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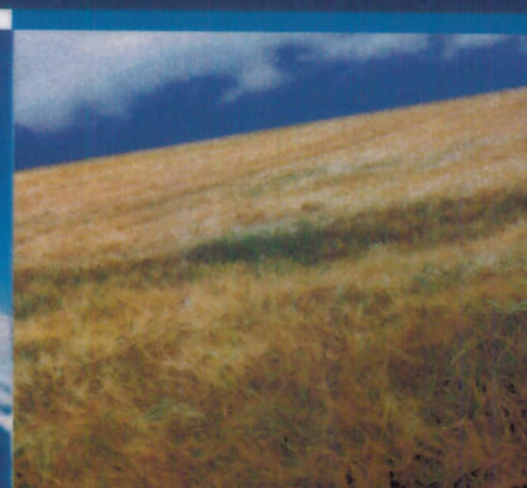
The International Conference of Climate Change, Recycling of Agricultural Resources, Technology Improvement and Agricultural Management



Organizaer : Huazhong Agricultural University
Sponsor: College of Economics and Management
College of land Management

Wuhan, China
2012

Small-holder Adoption of Conservation Agriculture in Lesotho and Mozambique

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Paper Presented at the
International Conference on Climate Change, Recycling of Agricultural Resources,
Technology Improvement and Agriculture Management
College of Economics & Management and College of Land Management
Huazhong Agricultural University
Wuhan, China
January 7 - 12, 2012

Acknowledgments

This research was sponsored by the United States Aid for International Development-Sustainable Agriculture and Natural Resource Management Collaborative Research and Support Program (USAID SANREM-CRSP). The coauthors thank Matt and Wendy Bruns and William McNair for their help with research. The views expressed in this manuscript or solely those of the co-authors and do not necessarily reflect USAID or the respective institutions.

Abstract

Conservation Agriculture (CA) has been practiced for three decades and is extensively adopted by large scale commercial farmers in the Americas and Australia and to a much lower extent by small-scale farmers around the world. In 2008 there were about 106 million hectares of permanent crops grown using CA systems in 2008. Conservation agriculture typically involves: (1) minimal soil disturbance; (2) covering soils with crop residues; and (3) rotating crops or intercropping with legumes (FAO, 2002; Thierfelder and Wall, 2010). Interventions such as mechanical tillage are reduced to an absolute minimum, and the use of agrochemicals and nutrients of mineral or organic origin are applied at optimal levels. The interactions between minimal soil disturbance, managing crop residues on fields, applying optimal nutrient levels, and controlling weed populations are often considered more consequential than the individual effects of these management activities. Instead of maximizing crop yield, the managerial objectives implied by CA is to optimize long-term soil fertility improvements through residue management and cover crop rotations, with higher maize yields and potentially lower input cost side-benefits. Agronomic research has documented that CA systems are more likely to generate higher maize yields than non-CA systems. However, even increases in expected biological yields may not be enough to encourage risk-averse small-holder farmers to adopt CA technologies. This research summarizes field trial information from Mozambique and Lesotho to understand the interplay between (1) optimal seeding and fertilizer input rates, and (2) and input and commodity prices to estimate the risk premium associated with conservation agriculture technology. Findings suggest that farm size (as measured by household wealth) plays a significant role in determining the amount producers would be willing to pay to eliminate risk associated with adoption of an alternative technology like conservation agriculture.

Key words: Conservation Agriculture; Lesotho; Mozambique; Risk; Yield.

1. Introduction

Growing awareness of the environmental problems caused by conventional agriculture has focused attention on the development of conservation agricultural systems. Combined with higher variable input costs, more intensive land use, and increasing demand, the long-term sustainability of conventional agronomic methods is uncertain. Conventional agronomic practices typically employ intensive tillage techniques that can damage soil structure and biological fertility and accelerate soil erosion and water run-off. Water quality and overall declines in fertility have been exacerbated by overuse of chemical fertilizers. Combined with improvements in plant genomics, conservation agriculture (CA) technologies could ameliorate the environmental impacts of agriculture and enhance its sustainability.

