB-W	Wheat PBW-343	5.20	232	647	415
							PEB-SMB	Mungbean	0.40	35	176	143
	CT	Rice BPT-5204	3.75	356	461	106	CT	Wheat PBW-343	3.00	305	407	102
2003-04	PEBTPR + R	Rice Sugandha-3	4.50	330	607	277	PEB-W	Wheat PBW-343	5.20	267	670	403
	CT	Rice MTU-7029	3.00	408	416	8	CT	Wheat PBW-343	3.00	318	437	119
2004-05	PEBDSR + R	Rice Sarju-52	4.00	320	569	249	PEB-W	Wheat PBW-343	5.33	237	734	498
	CT	Rice Sarju-52	1.88	421	274	-143	CT	Wheat PBW-343	3.12	337	497	159
2005-06	PEB-PP	Pigeon pea IPCL-88390	1.50	250	844	594	PEB-W	Wheat PBW-502	3.60	282	1040	76
	CT	Rice Sarju-52	3.20	402	461	2658.00	CT	Wheat PBW-502	2.40	366	600	234
2006-07	PEBDSR + R	Rice Sarju-52	2.25	321	337	690.00	PEB-W	Wheat PBW-502	5.00	452	1411	959
	CT	Rice Sarju-52	2.00	424	299	-125	CT	Wheat PBW-502	3.00	374	867	493
2007-08	PEBDSR+R	Rice Sarju-52	5.20	301	796	495	PBW-W	Wheat-PBW-502	4.60	283	1022	739
	CT	Rice Sarju-52	4.00	344	662	311	CT	Wheat-PBW-502	3.60	467	956	488
Average	*PEB*	*Rice*	*3.94*	*312*	*554*	*242*	*PEB*	*Wheat*	*4.82*	*292*	*921*	*515*
	CT	*Rice*	*2.97*	*393*	*430*	*36*	*CT*	*Wheat*	*3.02*	*361*	*657*	*266*

Year	Technology	Whole System (RW)			
		Total cost of the system (US $ ha-1)	Total return of the system (US $ ha-1)	Net return of the system (US $ ha-1)	B:C ratio
2002-03	FBTPR	555	1286	731	1.32
	CT	661	868	207	0.31
2003-04	PEBTPR + R	597	1210	680	1.14
	CT	726	852	126	0.17
2004-05	PEBDSR + R	557	1303	747	1.34
	CT	759	775	16	0.02
2005-06	PEB-PP	531	1884	1353	2.55
	CT	768	1061	293	0.38
2006-07	PEBDSR + R	773	1748	975	1.26
	CT	798	1166	368	0.46
2007-08	PEBDSR+R	584	1818	1233	2.11
	CT	819	1618	799	0.98
Average	*PEB*	*581*	*1553*	*952*	*1.64*
	CT	*755*	*1057*	*302*	*0.40*

Description of terminology used

FBTPR - Transplanted Rice on Fresh Beds.

PEBTPR+R- Transplanted rice on permanent beds with residue

PEBDSR+R- Direct seeded rice on permanent beds with residue.

PEB - PP- Permanent beds - Pigeon pea

PEB-SMB- Permanent beds - summer mungbean

PEB-W- Permanent beds - wheat

CT - Conventional Tillage/Traditional practice

BC – Benefit cost

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Opportunities for increasing food legume production through Conservation Agriculture based resource conserving technologies in rice-wheat System

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Introduction

Conservation Agriculture (CA) based resource conserving technologies (RCTs) like, ZT, SS, FIRB provide tremendous opportunity for increasing food legume production by its area expansion as well as improvement in productivity due to timely crop establishment, better utilization of underutilized land (rice fallows/lowland, excess moisture areas), more opportunity for system intensification/ diversification, saving in external inputs reduction in production cost and increase in input use efficiency (Abrol et al., 2005).. Introduction of food legumes with appropriate RCTs options have a good opportunity for intensification /diversification of the underutilized lands (rice fallows /flood prone/excess moisture areas) for their better utilization. The value of legumes for sustainability of the production system is well recognized but the key issue is where to diversify rice–wheat systems, and with what crops an in which season. The objective of this paper is to answer these questions and show that CA based RCTs provide an opportunity for re-introduction of legumes into RWCS to provide surface cover, additional grains and biomass for livestock such as to improve productivity and sustainability of RWCS in Indo-Gangetic plains of India. RCTs options like, ZT ,SS, FIRB have been providing tremendous opportunities to the farmers in the eastern Gangetic plains to increase the acreage of food legumes and improve their productivity though timely crop establishment, utilization of the under-utilized land (rice fallows/ wet lowlands) and saving in external inputs and reductions in production cost (Singh et al.,2005).

Materials and Methods

Farmers participatory on-farm trials on CA based RCTs were conducted in view of exploring possibility to include food legumes in the rice –wheat system in Ballia, Ghazipur, Mau and Varanasi districts of eastern Uttar Pradesh, India.. CA based RCTs trials were conducted with lentil, gram, pea, lathyrus, mungbean, cowpea, extra short duration pigeon pea . Zero till-drill and raised-bed planters were used for planting of the crops.

Results and Discussion

Results showed that furrow irrigated raised bed planting (BP/ FIRB) significantly increased pigeon pea yields and helped in substituting the rice crop. Inclusion of mungbean on raised bed after wheat in R-W system gave an average yield advantage of 0.4-0.6 t ha^{-1}. Farmers have shown positive interest in substitution of rice and/or inclusion of pigeon pea and mungbean in R-W system for reasons of enhanced productivity, profitability and sustainability (Table 1).

Table 1: Effect of crop establishment methods under different cropping systems in farmer's participatory trials in Eastern U.P, India.

Establishment methods/ cropping systems	Yield (t ha^{-1})		Mean rice yield equivalent[**] (t ha^{-1})	Mean Net return (US$ ha)[-1]
	2002-03	2003-04		
CT Maize-ZT Lentil	3.00-2.1 (2)	3.41-2.18 (2)	10.64	716
CT Rice-ZT Gram	3.00-2.23 (2)	4.13-1.89 (2)	9.91	603
CT Rice-ZT Pea	3.38-2.08 (2)	3.93-1.85 (2)	8.76	467
CT Rice-ZT Lentil	3.31-1.27 (2)	4.13-1.15 (2)	7.83	379
CT Rice-ZT Lathyrus	3.56-1.25 (2)	3.89-1.15 (8)	6.85	259
BP Rice-BP Wheat- BP Mungbean	3.75-5.2-0.6 (1)	4.20-4.0-0.50 (1)	12.14	742
UTR rice –ZT Wheat-ZT Mungbean	4.15-4.45-.61 (2)	4.25-4.13-.50 (6)	11.80	723
ZT Rice-BP Wheat-BP Mungbean	-	3.20-4.6-00.46 (1)	11.00	602
CT Rice-CT Wheat	3.38-3.88 (2)	3.65-3.71 (4)	8.53	307

* Numbers of participating farmers
** Indicates yield equivalent in terms of rough rice on the basis of prevailing market rates.
ZT -Zero tillage; DSR-Direct seeded rice; UTR Unpuddled transplanted rice; BP-Bed planting, CT-Conventional tillage; SS-Surface seeding; RLR- Rainfed lowland rice

Total annual yield equivalent of the cropping systems in terms of rice and total net returns (Table 1) showed that raised bed planting of Rice-Wheat-Mungbean cropping system gave highest yield equivalent of 12.14 t ha^{-1} and net return of US$. 742 ha[-1] followed by unpuddled transplanted Rice -ZT wheat - ZT mungbean (11.8t ha [-1] RYE and of US$. 723 ha^{-1} net return) where as CT maize- ZT lentil, recorded a remarkable rice yield equivalent (RYE) of 10.64 t ha^{-1} and net return (NR) US$ 716 ha^{-1}. Significant savings in seed in zero-till lentil, made it more remunerative. Further, zero-till establishment of pulses after rice increased the rice yield equivalent and profitability and CT Rice-ZT Chick pea registered the RYE of 9.91 t ha^{-1} and NR of US$ 603 ha^{-1} followed by CT Rice-ZT Pea (8.76 t ha^{-1} and US$ 467 ha^{-1}) and CT Rice - ZT Lentil (7.83 t ha^{-1} and US$ 379 ha^{-1}) as against CT Rice - CT Wheat (8.53 t ha^{-1} and US$ 307 ha^{-1}).

Results of farmer participatory trial showed that diversification and inclusion of pulses in RW system contributed to increased net return and sustainability of the cropping system. Establishment of pulses (lentil, gram, pea, lathyrus, pigeon pea and mungbean) through zero till / raised bed planting increased the yield equivalent and net return as compared to conventional RW system (Table 1).

Data presented in table (2) indicated that net return was US$ 1037 ha^{-1} with early pigeon pea-wheat system and was US$ 1200 ha^{-1} for the cowpea-wheat system. Net return from rice- wheat –mungbean system was US$ 937 ha^{-1}. Early pigeon pea –wheat gave remarkable

additional net return of US$ 829 ha^{-1} and US$ 301ha^{-1} over LDPP-fallow and RW systems, respectively. Cowpea-wheat system gave additional net return of US$ 464 ha^{-1} over conventional rice wheat system whereas rice-wheat–mungbean recoded additional net return of US$ 176 ha^{-1} over RW system.

Net income from conventional R-W system is US$ 671 ha^{-1} and introduction of Mungbean improves income by US$ 230 ha^{-1} in R-W system (Table 3). Income from conventional LDPP- fallow system is US$ 452 ha^{-1} and with introduction of extra-short duration Pigeonpea ICPL88039 it was possible to grow a wheat crop which increased the additional income by US$ 370ha^{-1}. When the ESPP-Wheat system is practiced on the raised-beds, it can further improve net returns by US$ 607 ha^{-1}. ESPP-Wheat system also gave higher additional net returns by US$ 151/ha^{-1} as compared to conventional R-W system.

Table- 2: Crop diversification through food legumes in Eastern U.P, India.

Technology used	Grain yield (t ha^{-1})		Total cost US$ ha^{-1}	Total Income US$ ha^{-1}	Net profit US$ ha^{-1}
	Range	Average			
Cow pea	3.70-8.50	5.70 (6)*	1051	1647	595
Wheat	3.80-4.50	4.00 (6)	362	967	605
	Total		*1413*	*2614*	*1200*
Rice	2.21-3.60	3.01 (6)	348	530	183
Wheat	3.80-4.50	4.02 (6)	338	892	553
	Total		*686*	*1422*	*736*
Rice	2.30-3.60	3.00 (8)	366	563	198
Wheat	3.60-4.60	4.11 (8)	325	902	576
Mungbeen	0.24-0.48	0.32 (8)	125	288	163
	Total		*816*	*1753*	*937*
Rice	2.01-3.80	3.01 (8)	348	543	194
Wheat	3.80-4.20	4.00 (8)	317	885	567
	Total		*665*	*1428*	*761*
Early pigeon pea	0.27-1.50	0.91 (5)	122	567	446
Wheat	3.60-4.60	4.11 (5)	325	916	591
	Total		*447*	*1483*	*1037*
Long duration Pigeon pea	0.30-0.60	0.46 (5)	**72**	**280**	**208**

* No. of Farmers' Participation

Table 3: Yield and Economics of different cropping/establishment systems in farmers' participatory trials in Eastern U.P., India.

Cropping System	Establishment methods	Yield (t ha^{-1})	Yield (t ha^{-1})	Total Cost of production US$ ha^{-1}	Net Returns US$ ha^{-1}	No. of farmers
ESPP-Wheat	Flat Zero till	0.99	3.90	508	822	8
ESPP-Wheat "	Raised bed	1.48	4.01	511	1278	4
LDPP- fallow	Conventional	1.01	--	153	452	12
Rice-Wheat-Mungbean	Flat Zero till	4.01	4.40 +0.51 Mung	825	901	8
Cowpea-Wheat	Raised beds	5.70**	4.00	1409	1201	4
Rice - Lentil	Flat ZT	3.72	1.24	522	690	4
Maize-Lentil	Flat ZT	3.5	2.14	533	958	4
Rice-Gram	Flat ZT	3.57	2.06	588	991	4
Rice-Pea	Flat ZT	3.66	1.97	569	870	4
Rice-Fallow	Conventional	3.87	--	367	262	7
Rice-Wheat*	Conventional*	3.62	4.03	732	671	30

** Green pod yield.
ESPP-Extra short duration pigeon pea
LDPP-Long duration pigeon pea is followed by a fallow as conventional practice

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Fine tuning of Happy Seeder for direct drilling of wheat into combine-harvested rice fields

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Keywords: Direct Drilling Machinery, Crop Residue Management, Happy Seeder

Introduction

Lack of suitable machinery is a major constraint to direct drilling into the heavy stubbles in intensively cultivated irrigated rice-wheat cropping systems of north-west India, mainly due to blockage in many parts of the seeding mechanism, and failure to obtain good soil-seed contact. In order to prepare fields for timely sowing of wheat, about 20 Mt of rice stubbles are burnt every year within a span of 20 days in Punjab, (India) alone. The development of the Happy Seeder (HS) was initiated at PAU, Ludhiana in collaboration with CSIRO Land and Water, Griffith Australia with the financial assistance from ACIAR in 2001. The present version of Turbo HS has passed through three major prototypes to reach its current stage of development (Sidhu et al., 2009). The Turbo HS consists of a rotor for managing the paddy residues and a zero till drill for sowing of wheat. Flails are mounted on the straw management (SM) rotor which cuts (hits/shear) the standing stubbles/ loose straw coming in front of the sowing tine and clean each tine twice in one rotation of rotor for proper placement of seed in soil. It was observed that the machine needed to be modified/ developed based on the feedbacks and issues raised by the farmers/ extension functionaries. Hence, fine-tuning of the Turbo HS was carried out in the second phase of the ACIAR project (2007-10) in collaboration with Charles Sturt University, Wagga Wagga, Australia.

Methods and Materials

Fine tuning of the HS machine was carried out on the following issues during 2007-10.

Power requirement
The HS consists of SM rotor and 9 furrow openers at 20 cm row to row spacing. In preliminary trials during 2007-08, it was observed that if row to row spacing of the machine is increased to 25.7 cm there was a small reduction in wheat yield. The new prototype having 7 furrow openers spaced at 25.7 cm was fabricated and evaluated during 2008-09. Two replicated field experiments on sandy loam at Sangrur and silt loam soils at PAU Ludhiana were conducted during 2008-09 to study the effect of date of sowing, row spacing (20 cm and 25.7 cm) using 9-row versus 7-row machines on wheat yields. The experiment was laid down in split plot design with three replications. Total rice straw load averaged 8.5-8.6 t ha^{-1}. Apart from the above replicated trials, 8 on-farm trials were also conducted to evaluate the newly developed HS (35 hp model, 7-row) at different locations in Punjab, India during 2008-09.

Maneuverability of HS:
HS weighs around 650 kg and after filling the seed, fertilizer total weights increase to 800 kg. It was difficult to lift the HS with existing 45hp tractors available in India. Another drawback is the placement of gear box (transmitting PTO power to SM rotor) at the front of SM drum of HS as a result the length of machine is increased. This shifts the centre of gravity of HS rearwards. This overhang needs to be reduced as it lifts the front tyres of the tractor and creates difficulty in tractor control.

Vibration reduction
Excessive vibrations lead to fatigue failure of welding joints and creates problem in seed and fertilizer metering. The main source of vibration in HS is SM rotor which rotates at 1200 to 1300 rpm and cleans/ clears residues coming on to the furrow openers of HS twice in one rotation.

Placement of ground wheel
Traction wheel for operating seed and fertilizer metering mechanism is provided on side and it runs behind the HS. Since HS operates in 7-10 t/ha residue load, ground wheel often jumps over the residues.

Chocking of machine under heavy Straw load
The HS was usually choked while operating in heavy straw loads (more than 10 t/ha) or poorly spread loose residue conditions.

On farm evaluation of fine-tuned HS
PAU, Ludhiana along with Department of Agriculture, Punjab has carried out 94 demonstrations of the modified 9-row HS in different districts from during 2009-10. Wheat yield and farmers response of using HS was recorded.

Results and Discussion

Power requirement of HS
There was no significant difference in wheat yields for 9 rows or 7 rows HS machine in replicated trials at both the locations. However, On-farm trials conducted in Sangrur district showed that average wheat yield for 7-rows machine was lower by 0.3 t/ha compared with 9-row, which may not be acceptable to the farmers. The poor performance of 7-row HS may be due to 20% less seed rows. In the earlier version of HS 'J' type flails were used for managing residues (Figure 1). New type of gamma flails were developed and tested for load on the tractor. It was observed that tractor load (calculated on fuel consumption basis) was reduced by 15 % and 6 % by changing the blade shape from 'J type' to gamma and serrated gamma type flails shapes, respectively. It was observed that in case of serrated gamma flails, small pieces of straw get struck in blades serration and reduce cutting ability of flails. This may the reason for higher fuel consumption compared to plain gamma blades. The new version of the HS can now be operated with 38 hp double clutch tractor after changing flails from 'J type' to gamma type.

Figure 1. J-type and Gamma-type flail blades used in HS

Maneuverability of HS
In the earlier version of HS gear box and other machine components were selected from the ones available in market. Now these components are fabricated in accordance with HS, resulting in weight reduction from 650 kg to 550 kg. Gear box is placed on the SM drum of HS and due to this the machine is moved towards the tractor. In older versions, the universal shaft length was short as gear box was installed at front side of machine due to this; the PTO of the tractor needed to be disengaged before raising the machine at each turn at headland while operating HS. This consumed lot of time while turning. The placement of gear box at back of machine has increased length of telescopic universal shaft which enables the raising/lowering of machine with engaged PTO gear.

Vibration reduction
In earlier version of HS, the flail blades were mounted on the rotor in two rows at 180^0 angle from each other. This arrangement created two peak loads during each rotation of rotor, which caused excessive vibrations in the machine. For continuous loading of rotor, the flails are rearranged in helical pattern, in order to have uniform load on machine rotor.

Placement of ground wheel
Traction wheel of the HS is shifted to front side of the machine. This arrangement reduces the ground wheel skid as passive wheel does roll over the straw residues as it actually push the residues into the soil.

Choking of machine The problem of machine choking in heavy straw load was solved by increasing the SM drum diameter from 580 mm to 750 mm as it increases the window opening area by 60% for removal/passage straw out of HS. With these modifications, any choking of the HS with loose rice straw is reduced significantly.
The above specifications have now been recommended and made available for all the HS manufacturers of the state.

On-farm evaluation of 9-row HS
Yield trends and farmers' response show that wheat yields are either similar or higher than the conventionally sown wheat. The average wheat yield was 4.48 and 4.35 t/ha for HS and conventional wheat plots, respectively. Similar trend was observed for all three years and average wheat yield for HS sown plots was 3.2 % more than the conventional sown wheat.

There still remain technical issues around operational weight and inability to operate in wet straw conditions. Along with PAU, manufacturers are continuing to undertake different changes in the design of the HS machine. In future, hydraulic motor may be attached to SM rotor of machine for transmitting PTO power to HS. This may lead to reduction in vibrations/weight of machine as gear box, universal shaft, transmission pulleys, etc. will become obsolete. In order to enable the machine to operate in wet straw conditions, the design of furrow openers may be changed from hoe type to disc type as passive discs furrow openers by virtue of their rotation will press on/push the residues in between the seeded rows.

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Influence of irrigation and nitrogen fertiliser management practices on nitrogen dynamics in rice-based cropping systems

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Introduction

Nitrogen is one of the most critical nutrient elements limiting growth in most rice-growing soils around the world. Improved understanding of the availability of N from the native organic N sources and the fate of added N fertiliser should aid in developing innovative N management practices and an increase in the efficiency of fertilizer. Optimal productivity of such an intensive rice production system is dependent on relatively large inputs of inorganic N-fertiliser as grain yield is closely correlated with N uptake. Despite the importance of N-fertiliser with productivity, the amount of N fertilizer applied by farmers and the native soil-N supply are not well matched. This imbalance contributes to low N fertiliser use-efficiency in such production system (Olk et al., 1999). The behaviour of soil nitrogen under wet soil conditions of lowland rice is markedly different from its behaviour under dry soil conditions. Under flooded conditions, most N to be taken up by rice is in ammonium form. Under alternate submerged and non-submerged (ASNS) conditions, nitrate can be formed during non-submerged periods and could be leached or undergo denitrification, making total N losses to be higher under ASNS than under continuously submerged (CS). However, there is limited information on nitrogen dynamics when the soil is fully or partly submerged for some period of time and when the soil remains mainly saturated during the non-submergence periods in coarse-textured soils with a relatively deep groundwater table. Further research is needed to determine the level of "dryness" in ASNS that does not reduce N-use efficiency (Tuong et al., 2005). The objective of this study was to evaluate the effects of irrigation and N fertiliser management practices on the dynamics of nitrogen (NH_4-N and NO_3-N) during rice growth over two years as part of the rice-rice-legume crop sequences.

Materials and Methods

A field experiment was conducted on a sandy loam soil at an irrigated rice field of the Research Station of BPTP NTB on the Island of Lombok in Indonesia. Two irrigation treatments (continuously submerged and alternate submerged and non-submerged, hereafter referred to as CS and ASNS, respectively) and three nitrogen fertiliser rates (0, 70 and 140 kg N ha^{-1} hereafter referred to as F0, F1 and F2 respectively) were arranged in a randomised split plot design as main plot and subplot, respectively with three replications. The field experiment was conducted during October 2007 to July 2009 involving two wet (October - March) and two dry seasons (April – July). Ponding depth under the CS irrigation treatment was allowed to fluctuate between 0-10 cm throughout the rice growth period. In the ASNS irrigation treatment, maximum ponding depth was 5 cm and any rainfall occurred above that level during rice growth was drained and the treatment remained without submergence for around 5–7 days for 4-6 times during the season. During this period, water level was allowed to drop down to 10 cm below the soil surface before renewed irrigation took place. Floodwater of each rice plot was sampled one day before and 10 days after N fertiliser application and brought to the laboratory and immediately analysed for ammonium and nitrate (NH_4-N and NO_3-N). Soil samples were collected at four main phenological stages of rice (tillering, panicle initiation, flowering and harvesting) from 0-20, 20-40, 40-70 and 70-100 cm soil depths and analysed for NH_4-N, NO_3-N, total-N and organic carbon (OC). Data were analysed using Genstat software (Version 9.2.0.153, VSN International Ltd, Oxford).

Results and Discussion

The results of two years field study on the effects of irrigation and N fertiliser treatments on the dynamics of nitrogen in rice-based cropping systems showed that NH_4-N and NO_3-N concentration in soil increased as N fertiliser application rates increased during rice growth periods. Soil NH_4-N concentration was not affected by irrigation in early the rice season but later effects were pronounced as the rice season cycle progressed, especially in the middle of rice growth (panicle initiation and flowering). In these periods, NH_4-N concentration in soil was higher in CS than in ASNS, mostly in the 0-20 cm soil depth (Figure 1), whereas NO_3-N concentration in soil was lower (data not presented). Lower NH_4-N concentration and higher NO3-N concentration of soil in ASNS than in CS could explain the occurrence of nitrification during non-submergence period in surface soil. When surface soil is exposed to aerobic conditions, nitrification starts to take place, which reduces the availability of NH_4-N (Reddy and Patrick, 1986; Aulakh and Bijay-Singh, 1997). A large number of nitrifying organisms have been shown to occur in the surface layers of flooded soils although nitrifying activity in flooded soils may be substantially lower than in unflooded soils (Engler and Patrick, 1974). Furthermore, most of the NH_4-N concentration was in surface soil, which may accelerate nitrification. Total-N and organic carbon of soil was not influenced by irrigation treatments in the first year (2007-2008) of the experiment but effects were pronounced in the second year (2008-2009) of the experiment. Total-N and organic carbon of soil was higher in CS than that in ASNS treatments at 0-20 cm soil depth, indicating that frequent drying and rewetting of soils subsequently enhanced carbon and nitrogen mineralisation. NH_4-N concentration of floodwater increased soon after N fertiliser was applied, indicating that urea (N fertiliser) was hydrolysed rapidly and simultaneously some of which may be transformed to NO_3-N through nitrification, although NH_4-N concentration in floodwater was higher than the NO_3-N concentration during the observation. Yoon et al. (2006) reported that inorganic N in rice floodwater consists of 65% NH_4-N and 30% NO_3-N on silty loam soil (Fluventic Haplaquepts) at Maryung-myun, Chonbuk province of Korea. In this study, the inorganic N in rice floodwater during whole seasons consisted of 63% NH_4-N and 37% NO_3-N. The proportion of NO_3-N in this study was higher than reported by Yoon et al. (2006) probably due to soil texture used in this study and rice culture management.
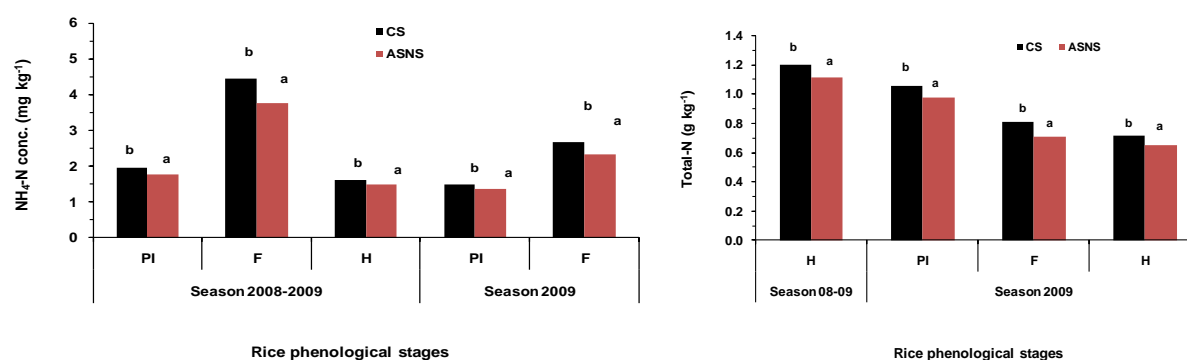
Figure 1. Influence of irrigation treatments (CS and ASNS) on NH$_4$-N (a) and total-N concentration in soil at 0-20 cm soil depth (b) at panicle initiation (PI), flowering (F) and harvesting (H) stages during rice reasons of 2008/2009 and 2009.

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Effect of stubble height and architecture on soil water capture

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Keywords: no-tillage, stubble irrigation, soil moisture

Introduction

Water is the primary constraint to crop production in semi-arid regions and rainfall in WA often occurs in light showers (Tullberg et al., 2007). Residue architecture and the amount of soil covered by loose residue alter the surface microclimate, and thereby impact the degree of water conservation (McMaster et al., 2000). However thermal and vapour transport properties of different residue types and architectures have received limited attention and remain poorly understood (Flerchinger et al., 2003). While cutting high and inter-row seeding has significant economic and crop management advantages, little is known about its influence on soil moisture capture and crop growth. The objective of this study was to investigate the effect of stubble cut-height and architecture (flat versus standing) on rainfall capture by evaluating soil moisture in both high and low rainfall events. We hypothesized that; high levels of stubble retention maximize soil moisture retention compared with low levels; and tall standing stubble increases capture of rainfall compared with flat residues. It is anticipated that the information generated from this research project will give growers and advisors more confidence to consider moving to this relatively new stubble management technique, hence improving wheat yield in Western Australia.

Materials and Methods

The experiment was conducted at Shenton Park Field Station of the University of Western Australia (32°13'S and 115°38'E) over a one month period in summer 2010, after winter wheat harvest, applying water by overhead sprinkler irrigation. The study consisted of a factorial arrangement of standing stubble (30 cm, 20 cm, and 10 cm cutting height levels) by flat stubble (4 tha^{-1}, 1 tha^{-1}, and 0 tha^{-1} tha stubble levels) treatments with a bare soil (control), in four randomized blocks. During the experiment, 20 mm of water was applied to all plots at an intensity of 13 mm/hr. Soil moisture content was measured with a Campbell Scientific Hyrdosense® Time Domain Reflectometry (TDR) probe at soil depths of 0-12 and 0-20 cm while soil temperature was measured with ibutton® data loggers placed 5 cm deep in the soil. Rainfall captured was determined by placing beakers on the soil or stubble surface (where flat stubble was present) with the rim 7 cm above the soil/stubble surface, and excavating a beaker into the soil so that the top of the beaker was level with the soil surface (below the stubble when flat stubble was present).

Results and Discussion

Effect of irrigation on water captured by stubble

Our study has demonstrated that stubble cut to 30 cm and 4 t ha^{-1} intercepted more water below stubble/soil surface compared to stubble cut to 10 cm (Figure 1). This suggests that in NT systems a significant amount of water can be intercepted by stubble and lost without reaching the soil following stubble irrigation. However the amount of water intercepted by stubble depends on rainfall intensity, amount of rainfall received, stubble cutting, stubble thickness and stubble pattern.
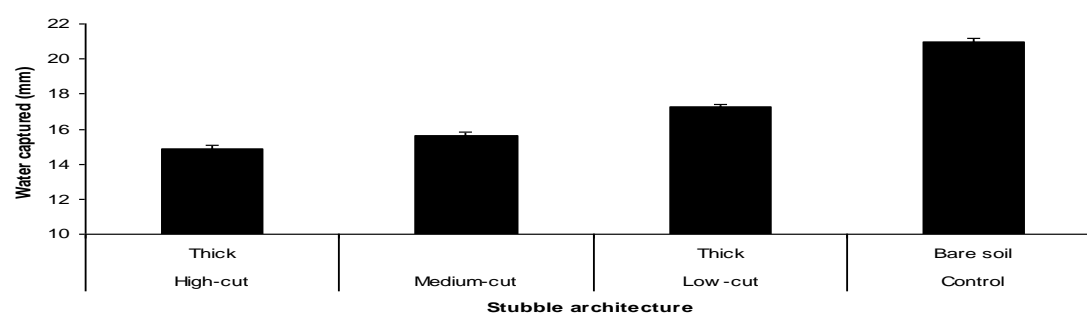

Figure 1. Effect of stubble architecture on water captured by beaker below stubble/soil surface after stubble irrigation

Effect of flat stubble in soil moisture content in no-tillage system

A significant difference (P<0.001) was observed in the change in volumetric soil moisture content among flat stubble treatments after stubble irrigation (Figure 2). Thick flat stubble recorded higher soil moisture content from the early to the end of soil drying process after stubble irrigation than bare soil, medium and nil stubble. This indicate that in Western Australia conditions NT with thick flat stubble can increase the amount of water stored in the soil from irrigation for subsequent use by crop. However the benefit of NT system in these conditions with high evaporative demand relative to seasonal precipitation can not be realized if less or no stubble is left on the soil surface. Although evaporation was not measured in this study, the tendency of thick stubble to lower soil temperature would presumably reduce evaporation soon after a rainfall event because the soil water moved deeper in the profile where it was less subject to loss during the later stages of evaporation.
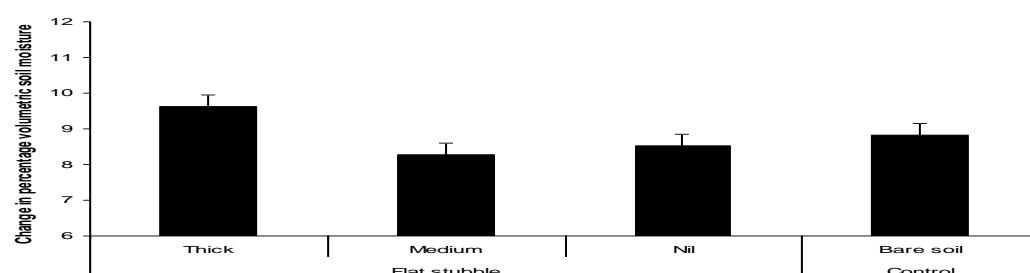

Figure 2. Effect of flat stubble on soil moisture content after stubble irrigation.

Effect of standing stubble on soil moisture content in no-tillage system

There was an interaction between height of standing stubble and time for volumetric soil moisture content following stubble irrigation (Figure 3). The stubble cut to 30 cm recorded higher soil moisture content 20.5 days after stubble irrigation than the stubble cut to 10 cm. This is probably due to the high-cut stubble reducing the wind speed at the soil surface compared with low-cut stubble (Smika, 1983).
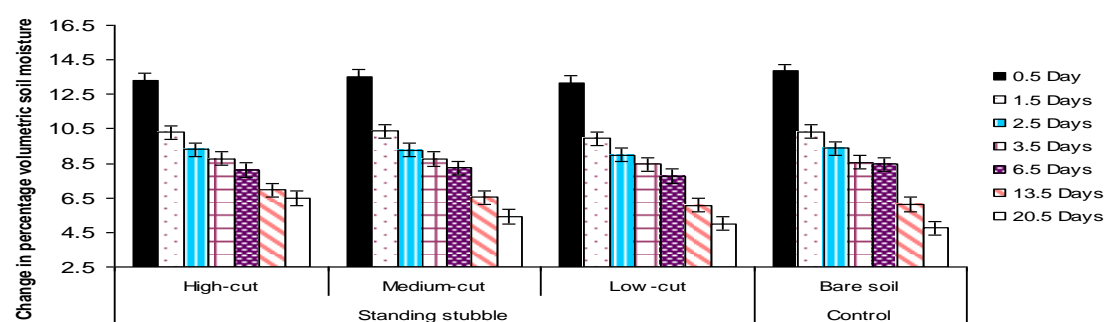

Figure 3. Effect of standing stubble on soil moisture content after stubble irrigation

Conclusions

- Stubble cutting height and thickness of flat stubble have significant effects on soil moisture.
- Stubble amount and orientation of stubble have significant effects on rainfall capture.
- There is a scope to manipulate the stubble to increase water use efficiency in WA conditions.

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Field method for detection and evaluation of soil compaction

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Keywords: soil protection, classification key, field diagnosis, soil valuation

Introduction

The "Classification Key for Detection and Valuation of Soil Compaction in the Field" was created in 2009 in Germany by Weyer and Boeddinghaus (2009). The idea was to provide farmers and also agricultural consultants and other persons dealing with soil with a method which can be used easily to determine the current condition of soils. The Classification Key comes along with a brochure describing soil compaction basics, its genesis, prevention, and amelioration measurements (Weyer and Boeddinghaus, 2009) and is particularly useful for farmers concerned about compaction in no-till and reduced tillage systems.

Criteria for the Classification Key

The "Classification Key for Detection and Valuation of Soil Compactions in the Field" was designed to meet the following criteria: it should (a) be useable under adverse conditions outside like dirt and rain, (b) be feasible for anybody to work with it without prior-knowledge about soil sciences, special equipment or laboratory work, (c) provide a clear evaluation of the current state of the soil, (d) give everybody the ability to detect soil compaction, (e) be easily understandable, and (f) indicate for further action depending on the evaluation results. To meet the first criteria the Classification Key was designed for a two-sided layout on water- and dirt-proof paper. The front page holds the Classification Key itself, while the back provides the user manual. A spade, knife, tape measure and hand probe are the only tools needed.

Set up of the Classification Key

The analysis of the soil compaction status is separated into four steps: I. Field Inspection, II. Field Diagnosis 1, III. Field Diagnosis 2, and IV. Evaluations at the Pit Wall. Combination of all four steps produces a quantified outcome. As soil compaction often occurs below the cultivation depth, like plough pans, it is advisable to evaluate the soil down to approximately 50 cm depth to include subsoil compactions. Table 1 shows the soil attributes that are to be analyzed in the four steps of this procedure. The soil attributes were chosen for their proven capability as diagnostic tools for the detection of soil compaction (Dietz and Weigelt, 1997, Boden, 2005). A clear evaluation of the soil compaction state was ensured by setting out a point system for the evaluation of each aspect. For this, the condition of each soil attribute is described by different levels (1 to 5) of degradation. In level 1 the soil state is good without signs of degradation, while level 5 is used for soil is displaying severe signs of degradation. A similar system to assess degradation was previously used by Dietz and Weigelt (1997) and the German soil mapping guideline KA5 (Dietz and Weigelt, 1997). Now, for the first time, it is combined with a factor system. The soil attributes were weighed with different factors from 1 to 5 depending on their usefulness for the detection of soil compaction (see Table 2). For example, we attribute "penetration resistance with the hand probe" e.g. was weighed with factor 3 as it is strongly dependent on the soil moisture content and some experience is necessary to assess the penetration resistance properly. Compared to that, "share of macropores", "soil structure", and "root growth and distribution" are clear indicators of which are independent of weather conditions and easily assessable by laymen. Therefore, these attributes were weighed with factor 5. The combination of the level of degradation of an attribute with its factor is the key element of the Classification Key. It enables anybody to provide a clear assessment of soil compaction. The degradation level evaluated is multiplied with the factor for every attribute. Afterwards, all results are summed up (see Table 2). The total sum that is reached is then compared with three evaluation classes. They describe the state of the soil with respect to compaction at the depth in question, and give initial suggestions of further actions. As soil conditions are never homogenous over the entire evaluation depth, every distinguishable layer has to be analysed separately. The total sum is valid only for the layer in question. At the end this gives a picture of the varying characteristics of the soil profile and helps to detect not only the problematic zones, but also gives a clue about likely reasons for the compaction. Anthropogenic sub soil compaction usually indicates too high loads in field traffic while compaction at the plough pan is likely to be caused by adverse cultivation practices. To reach the first evaluation class (37-74 points) the soil needs to range overall in the degradation levels 1 and 2. Here, the soil is perfectly healthy in terms of compaction. It can fulfill all functions such as habitat for plants and animals, filter for precipitation, regulator of nutrients and site for crop production. In the second class, 75-111 points and overall range in level 3, the soil shows first signs of compaction but there is a good chance for recovery without too much effort. The production system should be analyzed for compaction risks and adjusted towards more soil friendly treatments. Advice from soil scientists and crop production consultants can be helpful. If a soil shows severe signs of compaction, the overall degradation level of the attributes will be 4-5 which results in evaluation class 3 (above 112 points). The soil is compacted and cannot completely fulfill its functions anymore. It is no longer capable of ameliorating extreme conditions like droughts or heavy precipitation events, so productivity is at a risk. Changing climate conditions will therefore lead to even more insecurity for crop production in areas with soil compaction. Where a soil ranks in the third evaluation class, farmers are advised to consult specialists to find ways of changing the production system towards being more soil-friendly and to discuss means of amelioration.

How to work with the Classification Key

The job of the analyst is to assign the level of degradation to the evaluated soil attributes according to the front page of the Classification Key. There, the attributes can be found with a short description of their appearance in different degradation levels, which is supported by pictures to enable a better understanding. The pictography and understandable description of the soil attributes play a key role to meet the criteria b, c, d, and e as described above. The user manual on the back side of the Classification Key explains the single steps from searching a sampling site to sample taking and how to analyze it. Some of the attributes that need further explanation are described here as well. After soil analysis and calculation of the total sum, the analyst can read out the result directly from the bottom of the front page of the Classification Key, where the evaluation classes are described.

Table 1: Evaluated soil attributes

Step	Soil Attributes
Field Inspection	- condition of the soil surface - permeation resistance with the hand probe
Field Diagnosis 1 *analysis with the spade*	- root growth and distribution - transitions between soil layers - decomposition status of organic material - soil colour – iron and manganese spots as signs for damming wetness - soil odour
Field Diagnosis 2 *analysis with the drop-shatter test*	- soil structure - consolidation degree of aggregates
Evaluations at the Pit Wall	- bulk density - share of macropores

Table 2. Determination of the total sum

Attribute	Factor		Level		Sum
soil surface	1	x	1	=	1
permeation resistance	3	x	1	=	3
root growth	5	x	1	=	5
transitions between soil layers	3	x	3	=	9
state of decomposition	4	x	2	=	8
soil colour	3	x	2	=	6
soil odour	2	x	1	=	2
soil structure	5	x	1	=	5
consolidation degree of aggregates	4	x	1	=	4
bulk density	2	x	2	=	4
share of macropores	5	x	1	=	5
sum total					**52**

Field experience

The "Classification Key for Detection and Valuation of Soil Compactions in the Field" was used successfully in the field for the last two years. It is now a well established method for farmers and consultants to analyze soils. The Classification Key helps the users to gain a better understanding of soil and its needs.

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Tailoring wheat genotypes for conservation agriculture in different cropping systems: an innovative and much needed breeding paradigm

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Introduction

Rapidly growing food demand for the ever increasing human population, increasing competition for land and water among different sectors, land degradation, increasing energy costs, labour shortages and changing climates are the major challenges to food security facing the world community (Anon, 2008). Among the food grains, wheat accounts for 20% of human food: among consumers in developing countries it is the second most important source of calories (after rice) and is the largest source of protein. By 2050, the demand for wheat in the developing world will grow by 60% higher over current level (CIMMYT 2011). Therefore, there is a need to produce more in less favourable environments, on less land, with less water and energy resources. This warrants new thinking, direction and strategy for innovations in research and development.

Conservation Agriculture (CA) is practiced on over 108 m.ha globally under different production systems and ecologies has been shown to be a management strategy to address the emerging challenges of natural resource degradation, energy, water and labour crises and climate change effects. In South Asia, CA-based technologies are being practiced on ~ 2.0 mha in wheat under different cropping systems (Gupta and Sayre 2007). However, defining recommendation domains for different genotypes (genetic adaptation) for realizing best yield potential under various cropping systems and tillage practices are completely lacking and have never been part of breeding strategies. Though the contribution of agronomic management to yield gains is generally about equal to genetic gains, incorporating both in breeding programme to harness genotype x management interaction has generally not happened. Future productivity gains can be harnessed with a better understanding of the responses of each genotype to the production environments and a precise description of the genotypic variability for most promising traits. Wheat in India is mainly planted in three crop rotations viz., rice-wheat (RW), maize-wheat (MW) and pearlmillet-wheat (PmW). Together these account for 50 % total wheat acreage and ~75% of total wheat production. Therefore, in this study attempts have been made to evaluate genotype x system x tillage interactions to facilitate a new breeding strategy to tailor wheat genotypes suited to conservation agriculture under different cropping systems.

Materials and Methods

The experiment was initiated during winter 2009-10 on a sandy loam soil at Indian Agricultural Research Institute, Pusa New Delhi, India in collaboration with CIMMYT-India. A set of wheat genotypes were exposed and evaluated under contrasting tillage (no-till and conventional till) practices in three cropping systems (RW, MW and PmW) and compared with replicated best checks (recently released varieties). In MW and PmW systems, permanent beds were compared with conventional till whereas in the RW system, no-till on the flat was compared with conventional tillage. All crop residues remained in the field and were incorporated (conventional tillage) or left on the soil surface. The recommended standard levels of nutrients (N 125, P_2O_5 60 and K_2O 60 kg ha^{-1}) were applied to wheat. Standard recommended nutrient levels were also applied to other crops in the rotation. Similar plant stand were maintained across the genotypes by varying the seed rate according to 1000-kernel weight.

In MW and PmW rotations, single row of maize and pearlmillet were planted on top (centre) of the beds and two rows (25 cm apart) of wheat were drilled through the anchored residues on each bed. In case of the RW rotation, both rice and wheat were sown on flat configuration. Plot size was 5.6m^2.

For genotype x tillage interaction in MW rotation, 720 genotypes of wheat along with 90 plots of checks were evaluated under permanent beds and conventional till whereas in PmW and RW rotations a set of 200 entries were planted along with the best checks. For genotype x cropping system interactions, a set of 200 common entries planted under CA in different rotations were considered.

Results and Discussion

The results were interpreted in steps to provide a realistic idea of the tillage x genotype interactions. Three check varieties (developed under conventional tillage based breeding programs) were evaluated under contrasting tillage practices (permanent beds vs conventionally tilled) in the MW rotation and showed a differential yield response. The results (Table 1) show that PBW 550 had better adaptation to conventional till (5103 kg ha^{-1}) under the MW cropping system. Among the other two check varieties, mean average yield of DBW 17 was significantly higher under permanent beds whereas HD 2967 showed stable performance across the two environments. Overall experimental yield was significantly higher in permanent beds than in conventionally tilled . Terminal heat stress was important in the 2009/10 cropping season and permanent beds reduced the negative effects of this situation. As in no-till practice (permanent beds in MW and PmW and no-till flat in RW), the same set of check genotypes were used in all the three cropping system, a significant difference in the response of three genotypes in different cropping system was recorded. DBW 17 and HD 2967 were significantly higher yielding than PBW550 in MW and PmW cropping system whereas in RW there was no perceptible difference between the three check varieties. This indicates a strong genotype x cropping system interaction and the differential adpatation of different genotypes to different cropping system.

In the MW cropping system, a set of 720 genotypes was evaluated under permanent beds and conventionally tilled conditions. Results revealed that among the top 10 high yielding test entries (genotypes) in each production environment, only two entries were common indicating thereby, the presence of cross-over type of interaction for genotype and tillage. Importantly the highest yielding lines under permanent beds were generally also higher yielding under conventional till beds but the reverse was not true. The results, therefore, suggest that a separate breeding program for conservation agriculture is warranted. Also it appears that CA gives an advantage under conditions of terminal heat stress.

Table1. Comparisons of check varieties of wheat under contrasting tillage practices in maize-wheat cropping system

Variables	Tillage/genotypes (Checks)					
	Permanent beds			Conventionally tilled		
	Maize-wheat cropping system					
	DBW 17	PBW 550	HD 2967	DBW17	PBW 550	HD 2967
No of replications	30	30	30	30	30	30
Range	3083-4333	1933-3916	2100-4083	1806-3820	1572-5103	2013-4827
Average yield (kg/ha)	3593	2593	3103	3115	3491	2986
	Pearlmillet-wheat cropping system					
No of replications	11	11	11	-	-	-
Range	2064-4111	0928-2060	2266-4177	-	-	-
Average yield (kg/ha)	3022	1593	3133	-	-	-
	Rice-wheat cropping system					
No of replications	11	11	11	-	-	-
Range	1880-3309	1619-2857	1857-3047	-	-	-
Average yield (kg/ha)	2623	2483	2580	-	-	-

Among the 200 genotypes evaluated under three cropping systems (RW, PmW, MW) in CA the top ten performers encountered in each cropping system (Table 2) were different revealing the presence of a strong genotype x cropping system interaction. Since the best plot yield among the three checks was used a bench mark for selection, the gain in yield is more likely due to genotypic differences. Significant genotype x tillage and genotype x cropping system interactions suggest that a new breeding strategy is needed to tailor genotypes to different cropping systems (Trethowan et al 2009). Moreover the potential benefits of CA in addressing the emerging challenges of resource degradation, climate change and food security, can only be realized through tailoring genotypes for different production environments encompassing tillage and cropping system. Therefore, integration of genetic enhancement with management recommendations seems additive and should form part of new breeding strategy.

Table 2. Top ten high yielding test entries (genotypes) under no-till (permanent beds and flat) in different cropping system

Maize –wheat(PB)			Pearlmillet-wheat (PB)			Rice-wheat (No-till Flat)		
Rank	Entry no	Yield of the entry as percentage of the best plot of best check	Rank	Entry no	Yield of the entry as percentage of the best plot of best check	Rank	Entry no	Yield of the entry as percentage of the best plot of best check
1	09-103	115	1	09-591	118	1	09-648	127
2	09-107	110	2	09-602	115	2	09-588	124
3	09-39	108	3	09-598	114	3	09-598	118
4	09-117	107	4	09-38	113	4	09-640	117
5	09-33	105	5	09-596	113	5	09-590	113
6	09-93	104	6	09-601	113	6	09-589	112
7	09-282	103	7	09-630	109	7	09-612	112
8.	09-289	103	8.	09-128	102	8.	09-616	112
9.	09-489	103	9.	09-191	101	9.	09-586	109
10.	09-321	102	10.	09-180	99	10.	09-609	108

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Promoting no-till practices to stabilize durum wheat yields and sustain agricultural production in semi-arid regions of Algeria

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Keyword: degradation, cereals, chickpea, no-till, yield, farmers.

Introduction

In Algeria, arable lands are undergoing degradation at alarming rates, either due to inappropriate soil and vegetation uses or to weather impacts (drought and erosion). Farmers are obliged to manage simultaneously water scarcity and crop failures through traditional soil, water and crop management practices. Quantitatively, farmers are seeing their production declining and are losing their natural resource base on which agriculture depends (i.e. soils). Conventional agricultural practices that cause degradation of natural resources can no longer be considered sustainable and new alternative options are urgently needed.

Cereals are the major crops predominantly grown under rainfed conditions. Out of 3.5 million hectares annually planted to cereals, only one third could be considered favorable for agricultural production. Moreover, the northern part of Algeria is highly subject to soil erosion estimated annually at 2000 to 4000 tons/km² due to erratic rainfall and its high intensity during the rainy season. These factors are the main reason for very low and highly variable wheat yields that often do not exceed one ton/ha. Consequently, Algeria is a net importer of wheat, mainly of durum type, and its annual imports amount to 5 million tons.

Conservation agriculture, based on no-till and minimum tillage practices, would contribute to conservation, improvement and more efficient and sustainable use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. Besides increasing crop production, no tillage systems can considerably reduce costs, labor and energy use. Thus, conservation agriculture can play a central role in agricultural policy and ensure food security and sustainability of the national economy.

Research conducted in dryland areas around the world in general, and particularly in North Africa (20 years in Morocco; 7 years in Tunisia) and West Asia (15 years at ICARDA in Syria and Turkey) where the agricultural conditions are similar to those of Algeria, has shown considerable opportunities to implement agricultural practices that both improve production and contribute to optimization of water use and mitigation of land degradation. Cropping systems based on conservation agriculture practices have proved to be more sustainable that those with conventional farming technologies. In fact, no-tillage is practiced on 96 million hectares worldwide predominantly in North and South America (39 and 47 %, respectively), and its uptake is also increasing in other semi arid regions of the world. Based on the widespread uptake of these systems in many other countries, it is expected they could bring significant agricultural, ecological and economical benefits to Algeria and other Arab countries in West Asia and North Africa region.

In the last four years, Algeria introduced fifteen no-till drills to initiate a national program on the promotion of conservation agriculture based on no-till system. ITGC has already established contacts with advanced institutions from Spain and France to promote no-till technology in Algeria.

Overview of Achievements in Algeria

In the last four years, Algeria introduced fifteen no-till drills to initiate a national program on the promotion of conservation agriculture based on no-till system. ITGC has already established contacts with advanced institutions from Spain and France to promote no-till technology in Algeria.

Conservation Agriculture has been developing during the last two year. In 2010, 1523 hectares have been under CA management in 8 provinces of the Country. In 2011 the area under CA increased to 5559 hectares and touched 12 wilayas (provinces) mostly consisting in direct drill of dominantly cereals but also food legumes (DDZASA, 2011).

In 2010, results obtained in the wilaya of Setif, which has more practice/ experience and practice of CA, showed that direct drill (DD) allowed a grain yield of 2.1 tons/ha in wheat and 2.2 tons/ha in chickpea. However, first hand practice in Constantine wilaya allowed an average 2.5 ton/ha in cereals. These yield levels were respectively 14% and 11 % superior in Constantine and Setif areas and 120% superior to conventional management of chickpea in the area of Constantine that is DD has allowed a yield increase of 1.2 ton/ha in chickpea (ITGC, 2010a).

In 2011, important progress was going on and three out the 12 wilayas cumulated 88% of the realizations. These are: Oum El Bouaghi with 3105 ha (56%), Constantine with 1109 ha (20%) and Setif with 663 hectares (12%) (ITGC, 2010b).

It is to be note that up to 2011 only 16 direct drills have been purchased by institutes, state farms and few private farmers. This number is well below the possibility of putting up a more ample CA program in the vast agro-ecological zones of the country.

Table 1: number of direct seed drill in Algeria in 2011

Province	Farmer	Number of direct drill
Constantine	3 + ITGC	3 +1
Annaba	1	1
Tiaret	ITGC	1
Saida	ITGC	1
Oum El Bouagui	2	2
Tlemcen	2	2
Ghardaia	1	1
Alger	1	1
Sétif	2 + ITGC	2 + 1
Total	16	16

FERMES DE DEMONSTRATION ET DE PRODUCTION DE SEMENCES DE L'ITGC

Source; Cellule SIG, I.T.G.C.
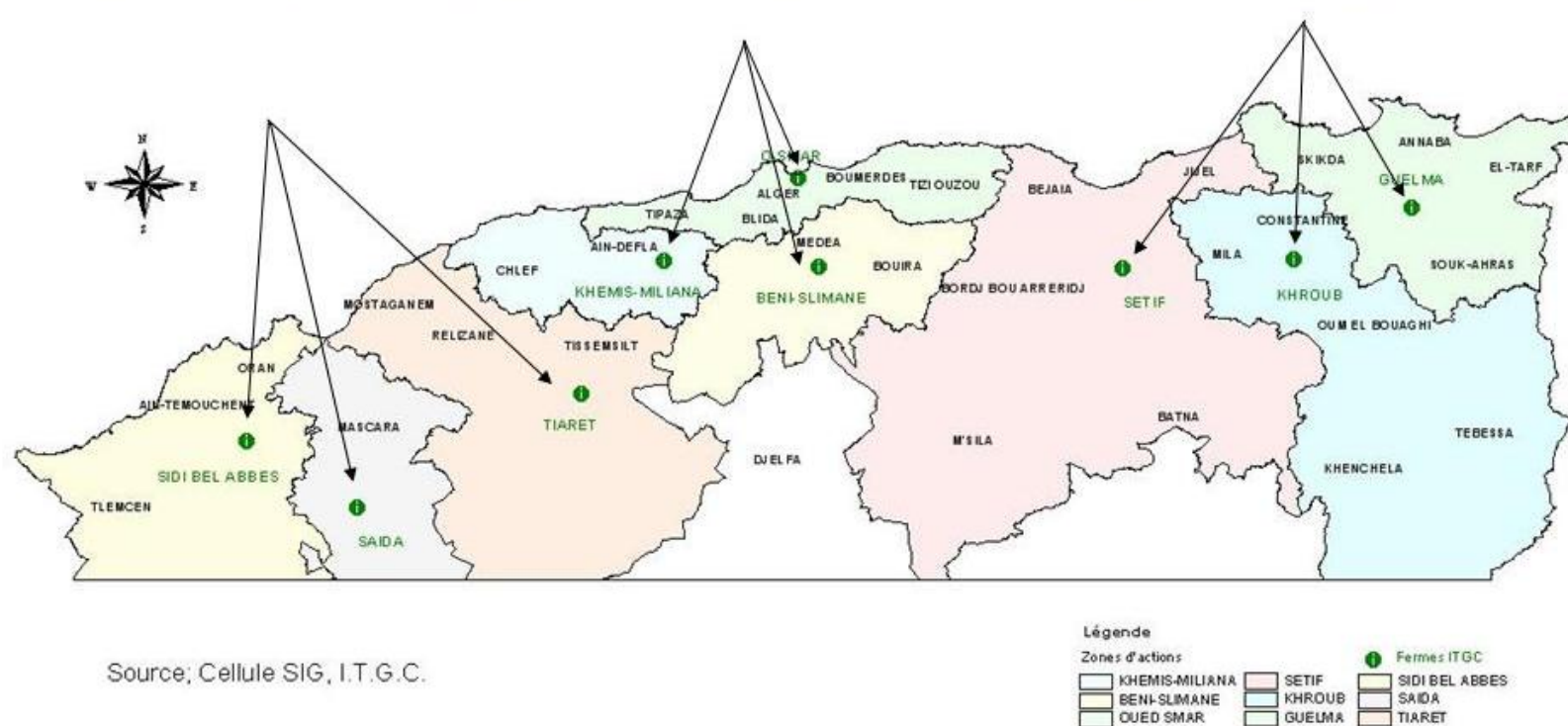
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Understanding "time" as a key constraint to achieving sustainable rice farming in Sri Lanka

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Introduction

The purpose of this study is to understand the context and the causal conditions of the constraints to achieving sustainable rice farming in Sri Lanka. While agricultural policy plays a major role in deciding the farming practices adopted by farmers at a broader scale, a number of societal drivers operating at village and farm level constrain farmers' decisions to adopt best management practices. Here in this paper we focus on understanding the village and farm-level constraints encountered by the farmers. Assuming a grounded theory approach (Glaser and Strauss 1967; Strauss and Corbin 1990) we locate "time" as a single major constraint to achieving sustainable rice farming in Sri Lanka and discuss its context and the causal conditions. We argue that "time" is only an indicative phenomenon. But the real constraint consists in the broader financial and resource insecurities that challenge the stability of the farming culture and lifestyle.

Materials and Methods

The data were derived from one-on-one in-depth interviews carried out with different stakeholders involved in rice farming in two selected high-yielding rice farming districts in Sri Lanka. The informants were selected using a purposive sample (Robson 2002). Forty-three informants including subsistence rice farmers, agriculture extension officers, agriculture scientists and agriculture policy makers from the districts of Hambantota and Embilipitiya were enrolled in the study. The interviews were semi-structured in format and the questions probed matters involving preferred and non-preferred farming practices, yields, income and other livelihood aspects related to rice farming. The sample size was determined in relation to the saturation of information (Glaser and Strauss 1967; Strauss and Corbin 1990). The data were analysed using open coding and axial coding to derive and develop concepts and themes (Strauss and Corbin 1990).

Results and Discussion

'The lack of time' was the single most cited constraint to adopting best management practices in farming.

> "I hire out my tractor and plough the fields of others for a wage, so I don't have the time to transplant"

> "I don't have the time for manual weeding, because I have to cook for the people working in the fields, … applied weedicide to the grasses [with medicinal value] in our home garden too"

> "The Udawalawe irrigation scheme release water at regular intervals of 3-3.5 months… we were asked to finish land preparation in 10 days, so we applied counter [a weedicide] to all the ground cover and shrubbery in the field"

As expressed by the farmers quoted above and other informants, time becomes a limiting factor for many reasons, which influence a farmer's decision to adopting best management practices (Figure1). Such action and/or interactions strategies (contextual interpretations) of influence range from the national agricultural policy, through local labour and agrochemical market operators to knowledge and beliefs of the key decision making figure in the farming household (see Figure 1). These contextual interpretations render time as a constraint and the response to this is often conceived as involuntary. Therefore, we identified "time" as a single major phenomenon constraining the adoption of best management practices in farming and located many forms of its contextual interpretations in relation to three critical causal conditions.
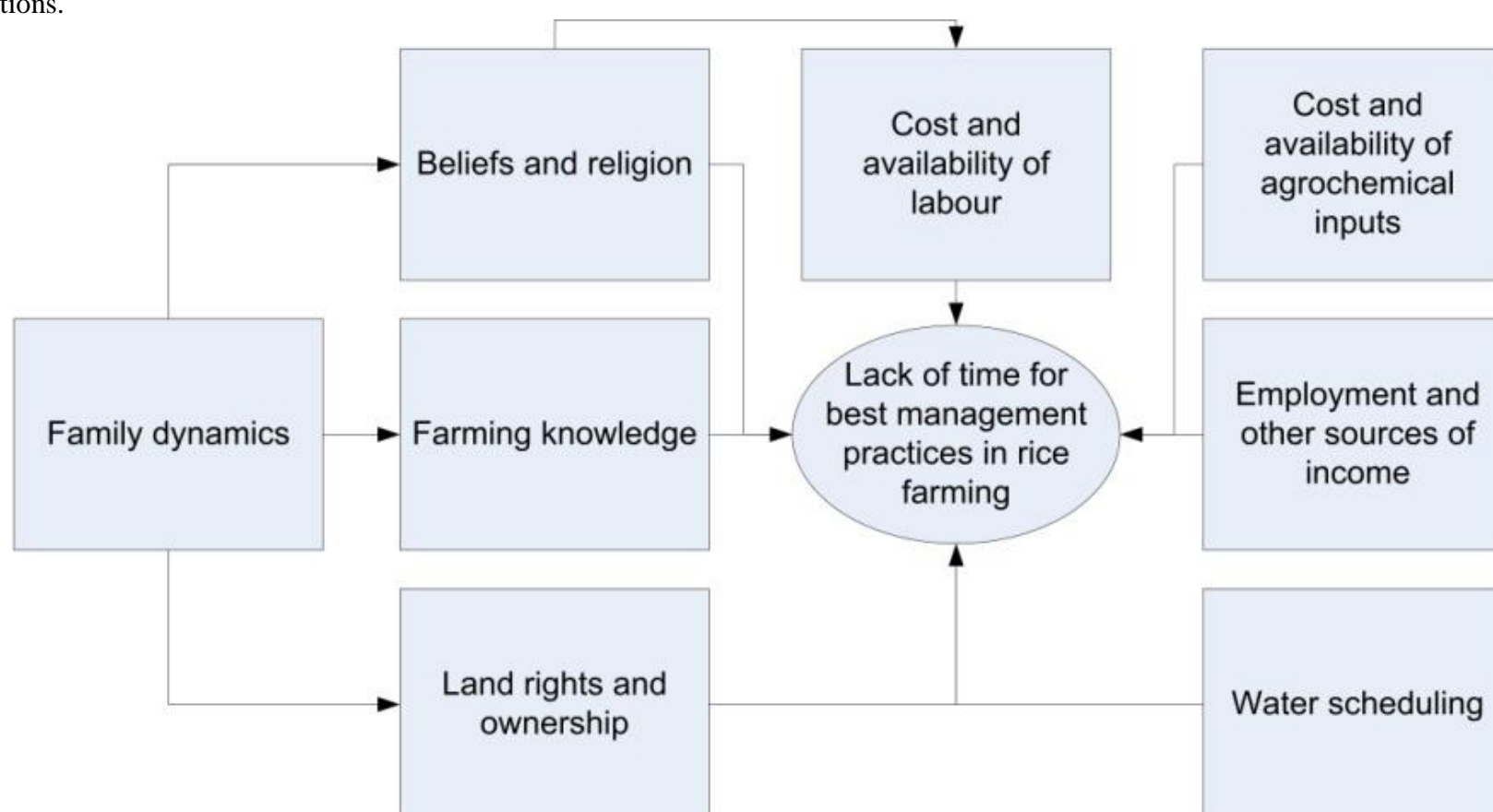
Figure 17: Actions and/or interaction strategies influencing a farmer's decision to adopt best management practices in rice farming

1. Financial insecurity: Rice farming at small scale is not a profitable trade. Therefore farmers undertake other employment such as paid labour work, retail business, taxi-driving and farming of other cash crops. As such they involuntarily choose to minimise the time invested in rice farming in an attempt to regain financial security by investing time in other income generating practices.

2. Land insecurity: More than 95% of farmers inherit farm land by descent. As a result over many generations the land has been divided up amongst the siblings and the current generation owns very small blocks of land (less than 0.5 acres) or no land at all (Abeygunawardane, unpublished data). Short-term leasing of land is risky in view of time-consuming investments in land-conserving agricultural practices. Therefore, farmers voluntarily refrain from practising best management practices on leased land.

3. Water insecurity: the Mahaweli scheme at all times and other irrigation schemes at times of water scarcity release irrigation water on a schedule for a limited period of time. Therefore, farmers resort to "quick-fix" farming practices.

The bottom line is that these causal conditions dictate farmers' decisions to adopt best management practices. Depending on the context these causal conditions may operate one at a time or simultaneously in combination. As a result, environmentally friendly traditional farming practises such as long fallow periods, application of green manure and animal waste, aquaculture in paddy fields, utilization of nutrients in irrigation water, planting trees on paddy fields, and indigenous pest control methods (Ulluwishewa 1991, 1992) have largely ceased to exist. The causal conditions engender a contextual interpretation of the central phenomenon; 'the lack of time'. By analysing the different interpretations of the central phenomenon, we postulate that the causal conditions of these interpretations relate to a single uniting theme: an interplay of financial and resource insecurities.

Sri Lanka is impelled by a vision of ancient prosperity founded upon and sustained by the cultivation of wet rice, which to date proves an ultimate development goal for many. Achieving self-sufficiency in rice has been the primary target of all successive governments since independence (Bandara and Jayasuriya 2009; Weerahewa et al. 2010) and it is deep seated within chauvinistic aspirations. As such rice farming is ingrained in Sri Lankan culture more as a lifestyle than a livelihood (Weerahewa et al. 2010). This so-called rice culture evolved and sustained itself as a dynamic but stable system for over two millennia. Central to this stability was the capacity of the system to provide its key actors, the farmers, with social, financial, resource and food security. The ever-changing socio-political environment of the system poses numerous challenges disrupting this balance. The system still sustains the social and food security that is so crucial to the rice culture in Sri Lanka and holds the system together as a single functional unit, whilst financial and resource securities are largely at stake.

The contextual interpretations identified here are a response by farmers to counter these financial and resource insecurities. Time is often the limiting factor in realizing these responses and so is expressed as the key constraint. Yet the real impediments to achieving a sustainable farming culture lie with the financial and resource insecurity experienced by farmers. Therefore, interventions to promote environmentally benign farming practices need to address the underlying financial and resource insecurities rather than the overlying contextual interpretations of the problem.

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Effect of improved fallows on maize productivity in Eastern and Southern Africa: a yield gap analysis

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Introduction

Soil fertility degradation has been described as a major constraint to food security in sub-Saharan Africa (SSA). A large proportion of the soils in SSA presents a variety of constraints to agricultural production such as nutrient deficiency, low soil organic matter, low water holding capacity, and high erosion potential. The low input of nutrients through fertilizer and manure application traditionally used by smallholder farmers in SSA has resulted in nutrient mining of agricultural soils and further soil fertility decline (Vitousek et al., 2009). Declining soil fertility is thus one of the root causes of low crop productivity. Agroforestry systems can be an efficient strategy to ease the problem of land degradation and nutrient depletion and therefore address food security issues by potentially improving crop productivity, sustaining crop yield increases, diversifying smallholder farmers' income and protecting the environment (Leakey, 2010). Further, agroforestry practices can be seen as an alternative or complement to the use of fertilizers, especially in the SSA where fertilizers are not always available, and when available their high cost usually limits their use by smallholder farmers (Barrios et al., 1998). However, variability of the outcome of the inclusion of trees in a cropping systems is high (Sileshi et al., 2011) and probably a result of inefficient tree species x environment interactions. Thus, we studied the implication of that variation to guide the decision of using improved fallow agroforestry practices in the right place. The main objective of this study is to identify which tree species used as improved fallow species works best in representative areas of Eastern and Southern Africa and what are the main factors that can explain the potential benefit of these trees within a maize-based system as affected by location, soil type, and climate.

Materials and Methods

Data from improved fallow trials were gathered from East and Southern African regional research stations of World Agroforestry Centre (ICRAF) with a focus on four main countries: Tanzania, Malawi, Zambia and Kenya. Most of the studies in Tanzania were conducted at Tumbi Agricultural research Station in Tabora (05002'S 032040'E, altitude 1190m). Rainfall is unimodal and annual average rainfall for the area is about 800mm. The soils are deep and well drained sandy loams classified as Ferric Acrisol. The Malawi data was collected from Makoka Agricultural Research Station near Zomba southern Malawi (15030'S15015 E, altitude 1030m). The rainfall is unimodal and ranges from 500-1600mm with average precipitation of 1024mm. The soils are clay loams classified as a Ferric Lixisol. The data generated from Zambia was conducted mainly at Mskera, Chipata Agricultural Research station (13039 S, 32034' E, altitude 1024m). Rainfall is unimodal ranging 887-1014 mm with mean annual rainfall of 960 mm .The soils are sandy loams classified as Ferric Luvisols. Unlike the three countries, the dataset from Kenya was generated from an on-farm research located in several districts of western Kenya. Rainfall in the region is bimodal with the total amount of rain ranging from 1400-1800mm occurring in two cropping seasons.

In this study, yield gap is not used in its well-known definition as the difference between potential and actual yield (van Ittersum et al., 2003).Yield gap is defined here as the difference between maize yield with tree or without tree. We analyze the yield gap according to soil type (Acrisols, Ferrasols, Leptosols, Nitisols, Phaeozems), seasonal rainfall and year, locations (altitude, geo-reference), and tree species (*Gliricidia sepium*, *Sesbania sesban*, *Tephrosia vogelii, Crotalaria,* natural fallows and others). Cumulative probabilities are calculated on yield gap for each tree species to give a first overview of the potential of each species to increase (or decrease) maize yield. Getting a first understanding of the potential of each species, we carry out a principal component analysis to define which factors influence the efficiency of the use of tree on maize production: soil type, locations and climate.

Results and Discussion

Figure 1 presents the cumulative probabilities of yield gain or loss according to the tree species introduced. We observed that in 60% of all cases (no matter the species and the locations) we have an increase of maize yield when a tree is introduced into the systems. Further, when *Tephrosia* is planted we observed that this proportion of yield increase can go up to 80 % while when maize is planted after natural fallows this drops to 30%. To explain these differences, we carried out a principal component analysis for each tree species to identify which factors are the most related to the yield gap. Figure 2 shows that the yield gap can be explained mostly by location in the case of *Tephrosia* while for the natural fallows yield gap appears to be more related to the location as well as the year (i.e. climatic variability).

This preliminary study helps to define the most important factors to consider for model adjustment of maize yield according to agroforestry systems. For instance, while modeling the introduction of *Tephrosia*, it appears that it will be more important to consider factors related with the location rather than the climatic variability while for natural fallow both should be considered carefully. These first results are consistent with Sileshi et al. (2011) analysis which defined a relation between effect of *Tephrosia* on maize yield and percent of clay, a factor location-dependent. However, the objective of our research will go one step further. In the next step, we aim at defining simple functional relationships for each factor identified in this study. These functional relationships will be defined by using model such as WANULCAS (van Noordwijk and Lusiana, 1999) run for a wide range of each of the factors identified (e.g. different locations from *Tephrosia*, while different climates for natural fallows).
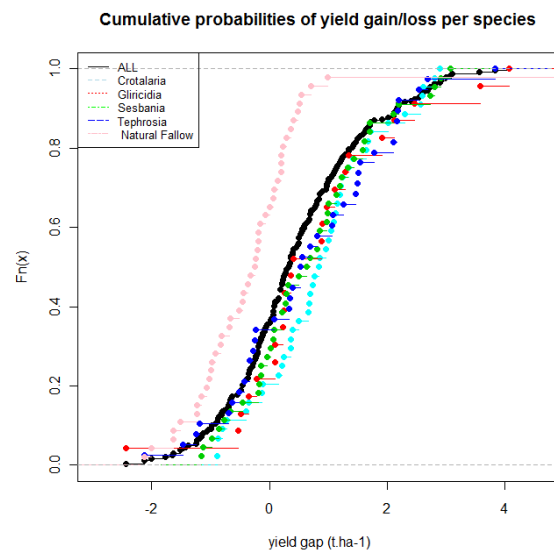
Figure 1. Cumulative probabilities of maize yield gain or loss if *Crotalaria, Gliricidia, Sesbania,Tephrosia* is introduced in the cropping system or after natural fallow.

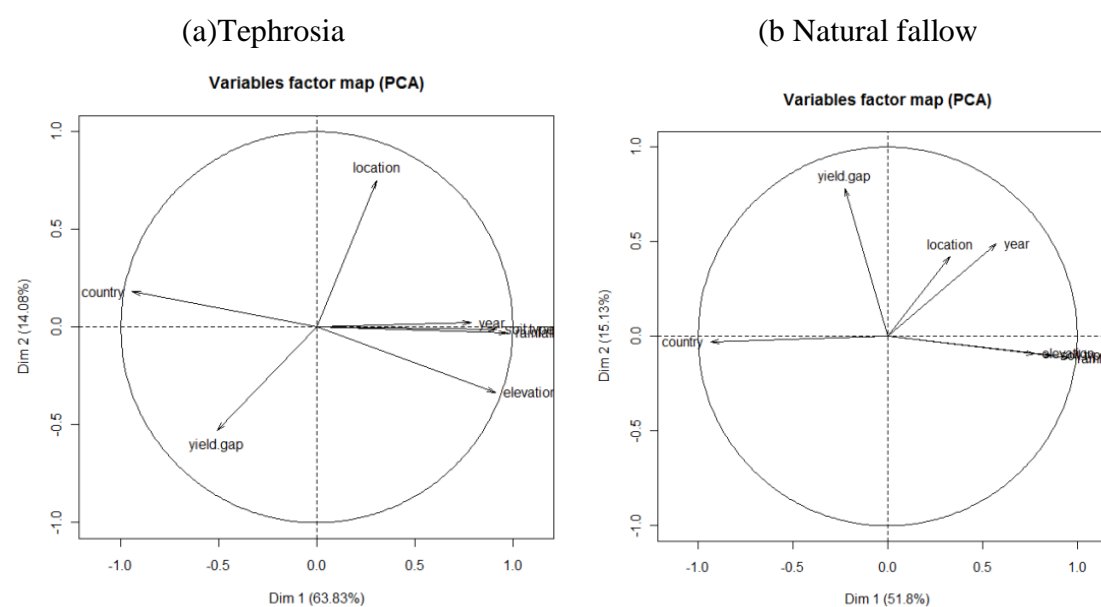(a)Tephrosia   (b Natural fallow

Figure 2. Identification of the diverse factors that explained the yield gap between monocrop maize and agroforesty maize based system: (a) with the introduction of *Tephrosia*, (b) in the case of natural fallows.

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Using agro-climatic models to estimate the Guineagrass potential production in Brazilian tropical Savanna

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Introduction

Currently, Brazil has the world's largest commercial herd of cattle, much of which is raised in extensive grazing farms. The area occupied by pastures in Brazil is approximately 172 million hectares, i.e. 69% of the total area dedicated to agricultural production. *Panicum maximum* grasses are particularly important in intensive production systems, i.e. irrigated and fertilized, because of their high annual productivity in Brazil's tropical climate. Managing these intensive systems will require designing robust farming systems and better allocations of limited and increasingly more expensive inputs, in highly variable climates and markets. The development of simulation models that consider the influence of the climate on forage production can facilitate the planning and administration of forage production on the farm. Moreover, simulation models are commonly used to estimate expected changes in climate on the productivity of agricultural systems. Agro-climatic models are, in general, simple to use, require wide available inputs, and can be useful tools for these purposes. When applied in such a specific environment, they can often give more accurate simulations than more complicated and data intensive mechanistic models. In addition, agro-climatic models are often much easier to develop and calibrate than mechanistic models (Teh, 2006). In this paper we parameterized and tested three alternative agro-climatic models, (i) a degree-day model (*DDi*), (ii) a photo-thermal-units model (*PUi*), and (iii) a growth climate index model (*GCI*), to estimate the dry matter production of *Panicum maximum* cv. Mombaça in São Paulo State, Brazil.

Materials and Methods

Experimental results from a *Panicum maximum* cv. Mombaça (Guineagrass) experiment run at Embrapa Southeast Cattle (São Carlos, Brazil, lat 21° 57' 42" S, long 47° 50' 28" W and altitude 860 m) were used to develop the required data sets for model calibration and validation. Guineagrass pastures were sown in 18/11/2009, fertilized and irrigated in order to develop data sets under potential production conditions. The plots, 36 m^2, were arranged in completely randomized blocks with four repetitions. Samples were taken above 0.3 m at time intervals determined by cumulative thermal times during each growth cycles (i.e. 250, 500, 750 and 1000 °C, base temperature = 0°C). After the last sampling time (1000° C), all the plots were uniformly cut 0.3 m above the soil to begin a new cycle of regrowth and sampling. There were 8 growth cycles over a period of 13 months (2010-2011). At each sampling we recorded total above ground biomass, i.e. green leaves + stems. A weather station recorded daily air temperature (maximum, minimum and average), rain, and incoming solar radiation. Non-linear and linear regressions were used to estimate the model parameters using SAS.

Model development:
The DDi was developed using equation 1:

$$DDi = \sum \left[(\max t_i + \min t_i)/2 \right] - bt \qquad \text{when} \qquad \text{mint}_i > bt \qquad \text{(eq. 1.1)},$$

$$DDi = \sum (\max t_i - bt)^2 / 2.(\max t_i - \min t_i) \quad \text{when} \quad bt > \text{mint}_i \qquad \text{(eq. 1.2)}$$

Where, maxt$_i$, mint$_i$ and bt are, the daily minimum and maximum air temperature and the minimum base temperature (bt=15.7ºC), respectively. The *PUi* model was calculated as in Villa Nova et al., (1983) (eq. 2):

$$PUi = \sum \frac{\left[\left(\frac{n}{2} \cdot DD \right)^{Ne/Ns+1} \right]}{Ne/Ns + 1} \qquad \text{(eq. 2)}$$

where n = days number of growth period, DD = total of degree-days of the period (as in eq. 1), Ne and Ns = length photoperiod at the end and at the start of the period. We used the *GCI* by Fitzpatrick and Nix (1973) where the growth rate is calculated based on the mean temperature, solar radiation and water availability (eq. 3):

$$GCI = LI \cdot TI \cdot MI \qquad \text{(eq. 3)}$$

where, LI = light index; TI = thermal index, and MI = moisture stress index (equal to 1.0 because the pasture was irrigated). The LI value is calculated from the incident solar radiation (IL = 1.0-exp[-3.5(Rs*23.92)/750)]), where Rs is the daily total solar radiation (MJ m^{-2}); and the TI value is calculated from average daily air temperature values. The model was validated with an independent dataset from 15 growth cycles of the same species recorded between 2005 and 2006 in São Carlos, SP Brazil, (Bertolone, 2009). The pasture was used for beef cattle grazing. After grazing, the pasture was fertilized with 50 (May-October) and 100 (November-April) kg N/ha. Model performance was tested by calculating the determination coefficient (R²) and the index "d" (Willmott et al, 1985).

Results and Discussion

Nonlinear and linear regressions were fitted to develop the relationships in eq. (1), (2) and (3) (Figure 1). The R^2 values indicate that simple relationships could be used to parameterize equations to predict the dry mass production of the Guineagrass. High correlation values, between the dry mass production and climatic parameters, were also observed by Araujo et al. (2010), working with tropical grass in Brazilian. These authors explained that the use of empirical models can be efficient to estimate the biomass production of tropical grasses under ample water and nutrients supply. During validation, the three climate models showed high accuracy. The *PUi* was the most accurate, with a slope of about 1.0 (Figure 2). This model also showed the highest precision (R^2 = 0.82) and index "d" (0.85). All models overestimated the dry mass production (Figure 2 and 3). The models' overestimation was probably caused by factors not contemplated in the models. One may have been phenology, as biomass production usually decreases during flowering. Another important point could be the pasture's age. While the experiment used to calibrate the models was in its first year of production, the experiment used to validate the models was established many years ago. We also have to consider the contrasting managements of the pastures in the calibration and

validation data sets. While the experiment used to calibrate the models was carried out under mechanical cuts, the experiment used to validate the models was carried out under grazing. Probably, all these factors may have influenced the difference between the observed and estimated values by the models in this paper. The *PUi* seems to outperform the other two models. Here we conclude that simple empirical models that use air temperature and daylength to estimate potential production of Guineagrass, can offer an attractive alternative to more complicated mechanistic models.
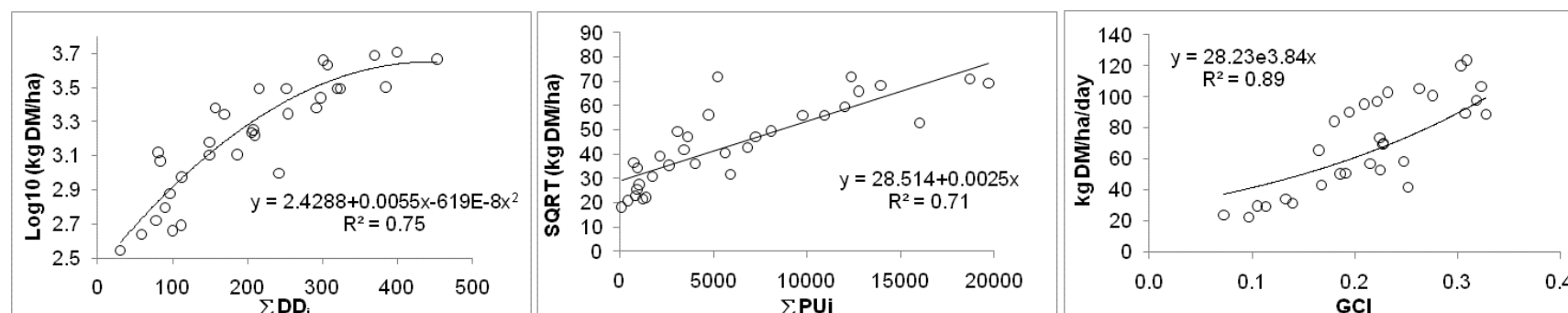
Figure 1. Calibration equations to estimate the dry mass (DM) production of the Guineagrass using a degree-day model (DDi), a photothermal-units model (PUi), and a growth climate index (GCI) model. Each point is the average of four replications. ($p \leq 0,01$).
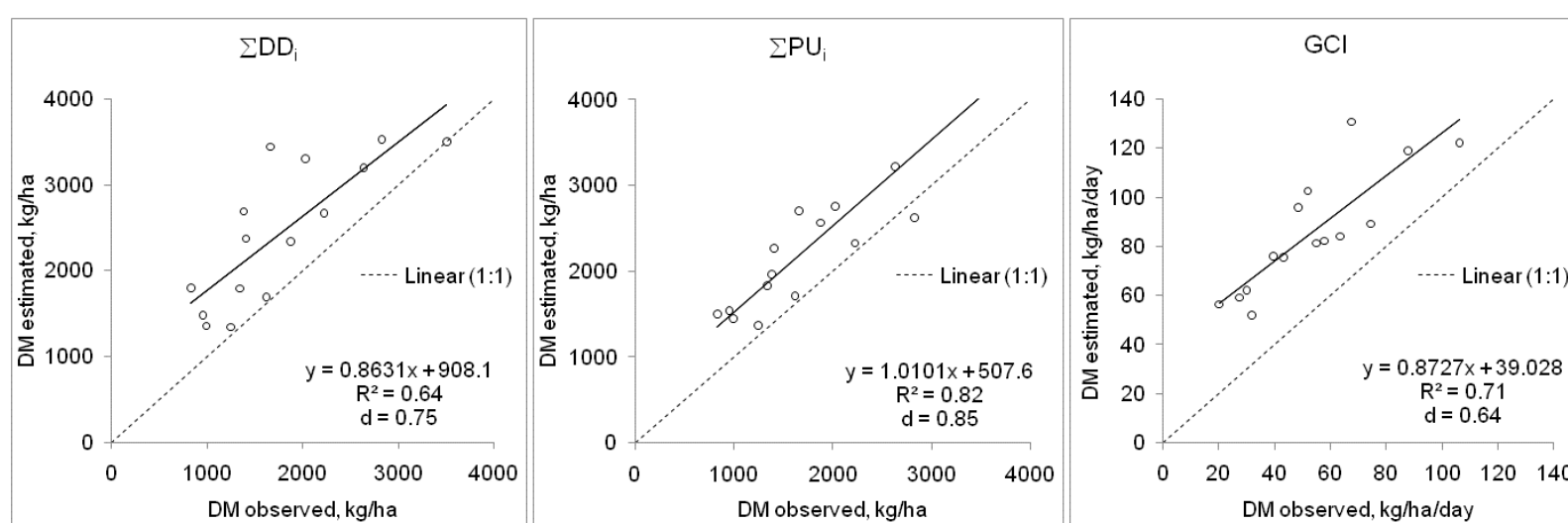
Figure 2. Observed and estimated values of the dry matter (DM) production of the Guineagrass. Degree-day model (DD_i), Photothermal-units model (PU_i) and Growth climate index (GCI). Index "d". ($p \leq 0,01$).
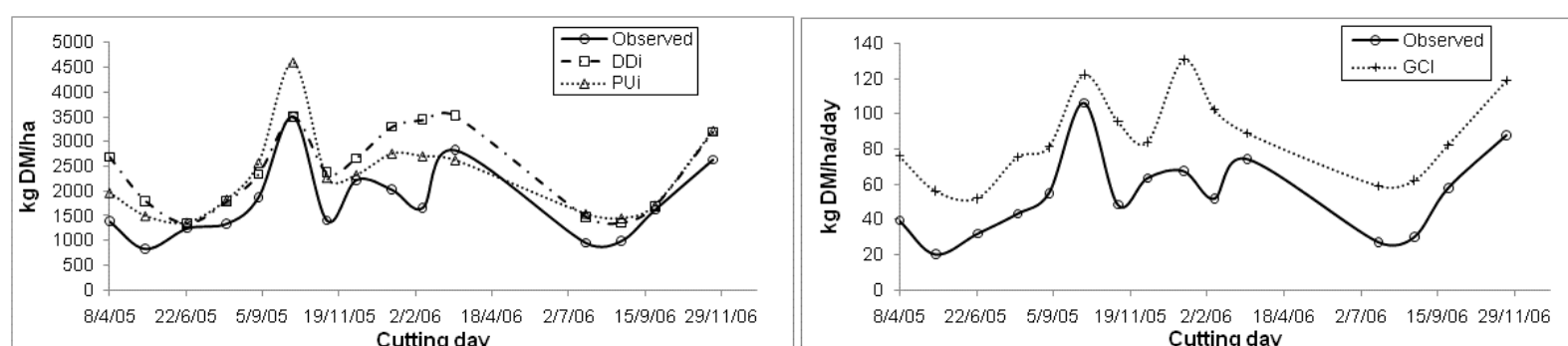
Figure 3. Time series of dry matter (DM) production of the Guineagrass simulated over two years in São Carlos, SP, Brazil. Degree-day model (DD_i), Photothermal-units model (PU_i) and Growth climate index (GCI).

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Designing and disseminating Conservation Agriculture according to context features: theory and practices

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Introduction

Conservation Agriculture (CA) dissemination efforts around the world brought out different trajectories in adoption (Derpsch, 2007; Napier and Camboni, 1993; Nowak, 1987). Focusing only on agronomic key factors in designing CA technologies failed in providing suitable solutions for their final adoption and extension, whatever the context (Erenstein 2003; Giller et al., 2009). This makes it clear that context features determine the level of social acceptability of the proposed innovations. Given that CA designing phase is a key component of its final acceptation, it therefore appears important to combine institutional principles,comprising both sociological and organizational features, with agronomic principles when setting up CA options.

Chauveau et al. (1999) distinguish different classes of socio economic contexts that may be identified according to soil conservation implementation. For CA dissemination, Food and Agricultural Organization (FAO) distinguishes three main classes including: a) modern intensified agriculture encountered in Northern Agriculture and South American farming systems with rapid adoption rate, b) medium to small farming systems, with relatively medium adoption rate, and c) small-scale agriculture of Africa and other developing countries, with low adoption rate. Recent works on adoption of soil conservation practices (Erenstein, 2003; Giller et al., 2011) identify main institutional features differentiating these contexts. These constraints include market imperfections and property rights definition failure.

This paper provides a theoretical framework to identify the main features of each agricultural context. Based on four case studies within different soil conservation projects funded by the French Development Agency including Cameroon, Madagascar, Mato grosso in Brazil and France. The paper finally defines a practical framework to organize soil conservation interventions, developing theoretical basics for priorities in CA designing or complementary efforts programming.

Institutional principles for designing and implementing conservation agriculture are proposed to complete basic agronomic principles adopted by international organizations on conservation agriculture. A detailed approach is proposed with key monitoring factors, especially for small-scale agriculture.

Materials and Methods

To facilitate the emergence of a theory of designing and implementing system's innovation in conservation agriculture, a qualitative approach in innovation adoption has been used, mainly through processual approach and case studies. Theoretical basis of the methodology was borrowed from Mukamurera et al. (2006), Dawson (1997) and Eisenhardt (1989). Processual approach in qualitative research relies on an iterative methodology to derive context impact on CA adoption. It is based on different case studies, each one characterized by specific features. The first step of the study consisted in identifying key factors influencing CA designing and adoption among different CA extension programs. A conceptual framework based on the three identified factors (agronomic constraints, market imperfections and property rights definition failure) was used to verify the impact of these factors on a wide sample of Countries from Derpsch (2007) and, thereafter, developed on four relevant case studies in different agro-economic contexts. Case studies were then considered in each of the three contexts distinguished by FAO, adding progressively new constraints. Case studies included Brazil and France for the first class of modern intensified agriculture, Madagascar for small-scale agriculture with market imperfections class (both with or without failure in property rights definition), and finally Northern Cameroon for small-scale marked by both market imperfections and property rights definition failure. To provide a more complete theoretical framework on soil conservation development policies, efforts have been specifically made on the last class (small scale agriculture), appearing to be the most constrained one. This was justified because in this class, both technical and institutional innovations were concerned, making the final theory toward designing suitable CA more complete and appropriate. In these countries, a large range of CA systems were designed on the basis of both technical and socio-economic constraints and extended in the framework of five-years-long rural development projects, over several thousand hectares. Extension of the various systems was monitored in databases and causes of abandon / conditions of adoption were analyzed in relation with the context.

Results and Discussion

The study confirms that complementarily to agronomic designing of CA, institutional adaptation is necessary and should be based on certain key institutional factors among which market failures and property rights definition. Market imperfections include failure of providing certain facilities like access to credit, agricultural inputs, or information, which, in certain conditions of financial constraints of farm units, may influence farmers' ability to invest in soil conservation (Erenstein 2003; Scoones and Toulmin, 1999). Property rights addresses different types of rights to soil (ownership, access and withdrawal) and the way soil conservation investments may be captured by the investor (Schlager and Ostrom, 1992).

Based on these factors, three different situations are encountered:
1.   Modern intensified agricultures of Northern Countries (Europe and America) and South America. Because they provide necessary incentives, they represent the most suitable environment for CA extension. In this context, efforts on CA designing consist of agronomic innovations according to soil conservation guidelines, since little institutional constraints do exist (Seguy et al. 1996). The three key agronomic principles of CA (permanent soil cover, minimum soil disturbance and appropriate crop rotations), when properly implemented, are often sufficient to ensure emergence of efficient and thus profitable technologies, with efficiency being the key for acceptance.
2.   Small-scale agriculture, subject to several market failures or imperfections, which include access to credit, access to specific agricultural inputs, and access to information. In this specific context, technical innovations may fail to disseminate, due to their entry cost within financial constraints for farmers. It therefore often appears more profitable for agricultural producers to invest in other short run alternatives than in soil conservation. Projects in Madagascar dealing with this constraint therefore focussed on low-

input systems and/or included an institutional support to facilitate access to credits, inputs, and information. The appropriate intervention scale is the farm household scale. CA adoption is slower and requires more institutional support than in the first class.

3. Small-scale agriculture with poorly defined property rights in agricultural resources and market imperfections (Cameroon and Madagascar). Poorly defined property rights are mainly found in context were common property, free access rules on land and land products are practiced, within different stakeholders, mostly in developing countries. Poorly defined property rights come together with market imperfections, making this context less favorable to CA technologies dissemination. Property rights definition failure is of crucial importance in soil conservation because it determines the way upcoming returns of conservation may be captured or divided by different stakeholders. The higher the return to the investor, the higher the investment in soil conservation (Scoones and Toulmin, 1999). In this case, CA designing and implementation must therefore include: i) technical support by designing CA systems taking into account agronomic and socio-economic constraints, ii) different types of institutional support, in relevance with market imperfections and iii) collective action which may enables emergence of new property rights regime ensuring individual or collective incentives to invest in soil conservation. The community village scale, may be the best suitable level of intervention, in addition to farm household and plot scale levels.

This study assembles theory and practice and shows that designing and implementation of suitable CA technologies may be based on five interacting principles: 1) Taking into consideration that system innovation is by definition concerned with both technical and institutional dimension of innovative process; 2) Providing diversified CA technologies and flexibility of the agronomic alternatives based on the three key agronomic principles. These alternatives should release as many socio-economic constraints as possible, address the plot scale objectives and farm unit preferences on time and reduce the risk; 3) Providing a global support (both technical and market supply) to make it possible for the farm unit to switch to a more favorable environment for soil conservation investment; 4) Identifying appropriate scale for property rights comprehension and facilitating local collective actions to derive suitable rules and collective incentives for soil conservation; 5) In more complex institutional environment, addressing different constraints progressing from collective to individual constraints and scales.

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Building social resilience through understanding capacities of smallholder farming in Papua New Guinea

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Introduction

The Papua New Guinea economy is in transition to a semi-commercial/commercial farming system. However, the majority of the population of PNG practice subsistence farming (Mopafi 2004). To accommodate change, understanding the capacity of farming communities to adapt and be socially resilient is essential (Adger 2000). We are implementing a project to increase vegetable production in Central Province (CP) for Port Moresby (PoM) markets (ACIAR 2010, Birch et al 2009) in partnership with Fresh Produce Development Agency (FPDA), National Agriculture Research Institute (NARI), Pacific Adventist University (PAU), Central Province Administration (CPA) and Greenfresh (GF), of PNG. Here, we discuss strengths and weakness of smallholder farming in several locations in CP in terms of adaptation to change and social resilience.

Methods

To gauge capacity for change and social resilience, we used the Appreciative Inquiry (AI) framework (Cooperrider et al 2003) and Rapid Supply Chain Appraisal (RSCA, Collins and Dunne, 2008). These elicit current vegetable farming realities and ideas for change within communities or contexts. Use of AI engages the community, builds trust among members and encourages sharing of knowledge (Raymond 2006). The method is cyclic and has four layers - the 4-Ds: Discovery, Dream, Design and Destiny. During initial interviews, we used the first two – Discovery and Dream – and asked participants to name the best and most problematic things about vegetable growing and to envision the future (Table 1). In a follow-up workshop with participants (often run on gendered lines), Dreams provide the entry point for exploring Design, which encourages thinking about strategies to improve vegetable growing, and Destiny, which encourages them to implement actions and provide feedback to the community (Watkins and Mohr 2001). This paper reports on the Discovery and Dream components undertaken with smallholder farmers in several locations in CP, chosen because of the (i) need to enhance socio-economic conditions (Birch et al, 2009) (ii) potential to improve vegetable production identified in consultation with the stakeholders and small farmers; and (iii) climatic conditions favourable to increase vegetable production for PoM. Thus, Bautama (Hiri district), Rigo–Koiari (Rigo district), (lowland areas SE of PoM) and Tapini (Goilala district, Highlands NW of PoM) were chosen. A collaborative approach to cross-cultural research is an important value underpinning AI/RSCA methodology, and was evaluated by our PNG partners for cultural appropriateness. We then decided to use focus groups instead of individual interviews, and constructed focus group questions (Table 1) with our PNG partners facilitating development of their research skills (Reason and Bradbury 2008).

Table 1: Matrix of AI and RSCA

Appreciative Inquiry (AI) Process		Rapid Supply Chain Appraisal (Collins and Dunne, 2008)			
		Value creation	Product	Communication	Chain governance
Discovery (The best of what is…)	1. What has worked well for you in growing crops in your village? 2. What have been your successes in marketing horticultural products?	• What are you most proud of in growing crops? • What do buyers see as being different or good about your produce?	• What is it that has worked well for you in growing crops in your village? • What has worked well for you in marketing crops in your village?	• Who was responsible? (Identification of the leader) • How did you know what to produce? • How did the group make the decisions?	• What has been the greatest achievement of the cooperative since it was formed? • What made this possible? What happened to achieve success? • Why did this work so well?
Dream (What might be…)	3. What dreams (ideas) do you have for the future, given your successes in horticulture?	• How might you get the best prices?	• What might your produce look like when you harvested it? • What might your produce look like when it arrived at the buyers?	• How might you find out what the buyers wanted? • How might you find out what the transporters wanted? • How might you make sure that everybody in your group knew what to do?	• How might you make sure (motivation) everyone in the family/village/cooperative did what they needed to do for everyone to be more successful?

Smallholder participants (men, women and young people) were contacted by FPDA to confirm their availability. Focus groups of men and women were conducted separately at each locality, in groups of 4 to 15, allowing both men and women to present their views. Questions were asked by Australian and PNG researchers in English and a local language e.g. *Tok Pisin, Motu*. Responses were recorded by the interviewer in English and accuracy was confirmed. A reflection process was included to ensure arrangements for and execution of interviews remained appropriate (Reason and Bradbury 2008), and to explore reasons for any differences among data from each interviewer.

Results and Discussion

As AI focuses on community strengths (Watkins and Mohr 2001; David and Michel 2004), it provides information on building the capacity of smallholder farmers and mitigating their vulnerability during social and economic change. However, negative institutional arrangements and structural issues may emerge and have to be explored by for example RSCA. Both strengths and weaknesses will influence processes of capacity building and adaptation to change. Key words repeated around growing and marketing of vegetables (themes) were identified but not ranked at this stage. Positive themes were around food security, family labour and farming commitment, whereas negative themes were clustered around inputs, transport, markets, services and socio-cultural constraints.

Strengths that favour the community capacity to adapt to change and resilience
(i) Food Security of farmers who grow food for the family and relatives, with surplus produce sold to meet family expenses e.g. school fees, and to improve diet through purchase of rice, meat, tea and sugar (also reported earlier for PNG in Mueller et al. 2001).
(ii) Family members (including children) labour contribute to farming, with women playing a vital role in selling produce in the market for cash to spend on family needs. This confirms reliance on family labour over costly hired labour. However, the disadvantage is the potential for delays in work due to absenteeism for social commitments or illness (Allen 1996).
(iii) Desire of participants including majority of youth to remain in farming – confirms that small scale farming with cash crops can be an attractive alternative to migrating to the cities, with youths wishing to expand their farms rather than migrating. However, concern that urban migration was reducing the farming workforce had been found in an earlier study (Birch et al 2009), and could be regarded as a weakness or even threat.

Weakness that constrain community capacity to adapt to change and resilience
(i) Limited availability and cost of inputs and knowledge gaps constraining production – in particular that most available vegetable seeds were not developed for local environments so crops did not perform well, lack of irrigation infrastructure necessitating laborious hand watering, lack of tools for soil preparation and limited knowledge of pest and disease control.
(ii) Poor access to markets, transport and support services and distance from research and extension services are major constraints that weaken linkages and limit resilience (Mopafi 2004).
(iii) Socio cultural constraints such as lack of individual land ownership, the absence of trust, inequality for women in production and marketing, intensive management of labour and the high priority of cultural obligations (Mopafi 2004) may also constrain cropping decisions and compromise production and community unity, and thereby resilience.
(iv) Post harvest constraints include difficulties with cash and selling small amounts of produce, lack of storage facilities and lack of knowledge about post-harvest preservation and packaging.

The strengths of subsistence farming predominantly relate to on-farm activity, perhaps founded in long established socio-cultural norms, while the weaknesses relate largely to inadequacy and unreliability of off-farm services with the exception of inadequacy of knowledge of technical and marketing aspects. The last mentioned point needs to be addressed through extension and education, while the off-farm weaknesses can only be addressed through major redesign of the systems involved. On-farm strengths will be enhanced by overcoming on- and off- farm weaknesses to improve the comparative economic strength of rural and urban communities.

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Rotational benefit and economic return of fall-seeded pea and lentil as cover crops in wheat-based no-till cropping systems

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Keywords: winter pea hay, winter lentil green manure, nitrogen recovery in grains

Introduction

Wheat (*Triticum aestivum* L.) is one of the dominant commodities in Montana, USA; about 2.2 million hectares of wheat are planted producing 6 million tons of grain annually. The widely adopted wheat-fallow or mono-cropping system has been able to stabilize the yield and be generally economically successful, but the system lacks diversity (Brummer, 1998) and has low precipitation use efficiency (Farahani et al., 1998; Tanaka et al., 2005) and high fuel and fertilizer inputs (Liebig et al., 2007). The system has resulted in some negative biological and environmental consequences, such as weed and disease infestation, degradation of soil (Pimentel et al., 1995) and ground and surface water (Kirschenmann, 2002). Fall-seeded pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medik) have been developed for hay, green manure or grain, yet the rotational benefits and economic returns have not been well understood for incorporating these crops into the wheat-based cropping systems in the Northern Great Plains. Nitrogen is the most expensive input for growing grain crops, and it is anticipated that the alternative cropping system that uses winter pea and lentil as rotation crops will reduce N fertilizer input thereby increasing the profitability of the production system. Using pea and lentil as cover crops harvested for forage or hay also integrates livestock and crops in the production system. This paper reports two no-till rotation studies carried out in central Montana. The objectives of this study were: 1) to investigate winter wheat yields affected by winter pea and lentil grown for hay or green manure, and 2) to estimate the economic returns of alternative cropping systems by including winter pea and lentil as hay or green manure under no-till practices.

Materials and Methods

Two crop rotation studies were conducted at the Central Agricultural Research Center (47°03'30" N; 109°57'30" W; 1400 m elevation), Montana State University, near Moccasin, MT from 2004 to 2010. The soil was classified as a Judith clay loam (fine-loamy, carbonatic, frigid Typic Calciborolls). The 98-yr average annual precipitation and air temperature were 388 mm and 6°C, respectively, with a typical frost-free period of 110 d. Experiment I: winter pea hay-winter wheat system (WP(h)-WW) was compared to fallow-winter wheat (FW-WW) and spring wheat-winter wheat (SW-WW) systems. Experiment II: winter lentil green manure-winter wheat system (WL(m)-WW) was compared to winter lentil grain-winter wheat system (WL(g)-WW). Four rates of nitrogen (N) were applied to the winter and spring wheat at 0, 45, 90, and 135 kg N ha^{-1}. The plot dimensions were 5 m x 8 m. The experiments were split-plot designs with four replications. Crop rotations were assigned to the main plots and the N rates were assigned to the subplots. Experiment I was initiated in the fall of 2004, and Experiment II was initiated in the fall of 2006. The two experiments were carried out side by side in a field that had been in no-till since 1996. Experiment I was conducted for three rotation cycles during 2005-2006, 2007-2008, and 2009-2010. Experiment II was conducted for two rotation cycles during 2007-2008 and 2009-2010. In the WP(h)-WW system, winter pea (cv. Grange) was seeded in early to mid-September and the winter pea forage was cut at flowering stage in mid June of the following year. After forage harvest, glyphosate was applied to terminate the winter pea crop. Winter wheat (cv. Yellowstone) was then planted into the winter pea stubble in mid September. In (WL(m)-WW) system, winter lentil (cv. Morton) was planted in early to mid September and terminated at flowering stage (mid June of the following year) by spraying glyphosate and 2,4-D herbicides. Winter wheat (cv. Yellowstone) was then planted into the lentil field in mid September.

Results and Discussion

In Experiment I, winter wheat grain yield in the FW-WW system (2140 kg ha^{-1}) was similar to the WP(h)-WW system (2190 kg ha^{-1}), but the yields in the FW-WW and WP(h)-WW systems were greater than in the SW-WW system (1160 kg ha^{-1}). The grain protein contents did not differ among the rotation systems. Winter wheat in the FW-WW and WP(h)-WW systems took up more N and had greater N recovery rates in the grains (NRG) than that in the SW-WW system. The net economic return was $196 ha^{-1} in the WP(h)-WW system, $116 ha^{-1} in the FW-WW, and $41 ha^{-1} in the SW-WW, respectively (Table 1). In Experiment II, winter wheat grain yield was greater in the WL(m)-WW system (1840 kg ha^{-1}) than in the WL(g)-WW (1470 kg ha^{-1}) system. Protein content was also greater in the WL(m)-WW system (128 g kg^{-1}) than in the WL(g)-WW system (119 g kg^{-1}). Nevertheless, the WL(g)-WW system generated $213 ha^{-1} net profit compared to $92 ha^{-1} in the WL(m)-WW system (Table 2). Winter wheat in rotation with pea and lentil has a higher NRG than that in rotation with spring wheat.

Table 1. Winter wheat yield, protein, total N uptake (TN), nitrogen recovery in grains (NRG), and net economic returns for Experiment I conducted in central Montana with three crop rotations during 2006, 2008, and 2010 crop years.

	Yield	Protein (g kg^{-1})	TN (kg ha^{-1})	NRG (%)	Net return (US$ ha^{-1})
2006	2440a¶	127a	69a	37.8a	160a
2008	1530b	110b	42b	15.6b	150b
2010	1510b	121a	40b	18.2b	43c
FW-WW	2140a	116a	56b	28.0a	116b
SW-WW	1160b	122a	32c	18.1b	41c
WP(h)-WW	2190a	119a	63a	25.4a	196a

¶Different letters following the values in the same column within the years or rotation treatments are significantly different according to the LSD at P<0.05 level.

Table 2. Winter wheat yield, protein, total N uptake (TN), nitrogen recovery in grains (NRG), and net economic returns for Experiment II conducted in central Montana with two crop rotations during 2008 and 2010 crop years.

	Yield	Protein (g kg^{-1})	TN (kg ha^{-1})	NRG (%)	Net return (US$ ha^{-1})
2008	1520b¶	115b	48a	16.7b	177a
2010	1780a	132a	53a	27.1a	129b
WL(g)-WW	1470b	119b	41b	20.9a	213a
WL(m)-WW	1840a	128a	59a	22.8a	92b

¶Different letters following the values in the same column within the years or rotation treatments are significantly different according to the LSD at P<0.05 level.