This paper reviews recent research in Lesotho and Mozambique sponsored by the United States Aid for International Development (USAID) project, the Sustainable Agriculture and Natural Resource Management Collaborative Research and Support Program (SANREM CRSP). To address these challenges, this project investigates the effectiveness of different no-till and tilled crop management systems. The goal of the project is to identify appropriate cereal, grass, and legume cover-crop mixes that protect the soil surface from erosion, increases soil organic matter, sequesters carbon, limits weed germination, enhances soil fertility, and increases yields and income through adaptation of conservation agriculture systems to local conditions.

2. Conservation Agriculture Overview

Conservation agriculture provides a potential solution to improving soil fertility and moderating the effects climate change is anticipated to have on food security in southern Africa (Thierfelder and Wall, 2010a, 2010b; Marongwe et al., 2011; Lal, 2004). The agronomic objective implied by CA is to sustain long-term soil fertility by managing crop residue and rotating food and cover crops; with the synergistic effects of these practices increasing yields and reducing input costs. Three principles characterize conservation agriculture: (1) minimal mechanical soil disturbance (e.g., direct sowing of crops into the soil); (2) permanent organic matter soil cover by crop residues of living or dead plant material; and (3) diversified crop rotations and/or intercropping associations with legumes (Kassam et al., 2009; Giller et al., 2009). Conventional tillage practices are eliminated, and fertilizers, herbicides, and other chemical inputs are potentially in the longer term, when the soil has adjusted two the new system to the advantage of both environmental and input costs (FAO, 2002). Crop residues enhance soil organic content and carbon sequestration, moderates evaporation, increases water infiltration (Thierfelder and, Wall 2009; Verhulst et al., 2010), and reduces incidences of runoff induced erosion following heavy rain storms in conservation versus conventional agriculture systems.

From a sustainable yield perspective, carbon is utilized more efficiently by soil microbes when fields are managed under CA systems (Jacinthe and Lal, 2009; Moscatelli et al., 2007). Soil organic matter content (SOC) accumulates after tillage is eliminated and residues are retained on the soil surface. Soil ecology changes, and can be measured by analyzing microbial community profiles (Six et al., 2006) (**Figure 1**). The metabolic activity of microbes produce soil organic carbon that is stabilized in no- or minimum-tillage systems which results from increased improvement of soil structure mediated by fungi and the deposition of fungal-derived carbon macroaggregates (Simpson et al., 2004). These pathways protect carbon from being mineralized (Nyamadzawo et al., 2009). Land with highly degraded soils can also sequester substantial amounts of carbon due to the pre-existing low carbon equilibrium levels (Lal, 2003). Conservation agriculture can reduce greenhouse gas (GHG) production by sequestering carbon.

Preliminary results from on-going work in Lesotho suggest that CA plots are sequestering C at rates fairly close to those found in the published literature (**Figure 2**).

3. Lesotho: Conservation and Conventional Agriculture Field Trials

In 2006, the Lesotho Bureau of Statistics (BOS) estimated that 61% of the working age population (ages 16 – 64) was economically active in agriculture (BOS 2006). Other estimates are much higher, possibly reflecting the importance of agriculture as means of subsistence. For example the United States Central Intelligence Agency (2008) estimated that 86% of the Basotho were dependent on agriculture for subsistence. Lesotho currently produces less than 30% of the food consumed compared to 50% as recently as the 1980's (World Food Program, 2007). Alarmingly, Lesotho is the only country in Southern Africa to harvest less food in 2009 than in 2008. The average subsistence maize yield Lesotho is less than 400 kg ha^{-1} $year^{-1}$), partly because of high soil erosion rates, low soil fertility and seasonal dry-spells, high agrochemical input costs, weed competition for moisture, and labor requirements for hand weeding. Break-even yields for subsistence farmers are about 2 Mg ha^{-1}; nearly seven-fold the average yield.