Results from three rotation cycles in this study indicate that the winter pea cover crop can replace part of the fallow period in the fallow-winter wheat system. Winter wheat following winter pea hay produced a yield similar to the FW-WW system. This result disagreed with the study conducted by Janke et al. (2002) in south central Kansas, USA, where the winter wheat yield was reduced by a winter annual legume cover crop. The discrepancy was due to the shallow soil profile in central Montana, which doesn't hold much moisture during the fallow period. The WP(h)-WW system in this study generated more net profits than the FW-WW system did, which approved the prediction of Janke et al. (2002) that terminating winter annual legume cover crop early in the spring and using it for livestock feed may improve the profitability of cover crop system. Apparently, the WL(g)-WW system in this study is the most profitable cropping system, which justifies the recent surging of lentil production in Montana. Further study is needed for soil quality improvement by legume cover crops.

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Exploring the relationship between path dependency and flexibility in farm systems

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Introduction

Evidence suggests that climate change is likely to increase the variability in seasonal conditions and pest and disease outbreaks that farmers will have to manage (Stokes and Howden 2010). Farm viability in these circumstances may depend on the capacity of farmers to organise their farm systems with an increased emphasis on flexibility (Burns and Stalker 1961). General systems theory suggests that the flexibility of a system is limited by how strongly that system is organised along one path towards a final state as this reduces the system's capacity to switch to other path options (von Bertalanffy 1968; Gresov and Drazin 1997). This concept aligns with the notion of investment path dependence. Path dependency theory states that current options available are limited by previous decisions that have been made (Crouch 1981; Holt and Schoorl 1985; Simon 1993).

This paper describes current PhD research to develop and validate a conceptual framework for considering the relationship between path dependence and flexibility in farm systems. The fundamental aim in this work is to reveal how this relationship affects options for farmers facing increased variability in their task environment (i.e. elements of the environment that directly affect the farm). Practically, this conceptual framework should be useful for identifying how agricultural policy and programs can support farm viability in the face of climate change.

How Farmers Manage Variability

The viability of a farm business is partially determined by the system's stability: the capacity to maintain system behaviour within acceptable limits when facing variability from the task environment (von Bertalanffy 1968). Stability is achieved, in part, by the system having a sufficient range of acceptable behaviours to match the range of expected states in the environment (Ashby 1969). If a farmer is not able to ensure that the range of behaviours of the farm system sufficiently match the range of behaviours of the environment, unmanaged input variability transfers through the system into output, affecting the viability of the business (Dillon 1992; Collinson 2001). Hence, managing variability in inputs is quite important for farmers.

Kaine et al. (2010) assert that the ability of a farmer to maintain system stability in the face of variability is determined by the farm's tactical and strategic flexibility. Tactical flexibility is the capacity of the pre-programmed responses (i.e. available farm practices) built into the system to enable the farmer to alter the use of the variable input (Kaine et al. 2010). Strategic flexibility is the capacity of the farm business strategy to allow the farmer to alter the farm's output mix, to reduce reliance on the variable input (Kaine et al. 2010). This work highlights the possibility for farmers to generate greater flexibility to manage variability by making adaptations that alter the farm's mix of tactical and strategic flexibility. However, the options available to farmers to change the farm's flexibility are constrained by previous investment decisions (David 1994; Liebowitz and Margolis 1995; Greener 2002).

Path Dependence and Flexibility

An investment path is the critical production path at the farm business level. So an investment path is a sequence of activities that are essential for production of the set of outputs of a farm business. The ability of the farmer to change production practices along an investment path, or to change to a new investment path, is always constrained by previous decisions made regarding the farm business (Simon 1993), even those decisions that have been abandoned or are no longer relevant (Holt and Schoorl 1985). In this sense, the path is the summary of the key continuing resource commitments flowing from decisions. Path dependency theory offers a way to consider the constraints of previous decisions and how they might affect farmers' future options.

Path dependence describes the sensitivity current decision-options in a system have to previous decisions (David 1994; Liebowitz and Margolis 1995). While a new organisation may have a number of investment path options to choose from, once a path has been chosen subsequent decisions are influenced by the structure developed from these earlier decisions (Ruttan 1997; Greener 2002). These subsequent decisions, in turn, are likely to reinforce the initial decisions and decrease the likelihood of changing paths (Greener 2002).

As path dependence increases the system becomes 'locked in' to a particular path. The lock in, or irreversibility, of an investment path is not inherently problematic; it is necessary to manage complexity in business (Liebowitz and Margolis 1995; Ruttan 1997; Greener 2002). Maximising productive efficiency along an existing investment path is important in farming as it enables the farmer to maximise the physical productivity available.

Sometimes the locked in path may be suboptimal or inferior (albeit not necessarily due to poor decision-making) (Liebowitz and Margolis 1995; Cowan and Gunby 1996). In such cases a decision needs to be made to either continue along the existing path or switch to a new path. All change has a cost to the system, including once-off switching costs and constraints on future decisions (Crouch 1981; Liebowitz and Margolis 1995; Cowan and Gunby 1996). Path dependence constrains the farmer's capacity to switch investment paths because of the high cost to do so (Collinson 2001). It may also impede the farmer from making other changes along an investment path that are not about optimising performance, such as adaptations to manage variability (Kaine et al. 2010).

The capacity to make changes between investment paths, as well as changes along an investment path that are not aimed at increasing productive efficiency, comprise the flexibility of the farm system. Hence, the constraining effect of path dependence on adaptation options in systems reduces flexibility (Kerr and Mooney 1988; Collinson 2001; Greener 2002). However, systems do make adaptations along and between investment paths, though the need to change must be perceived to be sufficient to warrant the cost to the system (Cowan and Gunby 1996).

Maintaining flexibility is an important strategy in managing uncertainty (Sanchez 1998). Changes likely to restrict a system's capacity to manage uncertainty will not be adopted, if possible, quite rationally (Lissack 1997). Given the amount of uncertainty that farmers face due to the unpredictable variability in the environment, maintaining some degree of flexibility in the farm system is a rational goal.

While important for managing uncertainty, flexibility has a cost to the system (Rosenhead et al. 1972). Maintaining the capacity to make changes along and between investment paths means that farmers need to manage any constraints due to path dependence, thereby sacrificing some productive efficiency. This suggests that farmers must balance the tensions between two competing goals; flexibility and the productive efficiency associated with path dependence (Rosenhead et al. 1972). Van Gigch (1974) contends that balancing such tensions, which he calls dilemmas, are common to all systems problems and must be addressed if a problem is to be solved.

How this tension is balanced, and where the emphasis is placed, will differ between farms. However, indications are that the increased variability of climate change will alter the task environment, making current balances between productive efficiency and flexibility inappropriate; these balances will need to shift towards greater flexibility. Given the cost of altering current systems to increase flexibility, such a shift may be a considerable threat to farm businesses.

To consider this further, the next step in this research is to conceptually map the path dependence of 80 dairy farms in Australia and New Zealand, and the affect this path dependence has on flexibility. The dairy industry has been selected because dairy farms tend to be single enterprise, reducing the complexity of mapping multiple outputs across multiple production processes. This investment path mapping will help to populate the conceptual model being developed with meaningful constructs such as an understanding of what production paths look like, and how multiple paths intersect in the farm system. From here, generalisable results will be identified.

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Evaluation of APSIM to simulate maize-bean cropping systems in eastern and southern Africa: an alternative approach

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Introduction

The Sustainable Intensification of Maize-Legume farming systems in Eastern and Southern Africa (SIMLESA) project (Mulugetta et al, 2011) is making a substantial investment in building African-based capacity for application of the cropping systems model, APSIM (Keating et al. 2005). As part of this effort, intensively monitored field experimentation is being conducted to evaluate APSIM's predictive performance for maize-legume based cropping systems, but this is a slowly evolving process. An alternative approach to expedite model evaluation and hasten the identification of possible model development needs is to conduct sensibility analyses based on surveyed local expert knowledge. That is, modelling yield distributions to conform to locally expected ranges of yield for given managements and season types. Here we present results from testing whether APSIM could adequately simulate expert knowledge i.e. expected yields, of important crops, maize and grain legumes across project sites, and whether or not it adequately simulated competitive effects in maize-bean intercropping systems.

Methods

Key Informant database

A relevant set of yield estimates for maize and legume crops and management conditions were obtained by surveying project agronomists with local experience of experimental and farmer-based yields. Key informants included agronomists from NARES-partners in each of the five SIMLESA project countries (Ethiopia, Kenya, Tanzania, Malawi, Mozambique). Surveyed information included varietal selection (cultivar, days to flowering and maturity), management (sowing windows, optimal sowing date, plant row spacing and population, fallow and in-crop weeds), and expected grain yield (average, poor and best seasons), of sole and intercropped configurations of the maize and legume crops. The legumes being tested included common bean, soybean, pigeonpea and cowpea. Mean yield estimates from six researcher-managed (i.e. recommended practices) sites where inputs have been verified were available and are presented here to assess yield variations between sites and between crop configurations.

Model inputs

Long term climate data was available for two of the SIMLESA sites, Kakamega in western Kenya (1979-2011) and Melkassa in central Ethiopia (1977-2007). APSIM was configured to simulate sole and intercropped maize and bean crops using recommended practices as described by the key informant's database. At Kakamega, both long (Mar-Jul) and short (Sep-Dec) rain-season crops were simulated; at Melkassa there is a single cropping season (Jun-Nov). Starting soil water conditions were set to 20mm of PAW in the surface layer. Soils were re-set to initial conditions (PAW, N and C) each season at sowing. A crop was simulated to be planted every season. Crops were simulated without weed competition and with crop residues removed from the field post-harvest. A soil description from western Kenya (Maseno, deep (1.8m) clay loam, PAWC= 155mm, SOC_{0-15cm} = 1.8%) was used to simulate soil water and N supply to crops at the two sites.

Model calibration

Starting soil mineral N (NO3-+NH4-N) was varied between simulations (from 5 to 27 kg N ha^{-1}) to calibrate the simulated sole maize grain yield to that of the key informant's mean yields. Existing APSIM-Maize cultivar descriptions were selected based on simulation of the crop duration of the recommended cultivars (Hybred614 = 160 days, Hybred513 = 123 days, Melkassa-2 = 132 days). The duration of the recommended bean cultivars (KK8 = 88days, Awash-1 = 89 days) was able to be simulated using an existing APSIM description ('caucaya' cultivar) and this description was also deemed adequate to simulate the bean yields at Melkassa. However, a much shorter duration bean cultivar description ('Othello', duration = 59 days) was used to simulate bean yields at Kakamega. Using the 'caucaya' description at Kakamega resulted in substantial over-prediction of the agronomist's bean yields and this inturn, dramatically reduced simulated maize yield in the intercropped configuration.

Model evaluation

APSIM's performance was evaluated between the yields provided by the agronomists' for poor, average and best yields at Kakamega and Melkassa, versus the simulated 10th, 50th and 90th yield percentiles, respectively.

Results and Discussion

Agronomist yield estimates

The most striking result from the key informant database is that with the exception of Ethiopia, most agronomists estimated that maize and legume crops could be intercropped at recommended practices with no or very little reduction in maize yield (Figure 1.). In contrast, intercropped legume crops were expected to suffer substantial yield declines (52%) across sites and legume species. In Ethiopia, intercropped maize was expected to have almost 30% yield reductions compared to sole maize. The more competitive effects of the bean crops in Ethiopia may reflect better adapted germplasm for intercropping with maize and could represent breeding material to develop improved maize-bean intercropping systems in the SIMLESA project overall, particularly at Kakamega.
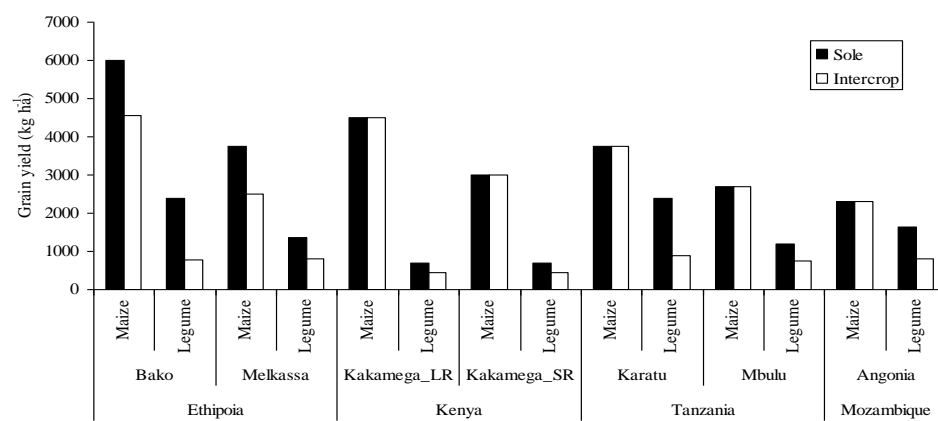
Figure 1. Agronomists expected grain yield of sole and intercropped maize and legume crops using recommended practices at 6 SIMLESA project

APSIM yield estimates

The calibrated bean model simulated the competitive effects of a maize intercrop generally in line with the agronomist's expectations (Figure 2a). On the other hand, the calibrated maize model simulated an average 42% yield decline wherever maize is intercropped with beans (Figure 2b), a substantially greater reduction than that estimated by agronomists at Kakamega (0% decline) and Melkassa (28%). In Figure 2, the simulated yield distributions of sole maize and bean crops in the Kakamega long rains and the Melkassa cropping seasons are fairly flat suggesting much less yield variability from rainfall patterns compared to the agronomist's expectations. In contrast, for the Kakamega short rains, the model predicts a greater yield reduction in poorer seasons for both bean (58% reduction vs 28%) and maize (33% reduction vs 16%) compared to the expert estimates.
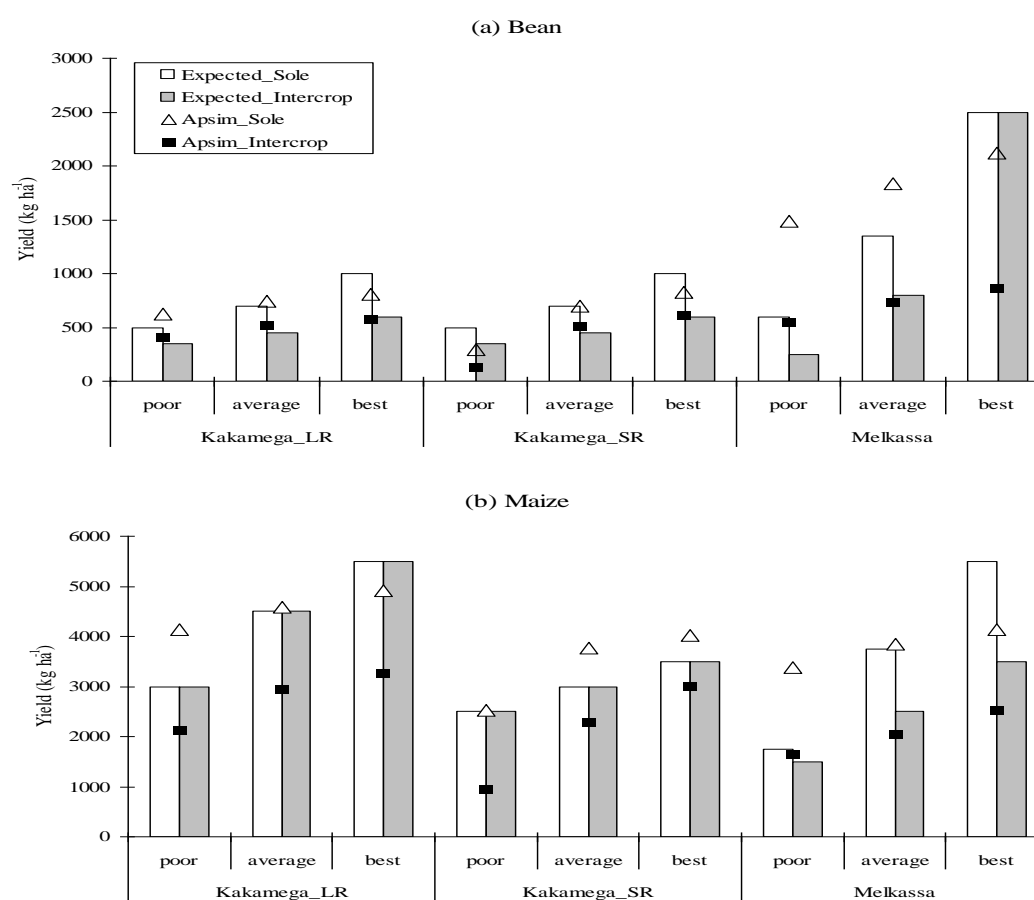
Figure 2. Agronomist's estimates of yield range (bars) at Kakamega and Melkassa sites for sole and intercropped bean(a) and maize(b) crops compared to simulated yield variations (symbols) using APSIM.

The calibration of bean simulations show a clear need to obtain better growth and development descriptions of the low yielding cultivars of common bean found in African farming systems. Project plans to further test APSIM using observed experimental data from across locations will help clarify how much of the yield variations described in the agronomists yield estimates is attributable to rainfall patterns, and to what degree other factors (pest, disease, weeds) are being considered in the poor-end yield expectations.

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Agroforestry systems as a strategy for sustainable production of oil palm in the Brazilian Amazon

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Keywords: biodiversity, environmental services, sustainable agriculture

Introduction

The palm oil (*Elaeis guineenses*) has many industrial uses and in high demand as ingredients of food products, cosmetics, pharmaceuticals and others, including fuel in diesel engines. The expectation regarding the culture of oil palm stems from its relevance to ecological and energy scenarios. However, the monoculture system of palm oil is considered one of the biggest drivers of tropical deforestation, emission of greenhouse gases and biodiversity loss. Under the context of producing in a more sustainable way, agroforestry systems (SAF) stand out as an alternative to shifting cultivation in the Amazon. The SAF main characteristic is the inclusion, through the consortium, of a greater variety of plants or animals. Thus there is in the same production system, plants having an annual cycle and perennial plants not associated with the creation of animals (Haddad, 2006). The SAF also feature low or no use of chemical inputs, high species diversity, structural complexity, and the shrub and tree component responsible for the conservation of soil and maintaining productivity, and especially the structural simplicity and high economic value of intercrop components (Nair and Dagar, 1991). The objective of this work was to study agroforestry systems for sustainable production of oil palm in the region of Tome-Açu, PA.

Methods

The Demonstration Units (DUs) of SAF Palm were installed at three farms in the cooperative CAMTA (Mixed Agricultural Cooperative of Tome Açu), located in the northeastern state of Pará, 230 km distant from Belém, the state capital, Brazil. The research field has a partnership with Embrapa Oriental and Occidental Amazon, and the Federal Rural University of Amazonia. The preparation of the area was conducted in Nov/2007 and deployment of the SAF's began with the planting of oil palm type Tenera (From Embrapa Occidental Amazon) in Feb/2008, when the seedlings were 15 months old. The DUs had the following history of land use: DU 1 - Orchard abandoned, DU 2 - **second-**growth **forest** for 8 years and DU 3 - degraded pasture. The treatments included 3 sites of production (land use) x 2 types of staging area (manual and mechanized) x 2 production arrangements (SAF biodiverse and SAF green manure). The composition of plant systems was defined in a participatory manner and in accordance with the interests of producers, involving a high diversity of fruit crops, timber, legumes and grasses. In the SAF biodiverse production arrangement, species associated with the oil palm were *Theobroma cacao*, *Euterpe oleracea*, *Oenocarpus sp*, *Virola surinamensis*, *Calophyllum brasiliensis* and *Pentaclethra macroloba*, and species associated with green manure were *Cajanus cajan*, *Canavalia ensiformis*, *Tithonia diversifolia*, *Pueraria phaseoloides*, *Inga edulis*, *Crotalaria spectabilis*, *Gliricidia sepium* and *Manihot esculenta*. In the SAF green manure production arrangement, only green manure species, as described above, were planted. Palm density varied from 81 to 99 plants per hectare. The SAF operations conducted periodically were pruning, fertilization, spraying and harvesting. The growth and development of oil palm plants were examined annually according to methodology described by Breure and Verdooren (1995). For research purposes, evaluation of productivity in SAF´s began with the harvest of fruit 30 months after planting, which was evaluated monthly until 36 months. After this point measurements were made fortnightly. Leaf analyses of green manure plants, introduced and wild species of the system were conducted to determine their capacity to supply the system with nutrients. The field activities and the technical coefficients of production in the SAF´s were collected daily and systematized monthly for later analysis.

Results and Discussion

The manual biodiverse treatments in DU1 and DU2 and treatment biodiverse in DU3 presented, so far, the best financial results, analyzed by the Internal Rate Return (IRR) applied to the sequence of cash flows for each treatment. These results were expected because these treatments have a higher number of commercial products and therefore higher revenue. The diversification of species in agroforestry systems is a strategy adopted in the pursuit of economic efficiency and food security. Initial production of palm oil was different between the three DU´s (276.7 kg/ha DU1; 184.9 kg/ha DU2; 456.1 kg/ha DU3) with DU3 showing the greatest promise. The initial behavior of production plants can vary throughout the productive life, thus the predominance of DU3 may change. However, what is evident is the suitability of *Elaeis guineensis* Tenera to the production system, with good growth and development observed thus far.

The leaf analyses of wild and green manure species identified the macro and micro nutrients incorporated into the system through the management (pruning) of the SAF Palm. As a source of nutrient, the following species are particularly notable: *Inga edulis, and Manihot esculenta* supplied nitrogen; *Tithonia diversifolia* and *Cajanus cajan* supplied phosphorus, *Tithonia diversifolia* supplied potassium, and *Crotalaria spectabilis* served as a source of boron. Among the wild species stood out *Solanum paniculatum, Jatropha gossypiifolia* and *Alternanthera dentate* (Table 1). This demonstrates the benefit of green manure, and is in agreement with the results presented by Silva (2002) and Bertalot et al. (2003).

All technical data gathered during this research project will be used to build the cost of raw materials and to assess the quality and viability of the system. Activities are being recorded on the use of manpower, fuel, raw materials, machine hours and quantities of products harvested, for both financial and environmental assessment, such as emissions and energy balance, in the hope that the agroforestry system offers an alternative that has less environmental impact and greater income. The field activities will be systematized to analyze the sustainability of this production model. Agroforestry systems are showing good prospects for meeting the sustainable production of palm oil, combining the production of oil and the conservation of biodiversity. The diversification of production systems involving the other palm species (green manure oil and timber) can be a strategy to reduce phytosanitary risks, increase income for the area considering the many commercial products provided throughout the year, less use of external inputs, in addition to social and environmental benefits that include the recovery of degraded areas and the maintenance of environmental services.

Table 1. Average leaf analyses of some wild and green manure species associated with SAF Palm.

Nutrients	Green manure species					Wild species		
	*C. spectabilis	*C. cajan	I. edulis	M. esculenta	T. diversifolia	S. paniculatum	J. gossypiifolia	A. dentata
N (%)	3,40	3,51	3,29	3,84	3,28	3,15	3,05	2,86
P (%)	0,28	0,23	0,11	0,23	0,20	0,13	0,18	0,09
K (%)	1,03	0,71	0,58	1,58	1,98	1,99	2,25	1,83
Ca (%)	1,60	0,93	1,89	1,33	2,60	1,63	2,16	1,05
Mg (%)	0,29	0,28	0,22	0,55	0,65	0,39	0,65	1,05
S (%)	0,25	0,19	0,19	0,23	0,23	0,22	0,19	0,21
Fe (ppm)	680,0	820,0	145,0	185,0	1250,0	230,0	245,0	150,0
Mn (ppm)	32,0	60,0	110,0	185,0	170,0	48,0	100,0	320,0
Cu (ppm)	13,0	12,0	11,0	8,0	10,0	30,0	7,0	5,0
Zn (ppm)	32,0	28,0	17,0	90,0	110,0	56,0	28,0	35,0
B (ppm)	38,0	30,0	24,60	29,10	84,0	30,4	32,0	29,4
Si (ppm)	190,0	160,0	245,0	185,0	230,0	240,0	285,0	205,0

* Plant with flower and seed
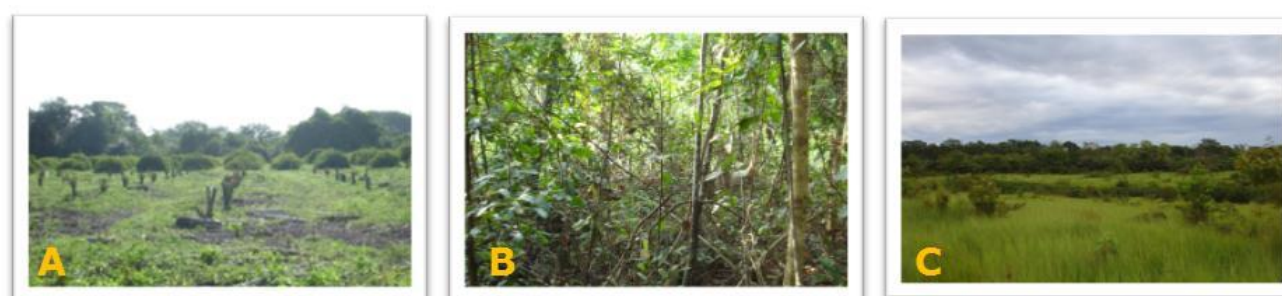
Figure 1. Start of implementation of SAF Palm, in Tomé Açu - PA – (A) DU 1 - Orchard abandoned; (B) DU 2 - *second*-growth *forest* for 8 years; (C) DU 3 - degraded pasture.

Figure 2. (A) Details of SAF green manure: double line of palm with kuzdu between line, in Tomé

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Breeding better maize germplasm for drier and hotter production environments

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Keywords: ASI, maize, population improvement, stay-green,

Introduction

The extreme season to season variability in productivity makes maize production under rainfed conditions more unreliable and risky in dry tropics and subtropics (Robertson et al. 2003). Abiotic stresses (mainly heat and drought stress) two weeks either side of flowering can severely affect fertilisation; seed set and eventually yield (Bänziger et al. 2000). Depending on the timing and severity of drought, yield loss can reach as high as 80% (Edmeades et al. 1992). Summer dominant rainfall areas of northern Australia are typically characterized by highly variable rainfall and extreme heat in the middle of summer. This provides opportunity to expose germplasm to drought and heat stresses at critical growth stages and study differential responses of germplasm.

The objective of this paper is to give a brief account of the strategy and traits employed to develop maize germplasm, tolerant to intermittent moisture and heat stress situations.

Materials and Methods

The program employs integrated population improvement and line development approaches. The purpose of the population improvement program is to build up desirable alleles for various traits, and ensure better genetic gain in the future. Since maize production in Australia is based on single cross hybrids, the program also needs to develop commercially acceptable inbred lines. To this effect, line development based on pedigree selection is followed.

Drought stress was imposed by withholding irrigation from 3 weeks prior to tasseling. S1 (1st selfed generation) individuals from breeding populations were created by selfing individuals with best flowering synchronizations (reduced Anthesis-Silking Interval, ASI). Yield trials were established in south east Queensland at Kingaroy (26º 33' S, 151º 50'E) and Hermitage (28º 21' S, 152º 10' E), from testcross progenies created by crossing S2 to a common tester. Yield trials were exposed to extreme heat stress by adjusting planting time so that flowering time coincides with the maximum heat period in summer. Plants were also exposed to severe competition by establishing 40,000 plants/ha. Stay green trait, rated at R5 (late grain fill stage), was used to assess tolerance to terminal stress. A rating of 1 was given when all leaves above the top ear were dry, and 10 was given when leaves above the top ear were green. Preliminary environment characterization was done using 110 years of climatic data from 32 site/soil combinations across Queensland and northern New South Wales. Simulated yield data were used to classify environments. Stress types and frequencies were identified on the basis of water supply/demand ratio around flowering.

Results and Discussion

Drought affects maize grain yield to a certain extent at almost all growth stages, but the plant is most susceptible during flowering (Grant et al. 1989). Extreme sensitivity seems confined to 2 days prior to silking and up to 22 days after silking, with a peak at 7 days after silking. Almost complete barrenness can occur if maize plants are stressed in the interval from just before tassel emergence to the beginning of grain fill (Grant et al. 1989). Targeting this critical growth stage under managed stress conditions, followed by adaptation trials helps identify genotypes adapted to intermittent stress conditions which may occur at any stage during the growing period. Classification of 32 site-soil combinations on the basis of simulated yield showed five major clusters, and yield variability was very high in clusters where frequency of flowering and terminal stress was high (Figure 1). Depending on the severity and the time of occurrence, the effects of moisture stress vary from poor seed set to poorly developed kernels. Figure 2 shows the relationships between ASI vs. yield; and stay green ratings vs. yield under dry land conditions. The relationships between ASI vs. yield explained about 23% of the observed variation. Evidently, the observed relationship in this experiment was not very strong. This was because the genotypes used for this analysis were selected for their better flowering synchronization under stress conditions; hence, the genetic variation for ASI was very limited. Stronger relationships could be expected if more genetically divergent germplasm in terms of ASI were studied. Nevertheless, the observed relationship confirmed that ASI is one of the critical traits that have to be used to improve maize yield under moisture stress conditions. Difference in terms of rate of leaf senescence appeared to be significantly but weakly correlated ($p < 0.05$) to grain yield (Figure 2). The strength of correlation between yield and stay green under terminal stress can be moderate (Bänziger et al. 2000). Moisture stress occurring during grain filling period affects primarily kernel size and weight (Campos et al. 2006). Moisture stress occurring after flowering causes rapid leaf senescence, restricting the capacity of the plants to supply carbohydrates to the rapidly developing kernel (Bänziger et al. 2000). Green leaves capable of photosynthesis may therefore contribute significantly to well developed kernels. The weak correlation in this study highlighted that stay green phenotypes may not necessarily be associated with better grain development and yield.
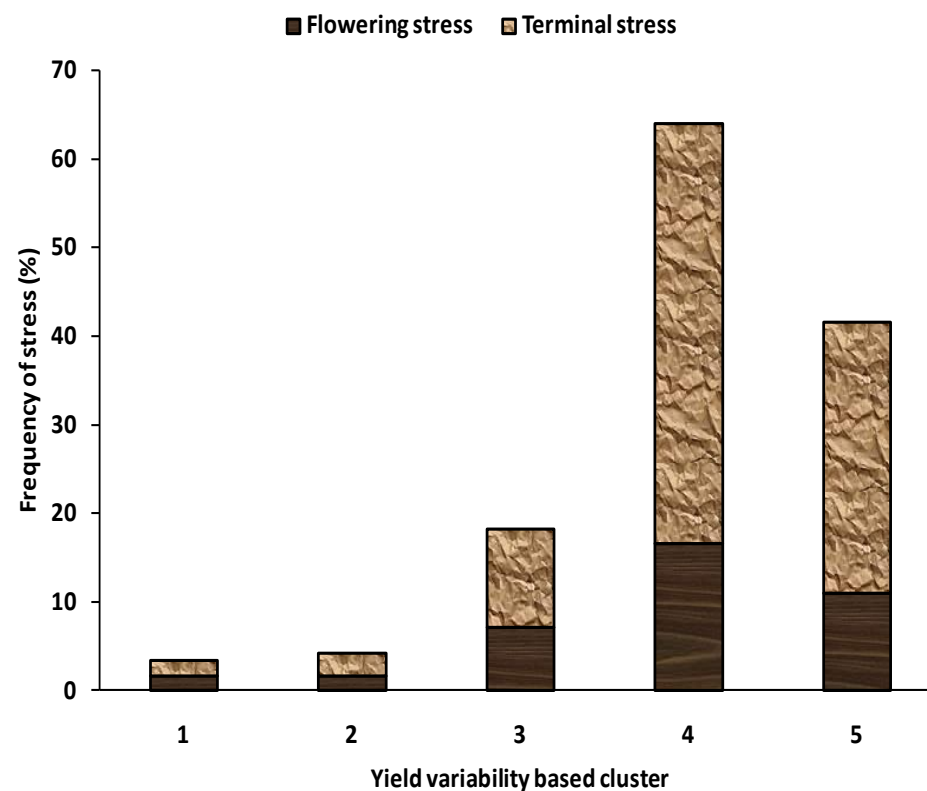
Figure 1. Graph showing the frequency of flowering and terminal stress in five major environmental clusters.
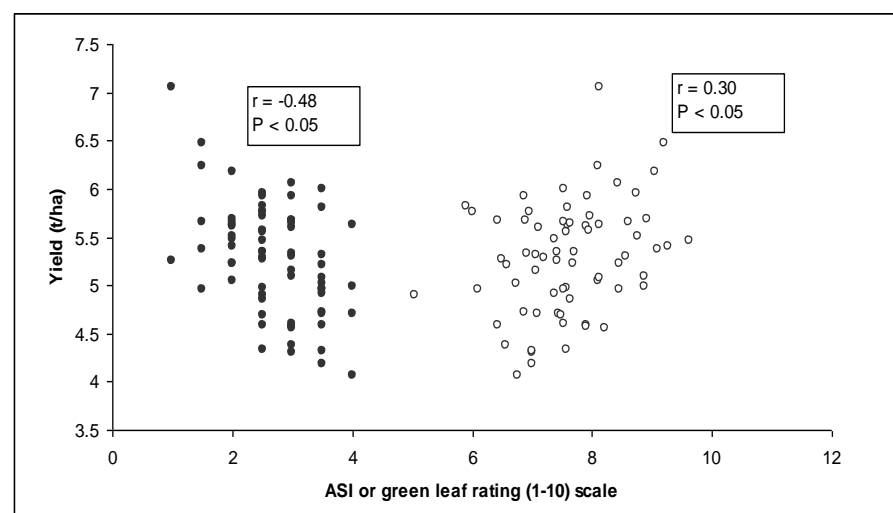

Figure 2. Relationship between yield and ASI (closed circle) and stay green ratings (open circle) for maize trial in 2011.

The preliminary results suggest that yield performance may be more dependent on ASI. However, the use of secondary traits such as capacity to retain green leaf area may be necessary to improve predictability of performance under intermittent stress situations.

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Acknowledgments

Minimum tillage systems can reduce heliothis pupae emergence in irrigated cotton farming systems

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Keywords: *Helicoverpa*, permanent beds, Vertisol, insect pest

Introduction

The heliothis moth (*Helicoverpa* spp.) is a major pest of cotton (*Gossypium hirsutum* L.) in Australia. The final stages of its life cycle involves maturing from its larval phase into a pupal phase during winter in a previously-constructed chamber in the soil at a depth of ~10 cm, prior to emerging through an emergence tunnel as an adult moth (QDPI, 2010). Post cotton-picking mechanical tillage can reduce the survival of pupae by killing them, by disrupting the emergence tunnels and by exposing the pupae to predators (QDPI, 2010). Past recommendations of post-cotton picking cultivation systems ("pupae busting") focussed solely on reducing pupae emergence by intensive (≥ 20 cm deep) tillage options (Marshall et al., 1996; Schoenfisch, 1999) with no consideration being given to the potential degradation of soil physical properties by the latter (McKenzie, 1998). The objective of this study was to evaluate pupae-busting tillage systems which minimised heliothis pupae emergence while at the same time, reducing tillage depth (< 10 cm) and intensity. In this paper, we present results of two experiments: one, conducted during 2002 which measured heliothis pupae numbers after cotton picking, soil structural condition (i.e. disturbance) and moth emergence, and another, conducted from 1998 to 2001 where pupae numbers after picking and moth emergence were measured. Although these experiments were conducted about 10 years ago, the findings are still very relevant as many cotton growers continue to use intensive tillage for pupae busting.

Materials and Methods

Both experiments were located at the Australian Cotton Research Institute, near Narrabri (149°47'E, 30°13'S) in NW New South Wales, Australia. Narrabri has a semi-arid climate with a mild winter and a hot summer. The hottest month is January (mean daily maximum of 35°C and minimum of 19 °C) and July the coldest (mean daily maximum of 18 °C and minimum of 3 °C). Mean annual rainfall is 593 mm. The soils under both experiments were Vertisols (fine, thermic, smectitic, Typic Haplusterts (Soil Survey Staff, 2010)). Mean particle size distribution in the 0-1 m depth was: 64 % clay, 11 % silt and 25 % sand.

Experiment 1: The cultivation treatments, implemented under dry soil conditions during 2002 were: (1) eliminator + wheat planter; (2) centre-busting + go-devils (disc-hiller); (3) aer-way cultivator; (4) centre-busting followed by disc-ploughing; (5) untreated control; (6) wheat planter alone. Some of these implements are shown in Figure 1. Soil disturbance (field macroporosity) in the surface 0.3 m was measured at field capacity with the "white-paint method" (Hulugalle et al., 2005) described briefly as follows: after saturation and draining of excess water, ten litres of 1:5 water soluble white acrylic paint:water mixture, followed by a further 20 litres of water, were applied to a 0.10 m deep, 0.20 m wide, 0.50 m long trench and allowed to infiltrate. One week later, 0.3 m deep x 1 m wide soil pits were dug with a spade at right-angles to the trench. After smoothing, the exposed profile face was photographed, the images downloaded onto a computer, and analysed with SOLICON 1.0 to estimate macroporosity at field capacity. SOLICON 1.0 is a software package which is able to capture and process digital images of soil profiles and estimate field porosity. Pupae numbers were monitored manually by carefully examining the top 0.1 m of the soil profile for pupal emergence tunnels and then locating the pupa or remains. Moth emergence was monitored in undisturbed areas by erecting gauze cages [1 m x 1 m] to catch emerging moths.
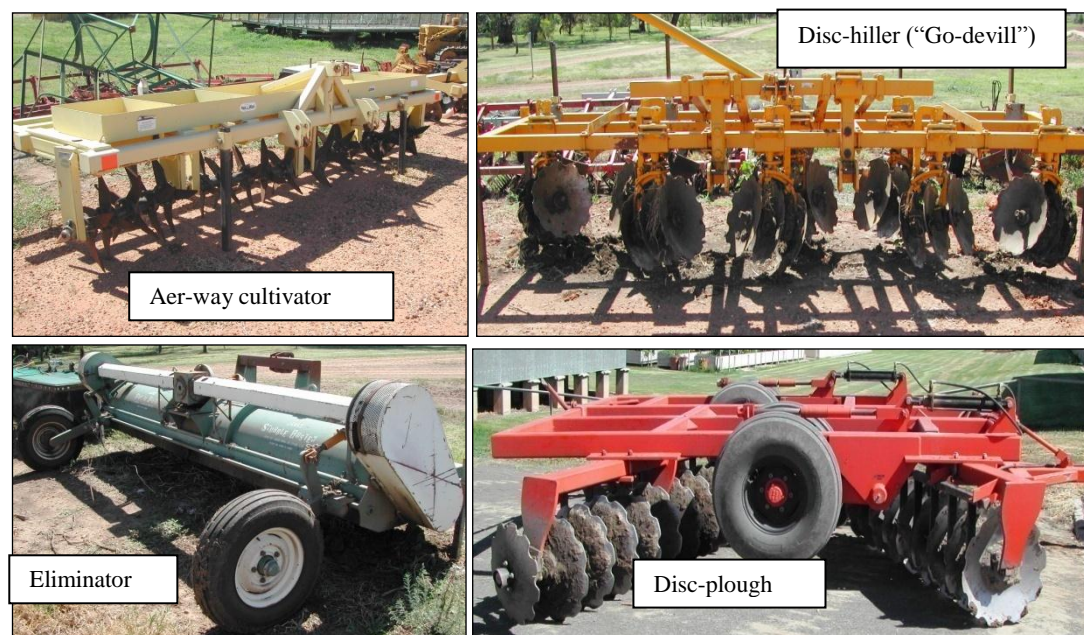
Figure 1. Tillage implements used in Experiment 1

Experiment 2: This experiment, conducted from 1998 to 2001, was located within a long-term experiment which had three treatments: continuous cotton sown after conventional-tillage (disc- and chisel ploughing followed by ridging every year), continuous cotton sown on permanent beds (slashing and root-cutting of cotton followed by go-devilling) and cotton-wheat (*Triticum aestivum* L.) rotation where cotton was sown into standing wheat stubble on permanent beds (Hulugalle et al., 2005)). Soil disturbance after slashing, root cutting and go-devilling is shown in Figure 2. Measurements of live pupae and emerged moths were made in all treatments after picking and before tillage. If significant numbers of live pupae were recorded, net cages were established in the two treatments which included permanent beds. No cages were located in the conventionally-tilled plots as it was assumed that all pupae were destroyed by this practice.

Results and Discussion

Experiment 1: Greatest soil disturbance occurred when centre busting was combined with go-devilling (Figure 3). Next in order of magnitude was when centre-busting was combined with discing. Soil disturbance caused by the other pupae-busting systems did not differ

significantly from the untreated control. Moth emergence in all but one of the cultivation systems was closely related to the intensity of soil disturbance (Figure 4). The exception was the aer-way cultivator, where the soil disturbance although similar to that in the untreated control had a relatively low level of moth emergence. The aer-way cultivator may have increased micro and mesopores, but not macropores, thus enabling parasitic wasps and parasitoids such as *Heteropelma scaposum* to gain access to the pupating heliothis larvae.

Figure 2 Soil disturbance after root-cutting and go-devilling in Experiment 2

Figure 3. Effect of "pupae-busting" on soil disturbance. Vertical bar is the standard error of the mean for each depth interval.

Figure 4. Variation of heliothis pupae emergence with soil disturbance (soil macroporosity in the 0-300 mm depth). Results for the aer-way cultivator were excluded when deriving the curve and equation.
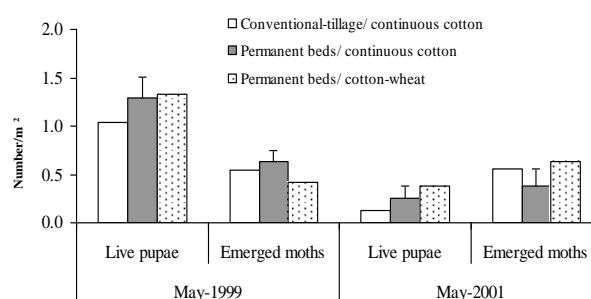
Figure 5. Effect of land preparation method and crop rotation on heliothis pupae and moth numbers after cotton picking but before imposition of tillage treatments for the winter. Vertical bars are standard errors of the means among tillage and cropping system for pupae and live moths.

Experiment 2: Significant numbers of live pupae or moths were detected before tillage only during May 1999 and 2001, but there were no differences among the three treatments (Figure 5). Cumulative moth emergence after tillage, between July and November, was however, negligible during both 1999 and 2001 (data not shown). A total of two moths emerged during 1999 in a single cage in the permanent beds/continuous cotton and a single moth emerged in the permanent beds/cotton-wheat. Similarly, during 2001 two moths emerged in a single cage in the permanent beds/continuous cotton. No moths were detected in any of the other cages located in both treatments. These results indicate that the soil disturbance caused by the combination of root-cutting and go-devilling sufficed to prevent heliothis moths emerging in permanent bed systems.

Conclusions

Pupae-busting systems that included operations such as centre-busting and go-devilling in combination with shallow discing or root-cutting under dry conditions caused sufficient disturbance in permanent beds to virtually eliminate heliothis pupae emergence. When these operations are done under dry conditions soil structural deterioration is negligible.

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Conservation Agriculture: sustainable crop intensification in rainfed peanut (*Arachis hypogaea* L.) production system for efficient resources use

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Keywords: rainfed peanut, intercropping, double cropping and relay cropping.

Introduction

Anantapur is the southern-most district of the Rayalaseema region of Andhra Pradesh, India. While agriculture remains the most important economic activity of the district, it is characterised by high levels of instability and uncertainty. Being located in the scarce rainfall zone of Andhra Pradesh state with normal rainfall of 553 mm, the district is drought-prone as it does not get the full benefit of either the south west or north east monsoons. Red alfisol soils are predominant which are characterised by hills and ridges and undulating and gently –sloping lands. In terms of the cultivable area, 70% of the district comes under classes III and IV of land capability classification, which are suitable for arable cropping with certain limitations. Peanut is the principal crop of this district being mostly grown as a mono crop in an area of 7.52 lakh ha, with highly unstable productivity due to unreliable rainfall, leading to partial and total crop failure. The intensification of resource use both spatially and temporally is one of the ultimate principles of crop intensification (Willey, 1979). Intercropping and sequence cropping systems can make better use of space and the entire rainy season, respectively, compared with monoculture systems. These systems have a great potential in enhancing income of farmers in rainfed alfisols, provided there is good rainfall and proper and timely agro-techniques. In addition to intercropping in peanut, there is also the possibility of crop intensification in time by growing a second crop after rainy season peanut, as the southern part of Anantapur district receives extended rainfall till the end of November, with the influence of North-East monsoon. Hence this study was undertaken to develop a viable peanut based intercropping and double cropping system for efficient resource use and profitable crop production.

Materials and Methods

Two field experiments were conducted simultaneously during two consecutive *kharif* seasons at Agricultural Research Station, Kadiri, India with the aim of establishing efficient peanut based intercropping and double cropping systems for rainfed alfisols. In the first experiment, peanut was sown at 30 cm spacings and intercropped with pigeonpea at 7:1, castor at 7:1, sorghum at 6:2, pearlmillet at 6:2, sunflower at 3:1, sesame at 3:1, greengram at 3:1 and soybean at 3:1 row ratios. All the treatments were tried in additive series version of intercropping, keeping the plant population (3.33 lakhs/ha) of base crop (Peanut) in all the treatments at 100 per cent of its sole crop, by adjusting the intra-row spacing. The intercrops were accommodated in the inter-rows of peanut as per the row proportion following the intra-row spacing of their respective sole crops. In the second experiment, peanut was grown during rainy season in all treatments and immediately after harvest of peanut, seven short duration crops viz., greengram, cowpea, sunflower, horsegram, clusterbean, pearlmillet and sorghum were grown in each treatment during the post rainy season. Rainfall received in *kharif* during the crop period of peanut was 390.5 mm (30 rainy days) and 429.4 mm (33 rainy days) in the first and second year respectively. While the rainfall received in *rabi* during the crop period of sequence crops, was 99.9 mm (6 rainy days) and 77.2 mm (4 rainy days) in first and second year, respectively. The pooled mean peanut pod yield, pod equivalent yield, Land Equivalent Ratio, Staple Land Equivalent Ratio and Area Time Equivalent Ratio of different intercropping systems and peanut pod equivalent yield, production efficiency and land use efficiency of different double cropping systems over two years, was statistically analysed following the analysis of variance for randomized block design as suggested by Panse and Sukhatme (1985).

Results and Discussion

Intercropping systems (Table. 1)
Pod yield of peanut was found to be the highest in peanut + pigeonpea system, which was comparable with peanut + castor system and significantly higher than all other intercropping systems. In comparison, the pod yield of peanut was found to be the lowest in peanut + pearlmillet system, which was comparable with peanut + sorghum and peanut + sesame. Higher yields of both the component crops in the two systems, peanut + pigeonpea and peanut + castor systems coupled with the higher price of saleable produce of intercrops resulted in production of the highest peanut pod equivalent yield in these intercropping systems. This suggests that intercropping pigeonpea or castor with peanut are the most appropriate systems to achieve high yield during rainy season. Lower prices of pearlmillet and sorghum resulted in the lowest peanut pod equivalent yield of peanut + pearlmillet and peanut + sorghum systems, though the yield of pearlmillet and sorghum was still fairly high compared to other intercrops tried. Higher groundnut pod equivalent yield in groundnut + pigeonpea 7:1 intercropping system was reported by Reddy and Jagannatham (1996), Jayaprada (1998) and Sampath Kumar et al., (2001), while groundnut + castor was found to achieve a higher groundnut pod equivalent yield by several earlier researchers (Guggari et al., 1994 and Jayaprada, 1998).

Efficiency evaluation indices viz., Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER) and Staple Land Equivalent Ratio (SLER) were highest with peanut + castor system, followed by peanut + pigeonpea system. Itnal et al., (1992) reported higher LER with peanut + pigeonpea intercropping. ATER also followed the similar trend to that of LER. Though the field duration of castor and pigeonpea crops was longer than other intercrops tried, the total yield of peanut + castor and peanut + pigeonpea systems was substantially higher than other intercropping systems resulting in higher values of ATER. The highest values of SLER were also recorded with peanut + castor and peanut + pigeonpea systems, while the lowest value was associated with peanut + greengram. The SLER takes into account the yield of component crops in sole cropping as well as intercropping, besides the proportion of land devoted for intercrops.

Double cropping systems (Table.2)
Since the economic yield of different sequence crops cannot be statistically compared, because of difference in the nature of yield of different crops, the absolute yields of different sequence crops were converted into peanut pod equivalent yield and presented in Table.2. Peanut pod equivalent yield of different sequence crops was significantly higher with clusterbean, than all other crop sequences, except for the double-cropped systems with greengram and cowpea. Soundara Rajan et al., (1990) also confirmed the possibilities of double cropping in rainfed alfisols of Chittoor district (Andhra Pradesh) provided there is extended rainfall due to the north-east monsoon. Different peanut based sequence cropping systems tried in the present investigation were evaluated for their efficiency, using the parameters such as

production efficiency and land use efficiency. Both the evaluation indices were the highest for the peanut - clusterbean system, indicating that productivity per unit area per unit time, as well as the efficiency with which the land was used for intensive crop production would ensure a high economic return.

Table 1. Pod / seed yield of component crops, peanut pod equivalent yield (kg ha^{-1}) and evaluation indices of different intercropping systems (mean data over two years).

	Pod yield of Peanut	Seed yield of Intercrops	Peanut pod equivalents	Land Equivalent Ratio	Area Time Equivalent Ratio	Staple Land Equivalent Ratio
Peanut + pigeonpea	1650 [a]	972	2541 [a]	1.64 [a]	1.36 [a]	0.96 [a]
Peanut + castor	1646 [a]	990	2536 [a]	1.63 [a]	1.36 [a]	0.96 [a]
Peanut + sorghum	1372 [d]	772	1822 [c]	1.23 [b]	1.21 [b]	0.86 [b]
Peanut + pearlmillet	1307 [d]	946	1819 [c]	1.22 [b]	1.14 [c]	0.87 [b]
Peanut + sunflower	1430 [c]	534	1964 [b]	1.27 [b]	1.17 [b]	0.86 [b]
Peanut + sesame	1395 [c]	208	1741 [dc]	1.29 [b]	1.20 [b]	0.87 [b]
Peanut + greengram	1464 [c]	180	1689 [ed]	1.18 [c]	1.06 [c]	0.82 [b]
Peanut+ soybean	1515 [b]	93	1584 [fe]	1.27 [b]	1.17 [b]	0.84 [b]
s.e.m. ±	35.6	--	53.6	0.04	0.03	0.03
CD (P=0.05)	76	--	115	0.09	0.06	0.06

Figures in a column superscribed by the same letters do not differ significantly.

Minimum support price of the produce (Rs kg^{-1}):

Groundnut pod	:	12.00	Sunflower seed	:	12.00
Pigeonpea seed	:	11.00	Sesame seed	:	20.00
Castor seed	:	12.00	Greengram seed	:	15.00
Sorghum seed	:	7.00	Soybean seed	:	9.00
Perlmillet seed	:	6.50	Cowpea seed	:	14.00
Horsegram seed	:	8.00	Clusterbean (green pods)	:	4.00
Pearlmillet seed	:	6.50			

Table 2. Economical yield (kg ha^{-1}) and efficiency of different peanut based double- cropping systems as a whole (mean data over two years).

Double cropping systems	First year		Second year		Peanut pod equivalents of cropping systems	Production efficiency	Land use efficiency
	Seed yield	Peanut Pod equivalent yield	Seed yield	Peanut Pod equivalent yield			
Peanut - Greengram	454	568 [d]	528	660 [c]	2286 [dc]	12.2 [b]	51.1 [edc]
Peanut - Cowpea	649	757 [b]	573	669 [c]	2385 [cb]	12.7 [b]	51.1 [edc]
Peanut - Sunflower	350	350 [e]	508	508 [d]	2101 [e]	11.1 [c]	52.0 [cb]
Peanut - Horsegram	998	665 [c]	1237	825 [b]	2417 [b]	12.7 [b]	51.8 [dcb]
Peanut - Clusterbean	3000	1000 [a]	4317	1439 [a]	2891 [a]	15.9 [a]	52.8 [a]
Peanut - Pearlmillet	429	232 [f]	458	248 [e]	1912 [f]	10.2 [d]	51.4 [dc]
Peanut - Sorghum	125	73 [g]	146	85 [f]	1751 [g]	9.2 [e]	52.4 [ab]
s.e.m. ±	--	28.2	--	31.4	61.3	0.2	0.3
CD (P=0.05)	--	61	--	68	134	0.5	0.7

*Peanut pod yield during rainy season: 1744 and 1599 kg ha^{-1} over first and second years.

Figures in a column superscribed by the same letters do not differ significantly.

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Grain yield of wheat following winter grazing in a low rainfall environment

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Keywords: Zadock's growth scale

Introduction

Cereal, largely wheat (*Triticum aestivum* L.), production is the primary enterprise of most dryland farms in the low rainfall winter rain dominant zone of southern Australia. Sheep (*Ovis aries* L) are used on a majority of those farms to graze pastures, grown in rotation with the wheat crops, and during the dry summer crop stubbles (Ewing *et.al*., 2005). A major constraint to the sheep enterprise is the scarcity of sheep feed from April to July when supplies of stubbles and pasture residues are exhausted, annual pastures take time to establish and feed demand is high due to lambing. There is interest in the potential for vegetative cereal crops to provide high-quality green feed during this period.

Recent research including whole farm biophysical (Moore, 2009) economic modelling (Doole *et.al*., 2009) and field based studies (Virgona et.al., 2006) have suggested that spring wheat does not provide a production or economic benefit in regions with annual rainfall below 350 mm. This assessment is based on the contention that the number of seasons that allow wheat establishment to occur early enough to produce worthwhile biomass, with consideration of the probability of frost and the need to graze prior to stem elongation, in this low rainfall zone is limited to a point considered unviable. In the medium to high rainfall zones they recommended longer season winter wheat to allow early seeding to increase the winter biomass while reducing the frost risk. This has been shown to support increased stocking rates with acceptable grain yield reductions, although this depends on the timing of defoliation plus the seasonal conditions.

This study evaluated the impact of defoliation timing on both spring and winter wheat grain yield over 3 seasons in the low rainfall grainbelt of southern Australia to better support an integrated mixed farming system.

Materials and Methods

Three years of trials were carried out on Minnipa Agricultural Centre (Latitude 32.833 S, Longitude 135.150 E) on an alkaline red calcareous sandy clay loam pH 7.8 (CaCl).

Experiments were sown with wheat varieties on 24 June 2005, 12 May 2006 and 16 May 2007 (Table 1). All plots in all 3 years received 11 kg/ha of N and 12 kg/ha of P at seeding. Pre seeding, Sprayseed[R] (135g/L paraquat, 115g/L diquat) at 1 L/ha was applied on 6 June 2005 and 9 May 2007. In 2006, glyphosate (460 ml/L a.i.) at 1 L/ha was applied on 12 May. No post-emergent chemicals were applied.

Table 1. Wheat varieties and seeding rates (kg/ha) sown at Minnipa in 2005, 2006 and 2007

	Seeding rate (kg/ha)*		
Variety	2005	2006	2007 (2)
Wyalkatchem	48	69	57
Yitpi	48	65	59
EGA Wedgetail	48	65	58

Plot sizes in all years were 24 m x 1.8 m. In 2005 and 2006 the plots were split in half for plus and minus mowing and grazing respectively, with the defoliated half of the replicate randomly allocated. In 2007 each treatment was allocated its individual plot, i.e., no split plots. Both sites were fully randomised blocks with 3 replicates in 2005 and 4 replicates in 2006 and 2007.

Plant establishment and biomass measurements were collected from 4 x 1 m rows with the biomass estimated after drying samples for 48 hours at 70^0C. Grain yields were calculated from machine harvesting whole plots, with grain samples retained for grain protein contents, test weights and screening percentage estimates.

In 2005 the plant establishment and biomass measurements, and mowing treatments, were carried out on 12 September (Zadock's growth scale 34-36). Grain yields were collected on 13 December. In 2006 plant establishment and biomass measurements were collected on 19 July (Zadock's growth scale 13-15) followed immediately with grazing at a rate of 227 Dry Sheep Equivalent (DSE)/ha on half of each replicate for 24 hours. Grain yield was collected on 23 October. In 2007 plant establishment and biomass measurements and mowing were completed on the 17 July (Zadock's growth scale 23-25) with grain yields collected on the 6 November.

Results and Discussion

The study measured the impact of defoliation at 3 different growth stages on the grain yield of an early and mid season spring wheat, and a longer season winter wheat over three seasons, two of which had growing season rainfall below 100 mm. It tested the opportunity to utilise wheat herbage to help fill the winter feed gap with a rapid defoliation.

Growing season rainfall (long term April-September 250 mm) was deficient in 2006 and 2007 with 97 and 87 mm respectively (Table 2).

Established plant numbers were similar between treatments in all years, and reflected the increased seeding rates in 2006 and 2007 (Table 3). Biomass at the time of defoliation was similar between cultivars in 2005 and 2006 but in 2007 Wyalkatchem produced less than Yitpi, and Yitpi less than Wedgetail. The biomass reflected the growth stage at time of defoliation, 2005 GS 34-36, 2006 GS 13-15 and 2007 GS 23-25.

As expected and reported previously (Virgona et.al., 2006), grazing post stem elongation resulted in loss in grain yield in the earlier maturing spring wheats but was not the case with the longer season variety Wedgetail with 61 mm of rain in September 2005. Defoliation pre-stem elongation with either a very intensive grazing or a mechanical mowing did not result in any yield loss in the 2006 and 2007 low

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rainfall seasons in any of the cultivars (Table 3). However, Wedgetail grain yields in 2006 and 2007 reflected the very dry spring periods. The only impact of defoliation on screening percentage or test weight was in 2005 when the screening percentage of Wyalkatchem was increased from 2.6 to 5.4% by defoliation.

Table 2. Rainfall (mm) at Minnipa Agricultural Centre in 2005, 2006 and 2007

Minnipa	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2005	8	2	1	5	8	66	31	31	61	28	24	22	286
2006	25	20	50	15	22	19	37	3	1	0	20	9	221
2007	13	0	66	17	13	14	23	14	6	5	18	52	241
Mean*	13	17	16	18	37	46	48	46	34	27	22	20	345

* 1915 – 2009 average rainfall at Minnipa.

Table 3. Cereal establishment (plants/m^2) biomass (tDM/ha) grain yield (t/ha) and protein content (%) in 2005, 2006 and 2007

Variety	Establishment	Biomass	Grain yield (t/ha)		Protein (%)	
2005	plants/m^2	tDM/ha	mown	unmown	mown	unmown
Wyalkatchem	111	0.7	0.7	1	13.3	12.8
Yitpi	115	0.6	0.7	1	14	13.9
Wedgetail	114	0.6	0.8	0.9	14.2	14
lsd (*P*=0.05)	nsd	nsd	0.16		0.3	
2006	plants/m^2	tDM/ha	grazed	ungrazed	grazed	ungrazed
Wyalkatchem	157	0.24	0.56	0.65	14.3	15.1
Yitpi	151	0.21	0.56	0.67	14.7	15
Wedgetail	153	0.19	0.42	0.45	16.4	16.5
lsd (*P*=0.05)	nsd	nsd	0.13		0.6	
2007	plants/m^2	tDM/ha	mown	unmown	mown	unmown
Wyalkatchem	144	0.3	0.9	1.1	13.5	13.1
Yitpi	147	0.4	0.9	1	14.5	15.2
Wedgetail	144	0.5	0.4	0.4	16.8	17
lsd (*P*=0.05)	nsd	0.1	0.17		0.7	

The results suggest there is an opportunity to graze spring wheat for a very short period pre-stem elongation with only minimal loss in grain yield. There was no measure of biomass utilisation to estimate the value in livestock production, and it could be assumed that the defoliation in 2006 at the 3 to 5 leaf stage (0.2 tDM/ha) would provide minimal livestock forage benefits and present soil protection risks. However 0.4 – 0.5 t/ha of biomass at early tillering would provide 1-200 kg/ha of high value forage in a period of low feed availability, thus improving the viability of the mixed farming system while maintaining adequate groundcover.

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Responses of spring wheat to nitrogen rates on a loess soil in a semi-arid climate on the western Loess Plateau, China

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Keywords: Spring wheat, N rates, Establishment, DM dynamics, WUE, NUE, APSIM

Introduction

In the semi-arid areas of the western Loess Plateau of China, agriculture is dominated by spring wheat (*Triticum aestivum* L.) monoculture. Wheat growth is limited by rainfall and mineral nitrogen availability. As the amount and distribution of rainfall is out of human control, using fertilizer is an important way to improve crop productivity.

A rapid canopy development achieved through N fertilizer application can result in a substantial reduction in soil evaporation and a corresponding increase in dry matter (DM) production and grain yield (Anderson, 1992), but high fertilization rates have been found to increase the severity of plant water deficits (Nielsen and Halvorson, 1991). Further, increasing N from 180 to 240 kg ha^{-1} led to an increase in lodging (Tripathi S. C., et al., 2003). Therefore, although the total yield of crops have been greatly improved by fertilizer, the yield increment decreased with increasing fertilizer application rate (Gu et al., 2000). In the western Loess Plateau, Huang et al. (2003) found that soil water decreased with increasing rates of fertilization in a winter wheat monoculture system, and predicted that if soil water depletion continued, yield would eventually decline. Therefore, a better understanding of spring wheat responses to N fertilizer rate is important to produce economically attractive and sustainable yield increases.

The response of wheat to N fertilizer has been generally well documented in many wheat growing regions (Garabet et al., 1998; Wu et al., 2001). In the study area, much of the previous study on N fertilizer rate for wheat has focused on grain yield and nitrogen use efficiency (NUE) to optimize N application rate and methods using short-term experiments and modeling (Sun, 1999; Wu et al., 2001). Limited information is available regarding the responses of wheat yield and NUE to N fertilizer in the long-term with variable climate in the region. Thus, the aim of this study was to optimize the N rate through analysing emergence, DM accumulation, grain yield, water use efficiency, and NUE at different N rates using field experiments and APSIM simulations.

Materials and Methods

The field experiment was conducted in Dingxi (35⁰28'N, 104⁰44'E, elevation 1971 m a.s.l.), Gansu province, northwest China. In this region, average radiation is 141.6kcal/cm^2, sunshine hours are 2476.6 hr, accumulated temperature above 10 is 2239. Table 1 shows the rainfall in the region. In the experiment year, it was very dry at flowering of the spring wheat, i.e. 10-20 June, although the monthly rainfall was a little higher than the average, consequently, the yield was much lower than the average. The study area contained a loess soil. Table 2 shows the physical and chemical properties of the soil.

Table 1. Monthly rainfall (mm) in the research year compared with long-term average (33 years)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
2003	6.5	0	36.4	22.0	66.8	57.5	84.5	148.7	66.9	65.2	8.3	4.5	567.3
Average	3.3	4.6	12.1	28.0	44.6	53.4	77.4	82.6	49.5	28.5	5.3	1.6	390.9
CV%	81.1	82.8	66.2	66.4	61.8	44.6	56.9	42.7	52.7	52.2	132.9	137.2	17.5

Table 2. Physical and chemical properties of the soil

Depth (cm)	Drained upper limit (cm^3/cm^3)	Wheat lower limit (cm^3/cm^3)	Depth (cm)	Bulk density (g/cm^3)	pH	Organic carbon (g/kg)	Total N	Total P
0-20	0.28	0.07	0-5	1.29	8.32	13.15	0.85	1.89
20-40	0.27	0.07	5-10	1.23	8.37	12.86	0.87	1.92
40-60	0.27	0.07	10-30	1.32	8.33	11.95	0.78	1.82
60-80	0.26	0.08	30-50	1.20	8.30	11.43	0.78	1.72
80-100	0.26	0.10	50-80	1.14	8.32	12.58	0.81	1.71
			80-100	1.14	8.37	12.91	0.80	1.75

The experimental design was a randomized complete block with three replicates, each plot measuring 3×10 m. The five treatments were five N rates: 0, 52.5, 105, 157.5 and 210 kg N ha^{-1}. Local variety Dingxi No. 35 was sown at a rate of 187.5 kg ha^{-1} with a row spacing of 0.2 m on 19 March. Calcium super phosphate (14% P_2O_5) at 105 kg P_2O_5 ha^{-1} and urea (46% N) at the different rates were applied just before sowing.

Soil moisture down to 30 cm was measured at sowing and harvesting for three layers: 0~5 cm, 5~10 cm and 10~30 cm. Plant establishment was counted 3 weeks after emergence. Dry matter was measured at 5-leaf, anthesis and maturity stages. All wheat plants were harvested after the edges (0.5 m) of the plot had been trimmed and discarded, grain yield were measured and calculated from plot yield.

Nitrogen use efficiency (NUE) in the application year was calculated according to following equation: NUE = $(Y_N - Y_0)/N$, where Y_N and Y_0 are the yield of the treatment with and without N fertilizer and N represents the N rate.

APSIM was used to simulate wheat yield responses to different N rates. In the study, crop (wheat), soil water (SOILWAT2), soil N (SOILN2) modules were linked within the APSIM framework. Soil and crop parameters were based on site-specific measurements. Daily rainfall, minimum and maximum air temperature and solar radiation for Dingxi from 1970 to 2000 were accessed from the local meteorology office.

Results and Discussion

From 0 to 210 kg N ha^{-1}, the N rate had no significant effect on spring wheat emergence and DM of spring wheat at flowering and maturity. The trend of wheat yield responses to N rates was still very clear, N rates over 52.5 kg ha^{-1} did not increase yield (Figure 1). The solid line in Figure 1 shows the average of APSIM simulation results from 1970 through 2000. Although the predicted yield is even lower than the yield in the experiment, it suggested the same trend, that increasing N rate over 52.5 kg ha^{-1} is a waste of fertilizer. The period from 1970 to 2000 represents a long time period with considerable variety in climate, especially rainfall. Thus the predicted yield responses to N rates over 31 years indicate that, for the sake of grain yield, the optimum N rate should be 52.5 kg ha^{-1} on average. Research in a different climate in Australia also showed that yield of fertilized spring wheat can decrease to levels below that of crops receiving no additional N (Van et al., 1998).

Nitrogen use efficiency of spring wheat decreased very quickly with increased N application (Figure 2). Thus, to obtain higher yield while minimizing N waste and preventing environmental pollution, the rate of 52.5 kg N ha^{-1} should be recommended for spring wheat in this region.
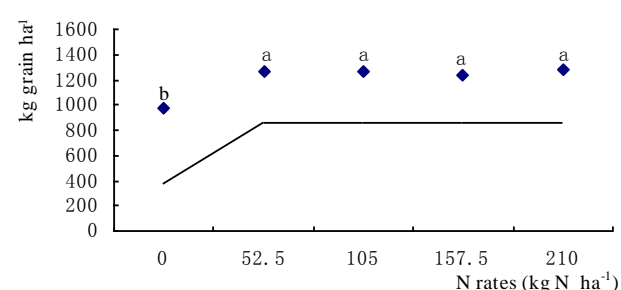
Figure 1. The response of wheat yield to N rates, the solid line shows the average yield in 1970-2000 obtained from APSIM model.
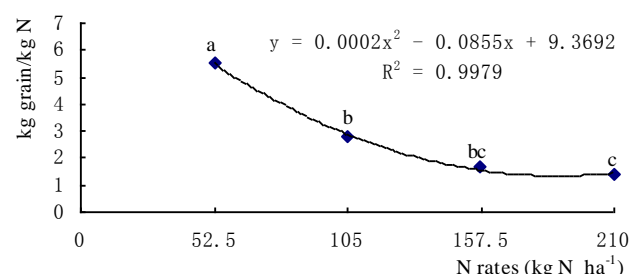
Figure 2. Nitrogen use efficiency of wheat at different N rates, the solid line and the equation show the trend of NUE response to N rates.

To sum up, both experimental and simulation results showed that to obtain economically attractive and sustainable yield increases, the optimum N rate should be 52.5 kg ha^{-1} on average. The APSIM model works well to simulate spring wheat growth in the western Loess Plateau of China.

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Less, or more: a preliminary systems study on nitrogen intensity of the wheat-maize system in the North China Plain

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Keywords: wheat, maize, double cropping, APSIM, nitrogen

Introduction

The North China Plain (NCP) is one of the major cereal producing areas in China and the world. It plays an important role in guaranteeing national and world food security. In a scenario where the economy, population and living standards are growing rapidly while the area of crop land is decreasing, productivity of crops or cropping systems must be increased. Wheat-maize double cropping is one of the most important cropping systems in the NCP as well as in China. There have been quite a few reports stating that farmers are applying too much nitrogen (N) in the system and that crop yields could be maintained or even increased with lower N application rates (Qiu, 2009). This paper attempts to clarify the issue of whether farmers are using too much nitrogen by using a system analysis approach to explore the relationship between potential yield, farmers' actual yields and N input. The surveyed performance of farmer's crops are compared to two benchmarks, to local demonstration crops and against simulated yield potentials.

Materials and Methods

A survey covering 351 farming households and demonstration plots in 6 counties in Hebei province was conducted in 2005 to collect on-farm crop production data including crops yields, fertilization rate, irrigation frequency and basic agronomy information. Annual productivity of the double cropping system at various nitrogen fertilization levels on a typical soil of the survey area with no water and other nutrients constraints was simulated with APSIM (Keating et al., 2003) using weather data during the same time period of the surveyed cropping season (i.e. October of 2004 to October of 2005) to create a production frontier (Keating et al., 2010) of crop productivity responding to nitrogen input level. The simulations were run for 10 years using station-recorded weather data of the same year, without resetting soil parameters, retaining the same management practices for each year, and applying the same N rate in each year to 'normalize' the effect of initial soil conditions on simulation output. Simulated annual productivities in the 10th year were used although the effect of initial soil N content on crop performance became stable after the sixth year. Both simulated and actual demonstration grain yields of wheat were adjusted to 12.5% moisture content and 14.0% moisture content for maize.

To quantify intensity of the system in output and input dimensions for the 351 crops, the relative yields (RY) for the combined annual production of wheat and maize and for each crop were calculated by dividing the actual yields by the simulated maximum yield. Relative nitrogen input (RN) was calculated by dividing the actual nitrogen input for each crop and annually by the simulated nitrogen input level at which maximum yield was achieved (Table 1). On-farm data and demonstration data were then compared against simulated data which served as a benchmark.

Results and Discussion

Simulated maximum annual production of the wheat-maize system during the 2004-2005 cropping season was 22.8 t ha^{-1} (wheat 10.3 t ha^{-1} and maize 12.5 t ha^{-1}) with a corresponding N input of 500 kg ha^{-1}. Average annual yield of the demonstration plots from 6 counties was 19.6 t ha^{-1} (wheat 9.1 t ha^{-1} and maize 10.5 t ha^{-1}) with a corresponding N input of 470 kg ha^{-1}. Average on-farm annual yield was 14.8 t ha^{-1} (wheat 7.1 t ha^{-1} and maize 7.7 t ha^{-1}) with a corresponding N input of 372 kg ha^{-1}.

The average N application rate of 372 kg ha^{-1} corresponds to a simulated annual production of 20.0 t ha^{-1} – 88% of the simulated maximum annual production. This level of production coincides with the less risky level of on-farm productivity of 85% of maximum yield suggested by Lobell et al. (2009). However, the actual average annual on-farm production achieved only 65% of the simulated maximum despite the level of N rate applied. Issues of land preparation, sowing date, sowing rate, nutrient balance in fertilization, plant protection, harvesting were reported as part of the farm surveys. As a comparison, the average annual yield of the demonstration plots achieved 86% of the simulated maximum which provides good evidence that crop yields can be lifted to higher levels by implementing better field agronomic measures. Further increases are potentially possible as the N rate applied in the demonstration plots corresponded to an annual simulated production of 21.9 t ha^{-1} which is 97% of the simulated maximum.

The simulated marginal annual yield increase between 400 kg ha^{-1} and 500 kg ha^{-1} N rate was 22 kg gain /kg N. According to the historical prices of grain (wheat 1.53 Yuan kg^{-1} and maize 1.11 Yuan kg^{-1}) and fertilizers (N 3.91 Yuan kg^{-1}), the profitable intensity level should be above 400 kg ha^{-1} N application rate (with a corresponding annual yield of 20.6 t ha^{-1}), although the actual profitable N application level could be slightly lower than that calculated considering that N input is not the only input that crop yield relies on.

Though RY and RN are not linearly correlated, they could be used as simple indicators of intensity from output and input dimensions. The average RY and RN of the demonstration plots are 0.86 and 0.94 while those across the surveyed farms average 0.65 and 0.74 respectively. These figures reveal a potential pathway for increasing crop productivity, firstly by improved field management practices but also with better N application. In Table 1, for wheat, 66.7% of farms used too much N and 6.6% applied inadequate N (i.e. less than 55% of N demand for achieving the simulated maximum yield). For maize, 27.4% of farms over-applied N and 31.6% used inadequate N. Annually across both crops, 43% of farms used too much N and 9.1% of them applied inadequate N. These figures suggest that N application in the wheat-maize system is not completely optimal in terms of the balance between crops – too much on wheat and too little on maize. Critically, most farms over-apply N but underperform in terms of their expected production levels if judged by what is achievable (production from demonstration plots) or potential (simulated production).

Table 1. Percentage of surveyed farms within different groups of relative yields and relative nitrogen inputs

	>1	0.75 − 1	0.55 − 0.75	< 0.55
Annual relative yield, RY_a	-	4.0	84.6	11.4
Relative yield of wheat, RY_w	-	3.4	86.3	10.3
Relative yield of maize, RY_m	-	3.4	59.0	37.6
Annual relative N input, RN_a	43.0	31.3	16.5	9.1
Relative N input on wheat, RN_w	66.7	22.8	3.9	6.6
Relative N input on maize, RN_m	27.4	16.5	24.5	31.6

Note: RY_a represents annual relative productivity; RY_w represents relative yield of wheat; RY_m represents relative yield of maize; RN_a represents annual relative N input; RN_w represents relative N input of wheat; and RN_m represents relative N input of maize.

On average, crop yields could be further increased before reaching the currently available technical potential (i.e. simulated maximum yield): wheat by 28.5 %, maize by 36% and annual productivity by 32.4 %. To achieve this, N application should be reduced by 10.2% on wheat, and increased by 111.3% on maize, and annual N input increased by 26.3% on average. However, the great variation among farms is evident.

The answer to the question 'Are farmers using too much N?' is not a simple yes or no. Many farms and crops have too much N applied, yet average annual N application levels are in accord with levels suggested by demonstration and simulation analyses. Clearly, productivity on the NCP could be increased if farmers could achieve higher yields for current N application rates. Likewise, N rates for some farmers could be reduced significantly without impacting on crop productivity.

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Intensifying Ethiopian agriculture: the role of improved seed system: constraints and opportunities

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Keywords: Technology, improved seed, rain fed, infrastructure

Introduction

Ethiopia has great agricultural potential due to its vast areas of fertile land, diverse climate, generally adequate rainfall and large labour pool. Despite this potential, however, Ethiopian agriculture has remained underdeveloped. Key constraints for development include recurrent droughts which have repeatedly affected the country since the early 1970s; a poor economic base (low productivity, weak infrastructure, and low level of technology); and over population. Furthermore, agriculture accounts for 42.9% of Gross Domestic Product (GDP) that employs 85% of the population, majority of which are small-scale farmers. These small-scale farmers heavily rely on subsistence farming. Nevertheless, the Ethiopian agricultural sector has an important opportunity to further develop the seed production sector. Thus, improving the seed sector by expanding the private and commercial sectors will pave the way for a stronger agricultural sector.

Subsistence Agriculture

Ethiopian agriculture is characterized by the use of inadequate production technologies that in a variable climate produces important fluctuations in crop yields, uncertainties, and food insecurities. Access and availability to improved production technologies including seed, fertilizers mechanization and markets are limited. The most recent estimate by the Ethiopian Central Statistical Authority (CSA, 2009) indicates, from a total cultivable area of 12.8 million ha, only about 8 million ha is under cereal crops[12]. Various studies indicate that improved seeds are used in less than 3% of the total cultivated area (See Table 1). For smallholder farmers, the main constraints are availability and affordability to quality seeds. This is particularly the case for poor farmers in remote and isolated villages. Given the low level of improved seeds and fertilizers in use, it is clear why agricultural productivity has been lagging behind. This has resulted in chronic food insecurities and pervasive poverty both in rural and urban centers across the country.

Table 1. Area planted with improved seeds and use of fertilizers (area fertilized) in Ethiopia (2005/2006)

Crops	Total area (ha)	Improved seeds Area (ha)	Area covered by fertilizer %	Fertilizers Area (ha)	%	Quantity (tons)
Cereals	8,463,080	335,369	4.0	4,330,710	51.2	433,071
Pulses	1,378,939	5,025	0.4	274,915	19.9	27,491
Oil crops	740,847	4,056	0.6	76210	10.3	7,621
Vegetables	95,194	559	0.6	66,349	69.7	6,634
Root crops	188,917	2114	1.1	118,229	62.6	11,822
Others	97,677	102	0.1	32,814	33.6	3,281
Total	10,964,654	347,225	3.2	4,899,227	44.7	489,922

Source: Central Statistical Agency, 2009

Analysis of the Ethiopian Seed Sector: Production, Certification, Marketing, and Distribution

Ethiopia's seed system begins with breeding programs at the Ethiopian Institute of Agricultural Research (EIAR), regional institutes, and universities. The National Release Committee reviews improved varieties before they are provided to the Ethiopian Seed Enterprise (ESE) for distribution. The ESE is a public company and the main provider of seeds in the country, supplying less than 20,000 tons of seed per year. Pioneer, is the only multinational seed company that having started operations more than 20 years ago, uses an out-growers scheme[13] to produce and market seed in the country. Their major focus is hybrid maize seed (See Table 2)

Seed Demand and Supply

According to recent official statistics the annual average area under maize is estimated to be about 1.8 -2.0 million ha/year. If the country has to meet the demand for improved seed for such an area it needs to produce at least 50,000 t/year of seed maize. For wheat, the demand for improved seed is ca. 225,000 t/year. Recent estimates by CIMMYT (Langyintuo et.al. 2008) revealed that only 11% of the total maize area is under hybrid and improved open pollination varieties (OPV) maize varieties. The same study estimated that in 2006/07, seven registered seed companies in Ethiopia sold about 2,000 t of hybrid maize and improved OPVs. Table 2 shows that total maize seed distributed in 2008 by the Ethiopian Seed Enterprise (which is the main player in the seed sector) is less 4,000 t/year. These numbers clearly contrast with the value of total demand given above (50,000 t/year) over the same period.

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[12] Out of a total of 110 million ha of land 65 million ha is cultivable of which only 12.8 million is presently cultivated, CSA, 2009

[13] A farmer (peasant, smallholder, or private commercial farms) who produces a certain crop/seed on behalf of the contractor. This out-grower should be capable of maintaining the standards of the contractor who produces seed.

Table 2. Maize seed produced by the two major companies in Ethiopia (tons

Year	Pioneer	ESE
2009	2,740	2,985
2008	2,612	3,616
2007	2,140	5,055

Source: ESE is the Ethiopian Seed Enterprise, 2009

Table 3. Country Indicators

Total Area of Ethiopia	1.104,300 sq km
Cultivable	65 million ha, Cultivated- 12 million ha
Population (2010)	88,013,491 million, Growth Rate 3.202 %
GDP (2010)`	$30.94 billion
Irrigation*	Irrigated- 1%, Rain Fed- 99%
Irrigation potential*	3.5 million hectares
Top three River Basins. There are a total of 12 River basins.*	Wabishebelle – 202,220 km^2 Abbay – 199,812km^2 Mereb – 5900 km^2

Source: CIA, WorldFact Book, 2010. Ethiopia, Ethiopian Water Authority.

Concluding remarks and the way forward

Clearly, Ethiopia has the potential to increase food production by increasing the area of land under agriculture, though the present availability of quality seeds falls well below present demand. Currently, there are about 26 private companies licensed to produce seed; 19 to import seed; 33 to retail; and 4 to export seed. However, very few are involved in marketing and distributing directly to end-users. Because of the costs associated with certification, the current system excludes small-scale farmers wishing to produce seed. There is a key role to be played by the private sector to bridge the gap between the supply and demand of seed, and make quality seed available to farmers in their villages in the right amount and at the right time. It is expected that the increased supply will also reduce prices, making the technology available to the poorer farmers, and thus increase productivity and economic activity, and reduce poverty and food insecurities across Ethiopia.

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Evaluation of a polyherbal supplementation on the methane emissions from dairy goats

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Introduction

Due to overwhelming scientific evidence that global warming is a result of increasing concentrations of green house gases, novel approaches are increasingly being investigated to reduce them. One of the key green house gases is methane, which is 21 times more potent than CO_2, as far as heat entrapping is concerned (EPA 2008). Methane (CH_4) production from ruminants has been identified as the single largest source of anthropogenic CH_4 (Mathison et al., 1998). According to FAO, the estimated CH_4 emission from enteric fermentation is 17–30% of global production; hence it is very important to reduce the methane emission from all major sources including enteric emission. In the past the major growth promoters were antibiotics. However, current research is looking for natural alternatives to antibiotics because of their residues in the environment and subsequent resistance to bacteria. At present scientists are working to improve feed efficiency and growth rate of livestock using useful herbs (Khan et al., 2010). As recognized by the World Health Organization, local ethno-veterinary medicines could play an important role in ensuring general well-being and welfare of livestock in the developing world (WHO, 2008). Since extracting the effective agent(s) from these herbs is uneconomic, it is better to use them in the form of a raw mixture. A few herbs have a galactogogue property which has the capacity of improving the palatability and aiding the digestion process. Therefore, it is desirable to use herbs, as these are a good source of plant secondary metabolites and available in the country in abundance and are relatively cheap. Farmers are also aware of their use and they can adopt this approach easily. Keeping these facts in view, the potential of a polyherbal supplement based on commonly available and cheap herbs was evaluated for its efficacy in reducing methane emission of dairy goats.

Materials and Methods

The experiment was carried out at the livestock farm of the National Dairy Research Institute, Deemed University (NDRI), Karnal, India. The research farm is situated in eastern zone of Haryana and in the Trans Gangetic Plain Region of India at an altitude of 250 m above mean sea level on 29^0 42'N latitude and 75^0 94'E longitude. The polyherbal supplement contained; *Asparagous racemosous* (Shatavari), *Leptadenia reticulata* (Jivanti), *Nigella sative* (Kolonji), *Cuminum cyminum* (Jeera) and *Pueraria Tuberosa* (Vidarikand). Individual herbs were procured from local market after assessing their quality in consultation with ayurvedic practitioners and drug manufacturers. The used parts of each herb were as follows; for Asparagous and Pueraria the root, Nigella and Cuminum the seed and Leptadenia the leaf. They were purchased as sun-dried products and each was then separately ground. The polyherbal supplement was prepared after mixing powdered specific parts of five herbs in the same proportions based on weight of dry matter. The dried samples of the feeds (concentrates and herbs) were passed through a 1 mm sieve and further dried at 105^0C for one hour to determine the dry matter. Methane emission responses to the supplements were tested with 18 cross bred of Alpine x Beetal (AB) goats (Mean body weights 44.6 ± 4.20 kg, genetic potential and parity). A general management program for de-worming, disease prevention, and hoof trimming was followed throughout. Eighteen advanced pregnant cross bred goats of an average age of 2 - 3 years were selected on the basis of milk production records from the herd and assigned randomly to three dietary treatments using a complete randomized design (CRD, n=6) to supplement polytherbal combination at 125 mg/kg body weight (BW) as low level polyherbal supplement (LS) and 250 mg/kg BW as high level polyherbal supplement (HS) for six weeks before kidding until weaning. One treatment with equal numbers of does served as control without supplement (NS). To avoid dominance behaviour and to ensure equal access to the supplement, each goat from every treatment was randomly assigned to separate pens, eliminating of possible biases due to environmental variation within the animal house. Pregnant goats were kept on isocaloric and isonitrogenous diet according to NRC (1981) feeding standard. The animals were kept in the shade in individual feeding pens. The experimental diets offered to the goats consisted of a concentrated mixture according to requirements during advanced pregnancy and green fodder (Berseem, botanical name of *Trifolium alexandrinum*) as *ad libitum*. Clean and fresh water was always available for consumption. The feed was given to the animals twice a day; in the morning at 9:00 AM and afternoon at 2:00 PM. The goats were adapted for 10 days to the experimental diets before measurements were undertaken. In vivo methane emission was measured by using SF_6 (sulphur hexafluoride) tracer technique (Singh 1996).

Results and Discussion

In Vitro Study
Methane production was not significantly affected by polyherbal supplementation of 0%, 1.5%, 2.5% and 5% DM. Values for CH_4 ml/g DM were 31.44 ± 3.15, 32.23 ± 3.15, 30.68 ± 3.15 and 36.90 ± 3.15 , while the corresponding values for CH_4 mM /g DM were 1.26 ± 0.13, 1.29 ± 0.13, 1.23 ± 0.13 and 1.48 ± 0.13 respectively (Table 1).

Table 1. Effect of different doses of Polyherbal supplement on CH_4 Production

Treatment Dose	0%	1.5%	2.5%	5%	SEM	P
CH_4 ml/g DM	31.44	32.23	30.68	36.90	3.15	NS
CH_4 Mm/g DM	1.26	1.29	1.23	1.48	0.13	NS

SEM: Standard error of the mean

In Vivo Study
The results of first day methane gas (CH_4) emission from dairy goats in control, group 2 and group 3 were 22.00 ± 4.44, 21.97 ± 4.44 and 22.29 ± 4.44 g/day, respectively, while the corresponding values for fifth day were 31.34 ± 5.90, 28.91 ± 5.90 and 32.25 ± 5.90 (Table 2). There were no significant (P>0.05) differences among the treatment groups, but there was slight CH_4 production reduction in T_2 compared to T_1 and T_3. However in 2nd day of methane gas collection, the collected CH_4 in all supplemented and control groups were remarked lower

than other 4th days gas collection trial, but in 5th day of gas collection, dairy goats in T_2 showed considerable reduction compared to T_3 and T_1. Overall least squares means of CH_4 for T_1, T_2 and T_3 were 28.76 ± 2.68, 27.72 ± 2.68 and 28.90 ± 2.68 respectively. It seems that polyherbal supplementation with lower doses tends to improve CH_4 reduction, when it expressed as g/kg digestible dry matter (DDM) and miM / kg DMI. Other literature on effects of polyherbal supplementation on methane gas (CH_4) emission in goats is not available.

Table 2. Least squares means of CH_4 emission (g/d) of lactating goats, initial and final BW (kg) and DMI (kg) in different treatment groups

Day	NS	Treatment LS	HS	SEM	P
1	22.00	21.97	22.29	4.44	NS
2	11.99	12.29	13.10	2.06	NS
3	42.24	38.19	40.20	10.60	NS
4	36.25	37.21	36.64	2.91	NS
5	31.34	28.91	32.25	5.90	NS
Overall	28.76	27.72	28.90	2.68	NS
CH_4 g/kg DMI	21.97	18.16	21.35	2.41	NS
CH_4 g/kg DDM	28.41	23.18	25.36	3.04	NS
CH_4 mM/kg DMI	1.37	1.13	1.33	0.15	NS
Initial BW (kg)	44.25 ±3.97	44.50±2.90	44.75± 3.03	-	-
Final BW (kg)	42.00±4.14	42.75±2.86	43.00±2.94	-	-
DMI (kg/d/h)	1790.39[b]	1790.26 [b]	1684.34[a]	11.35	0.001
DMI(kg)/100kg BW	4.44	4.11	4.02	0.45	NS

NS: Non polyherbal supplemented group
LS: Low polyherbal supplemented group
HS: High polyherbal supplemented group
Values in the rows with different superscripts are significantly different

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Prototyping rotation and association with cover crop and no till

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Keywords: whole farm systems modelling, cropping system, cover crop

Introduction

Crop rotations, between season and year, and within season, are one of the pillars of conservation agriculture (CA) (FAO, 2010; Reicosky, 2008). Moving from conventional to CA implies deep changes in the organization of cropping systems. The rules driving such changes have rarely been formalized, sometimes in a technical manual (Husson et al., 2009; IIRR, 2005), but never as a model as has been done for other non-CA cropping systems, *e.g.* ROTAT (Dogliotti et al., 2003) and ROTOR (Bachinger and Zander, 2007).

Our aim, by creating PRACT (Prototyping Rotation and Association with Cover crop and no Till) was to develop a tool not only able to select a single cover crop for a specific environment or specific goals, but to propose cropping systems defined by the association and/or rotation between cover crop and main productive crops. Until now PRACT has been applied to forty plants (Table 1) in the context of the lake Alaotra region of Madagascar.

Table 1. List of plants available in PRACT

Type of plants		Name of plants
Cover crops	Legumes	*Arachis pintoi, A. repens, Cajanus cajan, Desmodium uncinatum, Dolichos lablab, Crotalaria grahamiana, C. juncea, C. spectabilis, Lupinus alba, Mucuna pruriens, Pennisetum clandestinum, Stylosanthes guianensis, Trifolium repens, T. semipilosum, Vicia villosa, Vigna umbellata, V. unguiculata*
	Other plants	*Avena sativa, Brachiaria brizantha, B. humidicola, B. ruziziensis, Cynodon dactylon, Eleusine coracana, Hordeum vulgare, Lolium multiflorum, Pennisetum glaucum, Raphanus sativus, Sorghum bicolor*
Main crops		*Arachis hypogaea, Glycine max, Ipomea batatas, Manihot esculenta, Oryza sativa, Phaseolus vulgaris, Solanum tuberosum, Triticum durum, Vigna umbellata, V. unguiculata V. subterranea, Zea mays*

Materials and Methods

PRACT was developed with the database management system Microsoft® Access 2007. This software was chosen as it is accessible for potential users in Madagascar. PRACT allows the user, for a defined agro-climatic context, to generate crop rotations based on CA principles that are best adapted to face local constraints. It is constructed around a knowledge database including data on: crops, cover crops, agronomics units, and relation between these three elements (Figure 1). This knowledge database came from expert knowledge already formalised in a technical manual (Husson et al., 2009; Husson et al., 2011, in press). Agronomic units are areas which are homogeneous regarding position in the toposequence and biophysical conditions that impact plants. For Lake Alaotra in Madagascar each of the 22 agronomic units is defined by: i) position on the toposequence, ii) water logging status, iii) irrigation management, iv) soil texture, v) possibility or not to grow an off-season crops (Husson et al., 2011, in press). Plants (crops and cover crops) are defined by their name, their taxonomic level (variety, species, genus, family) and rules for being cultivated. These plants are characterized by their quantitative outputs (grain production, biomass/forage production) and qualitative impacts on agro-ecological functions (Table 2). The production of each crop/forage came from continuing surveys by development agencies (Domas et al., 2010). Qualitative indicators are documented from expert knowledge (Husson et al., 2009). They concern agro-ecological functions (soil structure improvement and soil organic matter increase, erosion control, N input, nutrient cycling, weed control, pest and disease control) and or characteristic such as "simplicity for management" which can help to sort cropping systems looking for easier systems to implement by farmers. During the generation of crop rotation/intercropping these indicators are aggregated to produce the same indicators at rotation/association level. Plants are also characterized by a series of rules which apply for different taxonomic levels from family to variety. In PRACT, agronomic rules can be defined in a relatively simple way through specific interfaces. Theses rules concern three domains: i) compatibility of plants with different agronomics units (with regard to their requirement in term of fertility, water availability for example), ii) possibility or not to associate plants between them (competition in time or space), iii) Possibility for one plant to follow another in the rotation. Two types of rules were defined: 1) "simple" rules, such as compatibility of plants to grow together in mixtures and compatibility between plants and agronomic units, and 2) more elaborate rules regarding plants successions and associations, *e.g.* for all upland agronomic units, if in year 1 the cover crop is *S. guianensis* then in year 2 the cover crop should be *S. guianensis*, because *S. guianensis* needs two seasons to produce sufficient biomass in uplands. Rules and fit responses of plants to agronomics units and indicators/outputs are defined with a seasonal time step, *i.e.* hot wet rainy season and dry cool off-season.
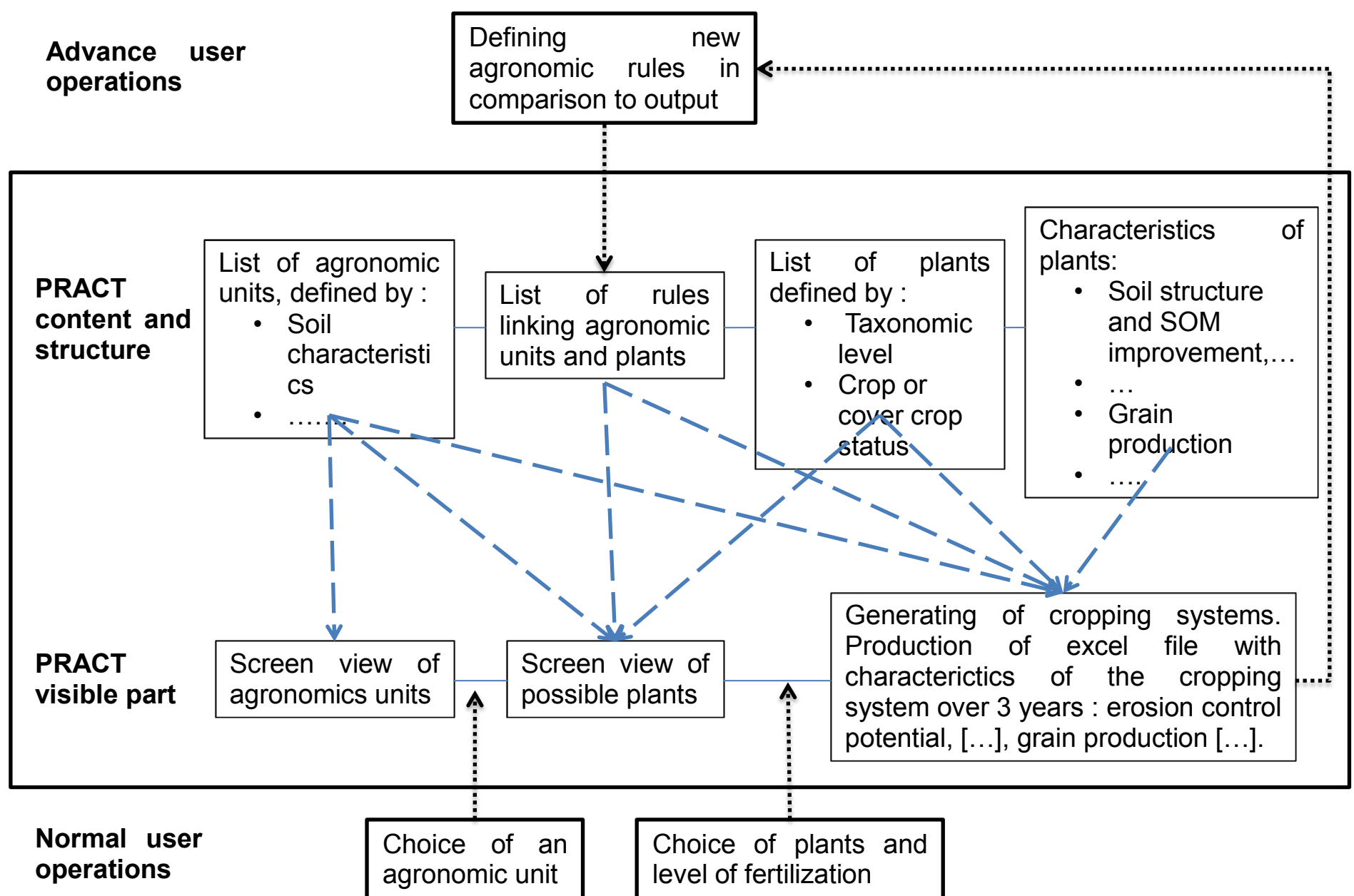
Figure 18: Simplified plan of the information processing in PRACT, interactions with the user and output.

Table 2. List of indicators and outputs defining each cropping systems generated by PRACT

Type	Indicators	Levels/units
Qualitative indicators (for each year of the cropping system)	Soil structure improvement and soil, organic matter increase, Erosion control, N input, Nutrient cycling, Weed control, Pest and disease control, Simplicity for management	Very high/ high/ average/ bad
Quantitative indicators, production (for each year of the cropping system)	Rice grain, Legume grain Cassava tuber, Above ground biomass of legumes, Above ground biomass of grass	kg/ha

Results and Discussion

PRACT allows the user to formalize expert knowledge in choosing rotations of crops and cover crops for CA systems. For example, an advanced user can easily modify rules in an interactive process if proposed systems are technically impossible. A new user can compare systems proposed by PRACT with their current cropping systems or a new rotation they intend to test. When comparing PRACT's cropping systems to farmers' ones, three situations can occur, they can be: equal, *a priori* worse, or *a priori* better from an expert point of view. In the second case the comparison allows formalization of technicians' and farmers' knowledge and eventually introduction of new rules or parameters in PRACT from expert knowledge (including farmers, technicians, and scientists). In the last case, technicians and farmers can plan to test the new proposed systems on a small area to evaluate them under real conditions. PRACT is also useful for generating a large range of cropping systems as inputs for farm modelling and for scenario testing. For example, as shown by Dogliotti et al. (2005), linear programming can be used to select among the cropping systems which better fit to farmers' goals and constraints. If PRACT were used in a decision support system (DSS), it should first be used as a stand-alone tool not connected with other programs, as users do not like "black boxes" where equations or calculations are not clear (McCown, 2002). Secondly, PRACT should be regarded as a "learning" tool rather than a "solver" (a tool from which output should be implemented without questioning the proposed choice). Third, the tool and any DSS version of PRACT is designed for technicians and scientists - not for direct use by farmers who in Madagascar have neither the means nor interest to use such a tool.

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Watermelon (*citrullus lanatus*) live mulch climatic adaptation capabilities in African humid tropics' cropping system

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Introduction

In-situ live mulch crops such as watermelon (*Citrullus lanatus*) can suppress weed populations resulting in reduced reliance on herbicides, reduced soil temperature, improved soil moisture, and additional income from sale of produce harvested in mixed cropping systems in sub Saharan Africa. Previous studies indicate that cover crops could suppress weed populations and reduce reliance on herbicides (Pelosi et al. 2009); and that in-situ live mulch cover crops give short term cash supplements from produce harvested thereby making adoption by farmers more attractive, easier and quicker (Ali, 1999). It is suspected that changes on crop production practices might be due to weed control, temperature, moisture, as well as flexibility in African humid tropics cropping systems. Grain amaranth (*Amaranthus cruentus* L.) is important for its higher protein content compared to other staple crops such as rice, maize, sorghum and millet (Bressani, 1988) in sub-Sahara Africa where meeting daily dietary requirements is challenging. It is drought tolerant and highly adaptable to the tropics as a potential crop thereby contributing to food self security of the region. Watermelon commands higher prices than the local non-exotic crops especially in the dry seasons. The present investigations therefore seek to quantify the impact of various densities of in-situ watermelon live mulch on weed control, yield potential and climatic change adaptation capability strategy in the humid tropics in an intercrop amaranth production system.

Materials and Methods

The experiment was conducted at National Institute of Horticultural Research (NIHORT) headquarters, Ibadan, Nigeria (3°54'E, 7°30'N, 213 m above sea level) from October 2009 to June 2010 using supplemental irrigation facilities during low rainfall periods. Treatments comprised three sowing densities of watermelon: 1.5 x 0.45m; 1.5 x 0.90m; 1.5 x 1.50m. Grain amaranth as an intercrop was transplanted at 0.75 x 0.75 m spacing. There was a control plot left bare without cropping and a check plot with only grain amaranth forming five treatments in each of five replicates in an RCBD design. Weeding was by hand held hoe at 3 week intervals commencing 3 weeks after planting (WAP) of watermelon. Naturally occurring weed population was used ie no supplemental weed planting was used. Net plot size was six data rows 15m long rows 0.75m apart (i.e. 15m x 4.5m) plus a border row on each side to minimize interference of the weed control treatments. Treatments, design and agronomic practices used were based on experimental results at NIHORT from 1985 to 1999 (NIHORT 1985-1999) and David (1997). Soil maximum and minimum temperature data were collected by inserting two maximum-minimum dial thermometers per plot at 0.10 m depth for 12weeks commencing 3weeks after transplanting amaranth. Readings were made 3weeks after amaranth transplanting (WAT), 50% amaranth anthesis, and harvest of amaranth. Readings made by instruments in each plot were averaged for use in data analyses. Soil moisture content in the surface 0.15 m was determined gravimetrically at 50% anthesis of amaranth. Four soil samples were taken randomly from each plot and combined in a sealed plastic bag for drying as soon as practicable. Soil was dried at 120 ^{0}C for three days, and soil moisture content expressed as percentage weight of moisture lost during drying relative to soil dry weight. Transmitted and incident Photosynthetic Photon Flux Density (PPFD) was measured using AccuPAR PAR 80 Model within 1 hour of solar noon during clear weather at 50% amaranth anthesis between the centre of amaranth and watermelon rows. Percent transmittance was determined from readings under and above vegetation after adjustment for measured differences among sensors in unobstructed sunlight readings. Weeds within four 0.50 m^2 quadrates per plot were sampled at 3 weeks after transplanting of amaranth, 50% amaranth anthesis and at amaranth harvest. Weeds within quadrats were cut at ground level, oven dried at 80°C until constant weight to determine total weed biomass. All data were subjected to analysis of variance using procedures of SAS software. Interaction effects are only reported when significant at P=0.05.

Results and Discussion

Averaged over the two consecutive croppings, amaranth grain and watermelon fruit yields were highest at 1.5 x 0.90 m watermelon plant spacing (Table 1). These values are within range reported by David (1997). Watermelon live mulch treatment consistently reduced weed density and biomass relative to the control in both croppings (Table 2). Lowest mean light penetration of live mulch was 0.29 and 0.22% in the first and second croppings respectively. All mulch densities transmitted less PPFD relative to the control (Table 3). Light levels of less than 0.1% transmittance are required to activate phytochrome-mediated germination and even lower levels are required for the very low fluence rate response (Kronenberg et al. 1986). This finding is supported by previous research that live mulch reduces light penetration to a quarter to a half of that in naturally weed infested soil (Teasdale et al. 1993). Maximum soil temperature was reduced by amaranth and melon in each cropping (Table 4), and there was a trend towards a significant increase in minimum soil temperature under live mulch. Bristow (1988) first observed this under mulch for modifying soil environmental temperature, but the implication in adapting to climate change will need be clarified (Challinor *et. al.* 2007). The practical implication is that live mulch could regulate soil temperature by reducing temperature in hotter environment and increasing it in colder environment and during cool periods of the day. Melon may have a greater influence on weed germination by affecting the daily amplitude between maximum and minimum temperatures (Table 4). A diurnal temperature change of approximately 10 ^{0}C is required for germination of some weed seeds (Taylorson 1987) but it is unknown whether the species (predominantly elephant grass) in this experiment has a temperature amplitude requirement. Soil moisture content was significantly greater in the live mulch treatments compared to the bare soil. Our research demonstrated that live mulch suppress weeds, had greater light extinction, and lower diurnal soil temperature amplitude that account for usefulness of live mulch in cropping systems, and we believe offer opportunities in adaptation of agricultural production systems under climate change scenarios.

Table 1: Yield of watermelon and grain amaranth with watermelon as a green mulch and amaranth as an intercrop

Mulch Treatment*	Watermelon (kg/m2)	Grain Amaranth (g/m2)
Check	-	88
1.5 x 0.45m	8.2	82
1.5 x 0.90m	8.6	93
1.5 x 1.5m	9.4	90
Lsd (P=0.05)	0.2	3.8

Table 2: Weed density and biomass with watermelon as a green mulch and grain amaranth as an intercrop.

Mulch Treatment*	Weed Density (No/m2)	Weed Biomass (g/m2)
Check	111	177
Control	1344	880
1.5 x 0.45m	832	182
1.5 x 0.90m	876	230
1.5 x 1.5m	964	500
Lsd (5%)	40.2	30.8
	Interaction (P=0.05)	
Mulch/control	*	*

Table 3: Light transmittance with watermelon as a green mulch and amaranth as an intercrop in two successive crops

Mulch Treatment	Light Transmittance ---------------------------- (% PPFD)* ----------------------		
	First Cropping	Second Cropping	Mean
Check	0.11	0.77	0.56
Control 0.88	0.65	0.77	
1.5 x 0.45m	0.29	0.22	0.26
1.5 x 0.90m	0.35	0.24	0.30
1.5 x 1.5m	0.38	0.25	0.32
Lsd (5%)	0.05	0.03	0.04

*Photosynthetic Photon Flux Density is % ratio of PPFD under mulch divided by unobstructed PPFD made above mulch.

Table 4: Soil maximum and minimum temperature under live mulch

Mulch Treatment*	------------ Soil Temperature (^{0}C)* ----------		
	Maximum	Minimum	Amplitude
Check	40.1	32.7	7.40
Control	44.3	38.0	6.30
1.5 x 0.45m	34.0	32.1	1.90
1.5 x 0.90m	36.1	31.8	4.30
1.5 x 1.5m	39.8	30.3	8.50
Lsd (5%)	0.88	1.04	0.42

*Averaged temperature recorded daily/weekly from 50% anthesis till final harvest of amaranth.