Maize yield response to fertilizer NPK and plant populations under CA management is important to understand with respect to designing extension materials and implementing extension programs. In Lesotho, a common CA practice is to plant maize seeds in basins (or "likoti"). Basins are dug prior to the first substantial rains. Producers are encouraged to leave residue on the plots (typically about 0.5 ha). Full CA adopters typically have 25-50% crop residue remaining on the soil surface. When the rains begin, farmers add fertilizer to the basins (about 12-8-4 kg ha^{-1}; assuming 3:2:1 (25) fertilizer is used at 100 kg ha^{-1})) and 2-3 seeds; typically about 28 000 seed ha^{-1}. Farmers may also side dress approximately 20 kg ha^{-1} of addition N (assuming 5 g of LAN per basin). Yet optimal seeding and fertilizer rates tailored for basin CA remain unknown. A research component of the Lesotho—Mozambique SANREM CRSP project is to determine optimal plant population densities and fertilizer rates for basin CA technologies.

Several of the Lesotho CA agronomic trials were designed to determine (1) biologically and economically optimal fertilizer rates for nitrogen (N), phosphorous (P) and potassium (K), and (2) optimal plant populations. The basin ("likoti") method was compared to conventional tillage practices and to maize planted using a no-till planter. The "Likoti" method is generally more labor intensive, while the no-till planter is tractor- or oxen-drawn. The agronomic trials were conducted in the Maphutseng River Valley near the town of Mohale's Hoek, southern Lesotho in 2010 and 2011. The soils at the research site were Mollisols (fine, mixed, smectitic Typic Haplustolls). The N and P research plots were 3-m by 6-m with rows 0.75-m wide. These plots were planted at populations of 17 777, 35 554, and 53 331 plants ha^{-1}. Fertilizer rates were 0, 50, 100, 150, and 200 kg ha^{-1} (for N) and 0, 30, 60, 90, and 120 kg ha^{-1} (for P). Potassium was uniformly applied at 20 kg ha^{-1} on the N-P plots. For the K trials, rates were 0, 20, 40, and 80 kg ha^{-1}. All plots were planted by hand using basins ("likoti") that were excavated by hoe.

The second method used a no-till planter to seed fields. These CA methods were compared to conventional tillage methods that used animal traction or hired labor, and a combination of animal traction and hired labor. These conventional technology sets are typical for the region studied, but "likoti" and no-till methods are relatively new. For each technology, break-even yields were calculated based on 2009 input and maize prices.

Weeding, inputs (herbicide, insecticide, fertilizer and labor) and chemical applications differentiate the total costs of each method. Per hectare costs appear to be lowest for the no-till operation (**Figure 3**). This result is largely driven by economies of scale. For relatively larger operations, the costs of the no-till planter can be spread over more hectares. Assuming smallholder operations (e.g., plots of 0.5 ha), the breakeven yield for "likoti" where family members are completely engaged in management of the system is lowest (0.80 Mg/ha), followed closely by the conventional tillage operation that uses only family labor (0.93 Mg/ha). The break-even yield was 2.11 Mg/ha for the no-till system (**Table 1**). Including labor costs in the overall partial budgeting of production costs suggests that sustainable CA systems will most likely involve combinations of chemical and mechanical weed control. The preliminary results also suggest that the CA technologies are likely sensitive to scale economies, which should be taken into consideration when designing policies targeting land use across various farm types and ecologies.

Yield response curves were estimated for each trial based on two years of production data (2010, 2011, N = 20 for each experiment). Maize response to fertilizer N-P-K was relatively flat, yet a faint parabolic curve was evident on visual inspection of the raw data (**Figure 3**). Yield response to plant population density was more easily discernable (**Figure 3**). Quadratic and square root response functions were used to estimate maize yield response to these inputs. A square root function fit best yield response to N, while a quadratic function produced the best for the maize yield/P, and K, and plant population series (**Table 2**). Optimal biological and economic rates were determined following the methods outlined in Lambert et al. (2006). Partial budget comparison of the technologies was based on a maize price of 2 R (Rand) /kg, and N-P-K costs of R21, R4.73, and R7.52/kg, respectively. Per unit seed costs were R 0.0075/seed (32000 seed in a 10 kg bag for R239.95).