Table 5: Soil moisture content under live mulch

Mulch Treatment	Moisture Content -------------------------- (%) ----------------------------		
	First Cropping	Second Cropping	Mean
Check	14.0	12.8	13.4
Control	15.0	13.0	14.0
1.5 x 0.45m	20.8	20.5	20.7
1.5 x 0.90m	18.1	18.0	18.1
1.5 x 1.5m	16.3	15.9	16.1
Lsd (5%)	0.89	0.91	0.64

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Irrigation strategy has a large effect on deep drainage during a long-term crop sequence in the Lockyer Valley, Australia

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Introduction

The Lockyer Valley in Southeast Queensland is an important area for crop production, supplying nearly 35% of Queensland's irrigated vegetables (Cox and Wilson 2005). Irrigation is widely used, so that high-value crops can be produced year-round. However, deep drainage is of concern as it may lead to increased ground water recharge or contamination of groundwater with salt and in turn lead to salinity. Estimation of deep drainage is difficult when crop rotations are complex because of involvement and interaction of different crop species and different management practices for the crops. One of the main influences on deep drainage is irrigation practice, and better understanding of the relationship between irrigation practice and deep drainage enhances our knowledge of sustainable land management.

The impact of irrigation practice on deep drainage has not been examined in the Lockyer Valley. We have applied simulation models to the study of deep drainage because they are low-cost relative to direct methods such as lysimetry, and able to assess hypothetical systems. The soil water balance model Howleaky (Rattray et al., 2004, Robinson et al., 2010) has been used to estimate deep drainage and other components of the soil water balance. It is a simple one dimensional, daily time step soil water balance model with options for scheduling irrigation events according to a range of criteria. The objective of this study is to compare irrigation strategies and to address how they affect deep drainage. This knowledge in turn helps to identify irrigation strategies that lead to efficient water use by crops and sustainable land management.

Materials and Methods

The simulation was for the period from November 1997 to April 2010 with the HowLeaky? V.5.28 soil water balance model (Rattray et al., 2004, Robinson et al., 2010). The study site was Forest Hill, Australia (27°36′ S 152°20′ E, about 83 km West of Brisbane, the state capital). The crop rotation included beetroot, broccoli, cotton, mung bean, sweet corn (all irrigated) and wheat (unirrigated). The rotation consisted of varied cropping sequences and bare fallow of differing duration between crops. The study site and the crops are somewhat representative of the soil, climate and cropping systems in Lockyer Valley. The simulated soil is a Black Vertosol (Isbell 1996) with 280mm of plant-available water capacity to 1200 mm depth and a volumetric drained upper limit of approximately 42% in the surface layers. The weather data are drawn from the Patched Point Dataset (http://www.longpaddock.qld.gov.au/silo/). Vegetation files for each crop were developed using a crop cover model which has inputs of green and total cover (%), residue cover (%) and root depth (mm) for various times of the year. Fallows were simulated as bare soil.

Four irrigation scenarios were simulated (Table 1), differing only in the irrigation amount and frequency, which were based on rules concerning soil water deficits and irrigation end-points. We calculated deep drainage and transpiration as annual amounts (mm/year), as well as a percentage of the total water balance (irrigation and rainfall, mm/year).

Results and Discussion

There were substantial differences in simulated irrigation demand and large difference in simulated deep drainage amongst the scenarios (Table 1). The estimated deep drainage for scenarios I and II compare well with the range of 91 to 218 mm/year independently estimated by Gunarwardena et al. (these proceedings). They used the SODICS model (Rose et al., 1979) and soil chemistry data indicating 2.4 t/ha/year of Cl$^-$ displacement below the root zone.

As shown in Figure 1, deep drainage is significantly related to irrigation and rainfall – there is an "envelope" of data that fits between the lines which represent upper and lower bounds for deep drainage for particular amounts of rainfall plus irrigation. Differences between years may be due to rainfall occurrence, crop type and irrigation management. Table 1 shows that as average annual irrigation increased from 516 mm (scenario III) to 751 mm (scenario I) deep drainage increased from 5 % to 18%. The slopes of the lines in Figure 1 (almost 1:1) indicate a strong association between deep drainage and irrigation greater than the crop requirement. In contrast to the deep drainage, the response of transpiration to increased irrigation was small (Table 1). That is, the extra irrigation in scenarios I and II was not utilised to a significant degree by the crops. Instead, it mostly contributed to deep drainage, evaporation and runoff.

Scenario III appears to satisfy crop water requirements while restricting deep drainage. Further study is required to determine whether this irrigation strategy is economically efficient. If so, such a strategy may assist sustainable land management by reducing diffuse and saline recharge and the risk of salinity. This study is also a demonstration of low-cost evaluation of management strategies via the HowLeaky? water balance model.

Table 1. Details of the four irrigation scenarios and the simulated average annual irrigation (I), deep drainage (DD) and transpiration (T) for the study site in the Lockyer Valley.

Irrigation scenario	Irrigation criteria		I (mm)	DD (mm)	DD/(I+R) (%)	T (mm)	T/(I+R) (%)
	Interval (based on SWD)	Target amount					
I	25 mm for beet and broccoli; 50 mm for cotton, mung bean and sweet corn	DUL+50% for beet and broccoli; DUL+25% for cotton, mung bean and sweet corn	751	265	18	667	46
II	50 mm for beet and broccoli; 75 mm for cotton and sweet corn; 60 mm for mung bean	DUL+25% for beet and broccoli; DUL for cotton, mung bean and sweet corn	552	94	8	653	52
III	= II	DUL for all crops	516	55	5	653	54
IV	= II	Fixed: 30 mm for beet and broccoli; 40 mm for cotton and sweet corn; 25 mm for mung bean	543	26	2	628	51

SWD = Soil water deficit; DUL=Drained upper limit; R=Rainfall
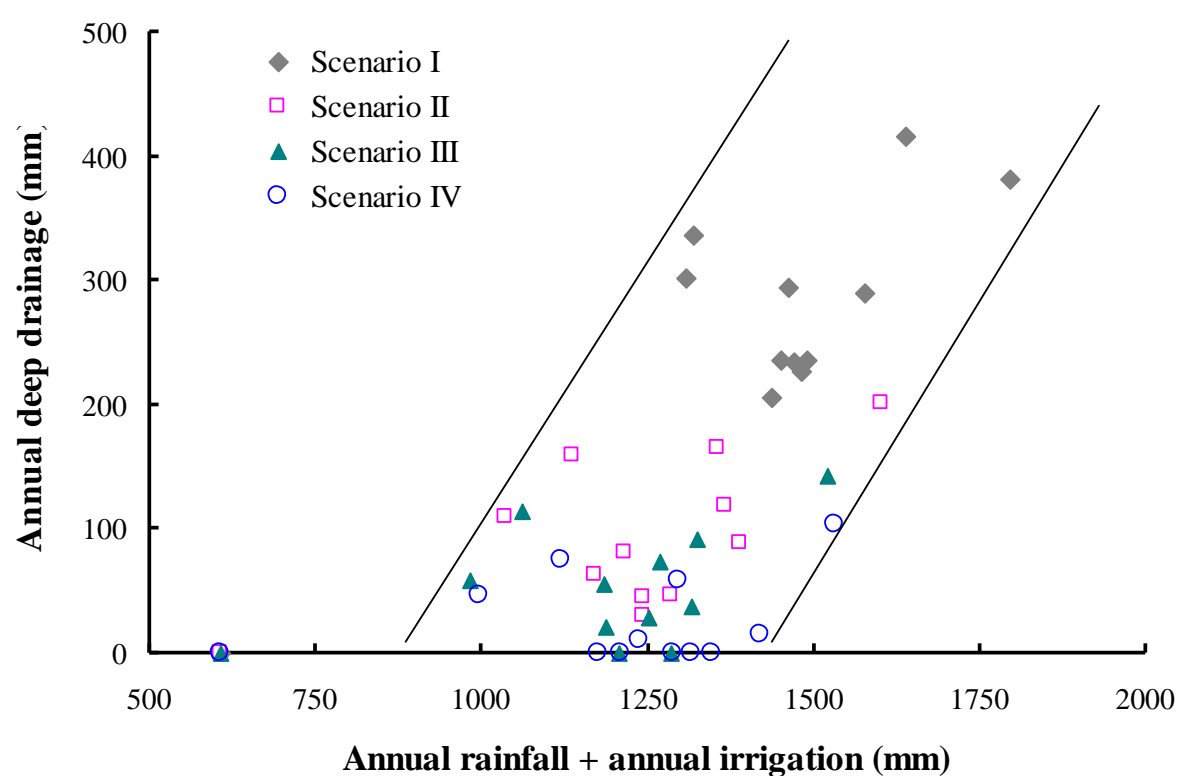
Figure 1. Relationship between annual deep drainage and annual irrigation + rainfall for four irrigation scenarios (see Table 1 for detail) for the study site in the Lockyer Valley.

Short term intensive rotational grazing in native pasture: II. Effects on soil nitrate and extractable P

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Keywords: nitrate, phosphate, rotational grazing, animal congregation, water contamination

Introduction

Soil available nitrogen and phosphorus in pasture could be one of the main non-point source pollutants for downstream water bodies' contamination. When nutrients are in excess of what plants can use, there is an increased risk of nutrients ending up in rivers and lakes through runoff and leaching. Grazing practices can degrade water quality if grazing is too intense; if paddocks are grazed when the soil is too wet; or if the duration of the rest period is too short. The likely impacts include contamination of water resources with nitrate, phosphate, pathogens and sediments through direct loss of soil, and runoff and leaching. In native pasture where no fertilizer and forage inputs (external supplement) are applied, grazing management is the only factor responsible for nutrient accumulation across paddocks and its subsequent effect on the environment. Traditional practices including continuous grazing has been largely documented to encourage runoff and soil loss (Greenwood and McKenzie 2001) as well as the imbalanced distribution of nutrients across paddocks. Nutrient deposition within pastures results from the tendency of grazing animals to congregate. They leave manure and urine around food and water sources, along fences and under shade, resulting in an uneven spread of nutrients across the paddock.

In contrast to continuous grazing, short period intensive rotational grazing, which includes long rest periods, encourages foraging and manure distribution across paddocks and discourages animal congregation. Such effects could improve nutrient balances within pastures and increase productivity, and reduce the potential for downstream water bodies' contamination. Based on the work of the authors and the literature reviewed, the objective of this paper is to highlight the extent to which grazing management modifies animal grazing behaviour and reduces the effects on both pasture productivity and environmental health.

Materials and Methods

Short period intensive rotational grazing (Savory and Parsons 1980), as an alternative to continuous grazing, has the potential to modify animal behaviour to achieve more even grazing, and subsequently a more uniform distribution of urine and faeces across paddocks. Under this grazing practice, a large herd of livestock is moved between a number of paddocks for short periods at a time, followed by long rest periods. General recommendations suggest 30-90 days for the rest durations, with the shorter rotations practiced during periods of rapid plant growth. There are few documented studies that detail information on the effects of short period intensive rotational grazing and grazing exclusion on soil available nutrients. Perhaps the case study of Currajong in Queensland conducted by the current authors (2008) is the only available results on how intensive rotational grazing decreases the imbalance in distribution of nutrients accumulated in congregation sites. The research paddocks had a long history of continuous grazing before conversion to rotational grazing in 2001.

In the experiment of Currajong (2001 – 2006), the paddocks assigned to continuous grazing were grazed with a light stocking rate of around 1.5 DSE (Dry Sheep Equivalent)/ha which is normal in the region. However the paddocks of short period intensive rotational grazing were stocked in with high rates of 12.6 ± 6 DSE/ha for differing short grazing durations of 14 ± 9 days and stocked out to rest the pasture for long periods of 101 ± 60 days during the study time. Apart from the soil analysis carried out throughout the paddocks, a long soil sampling transect was established from the center of an historical animal aggregation site (hilltop sheep camp site) extending into the pasture to monitor the soil nutrient changes during the application of the new practice. Some of the measured factors included soil organic nitrogen; soil nitrate and, ammonium (2M KCL), soil extractable P (0.5M NaHCO$_3$); pH and EC (1:5 soil/water suspension). For further details on the methodology, please refer to Rayment and Higginson 1992.

Results and Discussion

The limited works reported in the literature and the results of the case study of Currajong both show that rotational grazing in pasture provides more even distribution of livestock and hence a more uniform distribution of urine and faeces deposition across paddocks. The deposition uniformity is greatly affected by the intensity of grazing rotations. Research by Lory et al. (2000) revealed that under extensive continuous grazing, 27 years would be needed to get one manure pile on almost every square meter within a paddock, while under a two day rotational grazing it may take only two years.

In our rotational grazing system, a large paddock is subdivided into a number of smaller paddocks, allowing for better control of animal congregation habits. In large paddocks which are normally managed under continuous grazing, sheep graze and move like a herd, whereas in small paddocks, which is common in rotational grazing, sheep tend to graze and visit water points, mineral blocks (contain different amounts of calcium, sodium, potassium, phosphorus and chlorine) etc., one by one. The more paddocks that are used in rotation, the more uniform animal depositions are distributed. In one example, manure was distributed more evenly across the paddocks when 12 or 24 paddocks were used rather than only 3 paddocks (Gerrish et al. 1994).

Intensive short period rotational grazing, which includes long rest periods after each grazing event, adds more advantages to the basic version of rotational grazing. During rest periods, the defoliated plants have a chance to initiate a fast recovery and regrow when temperature and soil conditions are favourable. By allowing for plant recovery, nutrients are therefore removed reducing the potential for downstream water bodies' contamination in particular from the animal congregation sites. The best instance in this case is the results of the research conducted by the authors in Currajong, Queensland.

The Currajong outcomes showed that the average soil nitrate (NO$_3^-$) level in the research paddocks decreased sharply to 0.4 kg/ha ($p \leq 0.01$, Fig 1.a) in 2006 compared with 3.5 kg/ha in 2001, when the grazing strategy was first converted from continuous grazing to short period intensive rotational grazing. Such a reduction was much more pronounced (6.5 to 0.5 kg/ha) in a sub-paddock with a better soil condition in terms of slope and soil depth. The ratio of NO3:TON (nitrate:total organic nitrogen) (Figure 1b) and soil available phosphorus (Figure 1c) fell by factors of 7 and 3, respectively, showing the same reduction as nitrate under the rotational grazing.
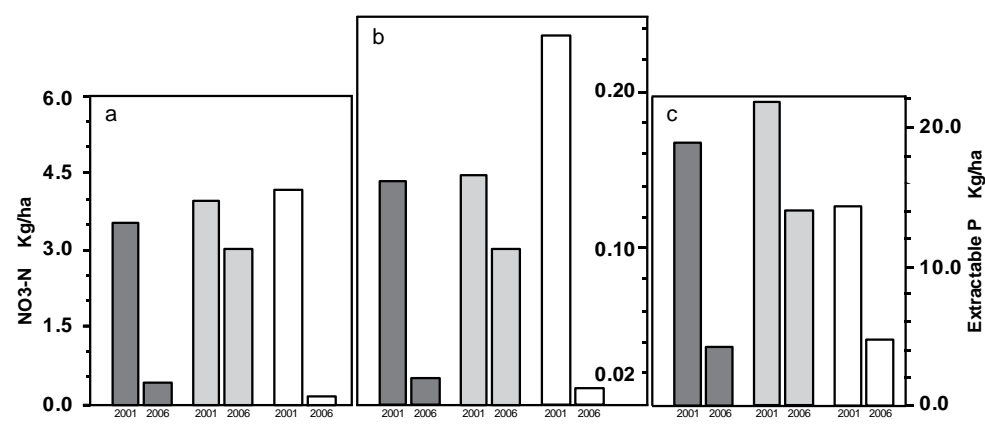
Figure 1) Changes in soil nitrate (a), NO3:TON ratio (b) and phosphate (c) from 2001 to 2006 under the short period rotational grazing ▓ , continuous grazing � and grazing exclusion ☐

In the paddocks of continuous grazing no significant changes occurred in both soil nitrate and the ratio of NO3:TON from 2001 to 2006. Soil extractable P however declined ($p \leq 0.01$) from 22 to 14 kg/ha over the above period. Decrease in soil P is mostly attributed to the increase in soil erosion under continuous grazing in particular over the second period of the study (2004-2006) (Sanjari et al. 2009). It is noted that grazing animals excrete phosphorus in faeces which is not mobile, but organic phosphorus can still be lost by water erosion.

The lowest nitrate concentration (0.17 mg/kg soil) was found under the grazing exclusion treatment in 2006. Nutrient reduction in these areas highlights the important role of grazing animals in nutrient cycling and pasture fertility. Thus a pasture with long term grazing exclusion is subject to a lower productivity through the decline in available soil nutrients. Unlike nitrate reduction under grazing exclusion, soil ammonium increased significantly from 4.56 in 2001 to 13.69 mg/kg in 2006. This result supports the concept in which ammonium concentration increases from a minimum in the first ecological stage of succession (the ecosystem has very low plant diversity and species live in hostile environment) to a maximum in the climax (the highest stage in ecological succession where plant diversity is high and the ecosystem becomes stable and does not undergo significant changes) and vice versa for NO3-N (Rice 1984). In other words in grasslands when herbivores are excluded for a long time, soil available nitrogen is kept more in the form of ammonium which is less subject to leaching than nitrate.

The outcomes of the short period rotational grazing on animal aggregation, has returned a major decrease in available nutrient concentrations at camp sites where a large amount of nutrients have been deposited over the long history of continuous grazing. The sharp reduction of phosphate and nitrate (Figure 2) with distance from the center of a hilltop sheep camp clearly shows the ability of the rotational grazing in modifying animal grazing behavior to achieve a more even distribution of urine and manure across paddocks.
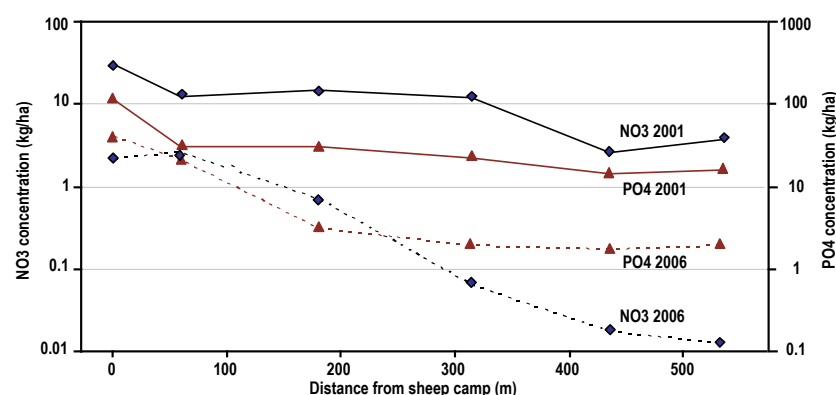
Figure 2. Decline in nitrate and extractable P concentrations in a sheep aggregation camp and surrounding area following conversion of the grazing practice to short intensive rotational grazing

Nutrient reduction in the sheep camp is also attributed to the massive re-growth of Couch grass (*Agropyron repense* L.), the dominant sheep camp's vegetation during rest periods taking up large quantities of the available nutrients from the camp. An example of 2650 and 3685 kg/ha dry matter re-growth recorded in our experiment within 16 and 60 days rest periods respectively. This clearly shows the ability of Couch grass to take up large quantities of the available nutrients from the camping site over the rest periods. Under continuous grazing however, the yearlong presence of animals in the paddock inhibit such a re-growth resulting in less nutrient consumption by the vegetation. A comparison of the soil nutrient concentrations before and after the application of intensive short period rotational grazing shows that animal camps under continuous grazing are of high environmental concern because of the high levels of associated nutrients, even in native pastures. While in short period intensive rotational grazing, nutrient concentrations fell quite far below the safe critical level (Ewanek J 1995; Johnson and Eckert 1995) for water contamination (160 and 330 kg/ha for nitrate and available P, respectively).

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DYSPALLOC, a model to simulate farmers' cropping plan decisions in their spatial and temporal dimensions

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Keywords: model for action, farm scale, decision rules, crop succession, landscape organization

Introduction

Farmers' cropping plan decisions have an impact on the spatial and temporal crop organization at farm and landscape levels, which in turn strongly impact many environmental issues (soil erosion, biodiversity, coexistence between GM and non GM crops, crop pest management etc.). It is generally accepted that managing landscape organization, considering both landscape composition and configuration, is a way to reconcile agricultural production and preservation of ecosystem services at the landscape scale (Foley et al., 2005). We thus consider it necessary to understand farmers' cropping plan decisions in their spatial and temporal dimensions, to anticipate their potential consequences on landscape organization. These decisions include choosing crops, allocation of crops to plots, and splitting agricultural plots (Schaller et al., 2010). The spatial dimension of cropping plan decisions is particularly important for understanding the spatial arrangement of crops in agricultural plots. Likewise, the temporal dimension of cropping plan decisions particularly matters for understanding when decisions are made during a year and when it could be opportune to coordinate farmers' decisions to favorably orientate the landscape organization (Dury et al., 2011).

In this paper, we present DYSPALLOC, a conceptual model of decisions for DYnamic-and-SPatially-explicit-ALLOcation-of-Crops-to-land, built on the basis of a French case study. The aim of this study is (i) to represent and simulate farmers' cropping plan decisions in their spatial and temporal dimensions at the farm scale, and (ii) to evaluate the model.

Materials and Methods

Farmers' decisions were represented through a generic framework derived from the "model for action" (Sebillotte and Soler, 1990) and including decisional variables, determinants, and decision rules (Schaller et al., 2010). The necessary data for using such a framework requires specific on-farm surveys. We carried out the surveys in the Niort plain region (France). We chose a reduced sample of 9 farms, in order to carry out 3 successive and detailed surveys about farmers' cropping plan decisions over time. We selected the farms so as to account for the regional diversity in farming systems and farm territory spatial structure. We indeed hypothesized that these two criteria highly influence farmers' decisions. All surveys (in May, November 2009 and May 2010) were semi-structured and aimed at encouraging the farmer to explain how he spatially allocated crops to land and split his farming territory into plots and to specify the reasons of his choices over different time scales. The surveys thus gave the possibility to identify farmers' plans regarding the choice of the cropping plan for 2010 and to check possible adjustments over time.

After having made an inventory of the elements constituting cropping plan decisions in space and time (based on the 9 farms), we focused on 4 farms (saturating the diversity in farming systems and farm territory spatial structure) in order to build the conceptual model DYSPALLOC, before carrying out an evaluation procedure on the 5 other farms.

Results and Discussion

Figure 1 represents the global structure of the DYSPALLOC model. It simulates a planned cropping plan in year n for year n+1 at the farm scale. The model represents farmers' decisions when the farm is in a "coherence phase" of its life cycle (Chantre et al., 2010), which is a time period during which the strategic decisions remain stable (labor, equipment, crop combination, etc.). We chose to represent the cropping plan decision process through the same model for all farmers, but the diversity in each farmer's decision rules can be accounted for through the input data. DYSPALLOC requires input data regarding the farm territory (e.g. area, soil types), the possible crops in the farming system, and crop succession decision rules. The model proceeds in 3 time steps:

(i) The first time step represents the strategic decisions which are made once for the entire "coherence phase". The strategic decisions include the crop functional hierarchy, which determines if a crop or a crop category will have priority access to land; the definition of permanent plot boundaries and of strategic suitable crop areas, which determines in which plots crops will be possibly allocated; and the definition of crop blocks, which defines groups of plots having the same possible crop succession over time.

(ii) The second time step represents annual decisions made by farmers during year n for planning the cropping plan for year n+1. These annual decisions consist first in identifying the possible crop allocations to existing plots considering constraints due to past allocations. Then the model proceeds in planning the compulsory crop allocations to plots (when only one choice is possible) and in planning preferential crop allocations to plots, according to preferential criteria (when several choices are possible). The main preferential criteria are: water access, spatial regrouping of crops, and minimization of the distance between the farmstead and forage crops. At this stage, the model provides a planned cropping plan for year n+1, with a crop or crop category allocated to each plot.

(iii) The third time step represents infra annual decisions made by farmers during the year n+1. These decisions make it possible to adjust the previous plan to new events occurring along the year and giving farmers new information. These events can be related to climate, market prices or commercial opportunities, technical operations, water access etc. These infra annual decisions give the possibility to explain the differences between the planned cropping plan and the final one.

In addition to these 3 time steps, another original feature of DYSPALLOC relies on the fact that it accounts for agricultural plot splitting: it describes 3 types of plot splitting. The first type represents the splitting of administrative CAP islets[14] depending on their individual characteristics; they are split into homogeneous pieces of land regarding soil type and water access (the split plots are called "elementary islets"). The second type of plot splitting is related to the global farm structure and to crop successions. The "elementary islets" are indeed split into "permanent plots" when their area is too large to ensure both crop succession and the stability of crop areas over time. The third type of plot splitting is the definition of "temporary plots" inside the "permanent plots" in order to temporarily adjust annual crop areas.

The evaluation procedure consisted of a comparison of the simulated planned cropping plans (before the third time step) via DYSPALLOC with the real planned cropping plans, identified through the surveys. We applied this procedure to the 5 surveyed farms that were not used

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[14] CAP islet = spatially continuous land area used by agricultural authorities to calculate the European CAP subsidies

for building the model. The difference between simulated and real planned crop areas on farms was less than 6% in all cases, and less than 3% in 4 of the 5 farms. DYSPALLOC spatially allocated the correct crops in the correct plots in 69 to 100% of the cases (84% on average), which represented 71 to 100% of the total farm area (86% on average) (Figure 2).
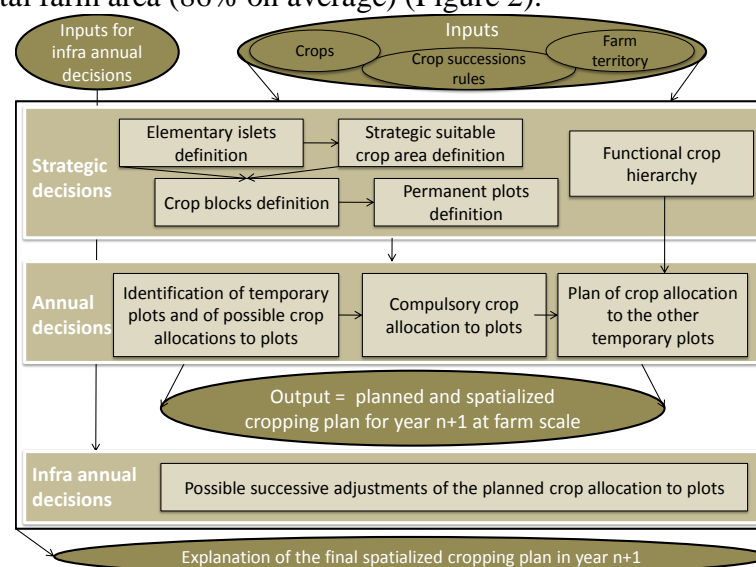

Figure 1. Global structure of the DYSPALLOC model: cropping plan decisions are made over 3 time steps (strategic, annual and infra annual)
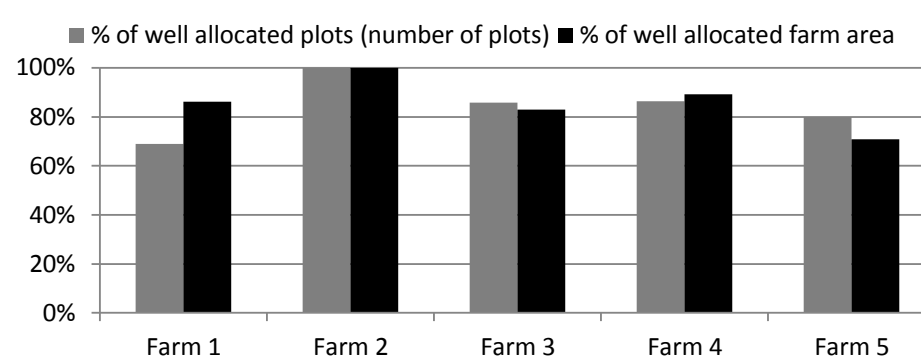
Figure 2. Validation of the DYSPALLOC model (proportion of correctly allocated plots and farm area)

Conclusions

DYSPALLOC is a useful model to simulate farmers' cropping plan decisions at the farm scale. It represents (i) its spatial dimension by accounting for agricultural plot splitting and crop spatial organization in those plots and (ii) its temporal dimension by accounting for the three type steps at which farmers' decisions are made (strategic, annual, infra annual). This conceptual model combining decision rules and calculations could be implemented in computer tools in order to simulate the impacts of farmer decisions on spatial and temporal landscape organization. It could also be used to examine farmer leeway and flexibility in cropping plan choices for improving landscape organization.

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Simulation of water management practices during rice growth in a tropical lowland rice-based farming systems using APSIM

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Keywords: continuously submerged (CS), alternately submerged and non-submerged (ASNS), APSIM-Oryza

Introduction

Rice is one of the biggest users of the world's freshwater resources because it is mostly grown under flooded or submerged condition. However, water is becoming increasingly scarce raising concerns over the sustainability of irrigated agriculture. Many rainfed areas are already drought-prone under present climatic conditions and are likely to experience more intense and more frequent drought events in the future due to climate change. Defining strategies for the planning and management of water resources in the agricultural sector has become a national and global priority. Increased efficiency in the use of water is essential for future food security in Asia where rice production needs to increase by 70% above the present amount by the year 2025 to meet demand (Tuong and Bhuiyan, 1999). Therefore, efforts to reduce water use, while keeping a high level of yield, are of great significance in the rice-based cropping systems. Modelling is an important and effective tool for explicitly describing the relationships among the components of complex systems. Modelling provides insight into relevant processes and their interactions, and can be applied to study effects of crop management, and to explore possible consequences of management modifications. In this paper, we evaluate the APSIM model under water-limited conditions of alternately submerged and non-submerged (ASNS), and under the non water-limited condition of continuously submerged (CS) management using four rice seasons during two years (2007-2009) of field experiments in irrigated farming systems in eastern Indonesia.

Materials and Methods

The field experiments were conducted with three replications at the experimental research station of BPTP Lombok NTB Indonesia (08°35' N; 116°13' E; 150 m elevation) involving two treatments of water regimes of CS and ASNS. Recommended irrigated rice management was practiced, and the N fertilizer at rates of 140 kg N ha^{-1} were applied in split applications with 20% at 7 days after transplanting (DAT), 30% at 29 DAT, and 50% at panicle initiation (45-50 DAT). Ponded water depth of each plot in both the CS and ASNS water treatments was kept between 0-20 mm during the first 7 DAT and was drained at 10 days before harvesting. In the CS treatment, ponded water was fluctuated between 0-10 cm throughout the growing period. In the ASNS treatment, water depth was fluctuated (0-5 cm) and included 5–7 days of non-submergence depending on rainfall conditions. The ponded water depths were measured daily in each plot with perforated tubes of 30 cm diameter that could record both aboveground and belowground water level during periods of nonsubmergence. The APSIM simulation framework is described in detail by Keating et al. (2003), and the key processes of ORYZA2000 have been well documented (Bouman and van Laar, 2006). Simulation of the transitional (flooded-non-flooded) soil conditions and pond processes within the APSIM framework has also been recently described (Gaydon et al., 2009). The key APSIM (version 7.1) modules deployed in this study were Rice (*Oryza sativa* L), SoilN (soil nitrogen), SoilWat (soil water balance), Surface Organic Matter and Pond. Data from the first year of the field trial (2007-2008) was used to parameterise and calibrate the model, with the second year of field date (2008-2009) used to validate the model.

Results and Discussion

In both wet- and dry-seasons of 2007/2008 and 2008, respectively under non water-limited condition of CS for the calibration test, the dynamics of simulated daily ponded depth closely followed measured values at most levels of ponded depth (Figure 1). APSIM simulation was able to reproduce similar results with measured values. The simulated values generally followed the measured values in the validation test in both wet- and dry seasons of 2008/2009 and 2009, respectively. The statistical analyses of goodness-of-fit parameters also indicated that simulated and measured values were matched for both calibration and validation tests (data not presented). The values of student's t-test for CS treatment in both seasons indicated that all simulated values are not significantly different from measured values at 95% confidence level. All of the indicators strongly suggest that the performance of the model was comparable for CS irrigation treatment in simulating the dynamics of ponded depth during rice growth periods of wet- and dry-seasons of 2007/2008 and 2008 for calibration test and for validation test. However, during water-limited condition of ASNS, the dynamic of daily water depth between simulated and measured values varied most of the time during the rice growth periods (Figure 1).

The performance of the model to simulate the dynamics of water depth under water-limited conditions during rice growth in the validation test was similar to the calibration test. The goodness-of-fit parameters indicated that the performance of the model to simulate water depth in ASNS irrigation treatment was lower than that in the CS irrigation treatment (data not presented). In particular, when measured water depth reached below soil surface, the simulated values deviated from measured values. These indicate that the performance of the model was weak for ASNS in simulating the dynamics of ponded depth during rice growth periods of wet- and dry-seasons for both calibration and validation tests. The dynamics of floodwater resulting from the model was comparable with the ORYZA2000 model reported by Belder et al. (2007). Simulated total amount of water input during rice growth periods in CS and ASNS irrigation treatments for both seasons in 2008 and 2009 growth periods (Table 1). In the CS irrigation treatment, simulated irrigation input was close to measured values with the difference of 13.1% and 5.8% for 2007/2008 and 2008 seasons respectively. In ASNS irrigation treatment, the performance of the model to simulate water input was similar to CS irrigation treatment. Total water input was 3.7% and 14.8% higher in simulated values than that measured values for 2007/1008 and 2008 seasons respectively. In the validation test for 2008/2009 and 2009 seasons, the performance of the model to reproduce water input was close to measured values in both wet- and dry-seasons for CS and ASNS irrigation treatments. This indicates a good performance of the model to simulate total water input in the lowland rice-based cropping systems under water-limited and non water-limited conditions. Moreover, rice grain yield and biomass of simulated values were close to measured values under CS and ASNS irrigation treatments for both calibration and validation data sets. The model generally could be used to simulate daily flood water dynamics and total water applied to the field in lowland rice-based cropping systems under limited and non-limited water irrigation scenarios during rice growth periods.

Table 1 Measured and simulated water input during rice growth periods in 2007/2008 and 2008 seasons for calibration test and in 2008/2009 and 2009 seasons for validation test.

Seasons	Water input (mm)	CS			ASNS		
		Measured (M)	Simulated (S)	% Difference (%)	Measured (M)	Simulated (S)	Difference (%)
Calibration test							
2007/ 2008	Irrigation	1080.3	938.4	13.1	690.0	750	-8.6
	Rainfall	1046	1046	0.0	940.0	940	0.0
	Total water input	2126.3	1984.4	6.7	1630.4	1690.0	-3.7
2008	Irrigation	1820.4	1714	5.8	1102.0	1300	-17.9
	Rainfall	233	233	0.0	233.0	233	0.0
	Total water input	2053.4	1947.0	5.2	1335.2	1533.0	-14.8
Validation test							
2008/ 2009	Irrigation	1234.0	1245.3	-0.9	689	700	-10.6
	Rainfall	964.7	964.7	0.0	849	849	0.0
	Total water input	2198.7	2210.0	-0.5	1538.0	1548.6	-10.6
2009	Irrigation	1864	1781	4.4	1198	1100	9.8
	Rainfall	409	409	0.0	392	392	0.0
	Total water input	2272.4	2189.8	3.6	1590.5	1492.3	9.8
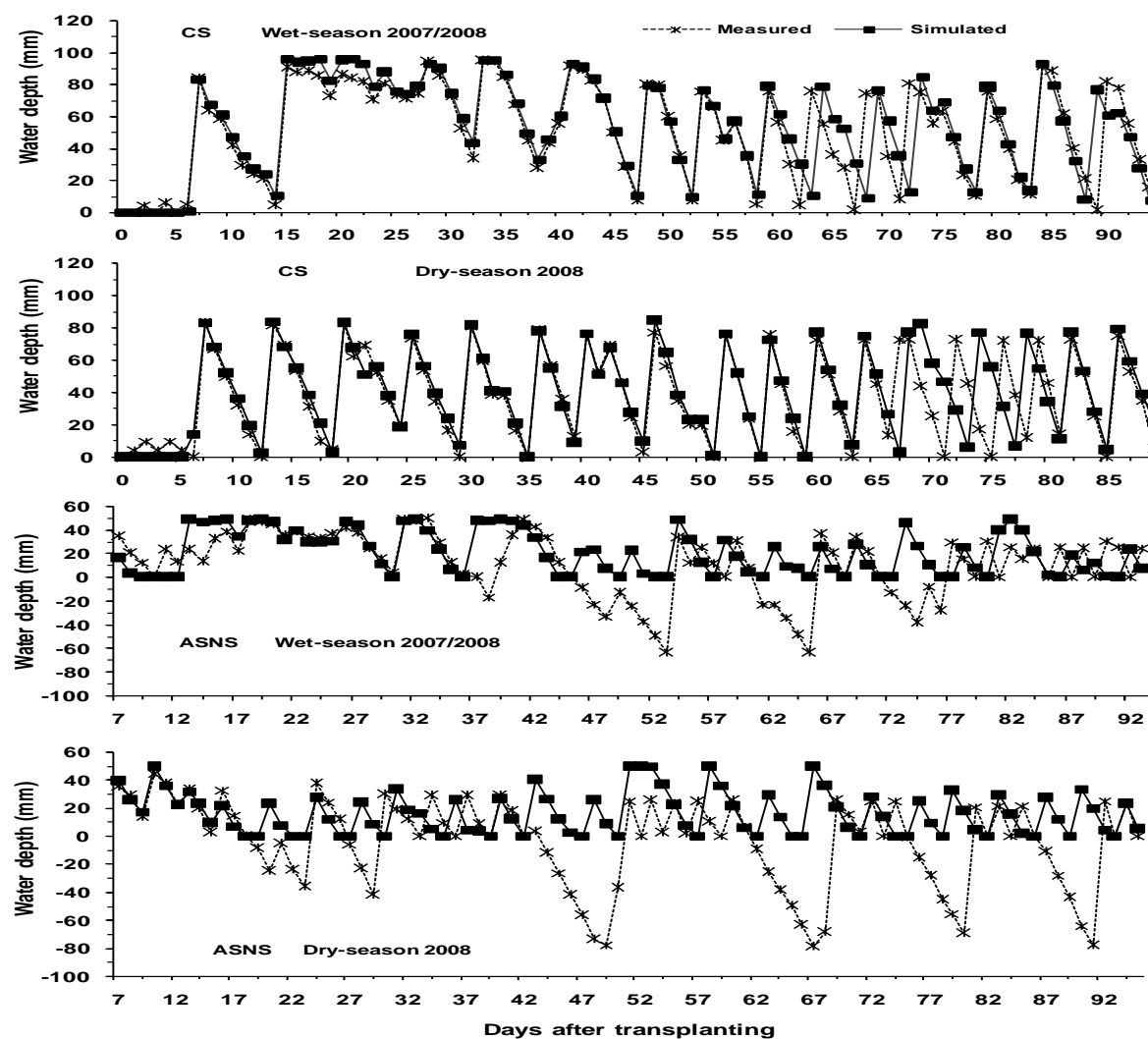
Figure 1 Simulated and measured daily water depth during rice growth period for CS and ASNS treatments in wet-season of 2007/2008 and dry-season of 2008 for the calibration test.

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Factors influencing the adoption of corn in irrigated rice-based farming systems in Lao PDR

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Key words: corn, adoption, irrigation, drivers and constraints

Introduction

Ensuring food security through productivity improvements in lowland rice production and increasing the profitability of lowland farming systems through the cultivation of cash crops are both key policy goals of the Lao Government. The cropping of corn in Lao PDR occurs in several agroecological zones including along river banks and under rainfed conditions in the sloping uplands. In 2009, farmers in Lao PDR harvested around 94,300 ha of irrigated rice, with large areas located in Savannakhet, Vientiane and Champassak Provinces. Recently, households with access to irrigation have been cultivating corn on paddy fields in the dry season as an alternative to producing a second crop of rice. While economic viability is a necessary condition for adoption of this system, many other factors influence its relative advantage over existing practices. These include access to resources, production and market risk, and compatibility with existing livelihood strategies. At the same time, the institutional and market environments both drive and constrain changes in agricultural practices.

Materials and Methods

Group discussions and key informant interviews were conducted in three villages across three provinces of Lao PDR in February 2011. Ban Keun (Vientiane Province), Muangkai (Savannakhet Province) and Kokdeua (Champassak Province) were selected because households in these villages had already diversified their dry-season production and were growing irrigated corn. The discussion focused on the history of irrigation activities in the village, the management of the irrigation system, physical and labour inputs to rice and non-rice crops, output prices and variability, and constraints to corn and rice production. After the general discussion with the group, a short structured interview was conducted with each key informant regarding their cropping and marketing.

Results and Discussion

The diversification of dry-season production, especially on a commercial scale, had occurred recently in each of the villages. Only a small percentage of farmers grew corn, covering a small portion of the total irrigated area (Table 1). Hence irrigated rice remained the dominant dry-season crop in all three villages. The farmer groups identified a number of reasons why households continued to plant rice, the primary reason being the desire for household self-sufficiency. Furthermore, rice production in the 2010 wet season suffered from widespread drought. Many households within and beyond the village were interested in leasing land to grow rice during the 2011 dry season from households who had already achieved self-sufficiency due to their ability to irrigate the wet-season crop. There was also increasing interest in dry-season rice as a result of a spike in rice prices. The price of glutinous rice in Laos has increased significantly in recent years, peaking in 2010 due to localised production failures and increased regional trade. There were variations in the rice price between the three villages, ranging from 2,800 kip/kg to 3,300 kip/kg[1], but this variation was less than for corn. Producing rice also remained an attractive option compared to corn given that farmers had experience in growing the crop.

Corn was identified as requiring less water than rice. Within the irrigable area there were zones that farmers considered unsuitable for corn production due to their low position in the toposequence, and zones considered less suitable for rice due to the large quantities of water required in upper terraces. Therefore, in only part of the irrigable area was there direct competition for land between the crops, however the competition for household labour and capital remains. Increased planting of non-rice crops provided challenges for water management, given the different water requirements of each crop within the landscape. Increases in the price of electricity and the associated water fees were contributing to changes in the cropping system, to the extent that some households had stopped growing any dry-season crop. The current area-based pricing provided limited incentive for individuals to change to more water-efficient crops like corn. Water fees that more closely reflect water usage are likely to provide additional incentives to changed cropping practices including diversification into corn and other non-rice crops.

Another reason for the increased interest in corn was that it requires less labour than rice (up to 70% less), however this varied significantly between villages depending on land preparation practices and post harvest activities, with corn requiring more labour than rice in Kok Deua. The price of hired labour has been risin g in recent years. The cost of labour also varied significantly between villages and seasons (Table 1), contributing to large variations in net returns. Rice cultivation was more competitive in Muangkai as a result of the lower labour costs and the reported lower number of days required for transplanting. Changes in planting techniques, such as row seeding, will improve the economic performance of rice where weeds can be controlled.

Fertiliser input for corn is higher than for rice, representing a high up-front cash cost. Nevertheless, the fertiliser rate has a marked effect on corn yields and can also improve quality. On-station trials found that additional nitrogen increased both the overall yield and grade achieved, improving net returns up to a rate of 135 kg N/ha. Table 2 presents a subset of the results from these trials, illustrating that without adequate fertiliser net returns were negative. Furthermore, without the improved grading from C to B, returns were negative even at higher levels of fertiliser, showing the importance of improving both quality and yield. The Table includes the estimated net returns based on the average, lowest, and highest yields of the trial conducted in 2010-11 dry season. Contract farming in Ban Keun had allowed farmers to use recommended rates of fertiliser with the cost deducted after harvest, overcoming the upfront cash constraint. An additional benefit identified was the carryover of nutrients from the corn crop to the subsequent wet-season rice crop. This is an important consideration given that households tend to put lower than recommended rates of fertiliser on rice as it is largely consumed by the household, with no associated cash flow.

The establishment of a corn canning factory has encouraged households to grow sweet corn in Ban Keun. If the corn crop is damaged by disease or pests the product is downgraded. The analysis shows the cobs downgraded to C class may not cover the costs of production. Farmers reported reverting to growing rice in some areas due to disease damage in the previous corn crop. The market for fresh cobs provides an opportunity for higher returns compared to processing in Ban Keun (Table 1), but marketing costs have not been included in the comparisons. In producing for the fresh market households are exposed to greater price variability, especially if the area of production increases. For example, according to a key informant in Ban Keun, the price of corn can be as low as 900kip/kg but rise to over 1,400

during periods of low supply. Fig. 1 compares the returns to land and labour for corn and rice in the three villages. There was wide variation between the sites in the reported returns due to the different production practices, labour costs, and market conditions described above (Table 1). The superior economic performance of corn in Kok Deua was due to the high price for cobs and the high number of cobs produced. Unlike Ban Keun, as long as a merchantable quality was achieved, the incentive was to increase cob numbers rather than weight. Farmers were achieving this with high-density plantings. In Ban Keun, rice gave a slightly higher economic return compared to corn due to the lower price paid for corn by the processing factory. However, the comparison is based on price data for 2010 when the price of rice was relatively high compared to 2009 and 2011, showing the difficulty of making a clear-cut statement about the economic superiority of either crop.
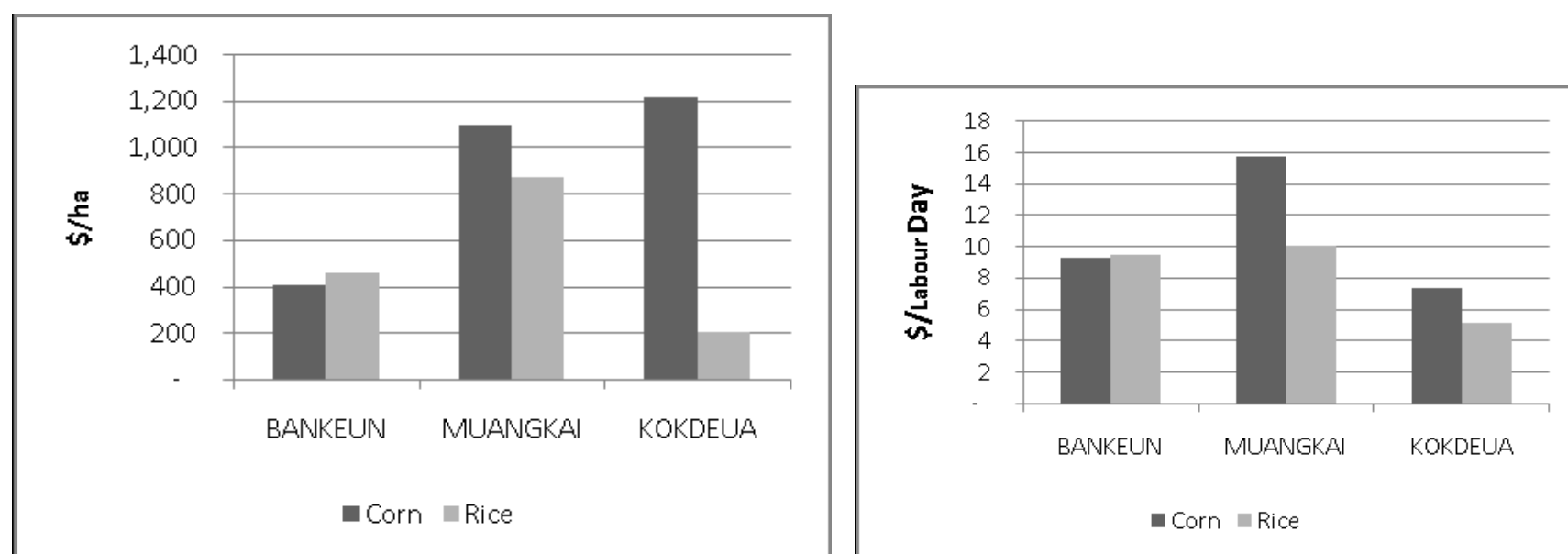
Figure 1a and 1b – Estimated returns to land and labour from corn and rice cultivation in three villages ($US)

Table 1 – Summary of village information

	Ban Keun	Ban Muangkai	Ban Kokdeua
Families	324	662	163
Households	318	632	na
Area with irrigation (ha)	45	76	53
Area of irrigated corn (ha)	38.5	26.5	3
Families growing corn	27	30	Na
Price of paddy rice (kip/kg)	3,100	3,300	2,800
Price of corn (kip)	1,150/kg	1,000/cob	1,300/cob
Wage labour rate (kip/day)	50,000	26,500	30,000
Water fee (kip/ha)	500,000	100,000	1,200,000

Ta ble 2 – The impact of fertiliser on corn yield, grade and income

Variety	Fertilizer rate (N-P_2O_5-K_2O)	Total cost/ha (US$)	AverageYield (kg/ha)	Grade	Gross income/ ha (US$)	Net return/ha (US$)		
						Average yield	Low yield	High yield
	170-45-45	1,334	11,519	B	1,584	250	71	346
Sugar	135-45-45	1,292	12,667	B	1,742	450	267	725
75	105-45-45	1,254	10,481	B	1,441	187	-299	335
	75-45-45	1,218	10,185	C	1,019	-200	-318	279
	135-22.5-22.5	1,215	9,519	C	952	-264	-282	-238

Conclusion

Growing corn in irrigated areas has the potential to provide higher returns to both land and labour compared to irrigated dry-season rice, partly by reducing the requirements for water and labour. However, corn production involves significantly more cash costs, mainly for fertiliser, leading to the possibility of negative cash returns if yields are low, while unpaid family labour is the major cost of rice production. Analysis of both production and marketing risk are the subject of ongoing research. The capacity of the market to absorb production increases is also a priority for ongoing analysis. A number of other factors will continue to influence the rate of diversification into non-rice crops, including water charging structures, the cost of labour, relative market prices, and contract farming arrangements. Water use efficiency of rice and non-rice crops, and the institutional arrangements required to provide incentives for producers to adopt efficient crops and technologies needs further investigation. Contract farming for processing provided lower returns compared to the market for fresh cobs, yet provided a certain market and access to credit for the key input of fertiliser. Fertiliser trials have highlighted the importance of improving quality as well as overall grain yield, and fertiliser applied to corn can carry over to the main rice crop. The incentive to grow dry-season corn cannot be viewed in isolation from a household's overall livelihood strategy, in which rice is likely to remain a central component. Hence the decision to plant corn will remain tied to the performance of the preceding wet-season rice crop and the household's level of self-sufficiency, a function of not only yields but also farm and household size.

Enabling technologies in agriculture: tackling food security and sustainability

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Introduction

The world's population is predicted to increase to 9.2 billion by 2050, and providing enough food will be an unprecedented challenge. This, in the context of current and future food production limits, changing consumption patterns and impacts of climate change, presents a considerable scientific, political and financial challenge. Furthermore, future global crop production will be threatened by increased mean temperatures and a higher frequency of extreme weather events. The amount of arable land globally has not appreciably changed in more than half a century, and it is unlikely to increase significantly in the future with increasing urbanisation, increased salinity and desertification (Godfray et al. 2010).

One way to consider the problem is to look at technologies that address the gap between potential and actual yields (yield gap) and those that can be applied to increase potential yield. Plant breeding to increase photosynthetic potential, induce heterosis, or further improve carbohydrate partitioning could increase the potential yield of crops (Fischer et al. 2009). An increase in potential yield of crop varieties can increase food production if all other parameters remain constant. However disease resistance and other factors affecting actual yield do not remain constant, so there is a continuing need to adapt our crops and farming practices to changing biotic and abiotic stresses. Conventional plant breeding will be integral to maintaining or increasing both actual and potential yield. The application of new technologies for plant improvement (like genetic modification), on farm management (including pest management) and farming practices will improve the actual yield and help reduce the yield gap. The application of new technologies can also assist in making farming more sustainable.

Integral to this is 'sustainable intensification', where yield is assessed not just per hectare, but also per unit of non-renewable inputs and impacts upon ecosystem services. Successful strategies that will facilitate 'sustainable intensification' are likely to be achieved through incremental improvements in both potential and actual crop yields sustained over many years with an overarching focus on increasing input use efficiency and decreasing negative environmental outcomes. Application of the latest technologies will be important to achieving sufficient future food production.

We present a review of enabling technologies that could allow Australian agriculture better meet the demands of future food security and sustainability.

Materials andMethods

We reviewed existing literature for key food security and sustainability challenges facing agriculture. We subsequently examined, in detail, agricultural applications of recent developments in the fields of biology, chemistry, biotechnology, nanotechnology and information and communications technology. Refined literature searches, using available web services, were conducted with search terms combining technologies and challenges. Search terms such as "salinity" and 'biotechnology" or "insects' and "precision agriculture" gave potential publications that were then assessed for relevance. Relevant areas of applicable technology were also explored using iterative searches to fully assess applications across for instance, crop protection, weed management, irrigation, abiotic and biotic stress tolerance and bioenergy. Information was also sourced from seminars, workshops and conferences.

We provide an analysis of the potential benefits of technologies and how these can help the agricultural sector adapt. Our analysis was limited to the technology and science aspects of maintaining or increasing production while improving environmental sustainability up to the 'farm gate'. The focus of t he analysis was largely confined to technologies applicable to economically important Australian food and feed crops.

Results and Discussion

The literature suggests that in order to meet the future demand for sustainable food production, plant breeders will need to focus on those traits with the greatest potential to increase or maintain yield under sub-optimal growth conditions as a result of environmental stresses (e.g. drought, heat, exposure to pests and diseases). Of critical importance is the development of new technologies that will facilitate accelerated breeding; through for example, new genotyping or phenotyping methods to identify new sources for genetic improvement, or through being able to 'mine', utilise and increase the diversity of genetic resources that are available for breeding (Tester and Langridge 2010).

The development of resistance of pests and diseases to current control methods is a major threat, as is a change in their patterns of distribution as a result of climate change (see for example Hoffmann et al. 2008). Understanding the basis for resistance to pesticides will provide for the development of new pesticides and application methods and pest management strategies (Peter East, pers comm).

We expect genetically modified crops to become more widespread in future. This may be through necessity or the development of new techniques in DNA modification which may be more acceptable to consumers. Besides the development of new crop varieties, farming practices and farming systems, the literature shows new developments in information systems and modelling and we suggest these will be important in sustainably increasing production on Australian farms, especially through integration with, or updating of, precision agriculture systems.

No single technology is likely to have a significant long lasting impact of a magnitude required to meet future food production in a wide range of environments. Advances made in general plant breeding technology will need to be integrated with advances made in other technologies such as precision agriculture, information technology and the material sciences. For example matching plant genotypes to management systems can provide yield benefits (Kirkegaard and Hunt 2010). The integration of technologies will require an awareness of a range of technologies and farming practices, and attention to suitable knowledge transfer approaches.

We provide a preliminary analysis of the benefits of technologies relevant to addressing food security in the context of climate change. As integration of disciplines is important in achieving the notion of a food secure future, the respective technologies will need to be assessed on a case by case basis to select appropriate combinations to promote more resilient agricultural production units.

There are numerous technologies available for development of a truly sustainable agricultural sector. Applications of enabling technologies need to be further encouraged and supported. It is also clear that no single technology will achieve the desired outcome. The choice of technologies should be driven through objective assessment of all available technologies and management practices.

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Integrating Conservation Agriculture with trees: trends and possibilities among Smallholder Zambian farmers

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Introduction

Conservation Agriculture (CA) is becoming an increasingly important component of the solutions for overcoming the problems of declining agricultural productivity in Southern Africa where it is presently being promoted and practised to varying degrees (FAO, 2011). The three principles of CA, namely minimum mechanical soil disturbance, permanent organic soil cover, and diversified crop rotations, are not always adopted by all farmers professing to be practising CA. Keeping soils covered by retaining crop residues within the fields is challenging as there are competing uses for them (Kassam and Friedrich, 2010). Challenges of crop residue retention in smallholder farming systems in the region have been widely reported (Chivenge et al, 2007) while the use of mineral fertilizers among smallholder farmers in Southern Africa is the lowest (8 kg ha^{-1}) in any of the developing regions (Agwe et al, 2007; Morris et al, 2007). Under-replacement of nutrients results in nutrient mining, declining soil fertility and reduced crop yields and a concomitant increase in household food insecurity. However, recent experience in Zambia and Zimbabwe, and work in many other countries, suggests that conservation agriculture with trees might do much to restore and replenish eroded and impoverished soils (World Agroforestry Centre, 2009). It may also help to address the challenge of crop residue retention by adding nutrients removed through crop harvest. Promotion of CA in Zambia is being done using a model that adds agro-forestry to the basket of CA practices. Three tree species being promoted by the Conservation Farming Unit (CFU) are *Faidherbia albida* (winter thorn), *Jatropha curacas (*physic nut*)* and *Moringa oleifera* (drumstick tree). Significantly higher nitrogen, organic carbon and potassium contents were reported under *F. Albida* canopies than outside in a recent study from Southern and Eastern Zambia (Umar et al, 2011a).

Jatropha has been promoted for planting as a live fence around farmers' fields and not as a field crop. This risk-averse option enables farmers to exclude free ranging livestock that consume crop residues, seedlings and perennial crops from their fields. It also positions farmers to engage in the developing bio-fuel industry through ensuring a ready supply of Jatropha seed on an economic scale and establishes circumstances for farmers to benefit from carbon credits if opportunities arise (CFU, 2006). The pods, flowers and leaves of the fast growing Moringa can be used as livestock fodder. We analyzed data from a random sample of 640 households collected annually over a period of four farming seasons (2006/7-2009/10). We examined the adoption trends of agro-forestry trees among farmers under Conservation Agriculture Programme (CAP) to determine the trends in smallholder households integrating agro-forestry in CA systems in Zambia by investigating how many trees CA farmers had on their fields and their experiences with them.

Materials and Methods

The study was carried out between June 2007 and October 2010. The households interviewed were randomly selected from lists of farming households associated with the CFU's Conservation Agriculture Programme (CAP). Data were collected through questionnaire survey and focus group discussions. Type and number of trees planted and/maintained on/near their fields was used both as an indicator of adoption and indicator of intensity of adoption. Three provinces, Southern, Central and Eastern Provinces, were selected as study areas based on current efforts in the promotion of CA under CAP.

Results and Discussion

The average number of the three tree species being promoted under CA had increased since the 2006/7 farming season when implementation of the CAP commenced (Table 1). CAP provided free planting material (either seedlings or seeds and polythene bags for starting tree nurseries) to the CA adopters associated with the programme. The average number of *F.albida* per household almost doubled between 2006/7 and 2008/9 seasons despite the low survival rate of only 32.8%. An average of 68 *F. albida* trees per household was planted by 33% of the sample over three seasons. It is interesting to note that the households continued to plant *F.albida* despite the low survival rate. Average number of Jatropha trees per household increased almost six fold in two seasons. However, only 17.6% of the sampled households planted Jatropha as live fences around their fields. Moringa seemed to be the least successful with only about 4 trees per household per season planted in the first two seasons of CAP implementation. This increased by 3.5 times to 14 trees per household during the 2009/10 season. Only 3.2% of the sampled households had planted Moringa. The small percentages of households planting the three tree species seemed to be a result of the low access to tree planting material through CAP. Only 20%, 39% and 6% of the households accessed Jatropha, *F. albida* and Moringa planting material respectively during the 2009/10 season (Figure 1). Proportion of households planting *F. albida* significantly increased (p=0.022) and so did the proportion of Moringa (p<0.0001) while that for Jatropha remained almost constant. Results suggest potential for integrating trees in CA. This is important especially with the reported challenges of crop residue retention among CA farmers in Zambia (Umar et al, 2011b). Prunings from the *F. albida* and Moringa make good livestock fodder and could help reduce the demand for crop residues as livestock fodder. Increased provision of tree planting material by CAP and from other sources could help harness the potential for CA with trees in Zambia. Challenges include the long time lag for farmers to realize benefits (5-10 years), attack from termites and increase in labour (watering, protecting trees from livestock and bush fire) and local perceptions. Increased farmer awareness on the benefits and training on tree management could further enhance the incorporation of such trees into smallholder CA systems.

Table 5. Integration of tress in CA over four seasons

Tree Species	Average number of trees per household	No. of trees planted under CA			Average Survival rate	Average engaged (%)
	2006/7	2007/8	2008/9	2009/10		
Faidherbia albida	17.6	89.9 (8.2)	69.3 (5.7)	45.0 (5.1)	32.8	33.4
Jatropha	44.0	171.3 (33)	316.7 (124)	131.6 (41)	62.8	17.6
Moringa	3.2	3.9 (0.92)	3.9 (1.1)	14.0 (9.2)	39.4	3.2

The figures in parentheses are standard errors.
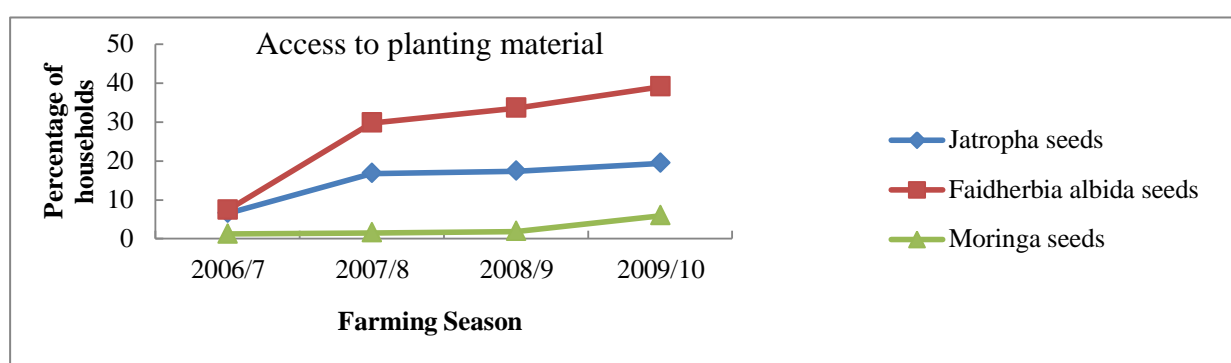
Figure 19. Percentage of CA households that accessed free tree planting materials under CAP.

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Sustainable Certified Agriculture: the farmer's production alternative

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Introduction

Mankind faces a challenging dilemma: the menace of a generalized hunger caused by insufficient food production or the destruction of the natural resources necessary to produce those foods. On the one hand, it is evident that the overexploitation of the land resource and the increase in world population could lead to the collapse of world economies (Solbrig 2005). Yet, on the other hand, the historic use of extensive agriculture mainly, based on tillage has caused soil degradation resulting in erosion and loss of the organic material of the soil.

At the same time, water reserves are becoming less reliable. Crop growth as well as surface and underground water availability are being affected. This situation could worsen with the climate change.

However, conservation agriculture in general and no-tillage in particular, offer a different productive alternative, that allows maintaining yields and reducing costs - minimizing the negative impact on the environment, especially on the soil resources. This means that with the present state of knowledge, no-till presents a real and concrete alternative that has proved to be more environmentally friendly than the conventional tillage system.

No-till, a conservation agriculture productive system based on the absence of tillage, crop rotations and stubble coverage on the soil's surface, changed the reigning paradigm proposing a new agriculture that is much closer to solving the dichotomy between productivity and environmentally friendly practices. No-till promotes a rational and sustainable use of the basic resources of agricultural ecosystems such as soil, water, air and biodiversity (Peiretti, 2004). The surface cultivated under no-till has increased in the last few years, specially in South America, exceeding a total of 95 million hectares worldwide (Derpsch, 2004). Almost half of the total cultivated area is located in Latin America, and Argentina has approximately 50% of those hectares. Different estimates reveal a total of 19 to 20 million hectares under no-till in Argentina (INDEC, 2006; AAPRESID, 2006).

However, no-till by itself is not enough to generate a productive and sustainable agriculture. No-till must be performed within a framework that entails crop rotation, integrated pest, weed and disease management, nutrient restoration and a rational and professional use of external supplies. These practices, as a whole, are called "Good Agricultural Practices" (GAP). Only when GAP are implemented can we say that we are applying a "production under the no-till system" achieving high levels of productivity, while maintaining the production capacity of the resources.

Description of the model

In this context, the Argentine Association of No-Till Farmers (AAPRESID) has begun an initiative to develop an Environmental and Productive Quality Management System in Conservation Agriculture with the objective to issue a certificate. To do this, it was necessary to create a Good Agricultural Practices Protocol and science based indicators that quantify the impact of agriculture in the environment. Thus, Aapresid developed "Agricultura Certificada" (AC), a quality management system, taking as a reference many other systems like GlobalGAP, ISO, etc.

The agricultural company that implements AC certification adopting the GAPs and indicators proposed in his farms, this process would benefit the business both technically and financially. The certification would entail the use of records, ordered information and soil management indicators, that will become added value tools for a more professional, exact and responsible agronomic management. With regards to the business strategy of the company, the certification will be an added value tool to take advantage of the positive effect of no-till and transform it into net income. This can be achieved by establishing a differential price for foods produced under a certified process or by a differential access to specific markets.

The "Environmental and Productive Quality Management in Conservation Agriculture – called AC" is a scheme that offers new tools to perform and scale up a more responsible and precise agriculture and cattle production from an environmental and productive point of view. These GAP protocols and soil management indicators were devised to describe and monitor productive actions and behaviors and to certify the agricultural production process.

The Quality Management System has a double function:
- to provide tools for a more professional management of agriculture since an accurate recording and analysis of the information and the indicators of soil quality will provide added value information to the management.
- to show the rest of society the way food production processes work and the impact they have on the environment. The quality system is a precise and standardized method to audit productive processes and, once it is known by society, it is expected to generate additional profits, better prices and access to preferential markets.

Discussion

Certified Agriculture constitutes a clear evidence of an economic, environmental and socially sustainable production that adds value to the agricultural production through information management for the decision-making process and the administrative procedures. Furthermore, it allows increased the resources-use efficiency, and as a consequence, improved profitability, while minimizing negative environmental impact. This is achieved through the implementation of good agricultural practices that were selected and agreed with researchers and specialists.

In turn, indicators allow measuring the impact of management practices, quantifying the current state of the production system and developing a professional and scientifically-based agronomic management.

This first version is mainly focused on Argentinean agriculture, but aims to achieve a global scope. Besides, it is applicable to all agricultural productions, whichever their destination is - food for human or animal consumption, meat, milk, biofuel, etc.

Among the benefits that farmers have already achieved by certifying his farms, we can mention:
- Improved diagnosis of the farm situation by the registry of all the activities, learning from mistakes and successes results in better information about the farm and improved use efficiency of the resources.
- Discounts in the purchase of herbicides, seeds and many other products that various agro-companies decided to make to support responsible farmers.
- Many other internal benefits as a consequence of the implementation of a quality management system.

Certified Agriculture is the production alternative that best combines the interests, usually confronted, in achieving a production that is economically feasible for farmers, environmentally sustainable, socially accepted and energetically efficient. In this way, Aapresid is working hard to achieve the recognition of its Sustainability certification program by different international initiatives as RTRS, RSB, FAO, ISGA, etc

This is the commitment that Aapresid assumes to help increase the local and global society's wellbeing in the resolution of the productivity versus environment conflict.

Acknowledgments

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Recognizing farmers' innovation of direct seeded Boro rice + Mustard mixed cropping systems and conservation agriculture based intervention for improvement

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Introduction

Many Asian farmers are shifting their rice establishment method from transplanting in puddled soil to direct seeding (DS) in either puddled or dry soil after dry tillage because the latter requires less labor, time, drudgery and cultivation cost (Bhushan et al., 2007,). Direct seeding requires only 34% of the total labor requirement of transplanted rice (Ho Nai-Kin et al., 2002) and 29% of the total cost of transplanted rice production without any yield loss. The Central East Bangladesh Hub (fundamental unit of activity in the project-a location that serves farm families and villages in an area) domain comprises eight districts. Narayangonj district is one of them and is situated in the south east part of the Hub domain area where the DS Boro rice (*Oryza sativa)* + Mustard (*Brassica campestris*) innovative practice is explored by the farmers. Mostly farmers are practicing direct seeded Boro rice + mustard (low yield local cultivar) mixed cropping by broadcast method with traditional crop management practices. Due to the lower yields and price of paddy, the profit in rice farming has become marginalized if it relies on hired labor. Under the Cereal Systems Initiative for south Asia (CSISA) project, adaptive research trial and delivery program aims to validate and fine tune both new technologies and the farmers' innovations before adoption and effective scaling up in wider areas. It also encourages farmers to conduct participatory research/experiments with options for further necessary improvement of local innovation within their available resources. Participatory research enhances and strengthens farmers, knowledge, innovative and adaptive capacity and farmer-to-farmer experience exchange.

Material and Methods

Farmers' innovation

The CSISA team heard that there is a farmer's innovative technology of direct seeding Boro (winter rice) plus mustard (local var. Tori 7) as mixed cropping systems practicing in single cropped area of Narayangonj and Chandpur districts. The CSISA team went to Bonder Upazila of Narayangonj organized FGD with farmers and recorded this technology. The farmers informed the team that after receding the monsoon water at the fag end of October they clan the land and wait for field capacity (Jo condition) and normally that start to occur at the first week of November. Traditionally farmers used 2-3 times ploughing for this practice. The rice seeds were sown after one or two ploughing and mustard seed after second/third ploughing by broadcasting method and levelled the field by ladder in the same day. Both the crops (Boro + Mustard) germinated together and grow. The seed rate of mustard and rice they used 8 and 80-100 kg ha^{-1}, respectively. Farmers did not apply any irrigation for mustard. They used fertilizers for mustard @ of 150-112-75-75 kg ha^{-1} urea, TSP, MoP and Zypsum, respectively which is lower than the recommended dose. Urea applied in two splits one half at basal during sowing time and rest half at flowering stage. For Boro rice they used 112-188 kg urea (one half at first irrigation and second half at panicle initiation stage), 37-53 ka TSP and 38 MoP per hectare (at first irrigation). Farmers harvested mustard first by mid February and after harvest of mustard they put flood irrigation to Boro rice and filled up the gap with same plot seedling where necessary. Finally farmers harvest the Boro rice at the end of May to first week of June.

CSISA Intervention

Before initiation of the CSISA program at the site level the following steps were followed such as i) farmers group selection in collaboration with department of agricultural extension (DAE) in participatory approach, ii) identifying resource, technology used, income, expenditure and socioeconomic factors through group discussion, iii) need assessment considering present practices and expected potential return, iv) planning for implementation of the alternatives, iv) execution of the planned intervention and vi) participatory review and evaluation with different stakeholders. Based on the potentials, suitable technological options were addressed to the farmers by the CSISA team. Introduction of HYV short duration mustard variety instead of local low yielder variety, two wheel power tiller operated seeders (PTOS) machine (working as easy operation with shallow rotary tilling, seeding in line, seed covering and land levelling in a single pass operation and saved 48 litre ha^{-1} of diesel i.e. reduced tillage) for sowing, improved crop management and increase capacity building of the farmers were identified as their potential areas of intervention. Firstly the farmers groups were trained up on the introduced technologies and motivated them to implement the program with competitive behaviour.

a. Participatory experimentation

A participatory adaptive trial was conducted at Narayangonj dring the year of 2010-11 to see the performance of different varieties of rice and mustard under Boro rice + Mustard cropping systems. The experiment was laid out in a split plot design with two mustard varieties in the main plot treatments and 3 rice varieties in the sub plot treatments with 5 dispersed replications to see the performance of the varieties with PTOS machine. The unit plot size was 50 m^2. The mustard was sown in broadcast method and priming rice seed was sown in line by PTOS with inclined seed meter device. The crops were sown on 13 Nov. 2010. Seed rate for rice was 30 kg ha^{-1} and for mustard 6 kg ha^{-1} (reduced rate).Standard crop management practices were followed. The farmers, extension personnel and researcher jointly managed the trial. Mustard was harvested first by mid February. Immediate after harvest of mustard put flood irrigation to Boro rice and filled up the gap with same plot seedling where necessary. Finally Boro rice was harvested at the end of May. Necessary data were collected in participation of the farmers and extension personnel.

b. Introduction of HYV, PTOS, crop management and capacity building for improvement

The demonstration trials were initiated with 30 farmers in a group at Bandar upazila of Naryngonj district during the rabi season of 2009-2010. First year CSISA provided training, quality seeds of mustard and rice and technical support. In the second year introduced two mustard varieties (BARI 14 and 15), PTOS machine, provided training for capacity building. The technology replicated in wider area of Naranyangonj district and one block at Manikgonj districts with participation of total 201 farmers during the Rabi season of 2010-2011. Same crop production methodology (as described in experiment part) was followed in the scaling up program. The mustard varieties were

BARI Mustard 14 and 15 and rice variety was BRRI Dhan 29. Seeding of mustard and rice was done during 7-20 November 2010 in both the locations. Mustard and rice were harvested during mid February and end of May 2011, respectively.

Results and Discussion

The results of the experimentation indicated that interaction effect of mustard varieties and rice varieties significantly affected yield and yield attributes. The highest rice yield obtained from BINA 5 (7.56 t ha^{-1}) followed by BRRI dhan 29 in combination with both BARI mustard 14 and 15. Signicantly lowest yield obtained from BRRI dhan 45 in combinations of both the mustard varieties. Similarly the highest grain yield produced by BARI mustard 15 (2.54 t ha^{-1}) irrespective of rice varieties, which is statistically similar to BARI mustard 14. The yield contributing parameters significantly supported the yield accordingly (Table 1). The results of the study also indicated that BINA 5 rice variety could be the option of rice variety selection beside the BRRI dhan 29 with the mustard varieties for direct seeding rice by used of PTOS machine for tillage operation.

The results of the demonstration trial with intervention indicated that the average yield of BARI mustard was 2.35 t ha^{-1}, which was 147 % higher than local variety (0.95 t ha^{-1}) at Narayangonj. The highest average yield of rice was obtained 6.45 t ha^{-1} from PTOS sown intervened plots (Table 2). The existing practice gave lowered yield. The use of PTOS machine reduced the seed rate of rice about 60 % and ploughing cost 50%. The net benefit was US$ 1216 ha^{-1} of putting mustard+rice systems by used of PTOS machine and other intervention in Narayangonj. Similarly in Manikgonj, the average net income was US$ 372. In Manikgonj, the rice yield was 1 t ha^{-1} lowered than the farmers' plots due to very less confident of farmers about the technology in the new area. Though the rice yield penalty was 1 t ha^{-1} but good harvest of mustard generated the net income of the farmers. In 2009-10, the average net income was US$ 882 ha^{-1}. Farmers' capacity building was improved through organized training, field day, travel seminar and supplied extension materials.

Table 1: Interaction effect of mustard and rice varieties on the yield and yield attributes during 2010-11.

Main plot	Sub plot	Rice					Mustard				
		Plant ht. (cm)	No. of Plants m[-2]	Grain panicle[-1]	1000grain Wt. (g)	Yield t/ha	plant ht (cm)	Plant sm[-2]	Capsules plant[-1]	1000 grain wt. (g)	Yield t ha^{-1}
BARI Mustard 14	BRRI 45	109.3	60.20	143.5	27.60	6.31	115.5	76.40	102.7	3.54	2.42
	BINA 5	120.2	63.00	219.6	31.20	7.53	117.2	63.00	104.5	3.48	2.24
	BRRI 29	112.7	116.4	167.8	26.70	7.16	113.7	60.40	103.7	3.60	2.20
BARI Mustard 15	BRRI 45	106.8	46.8	136.6	28.10	6.18	145.8	77.80	125.0	3.40	2.54
	BINA 5	121.2	42.40	221.6	31.60	7.56	146.9	75.20	120.3	3.38	2.42
	BRRI 29	114.0	94.40	169.5	26.30	7.03	153.0	76.80	123.0	3.60	2.51
CV (%)		3.56	18.89	8.55	3.90	5.31	7.27	15.04	3.57	5.61	8.64
LSD		5.45	17.86	20.23	1.49	0.49	12.86	14.44	5.42	0.26	0.28

Table 2: Agro-economic performance of Boro rice + Mustard systems during 2010-11.

Locations	Grain yield (t ha^{-1})				Cost of cultivation (US$ ha[-1])	Net income over farmers practice (US$ha[-1])
	Intervened plot		Farmers practice			
	Boro	Mustard	Boro	Mustard		
Narayangonj	6.45	2.35	5.1	0.95	989	1216
Manikgonj	6.00	1.9	7.0	0.80	989	372

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Response of Cucumber (Cucumbus sativus L.) to Deficit Irrigation in Saudi Arabia

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Keywords: water use efficient, drip irrigation, irrigation management, yield response factor

Introduction

The ecosystem of arid regions of Saudi Arabia is impoverished by scarcity of water resources and of the predominance of sandy soil, which consists more than 45% of the cultivated soils (Bashour et al., 1983). Sandy soils are particularly critical for water management due to their low water-holding capacity, high infiltration rate and low organic matter, which may induce low water use efficiency (Al-Omran et al., 2005). The water shortage and increasing demand for water in agriculture and other sectors compel the need to adoption of irrigation strategies in Saudi Arabia from open field to greenhouse under drip irrigation. Which may allow saving irrigation water (Al-Omran et al., 2010)? An approach to attain the objective of saving water and increasing water use efficiency is through using deficit irrigation program (DI) which crops are deliberately allowed some degree of deficit irrigation through the whole growth stage or at certain stages of the growth (Kirda, 2000). Deficit irrigation generally refers to fully irrigated crops which water is reduced or withheld during certain growth stages.

Mao et al. (2003) reported on their study on the effect of deficit irrigation on yield and water use of greenhouse grown cucumber in china that WUE decreased with increase of irrigation water applied from stem fruiting to the end. The objectives of this study were to determine the water requirement for cucumber grown under greenhouse with drip irrigation and to compare ETc from inside and outside the greenhouse. In addition, the determination of the effect of (DI) at different stages of growth of cucumber on yield and water use efficiency.

Materials and Methods

The study was located in al-Mohawis's project for greenhouses in Thadiq, 120 km to the north west of Riyadh (25°17N and 45° 53E). The climate of the area is continental. Sandy loam soil was used with EC = 2.60 dSm^{-1}, SAR = 3.30 and CaCO$_3$ = 27% and water with electrical conductivity (EC) of 1.03 dSm^{-1}. The experiment was placed on the area of (884 m^2) inside the greenhouse which was divided to 52 experimental units, each one was (17m^2), as well as a unit for traditional irrigation inside the greenhouse with the area of (272 m^2) connected directly to the traditional irrigation system which used to irrigate the greenhouse.

Four levels of irrigation 100%, 80%, 60%, and 40% of ET$_c$ were used for four stages of the cucumber growth:(1 – 15 days), (15 – 35), (35 – 65), (65-95 days) from the seedling of the plant, with decreasing the treatments of the level 40% to two stages: (1 – 65 day), (65-95 days. The numbers of treatments were 13 plus one traditional irrigation. The experiment was planted Cucumber with cv Bazz directly in the permanent soil with final average; two plants in every m^2. The space between two rows is one meter and half a meter between drippers. Dripping irrigation was used in irrigating greenhouse with steady releasing drippers (4 liter / hour) under firm pressure and temperature in the greenhouse. The amount of irrigation based on crop evapotranspiration (ETc) calculated from the following equation

$$ETc = Eo \ Kp \ Kc$$

Where ETc is the maximum daily ET in mm; Eo is the evaporation from class A pan in mm; Kp is the pan coefficient, calculated according to Allen et al. (1998). The first fruit ripening was after 32 days from sowing in the greenhouse. It was picked every couple of days with counting the fruit, weighing and classifying them according to the quality of every treatment until the end of the season.

Results and Discussion

Results indicated the following:

1. Using deficit irrigation program and scheduling irrigation can save more than 50% compare to the traditional practice without affecting the production.
2. The yield and the quality of the fruit were not apparently affected when the level of irrigation was decreased to 80% ET$_c$.
3. Greenhouse cucumber produces good yield at the level of 60% when the decrease was in the stage 3 and 4.
4. The efficiency of using the water was higher at the level of 60% in both greenhouse and open field.
5. The efficiency of using water, productivity of water, and the quality of the fruit is highly better when planting is inside greenhouses.

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Landcare – Australia's global solution to Conservation Agriculture

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Objective

Plan
Presentation followed by open discussion

Justification
This year is 21 years since the launch of Australia's conservation icon – **Landcare**.
Landcare is an Australian success story and recognised globally as a leading national conservation program. International Landcare is already established and can be focused to deliver sustainable agriculture in a world where increasing food production is of concern.

Australia's Landcare program could become the road map for Australia to contribute to this challenge, through:
- Providing knowledge & technology on natural resource management under the Landcare banner.
- Using the social model to deliver and to implement change in sustainable food production

Mr Tony Burke, National Minister for Agriculture, Fisheries and Forestry at the National Landcare Conference in Adelaide March 2010, said "*Landcare is Australia's most successful emigration policy*"
Adjunt Professor Julian Cribb in his recently released book; The Coming Famine, says "*Australia needs to establish a farm knowledge and export sector*". Professor Cribb, journalist for the Australian, spoke at a Landcare conference calling for Australia to become "*a primary international supplier of information on food, farming, land and water care*" and for " Landcare to become a billion dollar export industry", further stating that Landcare could become Australia's bequest to the Earth.
Professor Cribb's vision is very relevant today!

The fact remains that farming systems will need to support twice as many people by 2025. Landcare is the solution for food security; a unique program; a partnership of government, farmers, conservationists and community groups. As quoted by Andrew Campbell, "*Australia is well positioned with Government support to implement and to grasp the opportunity that Landcare provides*".

Australia has many of the structures and institutions in place to move forward. Why do we need to continue to embrace the Landcare model?

1. International Landcare is active in 17 countries.
- A strong movement is present in the Philippines with about 400 groups and according to Dr Dennis Garrity[1], farmer groups have begun self organising to accelerate innovation. Landcare is also established in African countries. Dr Garrity from the World Agroforestry Centre, has been quoted as saying " *As in Australia the focus of landcare is shifting towards catchment management through participation of local Landcare groups*"
- Father Charles Rue, St Columban's Missionary Society stated that "*Landcare is a model for overseas community Development*"[2]. Furthermore, " *Landcare embodies an ethic of wholeness that combines several admirable elements- care for the land , earning a dignified living from farming, being part of a human community, while looking to future generations*".

2. Australian Government support through the Australian Centre for International Agricultural Research (ACIAR) and a clearing house for information (DAFF).

3. Established project organisations delivering Landcare such as:
- Landcare Australia Limited (LAL)
- Australian Landcare International (ALI)
- Secretariat for International Landcare (SILC) which specialise in Training.

4. The world needs Landcare to combat environmental destruction and provide food for future generations. If we take a look at the following problems it becomes clear why we need to embrace the Landcare philosophy:
- increasing land degradation
- catastrophic impact of weather events
- declining arable land
- changing land use; biofuels have replaced crops
- need to grow more food
- more need for sustainable farming
- need for community understanding and ownership
- Landcare has multiple dimensions according to Professor Garrity

5. Australia needs to lead in Landcare; Why?
- Australia already has the structures;
- Australia has the knowledge;
- Landcare is a proven and accepted model;
Political and commercial opportunities are the next step for the government, scientist and agricultural leaders to embrace.

6. Australian Landcare has valuable assets which are the cornerstone for future progress:
- people development and structures for capacity building. A quote from Mr David Suzuki, "*it is people that make change not governments*".

- Landcare is institutionally unbound and flexible which makes Landcare unique and appealing. As Professor Garrity said "*when Groups federate they do not lose the strong grass root focus* ".
- truly owned by the people at local level; "*Landcare addresses the absences and failures in the communication idiom and local people have been organising around Landcare beyond its parameters*" as stated by Professor Kate Auty (2010 Oration).
- Landcare has prospered in Australia with 40 to 50% uptake by farmers[3]. This is because Landcare/conservation pays and farmers and hobby farmers see the benefits. Land management has improved, particularly in broad acre farming where productivity has increased.
- " *Landcare has changed the social norms in rural Australia, altering community notions of what it means to be a good farmer*", according to Andrew Campbell.

7. People own the issues and continue change after project funding has finished[4].
- theories don't act, it is people who do and act in local situations.
- "*Landcare is inherently decentralised*", according to Campbell.

8. Landcare uses local knowledge
As quoted by Professor Kate Auty, "*the community is a knowledge user but it is often overlooked as a knowledge producer*".

9. Healthy land provides healthy food and ultimately improves people health.
- There is growing interest in many countries to improve people's general health by growing healthy food.
- " *Our food choices have implications for environmental sustainability and the environment has implications for the food system's sustainability*", Professor Mark Lawrence addressing the Food , Farming Health Conference, 2010

Road map
The Australia Government needs to consider that Landcare has the program and model to deliver sustainable land management and is the vehicle to provide sustainable food production. The Australian Government must establish an International Landcare Working Party. It is essential that the Australian Government promote the Landcare model to the United Nations.

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Quotations

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Dennis Garrity PhD, Chairman World Agroforestry Centre, Nairobi, Kenya
Adjunt Professor Julian Cribb , author "The Coming Famine"
Professor Kate Auty BA(Hons) LLB, MEnv SC, Dip Int Law, PhD, (UNITAR),
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Conservation Agriculture advances with permanent rainfed cotton based cultivation with animal traction in Southern Mali

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Keywords: participatory experiments, cotton-cereal rotation, labour productivity, south-south technology transfer

Introduction

Rainfed cotton is a major source of access to credit and cash income for cultivation for more than 0.5 million small-holders in sub-Saharan Africa. In Southern Mali the main national agency for cotton development, (CMDT, *Compagnie Malienne pour le Développement des Textiles*), has been promoting animal traction for more than 40 years and today near 90% of cotton farms have access to animal traction implements for growing cotton and cereals with permanent cropping systems. This transition to animal traction has resulted in an increase of labour productivity although it was based on soil mining fertility. Over the last years the profitability of cotton production began to be questionable as the yields per ha continue to be low (800 to 900 seed-cotton kg/ha) and the cost of fertilizers continued to increase. To rebuild soil fertility and at the same time maintain or improve labour productivity, an on-farm based research program related to conservation agriculture technologies was conducted on three annual crop seasons. This project was presented in the third WCCA at Nairobi and based on (Bouba, et al., 2005):

- the responsibility of the national and regional cotton farmers' organizations;
- a participatory approach involving extension staff, farmers' groups, private sector and national/international research institutions;
- an international network allowing exchanges in some other more advanced projects as Cameroon and including the Brazilian experience on animal-conservation agriculture implements (Ribeiro, 2001).

In this paper we synthesized the main results obtained from cotton-cereal cropping systems with a focus on labour productivity in on-farm trials comparing three years, annual, bi-annual and tri-annual effects on conservation agriculture *vs.* conventional agriculture conversion. The main innovations chosen by farmers' organizations and reported here were: (i) animal-direct sowing machines, (ii) no-tillage and (iii) herbicide program management.

Materials and Methods

Southern Mali is characterized by an annual rainfall mean from 800 to 1200 mm mainly from June to September. Soils are sandy to loamy according to USDA classification. Soil organic matter is generally low at around 0.6% in the 10 cm topsoil. Trials were conducted on farmers' fields in three villages. Mean duration of permanent cultivation was from 15 to 40 years. Each farm during this 2005 to 2007 period had about 3 ha of cotton produced in rotation, mainly with maize, sorghum, and pearl millet. The average farm size was 9 ha with 12 bovines. All cotton producers had access to synthetic fertilizer. In each selected field, including both cotton and cereal, or one of each, two treatments were applied, conventional agriculture (CV) and conservation agriculture (CA) systems. Each CV treatment was the usual practice of the farmer and CA treatment techniques were updated each year. Each treatment was replicated twice at random. The minimum size of the plot was 625 m^2 allowing us to provide real work time for each recorded field operation. In 2005 we began with 6 farmers for 3 year experimentation. In 2006 14 new farmers maintained experiments for two years and 19 new farmers did only annual experimentation with cotton. In 2007 17 new farmers carried out annual experiments with cotton and 24 with cereals. During the first year all CA systems were sown manually. The second and the third years, 7 direct-sowing machines were imported from Brazil and replicated 14 of them locally. This replication was done with a small local company with a good reputation which worked together with the farmers and us. In CA systems improved herbicide program management were implemented by farmers using regular low-volume application with battery sprayers. Common herbicides provided by cotton companies were used in CV and CA, mainly glyphosate, atrazine, diuron and haloxyfop-methyl. Mulch soil cover was recorded with two visual estimations by the same two technicians in each site in 9 randomly hoops (0.4 m^2 each). Mulch biomass was kept, oven-dried and weighed for dry matter (DM) expression. Mulch biomass contained previous crop residue as well as some residual weeds and leaves coming for useful trees present in the fields, mainly *Vitellaria paradoxa*. For each operation, the number of workers and labour time were recorded for each plot. Crop yields were estimated on about 20% of the total plot area. As sorghum and pearl millet had about the same grain yield and stalk biomass production, these two crops were grouped in the analysis. Limited free livestock access to crop residue was attempted during the dry season mainly by choosing village areas with low animal density or by building temporary fences. The data was analysed by separating the duration of different experiments. The student test at a level of 5% significance was carried out to compare CV and CA data means for each crop and duration of different experiments.

Results and Discussion

Important and significant decreases in labour requirements were recorded during weeding management with conservation agriculture compared with conventional systems during the first year both for cereal and cotton (Figure 1). This reduction of labour was a major advance for farmers because weeding delays were recognized to cause crop productivity decrease. The gain obtained was mainly by savings in tillage operations which are more time consuming than herbicides interventions (Table 1). Nevertheless this decrease in labour requirement in CA compared to CV systems tended to decrease the following years and significant differences were not registered for second and third year periods. Furthermore there were no significant yield differences over the three different duration periods for the four crops (Table 1). For each experiment duration we found important total dry mulch biomass, 2.5 to 4.6 t/ha means before sowing time (Table 1) however the level of soil cover was low, 19% to 41% due to coarse residues and random residue post-harvest management. This is the limit of the conservation agriculture definition given by Wall (2007) which is around 30% of soil cover. Insufficient soil cover limits the physical control of weeds. During the final meetings all stakeholders concluded that CA systems could be applied during the first year following conventional systems. Cotton could be sown early and directly into cereal residues with direct-sowing techniques with the conventional animal traction or manually. Therefore the main advance was the proper adaptation of direct-sowing machines from Brazil showing high potential for south-south technology transfer. These machines could be also used in CV systems. However to maintain no-tillage in permanent cropping systems after the first year of cultivation, weed management should be improved without increasing herbicides or better yet to reduce them. Cover crops intercropping with cereals were also tested (Bouba, et al., 2005) but required more labour requirement. Thus short-term profitability for farmers could not be demonstrated. Therefore the second stage of conservation agriculture promotion should attempt to extend or reintroduce some traditional cereal-legume mixed intercropping and to improve weed

and residue management after crop harvests. Some other works done with the cotton-cereal rotation in another more advanced CA project in Madagascar showed that cereal-legume row intercropping would make easier cereal-legume management and better weed control than in CV systems. In conclusion all stakeholders agreed that the next project step needed to focus at the field level concerning labour efficiency before engaging new actions with farmers'organizations at the village and regional levels concerning livestock management and crop residue conservation in the fields.
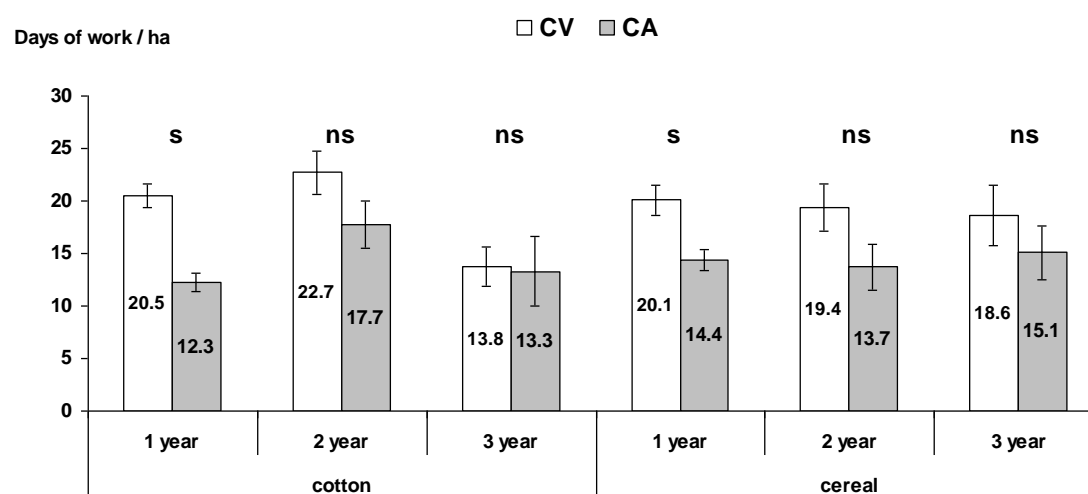
Figure 1. Mean labour for weed management (animal traction tillage, hoeing, herbicide spraying) during on-farm experimentation comparing conventional (CV) and conservation agriculture (CA) cropping systems depending on experiment duration (1, 2 or 3 years); mean comparisons at the 5% level; s = significant; ns = not significant.

Table 1. Mulch biomass and soil cover, tillage and herbicide interventions, crop yields during on-farm experimentation comparing conventional (CV) and conservation agriculture (CA) cropping systems.

Crop [1]	Experiment duration	CV-CA comparisons	Mulch at sowing time				Mean animal traction tillage [2]		Mean herbicide sprays [3]		Crop yield (seed-cotton or grain kg/ha) [4]	
			DM biomass (t/ha)		Soil cover (%)							
			CV	CA	CV	CA	CV	CA	CV	CA	CV	CA
cotton	1	112	< 1	3.8	< 10	24	*3.2*	*0.5*	*0.6*	*1.6*	850	810
	2	40	< 1	3.9	< 10	31	*2.6*	*0.4*	*1*	*1.5*	750	760
	3	12	< 1	4.6	< 10	39	*2*	*0*	1.6	1.8	670	820
sorghum or pearl millet	1	70	< 1	2.7	< 10	19	*2.7*	*0.4*	*0.4*	*0.8*	910	920
	2	26	< 1	2.8	< 10	24	*2.5*	*0.5*	*0.5*	*0.9*	960	960
	3	6	< 1	4.4	< 10	41	*2*	0.1	0.7	0.7	780	980
maize	1	20	< 1	3.5	< 10	20	*3.1*	*0.8*	*0.8*	*1.6*	2 920	2 730
	2	14	< 1	2.5	< 10	23	*2.8*	*0.9*	*0.7*	*1.5*	2 310	2 290
	3	6	< 1	3.5	< 10	33	*2.6*	*0*	0.7	1	2 840	2 670

[1] CV and CA: same chemical level of fertilization: cotton, 46N-23P-23K; maize, 75N, 17P, 17K; sorghum and pearl millet, < 10N-5P-5K

[2][3][4] Means in italics are significantly different (5% level); no italics, means are not significantly different.

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Calendar of activities agriculture of producers in the Brazilian Amazon and Atlantic forest

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Keywords: rural comnunities, vegetable production, festivities, cultural celebration

Introduction

Sustainable systems of crop production are premised on the rational use of natural resources, recognizing the importance of biological processes and the ability to contribute to the socioeconomic development of rural communities. The diversification of production provides more opportunities in rural areas. Many plant species provide important economic activities for industries (Balandrin et al, 1985). The calendar is a tool in rural property management and agricultural decision making. Created from the observation and perception of the seasons, moon and sun, contributes to the knowledge of the resources needed at each stage of production of plant or animal husbandry (Lagares and Almeida, 2009).

In the traditional production cycle of crops and harvests are important for ensuring social prosperity, economic and cultural families. This study aimed to aid the producer in the planning of rural activities and to identify cultural celebrations (religious festivals and local celebrations) that are part of the reality of farmers in the Amazon and Atlantic Forest.

Methods

This work was carried out in 2008/2009. Through survey data and structured interviews with farmers and technicians, were systematized information relating to agricultural practices, forestry and animal husbandry. The species were classified for purpose: consumption and market and production systems described in terms of the elements that compose it, may be growing, agroforestry and non-timber forest management. The weather conditions were described according to the seasons, the Amazon was considered only the seasons of winter and summer. The work was developed in partnership with thirteen community enterprises, suppliers of cosmetic ingredients for Natura and is distributed in the biomes: Amazon - Mixed Agricultural Cooperative of Tome Açu (Camta), Fruit Growers Cooperative Abaetetuba (Cofrutos), Women's Movement of Islands Belém (MMIB), Association of Producers of Campo Limpo, Association of Producers of Boa Vista, the Cooperative of Producers of Sustainable Development Reserve of Rio Iratapuru (RDS Iratapuru) and Reforestation Project Economic syndicated Dense (Reca) (Table 1); and Atlantic Forest - Land Medical Consortium (CTM), Cooperative Agricultural Project Onça (Onça), Cooperative of Organic Farmers in Southern Bahia (Cabruca), Cooperative Agro-ecological and Forest Products Handcrafted of Cloudy (Coopaflora) and Ervateira Putinguense (Table 2). Data were systematically maintaining the order of citation of species (plants and animals) by farmers and the festivities.

Results and Discussion

The calendar provides information about the species sold and / or used as food (which provide food security), cropping practices and management of non-timber forest products, and climatic conditions of each micro region. The data were systematized and organized according to the stages of production plant (the site preparation - planting - fertilization - pruning - cleaning - harvesting - drying - storage), livestock, as cited by farmers. Forest products were also included, highlighting the fruit species. Among the products used in food and marketing are the vegetables, spices, the fruits and herbs, used as cosmetic raw materials by Natura. Understand the activities that are conducted during the year by each partner providing rural Natura will help in planning field activities and the 2 hiring of supply. Information was described in a table through drawings representative (Figure 1). The festivities are sociocultural events that mark important periods of the year, including religious devotion as the Feast of the Candle of Belém ", in Belém, Pará. An observation of nature's cycle and seasons mark and outlines the work steps in the crop and / or forest throughout the year (Rigonato, 2003).

The systematization of information contributes to the planning of crops and agricultural activities and / or forestry, which may improve the management of rural property. In addition to generating income, agroforestry systems are important for food security and improved quality of life of rural people, providing many social and environmental services. According to Altieri (1989) the system's sustainability in the long term, preferably, should reduce energy use and resources, to employ methods of production that maximizes the ability of multiple land use, boost regional food production, reduce costs and increase efficiency and economic viability of small and medium farms, promoting a diverse system and potentially resistant.

Table 1. Community enterprises located in the Amazon.

Rural provider	City	State	Production system	Certification
Camta	Tomé-açu	PA	Agroforestry systems	-
Cofruta	Abaetetuba	PA	Agroforestry systems and Non-timber forest	IMO
Reca	Nova Califórnia	RO	Agroforestry systems	IBD
Comaru	Laranjal do Jari	AP	and Non-timber forest	FSC
Campo Limpo	Santo Antônio do Tauá	PA	Agroforestry systems	IBD
Boa Vista	Acará	PA	Agroforestry systems	IBD
MMIB	Cotijuba	PA	Agroforestry systems	IBD

Table 2. Community enterprises located in the Atlantic forest.

Rural provider	City	State	Production system	Certification
Cabruca	Tomé-açu	BA	Agroforestry systems	IBD
Onça	Abaetetuba	BA	Agroforestry systems	IBD
CTM	Nova Califórnia	SP	Agroforestry systems	IBD
Coopaflora	Laranjal do Jari	PR	Agroforestry systems and Non-timber forest	Ecocert
Coaprocor	Corumbataí do Sul	PR	Agroforestry systems	IBD
Ervateira	Cotijuba	PR	Agroforestry systems	IBD
Putinguense		PA	and Non-timber forest	
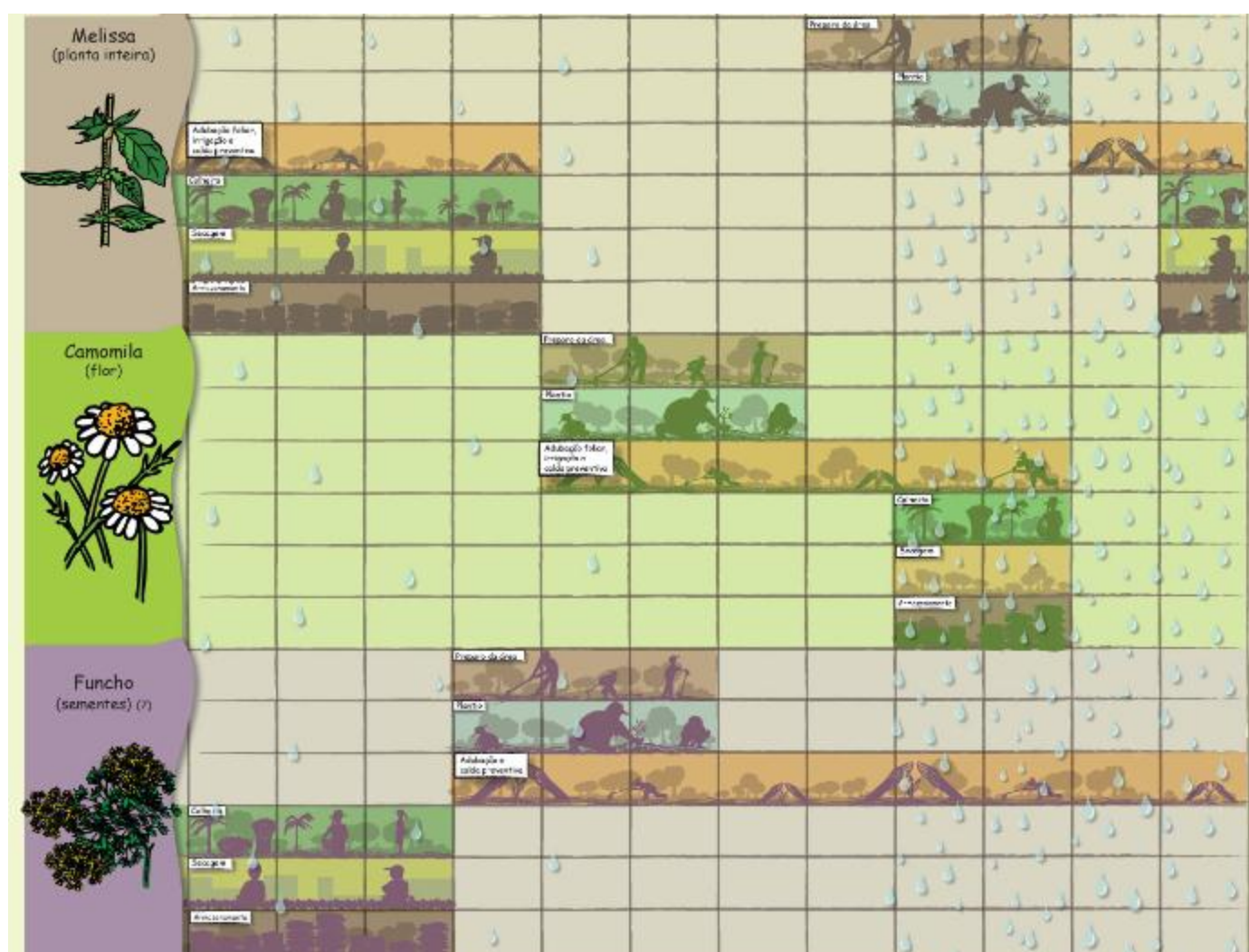
Figure 1. Systematization design of field data.

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Land grabbing and certification role in reducing gender gaps in productivity in rural sub-Sahara Africa

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Abstract

The importance of providing secure land rights to smallholder farmers in developing countries is now widely recognized. This paper analyses the impact of land certification on boosting productivity of female-headed households in sub-Sahara Africa, which are believed to be systematically more tenure insecure than their male counterparts. Based on parametric and semi-parametric analyses, the impact of certification on plot-level productivity is positive and significant. However, certification has different impacts on male and female productivity: male-headed households gain significantly and women gain only modestly. Hence, the results indicate that, while certification is clearly beneficial to farm-level productivity, it does not necessarily lead to more gains for female-headed households.

Keywords: land grabbing, certification, analyses, gender gap

Introduction

The population of West and Central Africa is growing at an extremely rapid rate. The population of the Sahel, for example, will have doubled within 30 years to around 150 million by 2040. This growth has begun to exert pressure on the land and hence on food security in the sub-Sahara region. Over 60% of the working population of WCA depend on the land for their livelihoods, given that all the economies depend on agriculture. The agricultural communities' access to land security is accepted as a basic condition for accessing the other services and opportunities essential to improve the welfare of the populations (Rakodi and Lloyd-Jones 2002). According to some analysts, the "colonial" system of the allocation of land rights in the form of the title deed is not necessarily the only [Slide 9] system, or simply might not turn out to be the single best option in the context of local and native populations (Habitat International, 2004; ODI, 2007; IFAD, 2008): because of its complexity, com-K, admin bottlenecks, Com-Arg. As the law grants the State sole rights over all the land, the government is indirectly organising a one-sided match: the vulnerability of the rural communities is blatant in terms of the use and enjoyment of the land in the true sense of the word.

Methods

The land continues to be a fundamental economic resource and an undeniable growth factor. Land reform could make the difference. Rather more innovative solutions exist for the acquisition of land which are fairer and more likely to be win the approval of the community, to meet the needs of the poorer citizens and enjoy a degree of social legitimacy. In the context of the current low-profit market affected by erratic seasonal climate which aggravates food crises and food riots, conflicts over land are bound to escalate or become more exaggerated.