The working hypothesis was that that 35,560 plants ha^{-1} would be the optimal population for CA basin plots. However, inspection of the yield-plant population response curve (Figure 3) suggests this rate is underestimated. The biologically optimal plant population rate was about twice our working hypothesis; 62 121 $seeds^{-1}$ (**Table 2**). Given the cost seed and maize prices, the economically optimal seeding rate was 60 184 $seeds^{-1}$, with a net return ha^{-1} of R28 916.

Biologically optimal rates (BOR) for N and P were (respectively) 67 and 166 kg ha^{-1}, respectively (**Table 2**). The biologically optimal rate for K was 0.02 kg ha^{-1}, but the response was not concave (the signs of the linear and quadratic terms were reversed). All estimated BOR fell within the range of the applied rates. Given the prevailing costs of inputs and maize prices, the economically optimal decision would be for a producer to apply 18, 155, and 0 kg ha^{-1} of N, P, or K, respectively. Respective NPK revenues ha^{-1} would be R 22 517, R 24 198, and R 22 005 ha^{-1}.

The yield response analyses are preliminary and should be put into perspective. The plant response data is only based on two growing seasons. Weather, field management problems, and other unforeseen events inevitably affect the data collected. More repetitions across years may reveal more responsive relationships between maize and seeding rates managed under CA systems. The relatively poor fit of the P and K models could improve with additional replications. Second, higher seeding rates should be considered for the plant population studies. There appears to be a relatively strong yield response to plant population density, but it is difficult to identify a response peak visually and empirically. Maize prices may also be lower than expected. Surplus maize grown in South Africa is market in Lesotho, which drives down the prices local producers could receive. Even though inputs are subsidized to varying degrees in Lesotho, they are generally higher because they are imported.

4. Mozambique's On-Farm Trials Conservation Agriculture

Mozambique has 1.4 million hectares of arable land suitable for producing maize. Like Lesotho, average yields are low (920 kg ha^{-1} in 2008 [FAOSTAT – http://faostat.fao.org]). The livelihoods of most farm families depend on small-scale agriculture. Maize is the main food crop, accounting for 50-90% of the population's caloric intake. Farms in remote areas are small and most fields are prepared using hoes, and crop residues are commonly burned to clear land. Soil erosion continues despite government efforts to promote conservation measures such as planting maize on ridges perpendicular to slopes. Erosion of Mozambique's arable lands will likely accelerate as food production intensifies to meet growing demand. Ongoing efforts by The International Maize and Wheat Improvement Center (CIMMYT), the USAID, and other non-government agencies focus on adapting CA technologies to the various agroecological environments in Mozambique and to maximize its future adoption.

However, wide-spread adoption of agricultural technologies is influenced by a variety of institutional factors; including knowledge and human capital producing institutions, credit-lending institutions, and legal institutions. Factor and commodity prices may also be strong incentives (or disincentives) for adopting new technologies, which in turn may be influenced by terms of trade and commodity exchange markets. On-the-ground extension efforts may play an important role in the adoption decision by providing demonstration areas or face-to-face advice. Finally, risk perception influences the rate at which a bundle of technologies percolate throughout a community of potential users. Early adopters may be characterized as being relatively risk neutral, integrating new technologies into their production systems. On the other hand, risk-averse latecomers may wait to see how neighbors fare with innovative practices, adopting some parts of technological bundles in a step-wise approach (e.g. using basins but not maintaining residue; maintaining residue but not rotating crops, etc.).

The agronomic literature typically refers to "risk" in terms as those associated with production variability caused by drought, pests, or disease. But more generally risk can be analyzed as the dispersion of an expected outcome around a central tendency (Dillon and Anderson, 1990). In addition to random weather patterns, disease, and pest outbreaks, the relative price of inputs and commodities may also significantly define the perception of risk associated with technology adoption (Serra et al., 2008).

What follows is a risk analysis of on-farm trials conducted in Mozambique from 2008 – 2011. Data were collected form agronomic trials led by CYMMIT in three provinces of Mozambique from 2008 – 2011. The first treatment (the "control") was a conventional control plot managed under traditional ridge and tillage practices. Residues were cleared by burning or used as forage. In the second treatment, maize was planted in basins hand-excavated with a hoe. A jab-planter was used to plant maize in the third treatment. In both CA treatments (basins and jab-planter treatments) crop residues were retained on the soil surface. Trials were farmer-managed, with the occasional oversight of extension personal. Costs were collected at the provincial levels reflecting regional market averages for inputs and labor. Maize prices were collected from the Mozambique Ministry of Agriculture (www.sima.minag.org.mz/). All prices were converted to 2010 US dollars. There were 631 observations corresponding with each technology over the study period.

Certainty equivalents (CE) for each alternative were estimated at different risk tolerance levels. A certainty equivalent value is the payoff (as net returns ha^{-1}) for which a producer is indifferent between an uncertain outcome and receiving a certain payment. Certainty equivalents for risk-averse individuals are always less than the expected monetary payoff (i.e., the simple weighted average of net returns) of an uncertain project. When faced with several technology alternatives with different uncertain returns, a risk-averse individual would always choose the alternative with the highest certainty equivalent (Lambert and Lowenberg-DeBoer, 2003).

For risk-averse individuals, beliefs about uncertainty are aptly described by concave, twice-differential functions; for example, the isoelastic utility function $U(\pi; \lambda) = \pi^{(1-\rho)}/(1-\rho)$, where ρ is a relative absolute risk aversion coefficient (Moschini and Hennessy, 2001) and π is the expected net returns ha^{-1} from a technology (Z) plus some initial level of wealth (W_0). The more risk-averse individuals are, the larger the risk aversion coefficient. The Constant Relative Risk Aversion (CRRA) class of utility models assumes that the amount an individual would invest in a risky project is proportional to an increase in wealth. In the context of technology adoption this implies that the decision to adopt a technology is scale-neutral.

The certainty equivalent is determined by solving the following expression for CE:

$$U(\text{CE} + W_0; \rho) = \sum_i p_i \, U(\pi; \rho),$$

where p_i are the probability associated with each outcome being observed (all assumed to be equally likely). Note that when ρ = 0 the farmer is risk neutral, and the CE equals the simple average of the payoff distribution. As the risk aversion coefficient increases, the certainty equivalent decreases relative to the expected monetary value. The difference reflects the monetary amount the producer would be willing to forgo to eliminate risk (or the “risk premium”).

Nonparametric comparison of the net returns ha^{-1} from two CA planting practices (basins and a jab planter) and conventional tillage practices suggest that the returns from the CA practices were significantly higher than that produced under the conventional tillage system

(**Figure 4**). However, the return distributions were not significantly different when the two CA practices were compared (**Table 3**). The expected net returns ha^{-1} for the basin and jab planter technologies were about 3 to 4 times higher (\$136 and 183 ha^{-1}, respectively) than the expected returns produced by the conventional tillage practice (\$41.56 ha^{-1}). The coefficient of variation (CV) was highest for the returns produced under the conventional tillage system (1,130); about 3 to 5 fold higher that the CVs of the basin and jab planter technologies (365 and 280, respectively). Thus, the CA technologies appear to be less risky alternatives compared to the conventional tillage system.

How much would producers be willing to pay to eliminate risk associated with a technology? We approach this question using a sensitivity analysis. The certainty equivalents associated with the estimated net returns ha^{-1} from conventional tillage and the CA technologies (basin planting and seeding with a jab planter) are calculated at initial wealth levels ranging from \$0 to 100, and a risk aversion levels ranging between 0 (risk neutral) and 1 (which reduces the utility function to a logarithmic functional form). To the extent that the risk premium represents the value attributed to a technology in terms of reducing return risk, clear differences emerge comparing the conventional tillage returns with those from the CA technologies (**Figure 5**). Initial wealth levels also appear to play a role in determining the risk premium. As the risk premium associated with a technology increases, the tradeoff between wealth and risk increases. Higher income levels and higher risk premium appear to translate into lower levels of risk aversion. The finding suggests that relatively wealthy smallholder farmers may be more willing to try new technologies.