Important questions
- What is our shared understanding of land tenure systems and rights (theoretical)
- How do the rural communities see the importance of the current land allocation system, particularly in the rainforest eco-zones? (Limitations)
- Which methods proposed by the research for assessing the land tenure system are applicable which point to a way out or an improvement? (Strategies)

Social aspects:
- Unfair allocation systems, imposed on the communities: acquisition of land resources (particularly those in forest zones coveted by agro-industries because of their high fertility and profitability) favouring the rich (multinationals) to the detriment of the poor local communities despite article 17 of the Universal Declaration of Human Rights "Everyone has the right to own property alone as well as in association with others."
- Qualified or petty-minded exclusion of women and minorities from land ownership: Women and minorities have no clear rights in black and white in the texts, or in the land allocation practices or procedures, although it is mainly they who are involved (working and managing the land on a day-to-day basis).
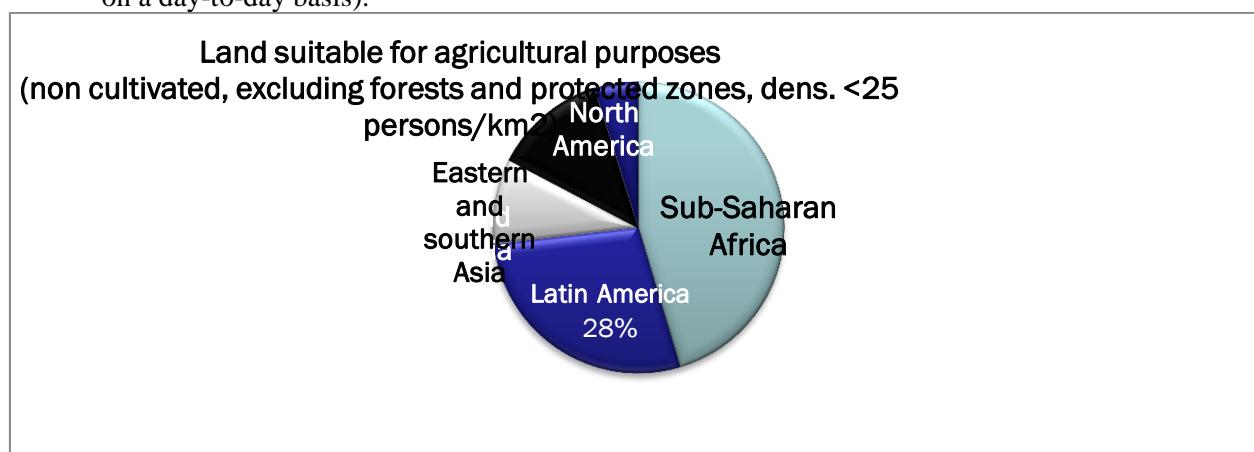
Figure 1: Global land acquisition: new challenges for ACP countries

Conclusions and Recommendations

- The State should incorporate the community compensation/motivation machinery to preserve the forests (UFA, AP) which they have preserved for centuries.
- Support and conservation partners should develop and implement alternative options to improve standards of living which protect the lands on the margins of the protected or concession zones.
- The institutionalization of the joint management system in the current protection of forest resources
-
- The government should automatically allocate land in the form of community forests wherever private companies are exploiting UFAs to the local communities.

- Policy reform should go back to the drawing board and clearly back the concept of "individual and collective usage" in the light of international agreements related to those which the African governments have ratified.
- Re-clarification of the term "public utility" in the interest of the c   ommunity and land ownership rights with a view to a revision of the land tenure system more supportive of the farmers in forest zones.
- certification has different impacts on male and female productivity: male-headed households gain significantly and women gain only modestly. Hence, the results indicate that, while certification is clearly beneficial to farm-level productivity, it does not necessarily lead to more gains for female-headed households.

Bio-economic optimisation of land use to manage natural resources

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Keywords: Salinity, land use change, ecosystem service, value

Introduction

Salinity affects both Australian farm land and streams and rivers. It has arisen because of changes in the groundwater and runoff dynamics following the introduction of European farming to a semi-arid environment. In South Eastern Australia salinity has little impact on farm productivity (Hajkowicz and Young, 2005) but significantly affects aquatic ecosystems and downstream water users. Simmons Creek in Southern New South Wales, Australia (35.69°S, 146.72°E) was identified as delivering high salt loads to streams from examining stream salinity data (Jolly et al., 2001). Changing agricultural land use from annual cropping to deep rooted perennials has been proposed as one way of reducing this high salt load (Murray CMA, 2007). Managing farm land to mitigate salinity provides an ecosystem service (ES), but, it will be disruptive and may reduce the income of the farmers providing this service. Previously salinity costs have been calculated as the off-site damage caused to household, industrial and commercial recipients of saline water (Thomas and Cruickshanks-Boyd, 2001). Here we value the ES provided by agriculture as the opportunity cost of income given up by farmers in delivering it. A linear programming approach is used to find the least cost solutions to a deliver a range of salt loads.

Methods

Within Simmonds Creek 13 sub-catchments were identified using terrain analysis (Figure 1) (Paydar and Gallant, 2003). Run on was either diffuse (added to rainfall) or discrete (in channels). Wiesner's swamp (sub-catchment 11) received runoff from the upper and mid catchment. Sub-catchments (12-13) adjacent to Billabong Creek and Wiesner's swamp itself drain directly to Billabong Creek. The groundwater of northern two-thirds of the catchment is isolated from Billabong Creek. The groundwater of southern third is saline (2,000 to 25,000 μS cm^{-1}), drains and delivers salt to the Billabong Creek (BILS., 2002; English et al., 2002). 14%[15] of deep drainage in the lower sub-catchment was assumed to reach Billabong Creek at the salinity of the groundwater. A survey identified five common land uses and allocated them to paddocks; within each sub-catchment each unique combination of land use, soil type and landscape position defined the origin of the bio-economic analysis (Nordblom et al., 2007).
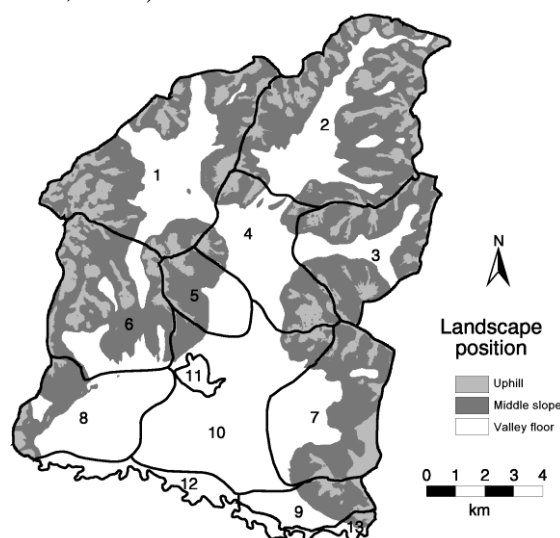
Figure 1. the Simmons Creek Sub-catchment, showing13 sub-catchments and their landscape positions.

The Agricultural Production Simulator (Keating et al., 2003) estimated the mean annual productivity (yield and gross margin) and agricultural water balance (surface runoff and drainage past the root zone) for each combination of the nine land uses and five soil type for 116 years (1881 – 2006). This one dimensional analysis was routed through the catchment using 'FLUSH' (Paydar and Gallant, 2008).
The bio-economic linear programming model integrated physical, biological and economic information to calculate the changes in land use required to deliver between 1000 t yr^{-1} and 9000 t yr^{-1} of salt to Billabong Creek in 1000 t increments at minimum cost.

Results

Land use had much more influence on gross margin, than soil type on which a land use was conducted (Figure 2a). The impact of soil was more pronounced, i.e. the drainage of native pasture on poor draining soil could be similar to a rotation including lucerne on well drained soil (Figure 2b). Thus, both the profit and the water balance of agricultural land can be manipulated by land use.
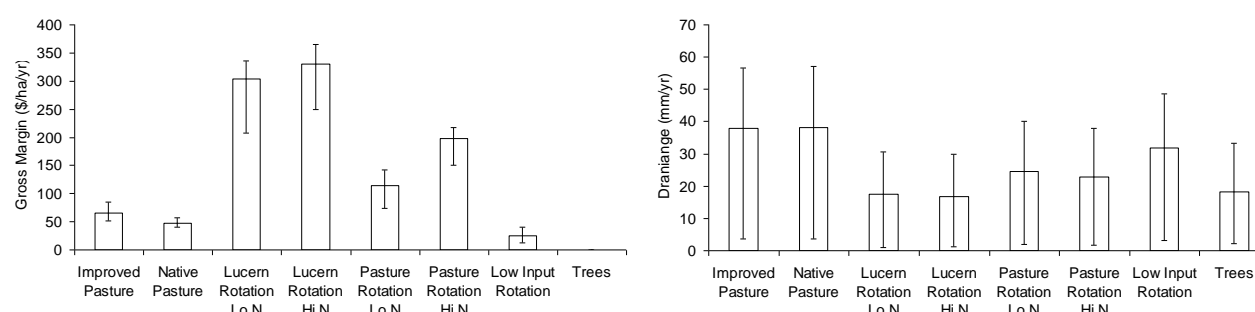
Figure 2. The gross margin and drainage of different land uses, the error bars indicate the variation due to soil type.

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[15]   This value was calculated as the fraction of the amount of deep drainage beneath current land use that would deliver the current annual salt load (10,000 t)

On a catchment level the model arranged land use to preserve as much of the most profitable land use as possible, in this case grain grown in rotation with high input pastures (Table1). When considering the whole catchment this allows some locations to shift into less profitable, more water intensive land use to reduce salt delivery to Billabong Creek. Change to less profitable land uses was limited to the lower Simmons Creek until the most extreme level of salt mitigation was called for (Table 1). As the demand for salt mitigation increases land used for native pastures is increasingly shifted into tree growing; as a last resort land used to grow highly profitable rotational crops is shifted to growing trees.

Table 1. The variation in area of land use change, grain yield and pasture biomass and farm profit with salt mitigation.

Salt load reduction (t)	Change to less productive land use (ha)		Whole Catchment		
	Lower catchment	Upper catchment	Grain Yield (1000 t)	Pasture biomass (1000 t)	Farm Profit ($M)
0	0	0	22.9	50.3	3.3
1000	56	0	23.0	51.2	3.3
2000	509	0	23.1	51.4	3.3
3000	1085	0	23.1	50.1	3.2
4000	1764	0	23.1	48.3	3.0
5000	2682	0	23.0	46.1	2.8
6000	3571	0	23.1	43.4	2.6
7000	4835	0	21.6	41.7	2.2
8000	7506	3250	19.6	39.6	1.9

This resulted in the upper Simmons Creek (sub-catchments 1-5) suffering little decline in farm income until calling for extreme 8000 to 9000 t yr^{-1} reductions in salt load (Table 1). The brunt of the land change to achieve these reductions in salt load is borne by sub-catchments 7, 8 and 10 in the lower Simmons Creek. Our results show the high cost of salinity mitigation and the within catchment inequity of catchment scale solutions to natural resource management.

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Market Integration of Small Holder Farmers through CA in Zimbabwe

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Summary

Smallholder farming in Africa is largely subsistence based, with little or no market integration for most farmers and very few farmers making a living of their farming income, resulting in poverty and migration. As farmers do not make money, investments in their farms and private sector support (e. g. mechanization, irrigation, improved inputs and credits) are virtually non-existent. However, many small holders' lands holdings could be sufficient to generate income, if utilized efficiently. However, most farmers are not able to increase production and productivity due to lack of access to markets, funding and adequate technical support. Input and output markets remain a major constraint for these farmers. Involvement of private sector for the input supply and produce marketing supply would result in a sustainable solution to this and would enable many farmers to generate income and commercialize their operations. But, increased involvement and investment of private sector in the small holder sector will mostly depend on productivity increases. Production and productivity increases in Zimbabwe through CA have been remarkable, this lead to a sizeable interest in private sector to get involved and support farmers. Now farmers can, through doing CA, not only increase their output, but also enter into market linkage arrangements, sustaining inputs and output markets and generate income.

Background

Productivity in the small holder sector is generally low and many land holdings are small, with farmers using most of that for food crops. In many cases productivity is so low that farmers cannot even achieve household food security. Consequently the available land is repeatedly overused, resulting in further declining productivity, degradation of soils and increased exposure to external factors and further declining livelihoods and food security.

Many agricultural support programs implemented by governments & donors do try to increase agricultural production and productivity to achieve food security, with single component programs (e. g. seed, or fertilizer), These programs are generally not having the expected impact and are not improving livelihoods, as farmers often cannot access inputs and sell outputs after interventions. Despite many efforts by stakeholders average small holder crop yields in Africa are stagnant or still declining, which exacerbates food insecurity and low incomes.

Any sustainable development and improvement of small holder farming would need to have enhanced support and approaches, expanding from supporting short-term food security. Farmers need to be enabled to become more productive, producing surplus and generating income to sustain their families, producing and selling cash crops, utilizing their land more efficiently, profitably and sustainably. But, most importantly, farmers need to be integrated into input and output markets and long term technical support.

Support Approaches

With the current low productivity and small farm areas it seems problematic for farmers to achieve surplus production. Also, because of the low yields most farmers need to use all their land and labor resources to produce food, not having any resources for commercial production. Additionally weak organizational structures of small holders, poor infrastructure and perceived high investment requirements hamper private sector and small-holder partnership.

However, production potential of many small holder farmers is much higher than current levels indicate, if farmers could - without major investments - achieve cereal yields of 3 or more MT/ha many would be able to generate good incomes from their farms and reduce the area needed for food production. Farmer then would have land and labor resources for cash crops.
To tap the full potential of the small holder sector it would be necessary to address all bottlenecks simultaneously, involving all stakeholders including the private sector and farmer organizations.
In interventions implemented in Zimbabwe, the focus is multi stakeholder involvement including farmers' training and improved farming standards (management/agronomic practices). Complementing support includes input and output markets and credits, while at the same time advocating for policy and incentives as an enabling environment is critical.
Only if the above factors are addressed simultaneously the support would achieve meaningful outputs, farmers do need to:

- improve yield levels swiftly, sustainably and without major capital investments.
- be integrated into input and output markets
- be organized in groups utilize economy of scale and improve bargaining power and easy interactions with partners
- have extension support and funding would need to be available

Zimbabwe Approach

In Zimbabwe FAO has partnered with farmers unions and private sector to support small holder farmers to support commercialization of small holder farmers.

The programs focus on some key areas, including:
1. Land and Farm Management (including CA)
2. Input and Output Support (Contract Growing, including initial funding)
3. Community and Farmer Capacity Building
4. Funding

Within this support, CA has been a central as it provides farmers a quick, reliable way to increase and stabilize yields without capital investments. Farmers are achieving higher production levels and production security, which can attract private sector to contract small holder farmers. The improved productivity opens opportunities to participate in markets and generating on farm incomes.

Through CA, backed by strong extension farmers are now able to plant on time using just hoes to prepare their land. Not only can farmers be on time, but the precise preparation of holes will give farmers exact plant population, planting spacing and depth, increasing yield potentials significantly. Furthermore the application of inputs (lime, fertilizer, manure) can be done more efficiently, as farmers can concentrate them in and around planting basins, reducing costs per unit. Farmers can also do the land preparation in the dry (winter) period to break peak labor demands. The land preparation by hand maybe seen as a step backwards, but it gives resource poor farmers an opportunity to do land preparation timely and precise. Timely and precise operations are the main factors for increased productivity, giving private sector confidence to invest. Private sector partners cooperating in market linkage programs for contract production of various crops have acknowledged these advantages and have endorsed CA as an appropriate and innovate concept for small holders, many companies have subscribed to the concept and contract farmers in particular who use CA[16]

The handmade planting holes, or planting basin are an ideal entry point for small holder farmers into commercialized production, farmers will in subsequent able to mechanize through animal drawn direct seeders or rippers.[17] CA approaches enable even farmers without draught power to participate, while 'better off' farmers can use mechanized conservation agriculture (animal and tractor drawn implements). Conservation agriculture ensures proper timing and good agricultural practices (e.g. spacing, plant population, fertilizer application), and allows farmers to synchronize their cropping (timely planting). It reduces tillage costs and efficient input use.

In ongoing programs 12 companies contract over 10.000 farmers currently, companies provide technical support and inputs for specific crops on a credit basis, which farmers pay back after harvest (contract growing). FAO and partners (farmers unions, government and donors) provide extension and capacity building back up and initial input support. Nationally private sector is contracting over 50.000 small holder farmers, many of which do use CA. For most of the private sector CA is a key component for their engagement[18]. Stating the ability of farmers to be timely, precise, able to synchronies their operations (resulting larger areas being ready at the same time). The buffer effect on rainfall of CA is seen as an important risk reduction. The more exact application of inputs is another advantage. Having seen the potential of small holders most companies are expanding numbers and individual (increased area) support for farmers.

Conclusions

CA is being promoted throughout sub-Saharan Africa as a response to low productivity levels and as an alternative to traditional tillage practices, which have kept small-holder farmers out of commercial production as investment and maintains costs for traditional tillage are unaffordable. CA is also reducing smallholder farmers' vulnerability to drought, addressing low draught power ownership levels, and combating increasing levels of soil degradation and loss of fertility.

Through the buy-in of private sector, farmers have the opportunity to integrate into markets and generate income. But most importantly CA offers many farmers the opportunity to generate income for their family and contribute to the economy

Given the vast potential of south east Africa, CA in combination with market linkages can unlock huge farming potentials in the region.

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[16] Currently 12 companies in various crops with over 10.000 farmers
[17] Mechanization programs are currently under way
[18] FAO assessment with private sector involved in small holder production

Designing training and education activities for the Border Rivers-Gwydir Catchment Management Authority to improve on-ground activities by landholders

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Introduction

The intention of the Border Rivers-Gwydir Catchment Management Authority (BR-G CMA), like many other regional organisations around Australia, is to provide a Training and Education program (TEP) that through its activities increases engagement of the community in "translating ideas into actions on-the-ground" (BR-G CMA 2007). The BR-G CMA believe by building communities' capacity through education and awareness raising, knowledge and skill building they would have "equipped community members to make their own decisions on natural resource management" (BR-G CMA 2007) that will lead to both private and public benefits through improved natural resource management. Monitoring and evaluating the success of the TEP in leading to behavioural change in landholders, such as stated in the Catchment Action Plan "by 2015 through education and awareness programs, 500 landholders adopt contracts ... for on ground work" (BR-G CMA 2007, p 50) is often difficult to assess. Training and education events (TEEs) are typically one-off events, sometimes undertaken in multiple localities, with evaluation surveys focusing on the organisation and delivery of the TEE, and rarely on how much influence the TEE could have on improved natural resource management, and certainly no tracking of participants to assess if there have been longer-term impacts on their land management from participation in the TEE.

The research brief from the BR-G CMA was to evaluate 4 TEEs undertaken over 2008-09, and to provide recommendations on:
1.   future design of education and training activities to increase likelihood of behavioural objectives being achieved;
2.   future evaluation procedures of education and training activities in order to be able to assess both immediate and long-term impacts to landholder behaviour;
3.   future methodology for assessing the longer term outcomes (flow-on effects) of education and training activities, sometime after completion.
Due to the condensed nature of this paper we will present the overall outcome of the TEEs evaluated, with a particular focus on where improvements need to occur and what the critical roles and responsibilities are within the organisation that need to change if TEEs are going to positively influence natural resource management behaviour of the community.

Material and Methods

The approach taken to achieve the research objectives is outlined below. We selected 4 TEEs for analysis with a total of 326 attendees over 28 days undertaken in 2008-09, that were different in their format and content – a grass identification workshop, an information day on Carbon, a 2 day river management training course, and an ecosystem and profitability forum with 4 speakers. The evaluation of each TEE was through their stated learning objectives as shown in the contract, discussed with the trainer (n=7), and gathered from any supplied learning materials. The learning objectives for each TEE were classified under knowledge, attitudinal, skill and behavioural (KASB) outcomes (a modified version of KASA by Bennett, 1975) which were expected to be achieved through attendees' participation in the day/s. The level of achievement of each of the learning areas were categorised as follows. The four categories were: no significant-, marginal-, moderate- and substantial-achievement of the learning objectives with respective quantitative levels set at 0-24%, 25-40%, 41-64%, and greater than 65% (if quantitative data was available) for each category. Each learning area's performance was categorised and provides an overview of its level of achievement, and was used to identify the highlights and lowlights of the education/extension day. The approach combined both a quantitative review of evaluation surveys undertaken at the time of the TEE, and qualitative phone interviews of selected attendees a year or more after they attended the TEE. Participation in the evaluation surveys occurred immediately after the event with many attendees unlikely to have undertaken the skill and behavioural objectives, whereas the phone interviews occurred much later after the TEE, in some cases up to 18 months, which gave the attendees plenty of time to reflect and act on their experience from the TEE. Questions for phone interview participants addressed each of the stated KASB learning objectives for each TEE. The BR-G CMA Training and Events Database (TED) (n=220) was used to gain access to evaluation surveys, and these responses were utilised to corroborate the smaller phone interview sample. Finally, qualitative phone interviews with 20 to 25% of attendees of the four TEEs (n_{total}=61) were undertaken for each TEE to draw out the level of achievement in specific learning areas.

Results and Discussion

The analogy we would like to use to explain how training and education events (TEEs) can be designed in future to increase the likelihood of achieving behavioural objectives as well as be able to assess both immediate and long-term impacts on landholder behaviour, is that the organisation or BR-G CMA is 'fabric' composed of warp and weft threads. The warp threads are the programs (e.g. on-ground works, training and education and community engagement) which run vertically, and the weft threads which run horizontally are holding the warp threads together and keeping the organisation [fabric] strong. Without weft threads the organisation [fabric] would unravel or become directionless. What are the weft threads in the BR-G CMA that hold the various programs (warp threads) together, make the connections between parallel investments and lead to behavioural change in the community?

We would suggest from the in-depth analysis of 4 TEEs that there are four strong weft threads. The four weft threads are: contract (obligations of trainer and CMA staff), TED (evaluation and client database), the trainer and the Community Support Officer (CSO). These four weft threads need to have more defined roles, responsibilities and functions to avoid an ad hoc, output-orientated Training and Education Program (TEP) that although well-received by attendees, has few evident or documented impacts on landholders' behaviour with regard to natural resource management. Contractual obligations of trainer and CMA staff, use of TED, the trainer and the CSO are all areas the CMA can influence, invest in and has control over. Improving the role and functionality of all four will contribute to raising the impact of TEP, creating lasting impacts and ongoing opportunities for the CMA, as well as counteracting the structural issues around their role in training and education for the CMA. The pervasive themes we formed through analysis of 61 participant interviews were that all four weft threads can contribute to: creating opportunity, improving consistency of message, understanding, meeting and setting realistic expectations and following through on commitments.

Overall the TEEs performed well, often meeting the output targets set in the contracts, and consistently achieved: moderate achievement of their knowledge objectives, marginal to moderate achievement of attitudinal objectives and no significant to marginal achievement in skill and behavioural objectives, with some exceptions such as the River Management Training Course (moderate achievement). The reason for the poorer level of achievement in skill and behavioural objectives by TEEs is a combination of factors which relate to not utilising the four weft threads to their full capacity. In designing training activities to increase the potential for landholders to adopt more sustainable NRM practices we recommend using the action learning cycle of "observe-reflect-plan-act" cycle, and adopting a checklist of roles and responsibilities for the improved use of the four weft threads.

A clear statement of all learning outcomes phrased in terms of knowledge, attitudinal, skill and behavioural outcomes or goals need to appear in the contractual agreement between the BR-G CMA and the trainers, and the course materials so importantly, they can be evaluated before and after the TEE, and re-evaluated 6 to 12 months after the TEE. These evaluations need to be then reflected on and used in future design of TEEs to improve level of achievement in learning objectives. Those TEEs that were preferred by attendees and achieved a higher level of skill and behavioural development were successful for several reasons, firstly they were more practically orientated, such as the Grass Identification Field Day, secondly they were well-aligned to the expectations of attendees (River Management Training Course), and thirdly they were aware of the attendees' goals and aspirations. The lack of follow-up by the CMA is about not capitalising on opportunities as once the trainer had delivered their contractual obligations and the 'job' was finished there was no-one to continue the dialogue with the TEE attendees. The CSO's role is pivotal for providing ongoing connection to BR-G CMA and their program of activities. The CSO also could provide feedback to the trainer on the day and how well they met the learning outcomes. The CSO could enable the collection of attendees' expectations of the day and ensure these expectations are reported or consulted again at the end of the session as well as ensuring the trainer via the contract articulates at the beginning of the day what they will deliver "At the end of the day you will be able to: …". On the day, most trainers still tended to deliver their TEE in a traditional "chalk and talk" teacher-centred style, and it remains to be seen how many were aware of "adult learning techniques" as espoused in the contract. We would recommend more active learning strategies be used and/or student-centred focus, which would mean that the trainer has a fuller appreciation of the attendees' background knowledge and can tailor their delivery accordingly. We would also recommend building in more time for discussions in smaller groups, breaking up the presentation style with activities that engage the audience more with the material, and using these activities to gauge where concepts are not understood or have been missed. Since, the average person's ability to concentrate drops off after 20 minutes it would be good to keep sessions to 40–50 minutes with two activities in each session.

The CSO's role would continue after the TEE has been completed with CSOs providing the point of contact for TEE attendees, and to assist them in making changes in their land management or how to apply for funding to undertake on-ground works. Case studies are another useful investment for BR-G CMA that can have ongoing value. Compiling case-studies of particular individuals whose stories can demonstrate the positive impacts of attending TEEs, and can be showcased at future TEEs provides 'grounded' examples of how through time and continued interest in the BR-G CMA activities, including TEES, have led to positive land management experiences. These case studies, in themselves, also provide evidence that TEEs are resulting in long-term changes in behaviour among attendees. The Training and Events Database (TED) is a resource that could be used to identify attendees who want to have on-going contact with the BR-G CMA or who would have interest in taking up incentive funding for on-ground works related to the training day – keeping the door open and the conversation alive.

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The role of Conservation Agriculture in increasing crop productivity for small holder farmers in Zimbabwe

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Key words: vulnerable, sustainability, institutional and socio-economic barriers, impact

Introduction

Yield levels and productivity of most small scale farmers in sub-Saharan Africa are generally low and have a declining trend in the region (Thierfelder and Wall, 2009). Most small scale farmers depend entirely or to a large extent on their own cereal production for food security. However, due to low productivity levels this causes huge threats to farmers' livelihoods as very few farmers can sell their surplus to generate income. This makes them extremely vulnerable and, in case of a drought, farmers need outside assistance in the form of seed, fertilizer or food aid.

Most communal/small holder farmers apply unsustainable soil and crop management practices. They plough the soil at shallow depth, remove all crop residues, graze or burn them and practice monoculture. In many cases land preparation is at a low standard, planting is often delayed and crops are not well managed (Elwell and Stocking, 1998). Additionally, erratic rainfall has impacted on production further, with complete crop failure in some areas in years with extended dry spells (Nyagumbo et al., 2009). Apart from water constraints, degradation of soil resources (due to salinization, water logging, soil erosion and nutrient depletion) affects the sustainability of food production across sub-Saharan Africa (Waliyar et al., 2003).

There is a growing understanding that the major cropping systems based on conventional mouldboard and hoe ploughing in sub-Saharan Africa are not suitable for this environment (Benites et al., 1998). Rockstrom and Falkenmark (2000) suggest that very substantial opportunities exist to increase small holder farmer yields through improved soil and water management. This paper presents CA as an intervention that can increase and sustain crop yields in the small holder farming sector in Zimbabwe. The paper focuses on the factors that negatively affect crop productivity and discusses the ways in which CA can address these.

Materials and Methods

The results presented and discussed in this paper are based on work done by both local and international institutions in and around Zimbabwe. Routine field surveys by government and other institutions relating to CA have been a further source of information. Local Research by the Institute of Agricultural Engineering (IAE), CYMMIT, ICRISAT, and routine surveys by the Governments' Department of Extension and the FAO are some of the key sources used in the paper. Some reference is also made to international researchers in the field of soil and water conservation.

Results and Discussions

CA aims to address the limiting factors in most small holder farming environments by removing the unsustainable parts (tillage, residue removal and monocropping) from the conventional agriculture system and, through application of the principles of minimum soil disturbance, crop residue retention and crop rotation, remove major constraints to agricultural production. CA addresses these constraints in various forms:

- High water losses through surface run-off from agricultural lands are decreased through increased infiltration and reduced water evaporation (minimum soil disturbance and maintenance of soil cover).
- Soil fertility decline is halted by maintaining or improving soil carbon stocks through efficient use of organic materials as soil cover as well as manure and precise application of fertilizers.
- Rotations with legumes and agro forestry species in rotations and interactions further add fertility to the soil.
- Increased crop productivity in CA systems on-site removes pressure from marginal areas as CA farmers are able to meet their food requirements from smaller land units.

The role of CA in mitigating negative climate change effects of increased temperature and erratic rainfalls has been shown by local researchers. Higher moisture content was observed in CA systems compared to conventional agriculture systems (Thierfelder and Wall, 2010). Significant reduction in run-off and increase in infiltration were demonstrated on local research trials (Nyagumbo, 2002; Thierfelder and Wall, 2009). Progressive yield increases recorded in on-farm studies carried out by CIMMYT clearly show the potential of CA systems even in marginal areas, on very sandy soils and with average rainfalls of around 600mm (Figure 1).

Local research evidence and field experiences have shown considerable benefits of CA in increasing and sustaining crop production. It should therefore be considered and further promoted as a potential cropping system that can reduce the risk of crop failure and provide household food security.

However, institutional and socio-economic barriers which include challenges in influencing policy changes within government, changing the mindsets of farming communities who have been farming using conventional agriculture for many years and the unreliability of input and output markets, need to be addressed to further increase the sustainable uptake of CA and consequently its impact on food security at national scale.
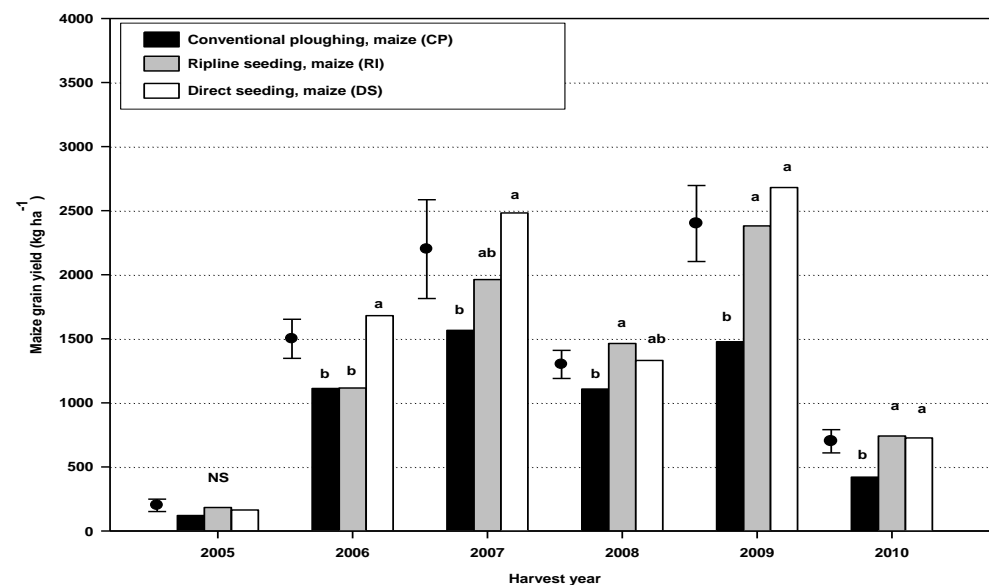
Figure 1: Mean average maize yields over several sites and seasons on sandveld soils at Chikato School, Zimuto communal lands, Masvingo comparing a conventionally ploughed control, ripline seeded and direct seeded CA treatments (Thierfelder and Wall, 2011)

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Understanding adoption of Conservation Agriculture in eastern and southern Africa

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Objective

 In eastern and southern Africa CIMMYT and its partners are attempting to generate improved CA options, understand the conditions and necessary interventions required to enhance both the adoption (intensity) and the impacts of CA technology on smallholder livelihoods.

The overall objective of the proposed workshop study is to understand and document adoption levels and to specifically determine the factors that affect the adoption process of CA. It is important to understand why some technologies fail to make the desired difference on farmers' production, income and livelihoods. Moreover, knowing the potential and actual impacts of CA technology adoption on rural livelihoods will enhance and contribute the design of appropriate policies and assist in raising awareness and subsequent support for CA R&D

Plan

The workshop will create a platform for CA scientists, farmers and policy makers to analyse the different c factors, and variables explaining the adoption of CA by the different categories of households from selected countries of Zimbabwe, Zambia, Malawi, and Mozambique, Ethiopia, Tanzania and Kenya where CIMMYT and its partners have been undertaking biophysical and socio economics research in CA. The workshop will attempt to bring together CA practitioners to understand, document and synthesize available body of knowledge that facilitates adaptation and adoption of CA in smallholder farming systems in eastern and southern Africa's small holder farming systems. Researchers, development practitioners and CA adopting farmers will share their varied experiences, lessons and challenges by presenting papers and facilitated discussions. The expected output will be a synthesis report of the presentations, discussions and recommendations.

Justification

Understanding the drivers of CA adoption, documenting, assessing the factors influencing the dynamics of the adoption process is very critical in explaining the process.
Adoption studies will help to:
- ▶ Monitor the level and pathways of adoption and its farm-level productivity impact during the technology dissemination process.
- ▶ Measure the extent of use of the technology, the performance of the technology (productivity changes, advantages, and disadvantages);
- ▶ Measure changes in farm management induced by the new technology; and
- ▶ Understand the characteristics of the diffusion process.

Prospects for up-scaling Conservation Agriculture in Zimbabwe using animal traction mechanization technologies

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Introduction

Conservation Agriculture (CA) in the form of basins, has been extensively promoted among Zimbabwe's smallholder farmers since 2004. The basin system is a subsystem of CA commonly and locally referred to as Conservation Farming (CF). It embraces the three basic principles as widely practised internationally namely minimum soil disturbance, provision of permanent soil cover and the use of crop rotations /associations (Kassam *et al.*, 2009). Apart from the three main principles, improved management practices are a central part of CA promotion in Zimbabwe including timely planting, weeding and establishment of precise plant populations (ZCATF, 2009). This paper presents key findings extracted from separate review studies and surveys conducted in Zimbabwe in the last 6 years with a special focus on the need for animal traction mechanization.

Methodology

Literature surveys were carried out on various publications and reports from research, NGOs and extension that have been produced on CA in Zimbabwe in the last 6 years. Expert consultations and opinions were obtained by carrying out semi-structured interviews with the leadership of various CA implementing institutions. Open focus group discussions and key informant interviews were used as the main tools for gathering views on opportunities, challenges, weaknesses, threats, lessons and best practices or innovations in CA as currently practiced in Zimbabwe. At least 10 districts were visited spanning across the different agro-ecological regions of the country from which stakeholder perceptions were gathered. Data generated from rapid appraisals made in 5 provinces of farmer perceptions from 67 respondents of animal traction rippers and direct seeders in comparison to conventional ploughing or conservation farming basins in 2011 was also used.

Findings

CA advances in smallholder farming areas

The study reveals that the number of farmers experimenting with CA in the form of CF basins, increased in the last seven years, from less than 2 000 farmers in 2003, to more than 100 000 farmers by March 2010 and currently estimated to occupy 139 362 ha (Marongwe, pers.comm). Most of these farmers constitute resource constrained farmers described as vulnerable groups with little or no access to draft animals and working on approximately 0.25 ha per household. CA has contributed to major benefits in terms of yield increases over the last 7 years and on many farms, attributed mainly to improved management and fertilization (Mazvimavi et al., 2009). The digging of basins prior to the rains reduces soil disturbance but also allows for timely and precision planting (Table 1). All additional nutrients are concentrated in the basin thereby creating a relatively more fertile micro environment within the basin. In dry years, the basins were also reported to exhibit a water harvesting effect while mulching with crop residues also tended to increase soil moisture content thereby helping to overcome extended dry spells.

Table 1. Advantages of using ripline and direct seeding versus the manual hoe prepared basins as perceived by farmers drawn from 5 provinces of Zimbabwe (N=67).

Advantage of ripline & direct seeding	% respondents	Disadvantages of ripline & direct seeding	% respondents
Labour reduction compared to basins	95	Planting position does not capture water	15
Less precise planting	10	Delayed planting if no oxen available	5
		Poor trash/residue handling	5

N=67

Major CA challenges

Despite the improved yields, major challenges to CA highlighted by farmers included high labour demand during initial preparation of basins, poor weed control and poor provision of adequate residue cover. These challenges often led to most farmers maintaining CA on small areas of less than 0.3 ha (Mazvimavi *et al.*, 2009) Any attempt to increase the area often resulted in serious compromises in quality of work often leading to lower yields.

Strategies for the future

Farmers overwhelmingly expressed the need for techniques which mechanize the preparation of fields using appropriate CA technologies e.g. use of animal drawn rippers (Figure 1a)and direct seeders (Figure 1b) as well as the need for chemical weed control. Studies show that it takes about 10km walking ha-1 when ripping compared to 50 km ha-1 when ploughing. The use of animal traction rippers or subsoilers (Figure 1a) and direct seeders (Figure 1b) could thus potentially reduce the drudgery associated with manual preparation of basins or ploughing as supported by farmers engaged in recent equipment surveys (table 1). At the same time such a strategy could increase the productivity of currently available draft animals through improved work rates (Figure 2) given that ownership of draft animals by smallholders in Zimbabwe is currently estimated at 50 % (ZimVac, 2009). So use of animal traction CA techniques could double up or treble the area cultivated per draft animal.

It is clear that CA based on planting basins cannot be scaled out meaningfully without a meaningful shift in the planting and weeding technologies. Based on experiences from animal traction CA studies, strategies to expand area under CA per household need to focus on

current labour bottlenecks i.e. through mechanized planting using animal traction direct seeders and rippers while weed control could be improved through the use of herbicides, let alone improving access to seed and fertilizer inputs. Yields from such mechanized systems have similarly been found to progressively increase relative to conventional ploughing (Figure 3). Sustainable intensification and out-scaling of CA in So uthern Africa will therefore have to embrace mechanization through tools such as jab planters for farmers with no draft power access, rippers and direct seeders for animal traction farmers and chemical weed control to achieve food security and improved livelihoods amongst small scale farmers of the region.

(a) animal drawn sub-soiler   (b) Animal drawn direct seeder
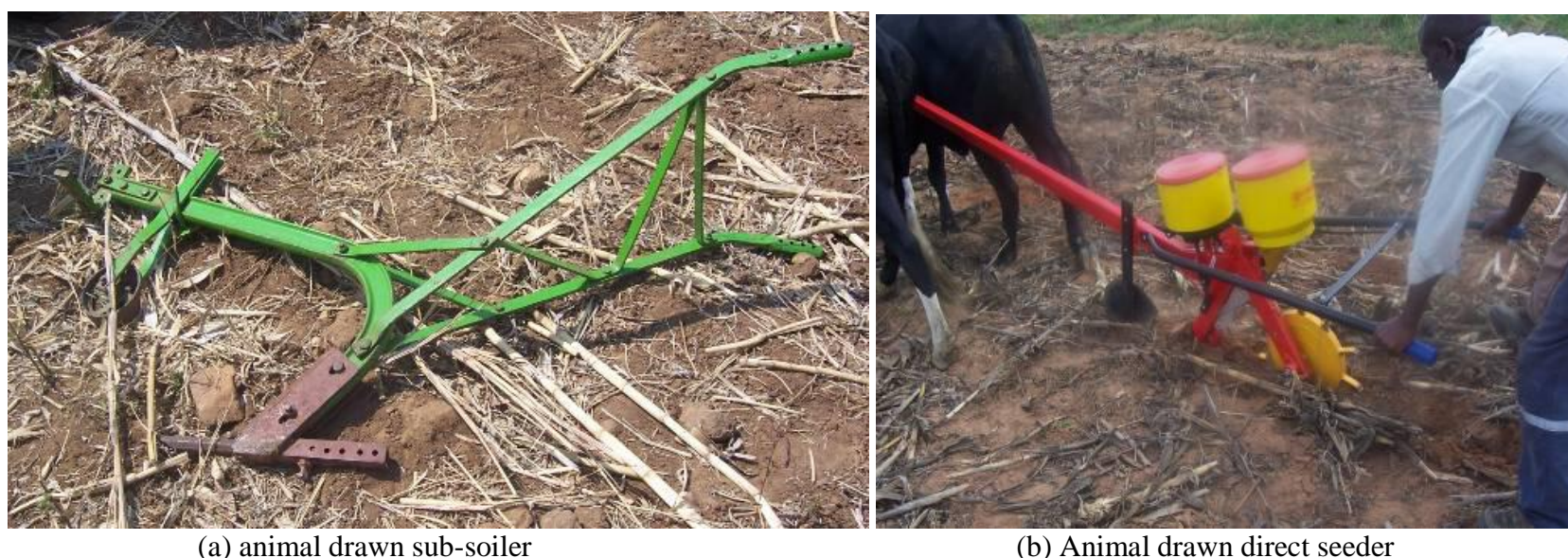
Figure 1: Animal traction CA equipment being tested in Zimbabwe
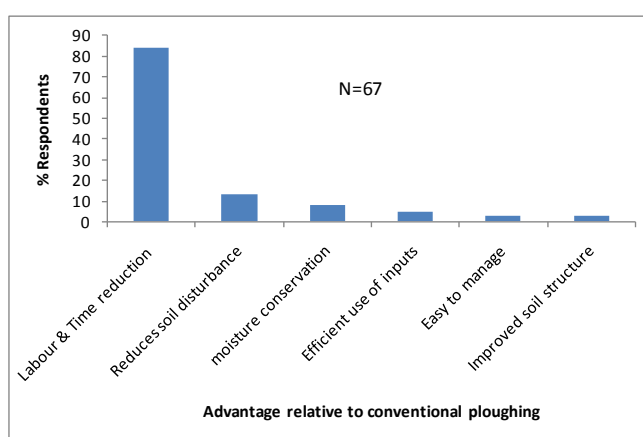
Figure 2. Advantages of animal ripline and direct seeding CA systems relative to conventional mouldboard ploughing as perceived by farmers across 5 provinces of Zimbabwe in 2011
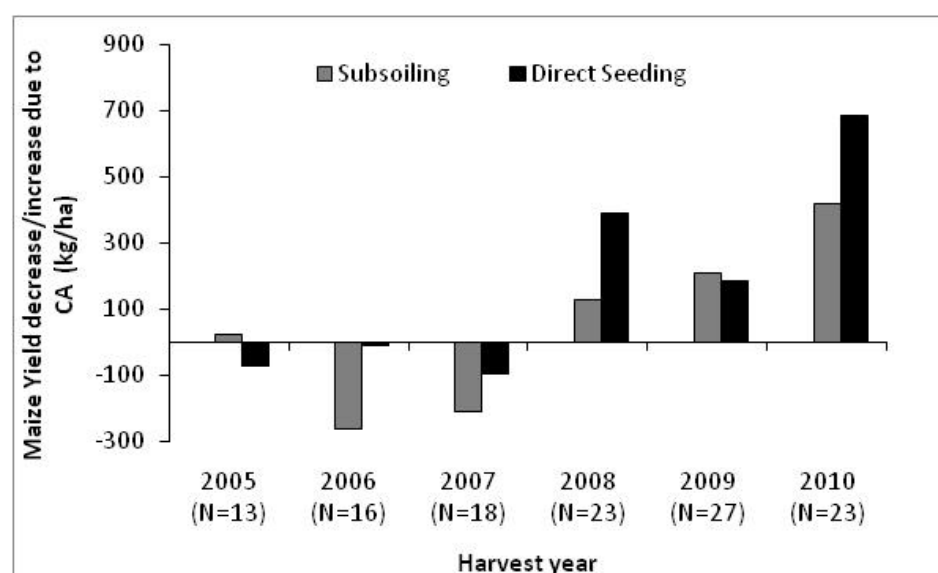
Figure 3. Average maize yield increase (kg ha-1) due to CA subsoiling and direct seeding systems relative to conventional mouldboard ploughing in Zimbabwe since 2005.

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Enhancing adoption of conservation agriculture practices through co-innovation platforms in sub-Saharan Africa

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Keywords: conservation agriculture, adoption, innovation platforms

Introduction

Conservation Agriculture (CA) is increasingly seen as an effective technology to increase farmers' resilience to climatic variability and address soil degradation resulting from agricultural practices that deplete the organic matter and nutrient content of the soil, aiming at higher crop productivity with lower production costs. However, the adoption of conservation agriculture (CA) by smallholder farmers in Africa has been limited so far (Giller *et al.*, 2009). In addition to technical problems and tradeoffs in its implementation, one problem is the promotion of CA as an indivisible package that farmers find hard to adopt in full, lacking involvement of farmers in the design of CA alternatives (Edquist, 1997).

Adoption of Conservation Agriculture practices

Although soil degradation and rehabilitation are physical processes, the underlying causes include social, economic, political and cultural drivers (Blaikie, 1985). Commonly found factors that influence farmers' decision making on land management include (e.g. Feder *et al.*, 1982; Posthumus *et al.*, 2010): bio-physical characteristics of the farm (agro-ecological zone, soil type, farming system), technology (e.g. complexity, effectiveness, profitability), land tenure, farmer characteristics (e.g. attitude, education, personal values), socio-political and economic context (e.g. markets, prices, policies, legislation). However, none of these factors are decisive on their own. Knowler and Bradshaw (2007) show that there are no universally significant factors that affect conservation agriculture adoption, although financial viability and social capital seem to be two key factors.

The adoption of conservation agriculture can be seen as a farmer accepting an innovation; it is not a characteristic of a person or object, but a process that can be divided into a number of 'levels' or phases (Prager, 2002; Lionberger, 1960). The model in Figure 1 illustrates the phases a farmer may go through before ultimately adopting soil conservation measures. Policies, subsidies or regulations can create shortcuts in the adoption process, generally omitting the cognitive phase. As a result, a farmer may adopt soil conservation measures even though he or she may not to be convinced that there is a problem and action is necessary, or that the action prescribed by the policy is the best way to tackle the problem (Prager and Posthumus, 2010). The adoption process of conservation agriculture is assumed to be a similar process as presented in Figure 1, except that soil degradation is not necessarily the motive for conservation agriculture.

Innovation platforms to enhance adoption

The transition from conventional agriculture to CA demands a combination of technological and institutional innovations to address the adoption constraints outlined in Figure 1. Although the transition is depicted as a linear process, in reality loops and iterations may be needed to tailor CA practices to local conditions. The complexity and knowledge-intensive nature of CA requires a strong capacity in problem solving from farmers, service providers and extension agents in order to tailor the technology to local conditions. An innovation systems perspective is therefore needed to tackle the challenges of CA.The active participation of farmers in iterative technology development through action research to facilitate co-learning and co-innovation may be a promising approach to promote CA in sub-Saharan Africa (e.g. Giller *et al.*, 2011; Wall, 2007).

The ABACO project[19] (Tittonell *et al.*, 2011) therefore aims to make use of co-innovation platforms to allow multi-directional knowledge transfer and iteration between the various stakeholders involved in agriculture to develop better targeted, site-specific propositions of what CA means and how it may be put into use. The co-innovation platforms will involve multiple stakeholders such as farmers, extension agents, researchers, supply companies, and policy makers that share knowledge and resources (Figure 2). Taking into account on local context, experiences and as a result of negotiations among involved stakeholders, co-innovation platforms will promote experimentation, adaptation and appropriation of CA technologies and other necessary innovative organizational arrangements, bridging the gaps between research, extension, marketing and farming. The co-innovation platforms will be preferentially located or supported at District level, but with strong linkages to stakeholders and activities taking place at national and local levels. The starting points for the establishment of the co-innovation platforms are in many cases existing Farmer Field Schools and Learning Centres. These entities are already aligned towards learning through doing, but they will need modification and expansion to become effective CA co-innovation platforms.

Most successful innovation platforms are typically built around commodities and a value chain, so that participants can envisage and experience tangible benefits over a finite, defined period. The introduction of CA promises benefits of uncertain magnitude, often over long periods of time. A challenge is therefore to identify and present the value of CA interventions in attractive terms, such that farmers and other stakeholders are motivated to form, maintain and grow the co-innovation platforms. Ecological education raising awareness on how tangible benefits (e.g. productivity, income) are obtained through ecological processes could be one of the drivers of the CA co-innovation platforms. The CA co-innovation platforms will include an exchange and learning component to allow continuous learning, monitoring and knowledge exchange throughout the project.
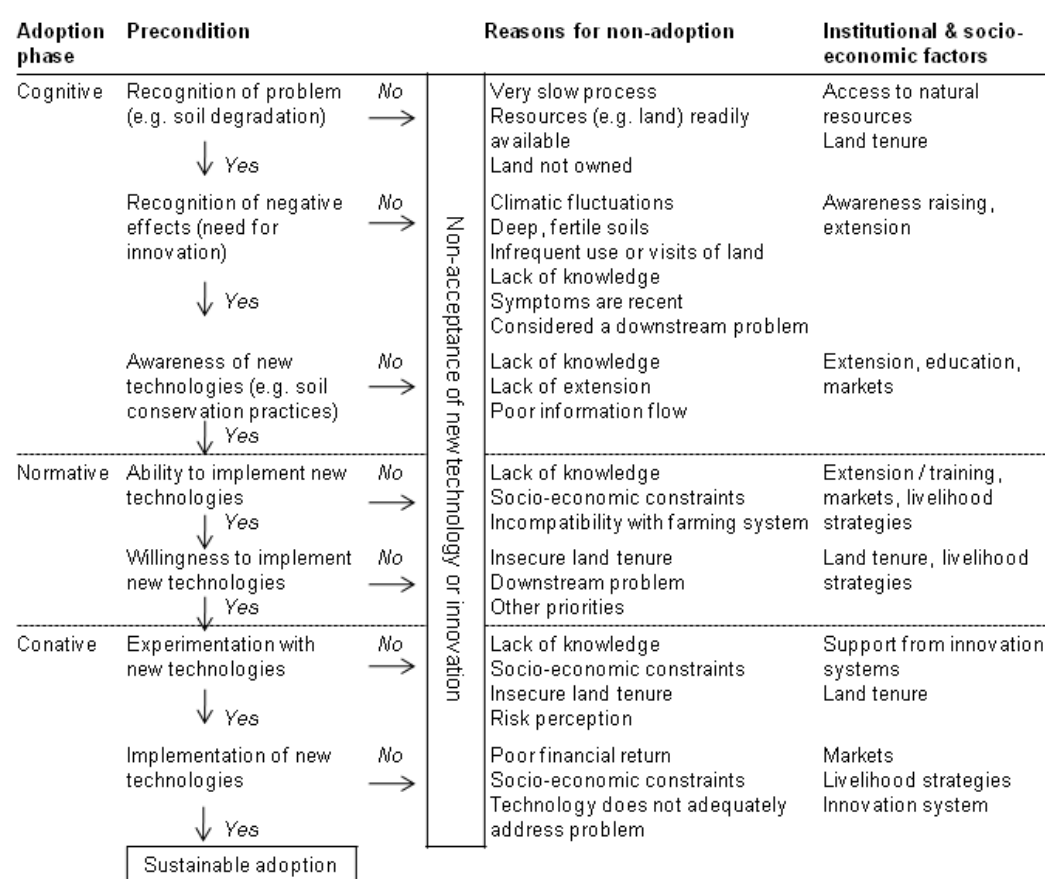
Figure 1. Levels and preconditions of the adoption process of soil conservation. The adoption process is not necessarily linear; there may be loops, short-cuts, or interruptions in the adoption process. Source: Prager and Posthumus, 2010; based on: Graaff, 1996; Lionberger, 1960; Prager, 2002.
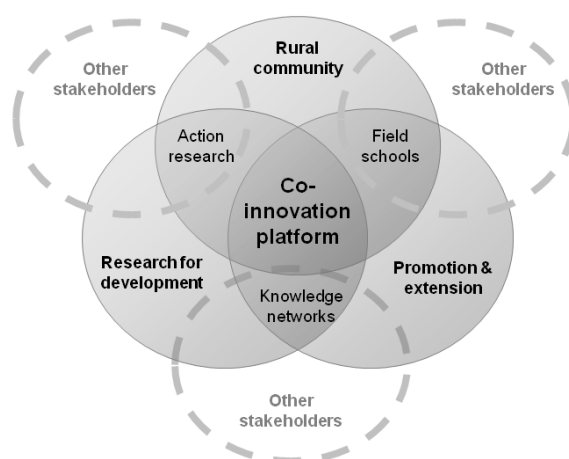
Figure 2. An abstract representation of a co-innovation platform and its possible fields of interaction. The identified 'Other stakeholders' will be different for each situation and include the government, the private sector and/or other organisations involved in the process.