While only suggestive, this finding could have implications with respect to the CA packages promoted in certain communities, noting that some technologies requiring relatively larger capital investments (i.e., no till planters, jab planters, etc.) may be more readily transferable than labor intensive technologies (i.e. hoe basins). The converse may hold true as well. Understanding the socioeconomic constraints and capacities is therefore a logical complement to agronomic trials. Asking farmers to adopt practices that have longitudinal benefits –but not necessarily obvious benefits to crop yield or soil properties—that extend beyond the current farming season is difficult and probably only accomplished through thoroughly understanding the available social capital. Social capital is a relatively new term that may, to varying degrees, explain technology adoption rates, and encompasses the characteristics of local social structures and how they impacts the social decision-making process. Social capital encompasses horizontal and vertical dimensions both politically and economically (Silici, 2010). Silici (2010) states that if the group is too homogenous there is less vertical interaction that can result in the group “getting by” but not “getting ahead.” Recognizing that difference in wealth may impact rates of adoption and identify community leaders and followers is part of this rubric. In tandem with region-specific agronomic data, socioeconomic information will help tailor and fine-tune CA packages to local economic and sociological contexts.

5. Conclusions

Development of the agricultural sector in Mozambique and Lesotho is constrained by a number of factors such as low soil fertility, climate change impacts (especially more frequent droughts), and limited input availability. Rural farm families are at risk in terms of food security and perpetually low yields. Conservation agriculture (CA) systems have the potential to increase row crop yields (Thierfelder and Wall, 2010). CA adoption by small-holder producers is also capacity-constrained because of weak or nonexistent institutions (Gowing and Palmer, 2008).

Other adoption constraints include problems accessing inputs, inaccurate information about improved technologies, and weak credit markets. But yield increases from CA systems are not usually enjoyed in the first few seasons and payoffs from CA may not be enjoyed until soil quality improves. Without reliable durable and self-sustaining social capital networks (e.g., Silici, 2010), adoption patterns will probably carry on sporadically (Mazvimavi et al., 2008; Gowing and Palmer, 2008) as producer balance the perceived risk associated with adopting new ways to produce food.

This paper presented some preliminary results of on-going research in Mozambique and Lesotho. In Lesotho, break-even yields for basin and no-till CA technologies were compared to break-even yields from conventional technologies. The yield responsiveness of maize produced using the basin CA technology to N, P, K, and plant population was estimated to determine biologically and economically optimal rates for these inputs under CA management. The break-even yields analysis suggests that a small-holder farm family using herbicides and manual labor could increase yields by 3-fold.

Four years of on-farm data from Mozambique was analyzed in terms of risk, including a sensitivity analysis that employed a utility function which allowed for risk premium to vary depending on hypothetical wealth endowments of producers. Preliminary result are encouraging, suggesting that residue cover and seeding maize using basins or jab planters may consistently generate higher per hectare net returns than conventional practices would in Mozambique. In terms of policies promoting the adoption of agronomic technologies in risk-averse settings, accurate estimation of risk premium may be useful for program budgeting, extension efforts, and planning purposes.

Increasing fertilizer and seed input costs in high risk production areas suggest that CA systems that intensify farm productivity must be developed at landscape levels. However, this perspective is at odds with "extensive" expansion approaches whereby producers farm more land to achieve desired production goals. It may be posited that extensive adoption of CA will hinge on the ability of smallholder producers to procure and efficiently use chemical herbicide and pesticides to reduce the time needed to weed. Alternative approaches to spread labor hours over a wider area might entail 'block farming', or labor exchange farmer groups managing different fields. At the other end of the spectrum, integrating mechanical or animal drawn no-till planters into larger, medium-scale operations also remains a challenge. In places where animal traction is frequently used, no-till planters have to be heavy enough to penetrate soil surfaces, but light enough to manually control. But tractor-drawn no-till planters are rare in Lesotho and Mozambique, and replacement parts are costly and hard to locate. This lacuna opens the door for no-till planter innovations with parts that can be replaced with recycled farm implements.

Many smallholder producers are likely to perceive "sustainability" as growing enough grain to eat over a single cropping season. This idea is likely at odds with definitions of "sustainability" maintained by scientists and development agents who operate more often at "macro" or regional levels. Finding additional methods to sequester carbon is at the forefront of international debate, as well as finding and implementing tools to mitigate climate change. CA technologies may play an important part of this puzzle, and could play an even larger role in southern Africa as the risk of annual temperature increases and extended periods of drought increase. Indeed, some anticipate that climate change could reduce average maize grain yields up to 30% (Lobell et al., 2008). Down the road, could optimists envision small holder producers practicing some types of CA exchanging carbon credits with emission polluting industries?

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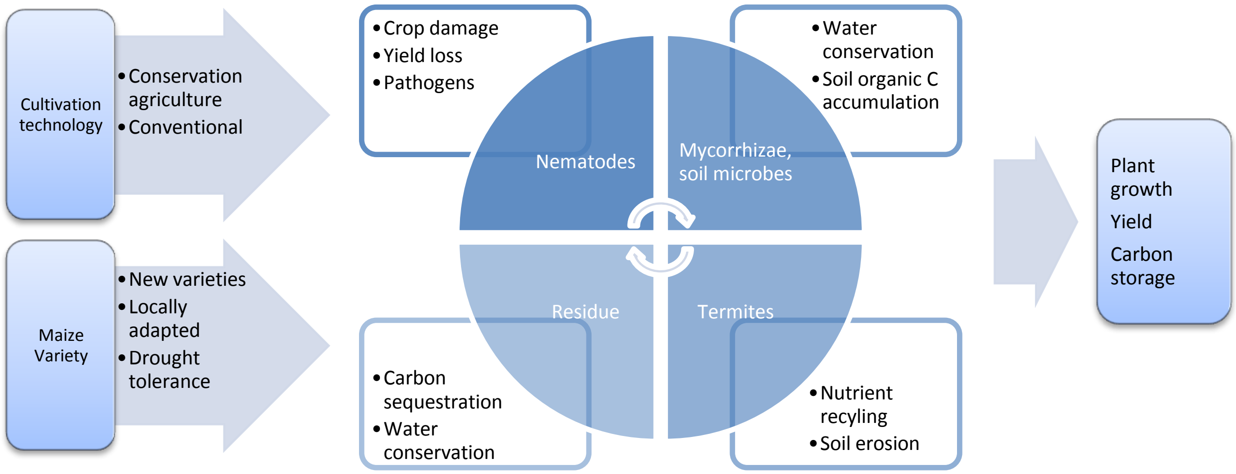

Figure 1. Macro-interactions between carbon flux, microbial populations, crop plant growth, and conservation agriculture.