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"Regional Initiative for Agroecology-Climate Change" in the Indian Ocean Islands (IRACC network)

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Keywords: climate change, agroecology, Indian Ocean, network, database, platform, working group, regional

Introduction

The Indian Ocean islands have always been affected by extreme weather events such as tropical storms and hurricanes, particularly during the period from December to April. During the past thirty years, the climate (NAPA, 2006) has been marked by fluctuations in rainfall and a season shift, early and prolonged droughts, and a rise in average temperature. This trend and the intensity of these phenomena increase, as well as their impacts, not only on natural habitats and humans, but also on socio-economic activities. Investigations showed that the sources of vulnerability of the islands are their economies heavily dependent on agriculture, soils which are fragile and vulnerable to erosion, a fragile natural environment, a relatively high population growth, an agricultural extensification, poor occupancy of soils, inadequate institutional capacity and a context of low economic diversification.

To bring solutions to these problems affecting particularly small farmers, the Indian Ocean Commission (IOC) with the financial support of the International Fund Agriculture Development (IFAD) had implemented a project of agroecology (FIDA, COI juin 2008) that will try to involve the largest number of small farmers and stakeholders in located in the islands of Comoros, Madagascar, Mauritius, Reunion, Seychelles and Zanzibar[20]. Agroecological practices are appropriate responses both to *(i)* better prepare the smallholder agriculture in the country members of IOC to meet those growing needs or new product quality in a sustainable way and *(ii)* to significantly contribute to the fight against the effects of climate change. This Agroecology Project[21], also called IRACC for **I**nitiative **R**égionale **A**groécologie **C**hangement **C**limatique (Regional Initiative for Agroecology-Climate Change), is implemented through a network of operators comprising, in its launching phase by: 1) agricultural projects financed by IFAD, SGP/GEF Mauritius Branch and other funding organizations, 2) National Agriculture Extension Services, 3) Research Centers, 4) NGOs,5)Farmers' associations and federations, 6) Agriculture training centers, 7) private sector. The members' list is still open as new projects and organisms, having the same agricultural development objectives to face problems linked with climate change, are welcome.

Materials and Methods

The accomplishment of the activities listed in the IRACC is based on teamworking through a network covering all the Indian Ocean islands. Each country created one Agroecology Platform supported by one or several technical working groups that are in charge of developing agroecology through main activities such as:
- Exchange visits between farmers and technicians,
- Exchange of experiences between practitioners
- Exchange of innovating techniques,
- Success story sharing in terms of agroecology
- Exchange of documentation and information
- Feeding and updating the network web data basis[22],
- Production and marketing of plant material,
- Creation of technical references,
- Creation of Competence Centre,
- Identification of training for stakeholders (research, extension),
- Coordination of research program
- Development of action plan on agroecology
- Communication and promotion of activities carried out within the network

, platforms and technical working groupsare the bodies' relay of the IRACC and are in permanent contact with the fields. They are the tools that allow countries to discuss freely problems of dissemination, diseases and pests, training, research, export… and technical solutions based on agroecology experiences. Problems can be solved by technical working groupsat the local level and if not so, which addresses to the platform at national level that can refer towards the regional level. Technical working groups can also directly make contact with the Competence Centre listed in the regional database.

Platforms and technical working groupsmeet regularly and can express opinions on the development of agriculture by agricultural extension services and projects through the techniques related to adaptation on climate change. They createdCompetence Centre and established the listing of the technical references for the database at the local, national and regional level. Technical Working Groups' members also organized to supply the national and regional database. They should contribute to the functioning of the forums and the Website animation.
The Agroecology Platforms consist of representatives of theorganizations involved in the development of agriculture. They must be capable ofintegrating agroecology into the local and national agricultural policies. In the other hand, technical Working Groups should have the capacity to bring answers to the questions concerning the agroecology in the technical, scientific and economic domains. Basically, working groups are composed by the following structures: Extension Services, Plant Protection Services, Agricultural Research Center, Agricultural Training Center, Universities, NGOs, Farmers' Organization, Seeds' producers, Importers/Exporters…

The main facilitator of the network is the Regional Coordination Unit (RCU) of IRACC based at the Indian Ocean Commission Office in Mauritius.

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[20]Zanzibar is not member of IOC but it is an IFAD intervention area located in the Indian Ocean.

[21]http://www.coi-ioc.org tab Activités>Environnement>Agroécologie

[22]The database on Pest and Disease Control of the former IOC project "Regional Programme for Plant Protection" www.prpv.org will be updated and strengthened in the new internet portal.

Results and Discussion

IRACC project has no funding to perform field works. It relies on ongoing projects and extension services' activities to develop the agroecology approach. This strategy, by seeking integration of existing actions, aims at avoiding initiation of activities that are already going on elsewhere. Within one year, the RCU did seek with success the participation and commitment of other ongoing agricultural projects and funding organization for the development of agroecology:

- All IFAD on-going projects are actively involved in the IRACC. They support the creation of platforms and working groups, and adopt the agroecology on-farm approach;
- GEF / SGP UNDP Mauritius, in its financing programme 2011, gave priority to mini-projects connected to agroecology practices,
- Many agricultural projects funded by the Agence Française de Développement, the World Bank and the European Community are joining IRACC;
- Reunion island (France) is contributing to the realization of IRACC through the "e-PRPV" project implemented by CIRAD Réunion (CIRAD, 2010). It is developing a new regional internet information portal, a tool to overview networks of actors in the agricultural field, which consolidate a regional data basis on diseases and pests, and will perform various actions in terms of agroecological plant protection. Among these actions, Reunion (France) as a donor, has notably proposed:
    - To help the countries to strengthen their expertise in diagnosingcrops' diseases and pests,
    - To perform testing in order to help homologation of inputs, which are more respectful of environment,
    - To train technicians and farmers in integrated farm management, assist organic farming, and organize an exchange between farmers in the Indian Ocean islands.

In the same time, the RCU could initiate activities to strengthen platforms and working groups' capacities, and to sustain networking at regional level.

IRACC project is based on the establishment and use of tools:
- Those for a limited timeframe use: the IRACC project, the National Focal Points, the Steering Committee, the annual work plan, monitoring and evaluation workshops;
- And those for sustainable use: technical working groups, agroecology platforms, technical references, Competence Center, networking, tool updates.

The experiences on conservation agriculture dissemination in Madagascar showed that four to five years of continuous practice are requested to master this concept. This year 2011, IRACC is in its first year of on-farm action.

Platform and technical working groups are expected to become perennial structures that can advise and propose technical orientation. From 2012, each country will establish a medium-term action plan of five years to develop agroecology approach. It will correspond to an important regional action plan that requires consequent financial support from donors.

IRACC is an example of regional cooperation that is going to value all the results of regional agricultural projects implemented by the Indian Ocean Commission, the International Fund for Agriculture Development (IFAD) and the Reunion island (France). Moreover, all the knowledge and experiences acquired through agriculture activities in all islands will be valued (cropping system in permanent cover/Madagascar, tied cow to a picket/Comoros, Tsabo nohatsaraina (agroforestry associated with conservation agriculture)/Madagascar, shade house on terraces/Seychelles, plant protection alternatives…. The network approach is going to save expenses and is going to reduce errors. Finally, in view of activities progress and the commitment of all countries, the network approach could rapidly give positive results for the region.

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Participatory learning for technology shaping and its dissemination: a case of Nepal

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Keywords: Appropriate technology, SRI, participation, poor farmers, local resource, local knowledge

Introduction

System of Rice Intensification (SRI) is a new method of rice cultivation developed in Madagascar. It was first introduced outside Madagascar after 1999 in China and followed by Indonesia and India (Uphoff 2007; Prasad 2006) with the support of Cornel International Institute for Agriculture Development (CIIFAD). Rice yields by this method were found more than those by conventional method using locally available varieties, without increasing inputs (water, seed, and chemicals) and investment. This is the most important aspect of SRI for farmers who have poor resource in less developed countries.

Prof. John Duxbury of Cornell University in 1998 and 1999 tried SRI unsuccessfully at research stations of the National Agricultural Research Council. In 2001, there was another trial at the Bhairahawa research station under the National Wheat Research Program, which did not show 'the SRI effect' either, as conventional practices gave a higher yield (by 5.6%). This seemed that SRI practices 'do not work' in Nepal (Uphoff 2007). In 2003 first trial was conducted by district agriculture development office (DADO) Morang on a small plot (about 100 square meters) and the result was very encouraging. Yield of that SRI plot was more than 7 tons/ha while it was less than 4 tons/ha under the conventional plot. That result encouraged the DADO staffs very much. In the following year numbers of SRI farmers and the areas under SRI increased but in the mean time problems and challenge also appeared.

SRI is a combination of some practices used to fully exploit the potential of the rice plant. But main recommendations of SRI method (Stoop et al. 2002; Uphoff 2007) didn't work equally in every plot/place. In some plots the performance of SRI was unpleasant compared to conventional method. That was challenging situation to the DADO staffs. This paper presents those problems and the outcome we found out during the SRI dissemination program during 2003-2006 in Morang district of Nepal.

Field activities, problems and outcome of joint learning

There was a lot of diversity in land type, fertility status, water availability for the irrigation, varieties of rice, socio-economic status of farmers, and labor availability etc. In such diversified situations we need to explore main bottlenecks and its possible solutions for the SRI farmers. First of all, DADO staffs discussed problems and then decided to conduct an in-depth study of SRI in the field. During the field study farmers reported about their farm conditions, SRI practices and results. The study showed that SRI performance was influenced by the diversified farm conditions. Similar recommendation didn't work equally everywhere, therefore practices must be adjusted/reshaped to farming situations.

Water management

SRI needs less water than conventional method but there must be assured irrigation facility. Alternate wetting and drying (AWD) irrigation is one of the main recommendations of SRI. In the early stage of rice it was recommended that soil should keep moist (no stagnation of water on the field) and 3-4 times for soil drying up to cracking stage. This recommendation worked well on the loose soil with high organic matter content. But on heavy clay soil drying effect has found negative. Heavy clay soil became very hard and problematic for root growth after drying. This indicated that recommendation on water management of rice field should be based on soil type. In the loose soil with rich organic matter it could be dried up to cracking stage but heavy clay soil should keep moist for the better growth (root and shoot) of rice. Based on that reality and farmers reaction we changed our SRI recommendation of water management according to soil types after 3rd season.

Variety and spacing

Initially we recommended 25x25cm or 30x30cm spacing for all rice varieties in all type soils. Rice varieties used by SRI farmers in early days were long duration and high tillering capacity. The growth and development of those rice varieties went very well but some short duration and low tillering modern varieties did not achieve expect outputs. We observed that fertile tiller, panicle size and number of grains/panicle were better with wider spacing but total number of panicles per unit areas was less for some varieties. As a result, the rice production decreased. Next season we conducted trials on varieties and spacing on the farmers' field. The trials results indicated that short duration varieties and some newly released varieties were less tillering and needed closer spacing (20x20cm) than that previously recommended. The best result according to varieties is given on Table 1. Through the two previous trials we recommended three spacing 20x20, 25x25 and 30x30 cm according to rice varieties, soil fertility status and they worked well.

Table 1. Best yield of different rice varieties with best spacing in Morang, Nepal. 2005

SN	Rice variety	Crop duration (days)	Highest yield (t/ha)	Best spacing for highest yield
1	Basdhan/Kanchi	145	11	25x25 cm
2	Mansuli	155	9.9	30x30 cm
3	Swarna	155	9	25x25 cm
4	Sugandha	120	7	20x20 cm
5	Radha 12	155	9.6	25x25 cm
6	Hardinath 1	120	8.4	20x20 cm

Weed management

Young seedling, wider spacing, and AWD irrigation create favorable environment for weed growth. Weed management is one of the crucial tasks for SRI method. Initially DADO recommended manual weeding for SRI. It required 3-4 times of weeding for better weed management and labor requirements for such weeding were more than double compared to conventional method. Farmers reported that it was difficult to manage more labor for larger SRI field. To solve that problem in 2005 DADO introduced a two-wheelers rotary mechanical weeder (cono weeder), and farmers tried it in different type of soil and situations. One important thing for mechanical weeding was the availability of water in the field to roll the weeder. Another thing was that most of the female labor felt it was very difficult to roll it in the

field. As a result, only male labor used it in their field. Although rotary weeder cut down the labor requirement by 3/4th, there was a problem, as conventionally rice weeding is done by female labor. Thus, some farmers made their own weeder (light weight and easy to operate), some maintained closer spacing (20x20cm) to reduce weed growth and some others combined chemical (use weedicide) and manual weeding for better weed management. Based on our experience, we suggested different weed management strategies for the SRI farmers.

Trends of SRI dissemination in Morang

In the beginning it was very difficult to convince farmers to change their conventional rice farming practices. Farmers didn't believe that younger delicate seedlings could survive; they were scared of wider spacing of planting; water management was different from their conventional method because they always hold/flooded water into their field conventionally; and they didn't believe the alternate waiting and drying system. Slowly farmers and extension workers gained confidence on SRI practices after joint trials and learning experience, and they felt more comfortable to communicate and interact with each other. Such interaction helped them to modify/re-shape the general recommendations according to local situations and such modification in technology transfer has accelerated SRI dissemination in later stage. Figure 1 shows the SRI dissemination trends in Morang. The SRI has spread more than 30 districts in Nepal.
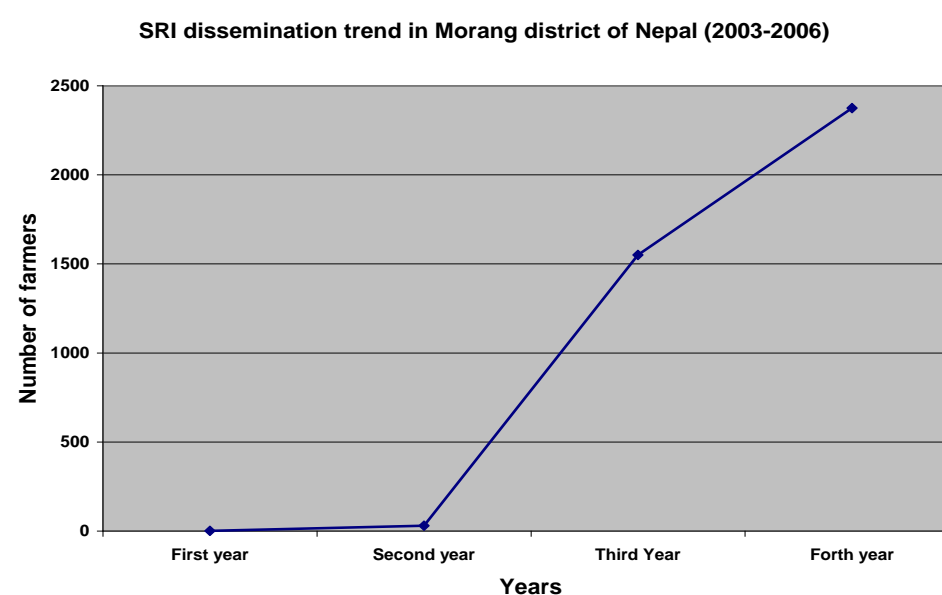
Figure 1: SRI dissemination trend in Morang district

Change in the attitude of extension worker and farmers

Initially most of the extension workers thought that they were the source of information and farmers were passive recipients of technical information, therefore they always tried to influence and dictate farmers to adopt new technology. However, when they started to work with farmers, they found some failure cases of their own recommendations. As a result, they started to discuss this with other extension workers and subject matter specialist (SMS), and they went to the fields to learn with farmers. Because farmers are always in the field and they observed and noticed all changes of their plants, this provided opportunities for the extension workers to learn more knowledge about plant and to develop a partnership with farmers. By doing this, farmers slowly started to open up and share their experiences and thinking. When DADO started to incorporate their findings/suggestions into new technology, farmers also became proactive to test and disseminate new information. Both extension workers and farmers learned from each other to disseminate new technology like SRI.

Conclusion

Participation of farmers in all steps of SRI trials and demonstrations help to re-shape the technology. Extension workers working together with farmers in diversified farming and agro-ecological conditions enhanced some of the SRI recommendations/practices according to soil type and other conditions, in particular varieties and farmers' socio-economic situation. These modifications proved to have good results and SRI has been disseminated to several districts of the country. These results emphasized that such partnership and modification can be helpful to increase technology acceptance, especially for those farmers who have poor resource and living far from modern agriculture development.

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The use of earthworms as bioindicators in no-till systems in Brazil

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Keywords: oligochaeta, conservation agriculture, soil quality assessment

Introduction

No-tillage is a widely practiced soil management system in Brazil, currently covering over 26 million ha (Febrapdp, 2011). This system includes permanent soil cover by plant residue, minimum soil physical disturbance and crop rotation with cover crops, linked with integrated pest management. Among other consequences, it promotes the role of soil organisms in soil fertility due a lower degree of disturbance (Bartz et al., 2010), when compared to other forms of management that employ intensive soil disturbance. Earthworms, in particular, play a predominant role in the formation and maintenance of soil structure (Lavelle, 1997) and their diversity, density and biomass are strongly influenced by soil management (Fragoso, 2001). Furthermore, their population can be used as an indicator of soil quality in agricultural ecosystems (Paoletti, 1999). The use of earthworms as indicators of no-till soil quality is also based on the perception of farmers in the development of this system in Brazil, since earthworm populations increased with the adoption of no-till and even became the symbol of no-till farmer associations. In fact, earthworms are generally considered by farmers to be a sign or indication of healthy soil. The present study was part of the Participatory Methods to Assess Quality in No-Till Systems in the Paraná River Basin 3, Brazil, a cooperation between Itaipu Binational and the Brazilian No-Till Federation (FEBRAPDP) and was undertaken to assess the abundance and diversity of earthworms in farmlands under no-till in six watersheds in western Paraná to validate a proposal of classification of the no-till sites based on the abundance and diversity of earthworms.

Materials and Methods

The main soil types in the region are Rhodic Ferralsols, according to FAO Soil Units. The climate is typical subtropical Cfa, according to Koeppen's classification, characterized by having hot and humid summers and no defined dry season. The annual rainfall is <1800 mm and average annual temperature in the summer is around 27° C (Iapar, 2011). Samples were taken in February-March of 2010 and 2011 in a total of 34 and 25 farms respectively, in six watersheds of six municipalities (Table 1), as well as six native forest fragments and an *Araucaria angustifolia* reforestation. The earthworms were sampled at the end of wet season using an adaptation of the TSBF - Tropical Soil Biology and Fertility Method (Anderson and Ingram, 1993), consisting in the removal of 5 monoliths 20 x 20 x 20 cm deep, spaced at least 20 m from each other, in a transect line. Hand sorting was performed in the field and earthworms were stored in plastic bags containing 5% formaldehyde solution. Earthworms were counted and identified to family, genus and species levels when possible, following identification keys and species descriptions. Abundance values were expressed in individuals (ind) m^{-2}. This simple sampling method is geared towards enabling the farmers themselves to carry out earthworm population assessments on their own farms.

Results and Discussion

In the samples taken in 2010, earthworm abundance ranged from 5 to 600 ind m^{-2} while the number of earthworm species ranged from one to six (Table 1, Bartz, 2011). There were sites that had only juvenile earthworms, preventing the identification at species level, so these sites were considered as having only one species. In the 2011 samples, earthworm abundance ranged from 5 to 1150 ind m^{-2} and the number of species from one to seven in the no-till sites. In general exotic earthworm species tended to predominate in the no-till sites, but these systems also allowed the survival of native species, although in low densities. The species richness in no-tillage systems is in most cases similar to the native forests, due to invasion of exotic species in both systems. The abundance values encountered were similar to what is often reported for temperate climate forests and cropping systems (Edwards and Bohlen, 1996), although the biomass values (data not shown) tend to be lower, due to the predominance of the very small acanthodriline *Dichogaster* spp. and small species of the Glossoscolecidae (*Fimoscolex* and *Glossoscolex* spp.) and Ocnerodrilidae (*Belladrilus* sp.) families.

In northern Paraná, no-tillage sites with similar climatic and soil conditions to those in the present study had earthworm abundance and species richness ranging from 3 to 291 ind m^{-2}, with the lowest values obtained in the dry season, while the number of species varied from one to more than four species (Bartz, 2011). Taking into account the results of the present study and the data available for northern Paraná, we proposed a classification of the no-tillage sites according to abundance and number of earthworm species (Table 2). Eight of the 25 farms (32% of the total) fell into the excellent category for abundance and only two for diversity (8%), while five farms fell into the poor category for abundance and diversity (20%). Most farms fell into the intermediate categories of good or moderate. The proposed classification using earthworms as bioindicators appears to be a useful way to classify soil quality in no-till farms in western and northern Paraná State, Brazil. However, the methodology must still be tested in other locations, soil types and other agroecosystems, as well as be compared to other soil chemical and physical attributes used to classify soil quality, in order to validate the present classification scheme.

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Table 1. Average number of earthworms and number of earthworms species in the no-till (NT), forest (F) and reforestation (RF) sites.

Watershed	Site	Average number of earthworms (ind m^{-2})		Number of earthworms species	
		Feb.10	Feb.11	Feb.10	Feb.11
Ajuricaba	NT1	50	200	1	3
	NT2	605	1150	6	4
	NT3	65	350	3	4
	NT4	40	75	2	2
	NT5	305	-*	5	-
	F	105	75	4	2
Buriti	NT6	70	275	4	4
	NT7	60	385	2	6
	NT8	25	190	1	4
	NT9	85	-	6	-
	NT10	205	-	6	-
	F	10	0	2	0
Facão Torto	NT11	340	10	4	0
	NT12	190	175	3	7
	NT13	295	55	3	3
	NT14	10	25	1	2
	F	275	355	4	4
Pacurí	NT15	110	75	4	3
	NT16	285	30	5	2
	NT17	80	30	4	3
	NT18	30	-	1	-
	NT19	125	-	2	-
	F	25	0	3	0
Mineira	NT20	5	220	1	5
	NT21	45	40	4	2
	NT22	55	15	1	1
	NT23	235	5	3	1
	NT25	105	-	4	-
	F	55	10	1	1
Toledo	NT26	185	205	3	2
	NT27	50	5	2	0
	NT28	20	875	2	4
	NT29	50	90	1	2
	NT30	30	110	2	2
	NT31	20	110	1	3
	NT32	120	5	4	0
	NT33	55	-	1	-
	NT34	265	-	3	-
	NT35	95	-	4	-
	RF	285	10	6	2
	F	-	0	-	0

* Sites not sampled.

Table 2. Proposed classification of no-till systems according to earthworm abundance and diversity observed in the Ferralsols of the warmer climate regions (Cfa Koeppen) of Paraná State, Brazil.

Classification	Average number of earthworms (ind m^{-2})	Number of farms in each abundance category	Number of earthworm species	Number of farms in each diversity category
Excelent	≥ 200	8	> 6	2
Good	≥ 100 to <200	4	4 - 5	6
Moderate	≥ 50 to <100	8	2 - 3	12
Poor	< 50	5	1	5

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Brazilian public policy to mitigate and adapt for climate change and develop a low-carbon agriculture plan

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Introduction

The greenhouse gases (GHG) concentration in the atmosphere are increasing and this process is the fundamental cause of the Global Warming. The consequence of this phenomenon has worried many countries. The atmospheric warming is occurring by non-natural means due to human interference and it can lead to climate change. In the last decades, it has been observed increasing intensity of dry seasons, floods, cyclones, tornadoes, melting glaciers, increase in sea level, etc. This new climate scenario can adversely affect agriculture and other economic activities. A lot of proposals have been presented to mitigate the effects of Global Warming. In agriculture, sustainable technologies can be adopted to mitigate GHG emissions, while promoting the retention of carbon in biomass and soil.

Conservation Agriculture and GHG Mitigation

Agriculture and livestock are important economic activities in Brazil. However, agricultural activities may generate GHG emissions by several processes (MCT, 2010). Together, agriculture and livestock account for one quarter of Brazilian total emissions. The constant expansion of new agriculture and livestock areas pressure the conversion of native forests into productive areas, making the change of land use one of the main sources of GHG emissions in Brazil (Gouvello, 2010). Also, soil tillage promotes CO_2 emission by oxidation when the losses are greater than the carbon additions in the form of straw (Sá et al. 2001; Sá et al., 2004). Among the strategies for reducing GHG emissions are decrease burning of fossil fuels, reduction of deforestation and forest fires, adequate soil management for maximizing carbon sequestration (Carvalho et al., 2008, Carvalho et al. 2009).

Brazilian Commitments on Climate Changes

In the last COP-15, in Copenhagen, Denmark, the Brazilian government committed to reduce GHG intensity by 36.1% to 38.9% until 2020. It is estimated that about 1 billion Mg CO_2 equivalent will be sequestered from the atmosphere. Actions have being implemented in the Amazon and Cerrado (Brazilian Savannah) regions to disseminate conservation agriculture and to increase energy efficiency. It is expected to reduce deforestation by 80% in the Amazon and 40% in the Cerrado. In agriculture, these actions are related with adoption of technologies which potentially may promote reduction of GHG emissions such as Renovation of Degraded Pastures (expanding in 15 million hectares), Crop-Livestock-Forest Integration (expanding in 4 million hectares), No-Tillage Systems (expanding in 8 million hectares), Biological Nitrogen Fixation (expanding in 5.5 million hectares) and Swine Manure Treatment (of 4.4 million m[3]). Brazilian Government approved an Act establishing the National Policy on Climate Change (Brasil, 2009; Brasil, 2010).

Brazilian Public Policy to Mitigate and Adapt for Climate Change and Develop a Low-Carbon Agriculture Plan

The general goal of this plan is to stimulate conservation agriculture practices that reduce GHG emissions and increase carbon sequestration. And the specific goals are: implement Brazilian commitments signed in the COP-15; promote strong efforts to achieve zero illegal deforestation throughout the country by technological improvements in livestock; adopt conservation agriculture (Renovation of Degraded Pastures, Crop-Livestock-Forest Integration, No-Tillage, Biological Nitrogen Fixation and Treatment of Swine Residues); encourage new research on crop adaptation to climate change; and, intensify the Swine Manure Treatment.

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Identifying and classifying farmland management zones

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Introduction

As the demand for life-cycle analysis and place-based programs for agricultural issues such as carbon footprints, water contamination and climate change adaptation increase, the need for holistic, systems-based spatial analysis becomes critical. One aspect of that is the need to be able to identify, map and describe the location and extent of different land management systems. The land management system utilized by a farm operator can be broadly defined on the basis of soils, landscape and crops, with soil and landscape identifying the biophysical factors the producer has to work with and land use identifying the type and nature of inputs, activities and outputs of production. Our research efforts are oriented toward the development of methods of identifying and mapping farmland management systems in order to provide a more holistic approach to program and policy interventions. This paper outlines a study to identify local "management zones" through unsupervised clustering and mapping of raster versions of topographic, soil and land use input variables. Our preliminary investigations were carried out in a study site in Eastern Ontario, Canada.

Materials and Methods

The study area encompasses approximately 5000 km^2 in Eastern Ontario, in central Canada. Soils, slope and land cover maps provided the fundamental analytical data, while spot elevation data, roads, railroads, contour lines and hydrographic features were used to provide spatial reference information.

Digital elevation data with a pixel size of 0.75 seconds was used to derive slope values on a 20m x 20m grid, and these were grouped to 4 classes; 0-4%, 5-9%, 10-15% and >15%.

Raster soils data for the study area was developed from the Soil Landscapes of Canada (Soil Landscapes of Canada Working Group, 2011), a vector product with polygons characterized on the basis of up to 5 individual soil components. The proportion of the polygon that each component comprises is provided, but the specific location(s) of the component is unknown. Each component is rated on a 7-class scale as to the capability of the soil to support field-crop agriculture, with classes $1 - 4$ indicating soils which have the capability for continuous field crop production with improvements that are reasonable to be performed by the landowner (fertilization, artificial drainage, adjustment of pH, removal of field stones, etc.). The soil map was rasterized to the same grid used for slopes and each pixel was assigned a class representing the probability of being in capability class 1-4, based on the percentage composition of capability classes in the polygon. The probability of being in capability class 1-4 was grouped to ten classes (0%-10%, 10%-20%, 20%-30%, etc.).

A land cover map depicting conditions circa 2000 (Agriculture and Agri-Food Canada, 2008) was brought in as a 30m-resolution raster layer and resampled to the same pixels as the other inputs using the nearest neighbour option. Since the focus of the study was agricultural systems, all 'non-vegetated' classes (unclassified, water, roads, built-up) were grouped to an 'Other' class, while the classes Forest, Shrubland, Grassland, Perennial crops (hay and pasture) and Annual crops were retained.

An unsupervised clustering was performed using the following three input layers: Land Cover (class values ranging from 3 to 7), Slope (class values ranging from 1 to 4), and probability of high Soil Capability (class values ranging from 0 to 10). Five, ten and 20 clusters were generated and outputs in the form of maps and data tables providing the median, minimum, maximum, number of pixels and proportion of the total area for each of the three input layers for each cluster were generated. The mapped clusters were overlain with generalized soil-landscape boundaries in order to assess the spatial relationship between management zones and landscape conditions.

Results and Discussion

The 5-cluster results separated forest, shrubland and grassland on poor quality soils from agricultural uses on high-quality soils, but it failed to distinguish between annual and perennial crops, while the 10-cluster results did not distinguish annual crops on different soil capability areas.

The 20-cluster results provide high detail and relevant separations as presented in Figure 1. A descriptive name was assigned to each cluster and is presented with the tabular data in Table 1. The most common (in terms of area) clusters are highlighted, and show annual crops on level, high-capability land as being the most predominant combination, while Forest on the same kind of land, Forest on level, low-capability land and Hay and Pasture on level, high-capability land are also widespread. Crops (Annual and Perennial) and Grassland tend to be on high-capability land, while Forest and Shrubland are about equally split between high and low-capability soils.

Maps and data such as these could prove beneficial for program planning and policy-development purposes, as they identify specific locations of potential land use change. For example, under incvreasing economic returns for agricultural commodities, high-capability land with forest and shrubland could be considered to be under threat of conversion to agriculture, while annual crops on low-capability land can be considered likely to be converted out of agriculture. The area and location of such situations can be readily assessed and summarized in order to provide an indication of the need for and the intensity and impact of public interventions. Similarly, assessments of the area with potential for a specific application, such as production of biofuel crops on marginal land, or the potential for increased agricultural production through enhancement of sub-optimal land use such as hay and pasture on high-capability soil that is common around rural built-up areas, can be readily made.

Table 1. Area of each cluster and mode (Md), minimum (Mn) and maximum (Mx) value of each input variable for the 6 largest clusters of the 20-cluster output

Cluster (Descriptive Name)	Area (%)	Land Cover Class			Slope Class			Soil Capability Percent Class		
		Md	Mn	Mx	Md	Mn	Mx	Md	Mn	Mx
Annual crops–Flat–High Capability	19.4	7	7	7	1	0	1	10	10	10
Forest–Flat–Low Capability	17.3	3	3	3	1	0	1	0	0	0
Perennial crops–Flat–High Capability	16.7	6	6	6	1	0	1	10	10	10
Forest–Flat–High Capability	16.3	3	3	3	1	0	1	10	10	10
Shrubland–Flat–Low Capability	4.8	4	4	7	1	0	4	0	0	0
Shrubland–Flat–High Capability	4.2	4	4	4	1	0	1	10	10	10
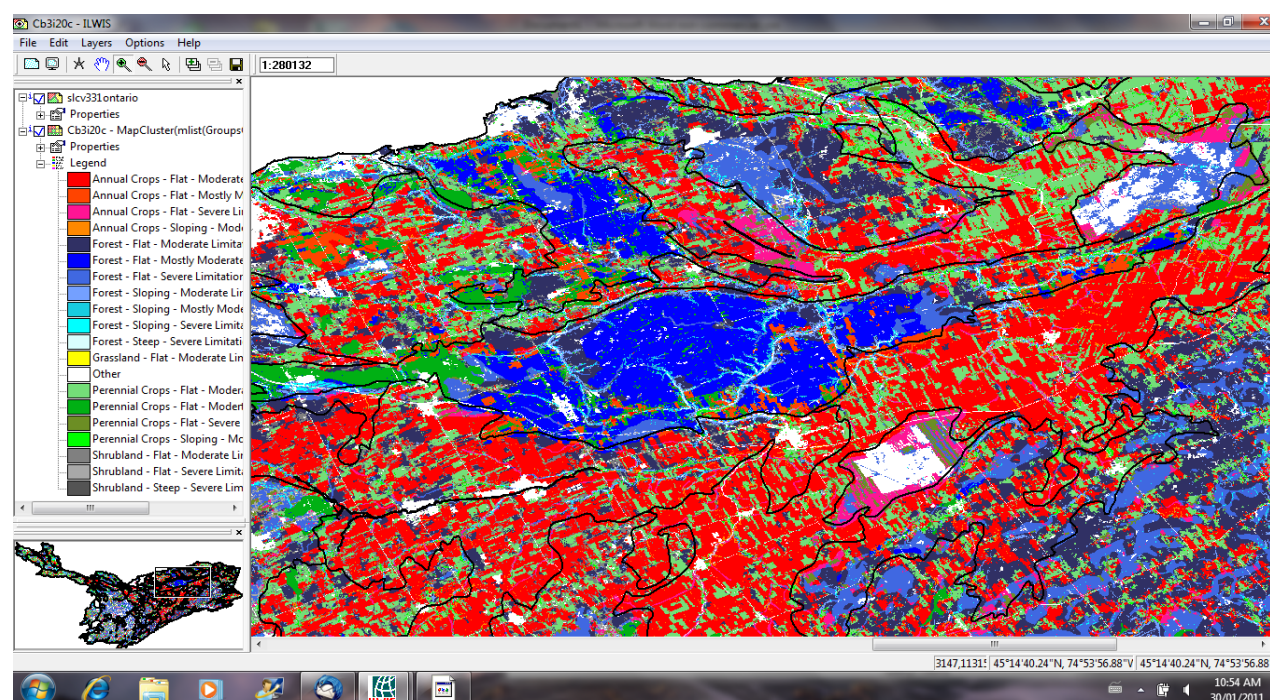
Figure 1. Map of a portion of the study area showing the 20-cluster results overlain with soil-landscape polygon boundaries

Future Research

We are currently establishing field validation procedures for a several detailed sites in order to determine the reliability of the methodology in defining 'real' systems. Future work will focus on incorporating individual crops rather than simply 'annual' or 'perennial' and on enhancing the soils component by incorporating information on the type of biophysical limitation (e.g. poor structure, low fertility, low moisture-holding capacity, stones, excess water) that causes a soil to be downgraded to a lower capability rating. By incorporating these features, we will be able to provide a much better assessment of the relationship between current use and biophysical capacity. We are also working on the integration of this 'land-based' approach with ongoing work on identifying and characterizing farming systems through temporal analysis of individual farm records from the Census of Agriculture (Huffman et al., 2009).

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Nutrients – the real constraint to sequestering carbon in soil organic matter?

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Introduction

Soil organic carbon (SOC) levels are a balance between carbon (C) inputs and outputs. Despite some claims that SOC levels are directly related to C inputs only (e.g. Christopher and Lal 2007 and references therein), many studies have shown surprisingly little response in SOC due to large differences in residue input. For example Soon (1998) found no difference in SOC levels between complete residue removal and residue incorporated over a ten year period and SOC levels decreased in both treatments. A similar outcome was reported by Rumpel (2008) where 31 years of stubble burning compared to residue retention had no impact on SOC stocks or composition. Campbell et al (1991) found various rotation and fertiliser treatments differing by up to 50% in C return to the soil showed no difference in SOC after a similar period of 31 years. While Walker and Adams (1958) hypothesised that soil organic matter (SOM), presumably as a whole, has constant proportions of C:N:P:S, Himes (1998) hypothesised that only the stable portion of the SOM, or humus, has constant proportions of these elements. This prompts a further hypothesis - that the availability of N, P and S may limit the formation of humus, not only by limiting primary production (and thereby organic C inputs) but also by limiting the conversion of C inputs to humus (humification efficiency).

We tested these two hypotheses by (i) comparing the C:N:P:S ratios in the humus fraction for a wide range of soils and (ii) measuring changes in SOC in soils incubated with a standard amount of wheat straw with and without the addition of supplementary N, P and S.

Materials and Methods

Freshly-collected Australian soils were analysed for total C, N, P, organic P (OP) and S, and the ratios were compared with values for soils from numerous locations around the world, hereafter known as the International soils. The main Australian soils were chosen from four agricultural areas in Australia with varying rainfall and soil type. Farmers in the region near each experimental site were also invited to provide soils for evaluation with no restriction on the type of soil to be submitted. Soils included cropped, pasture and virgin soils. The cropped soils were generally regularly fertilised while the pastures soils ranged from irregularly to rarely fertilised. A total of 59 Australian soils (4 main and 55 farmer) were analysed and data from a total of 976 International soils were examined - 761 for C:N; 478 for C:P and 531 for C:S.

Total C and N were determined using a dry combustion, total acid extractable P and S were determined by inductively-coupled plasma optical-emission spectroscopy following microwave-assisted acid digestion using reverse-aqua regia according to method 3051A of the USEPA (1998). Organic P was determined by the ignition-extraction procedure of Olsen and Sommers (1982).

A further experiment involved incubating the four contrasting Australian soils with wheat straw with and without supplementary nutrients. The experiment involved repeated additions of the equivalent of 10t/ha wheat straw to soil in large tubs over multiple cycles, with and without multiple supplementary nutrients (52, 20 and 13 kg/ha N, P and S equivalent). Each cycle involved incubating the soils for three months at optimum moisture and temperature to facilitate the wheat straw decomposition. After each three month cycle total C, N, P and S in the humus fraction were measured (as above) and further straw (and nutrients if necessary) was added. A total of 7 incubation cycles were completed over 21 months.

Results and Discussion

There was a constant ratio between C:N and C:S in the soils and a similar but more variable relationship between C:OP (Figure 1). On average, it took 833 units of N and 143 units of S to sequester 10,000 units of C as humus. Due to methodological and theoretical considerations we were unable to place such a predictable estimate for the amount of P required, but the range was from between 53 to 188 units of P. There appears to be a relationship between C and P but more research is needed to provide a more definitive estimate on the amount of P required per 10,000 units of humus carbon.
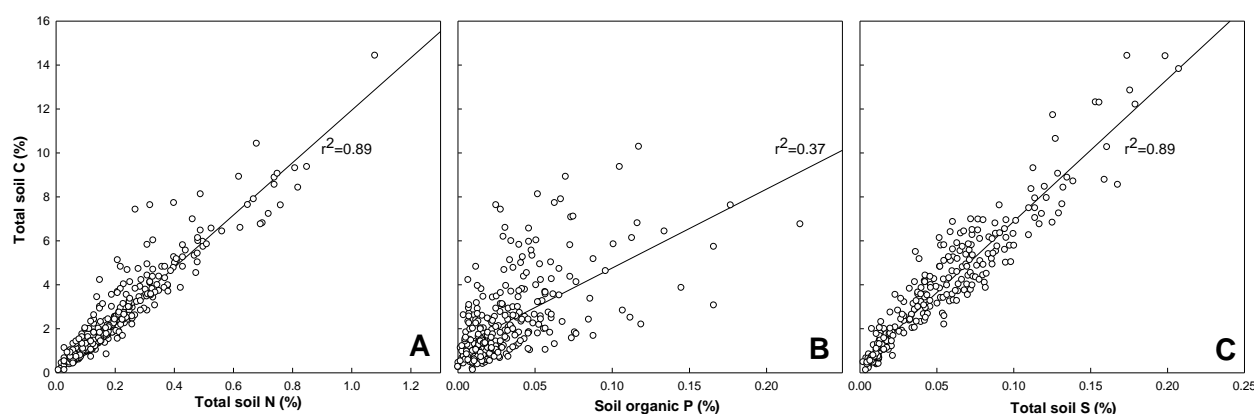
Figure 1. (A) Total C:N; (B) C:organic P (C) C:S for Australian and International soils

All soils incubated with supplementary nutrients sequestered more carbon into the humus pool than soils without supplementary nutrient addition. Soil N, P and S increased in unison with humus C increases (e.g. Figure 2 – Leeton soil).
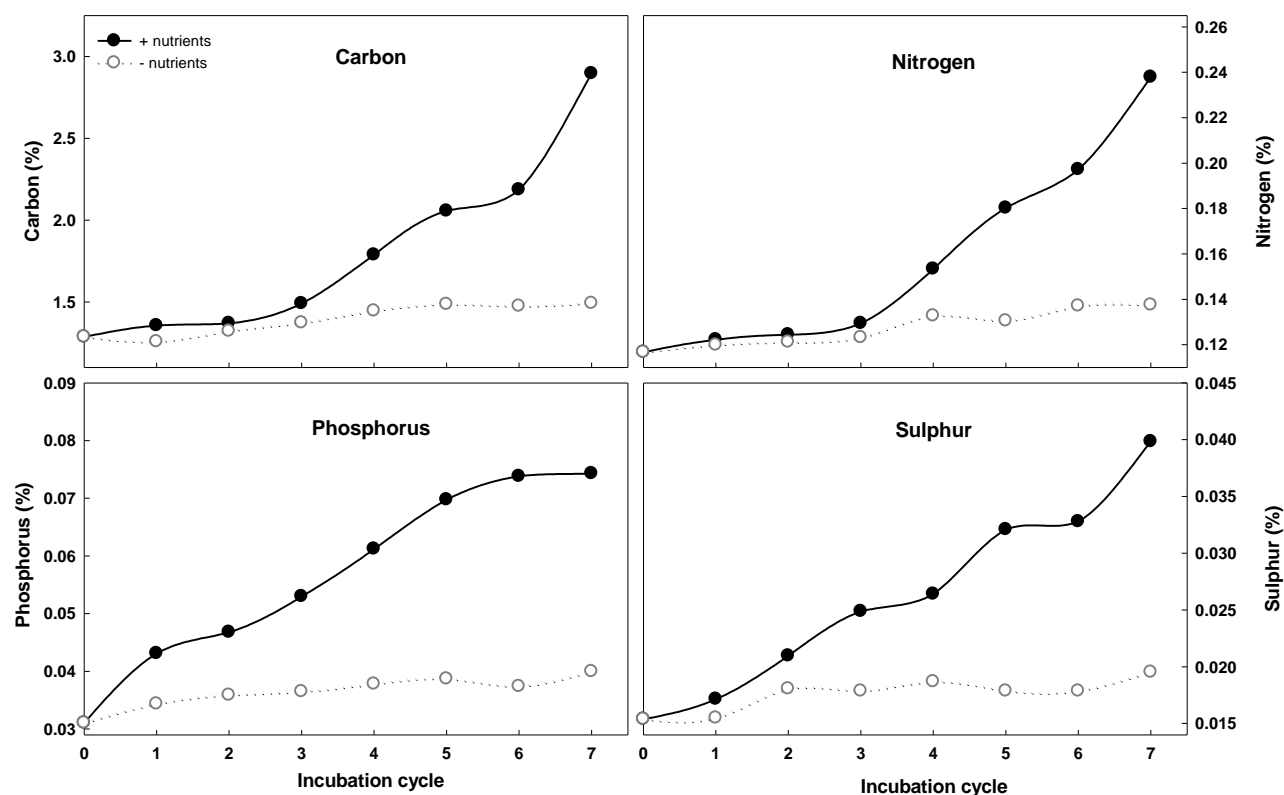
Figure 2. Change in soil C, N, P and S over 7 incubations cycles for Leeton soil. During each incubation phase, wheat straw equivalent to 10t/ha DW was added with or without supplementary nutrients equivalent to 52, 20 and 13 kg/ha N:P:S.

Together these data demonstrate that sequestering carbon into the stable SOC pool requires predictable amounts of N, P and S and that carbon sequestration will be limited where these nutrients are insufficient despite large amounts of carbon input. The estimated cost of the nutrients required to sequester one tonne of humus carbon was $248, (Table 1) if nutrients are valued at fertiliser equivalents. This "hidden cost" of N, P and S needed to foster "soil carbon sequestration" needs to be accounted for when considering a carbon sequestration strategy. Many of the circumstances in which surprisingly little carbon has been sequestered under conservation agriculture practices such as no-till can be adequately explained by the stoichiometry of C:N:P:S in stable soil organic matter demonstrated in these experiments.

Table 1: Estimated potential value of N, P and S required to sequester each tonne of humus-C

Nutrient	Amount (kg)	Approx price/kg nutrient	Approx Cost ($)
N	80	1.50	120
P	20	5.00	100
S	14	2.00	28
			$248

Prices are in Australian dollars and calculated from 2009 fertiliser costs

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Conservation Agriculture and watershed management in Brazil: the Itaipu watershed (Paraná 3)

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Introduction

Agriculture has large impacts on quality of water resources. Conventional intensive farming results frequently in high level of sediments in rivers and causes phosphorus and pesticides pollutions. Conservation agriculture is a way to maintain high productivity at the long term and to protect water resources. Indeed, conservation agriculture improves infiltration, soil adsorption capacity and reduces erosion. In some watersheds in the world, it is a mean to restore water resources quality. The Itaipu dam area constitutes an experience where no-till have reduced soil erosion since the 1990. Now, the challenge is to make evolve the farming systems to conservation agriculture, with permanent soil cover and crop rotations, in order to improve water quality of Itaipu lake.

Materials and Methods

Itaipu is the largest dam in the world in terms of annual generating electricity. It is located on the Paraná river, in the frontier between Paraguay and Brazil (cf. Figure 1). The climate of dam area is sub-tropical without dry season, violent rain storms are frequent with high rainfall intensity (more than 20 mm.day^{-1}). The soils are deep red latosols, with good fertility potential. These conditions allow an intensive farming with three harvests a year: soya (main crop), corn (*safrinha*, summer end crop), wheat or oats (winter crop).

Itaipu lake receives important flows of sediments and nutrients of agricultural lands what causes the lake eutrophication and a risk of premature filling. To reduce these flows, a management plan has been established in the watershed of eastern edge of Itaipu lake, called Paraná 3 watershed. The plan has been financed for several years by *Itaipu Binacional* within an integrated program called *Cultivando Água Boa* which includes different objectives like urban waste water treatment, forest protection on the river and lake banks, environmental education, communities development and conservation agriculture. This plan is applied to the whole Paraná 3 watershed (8 000 km²).

Conservation agriculture is an important mean to reduce erosion and lake pollution. Our research is based on territorial analysis with geographic data base and on qualitative interviews of farmers and watershed managers. We identify the agricultural practices, the motivations, the interests and the difficulties encountered by farmers to progress in conservation agriculture and the effects of public policies on their practices.

Results and Discussion

Since the decade 1990s, the agriculture in the Paraná 3 watershed evolved to a better soil conservation. Contouring is systematically used. The larger part of the watershed is covered with anti-erosive benches whose realization was financed by the program *Cultivando Água Boa*. The benches retain the superficial runoff generated by intensive rains. The high soil hydraulic conductivity allows a fast infiltration of the water upstream of the bench without damage for the crops. So, most farmers accept the benches, but half maintains them well, the others remove some of them when they consider them too dense for agricultural machinery.

Figure 1 underlines the importance of no-till on the Paraná 3 watershed. No-till with permanent cover is practiced largely more in this watershed than in the remainder of the Paraná State. This situation is explained by the high fertility potential which allows two or three harvests by year and encourages to reduce turnaround time between crops. There are differences in extent of this system between the *municipios* close to the lake, in hilly area, where a quarter to half of farms is still in conventional tillage and the more remote *municipios*, located on the eastern plateau, where conventional tillage is very minority. These differences can be explained mainly by the size of the farms, larger on the plateau where no-till is more practiced.

For the farmers, reducing erosion and runoff is the main reason to adopt no-till. Before no-till adoption, an intensive rainfall was able to destroy the young plants. Other main motivations are to save time, to reduce the fuel consumption and to increase the soil water capacity for a better resistance to the drought. The farmers observe that the crop residues form mulch which protects the soil at the time of the growth of the young seedlings. The mulch and the biological activity reduce the soil compaction and improve the infiltration very clearly.

If no-till constitutes a real progress, the impacts of agriculture on erosion and pollution could be improved by conservation agriculture with a higher organic matter production by a maintenance of crop residues and installation of cover crops. Indeed, soya leaves few residues which mineralize quickly (because the C/N index is low and the climate is hot and wet a large part of the year). A larger mulch production and the cover crops could reduce the herbicides using, as farmers of the area have observed.

Inserted in the activities of the *Cultivando Água Boa* program the Brazilian Federation of No Till Farmers Association – FEBRAPDP supported by Itaipu Binacional has developed a participatory assessment of no till system (conservation agriculture – CA) quality deployed in the Paraná River Basin 3. The system is a tool for land management using free open source software for simplified analysis of CA quality. This tool allows the farmer or his technician assistant load the system with your data and the program automatically provides the scoring of his growing plot graphically identified on Google Earth and relating it to the ranking of his micro watershed. Moreover, the system generates a continuous improvement plan to optimize the current score analyzing farmer management actions considering the records obtained in the various indicators suggesting the future actions required.

The adoption of a conservation farming system is based on a deep change of the production system and appropriation of knowledge about natural processes. The success of no-till is based on increasing incomes but the sustainability of soil use requires an integrated approach associating no-till with cover crops and crop rotation.
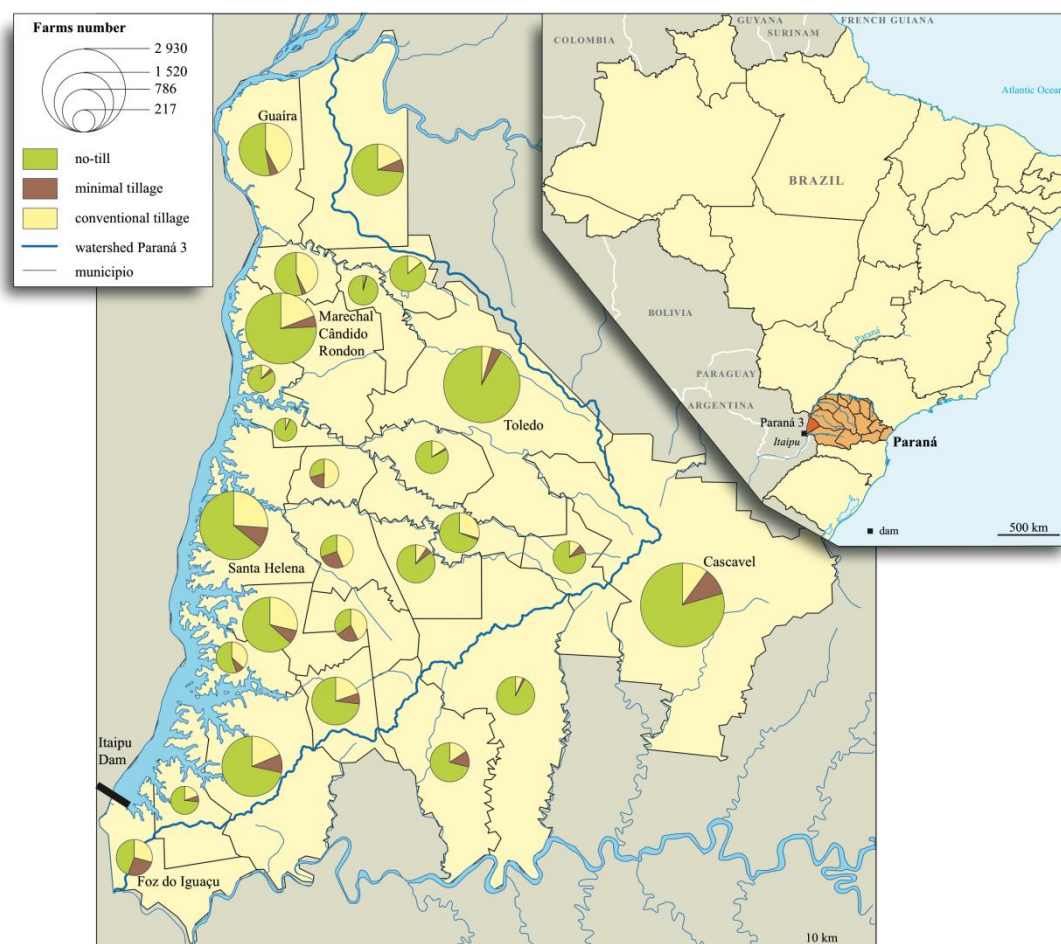
Figure 1. No-till and conventional tillage in the Paraná 3 watershed (Source: IBGE)

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