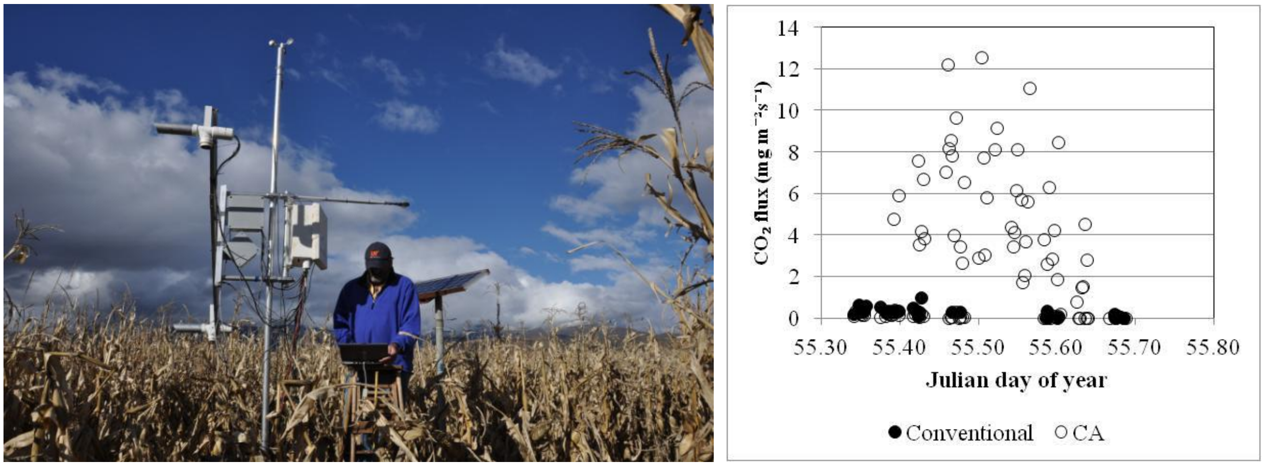

Figure 2. Left panel: Instrumentation recording Bowen's (1926) energy balance in Lesotho. Right panel: CO_2 is being sequestered as C in the plant biomass (kg CO_2-C sec^{-1}). Preliminary results for trials in Lesotho suggest a C sequestration rate of 30-50 kg ha^{-1} year^{-1} by Julian Day 55, which is just after maize grain fill. Because of the high correlation between water use and grain yield this C sequestration detection method also provides good insight into the overall energy efficiency of the production system. Key: Conventional = plough tillage; CA = no-till conservation agriculture.

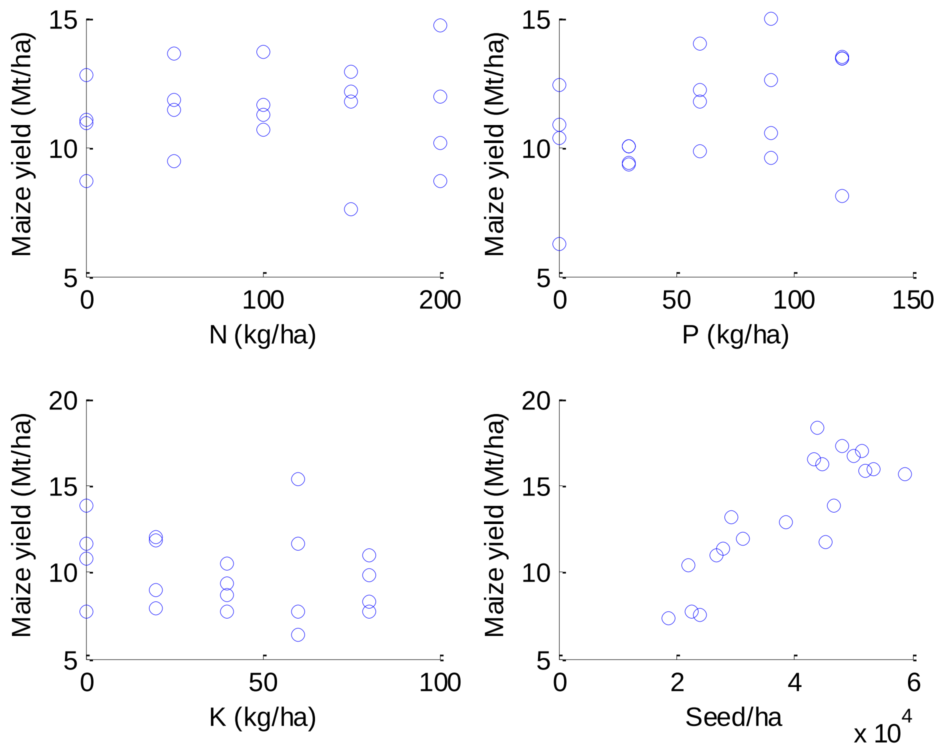

Figure 3. Maize yield response to fertilizer N-P-K and plant population density; Maphutseng, Lesotho. Maize was grown using the basin ("likoti") conservation agriculture method.

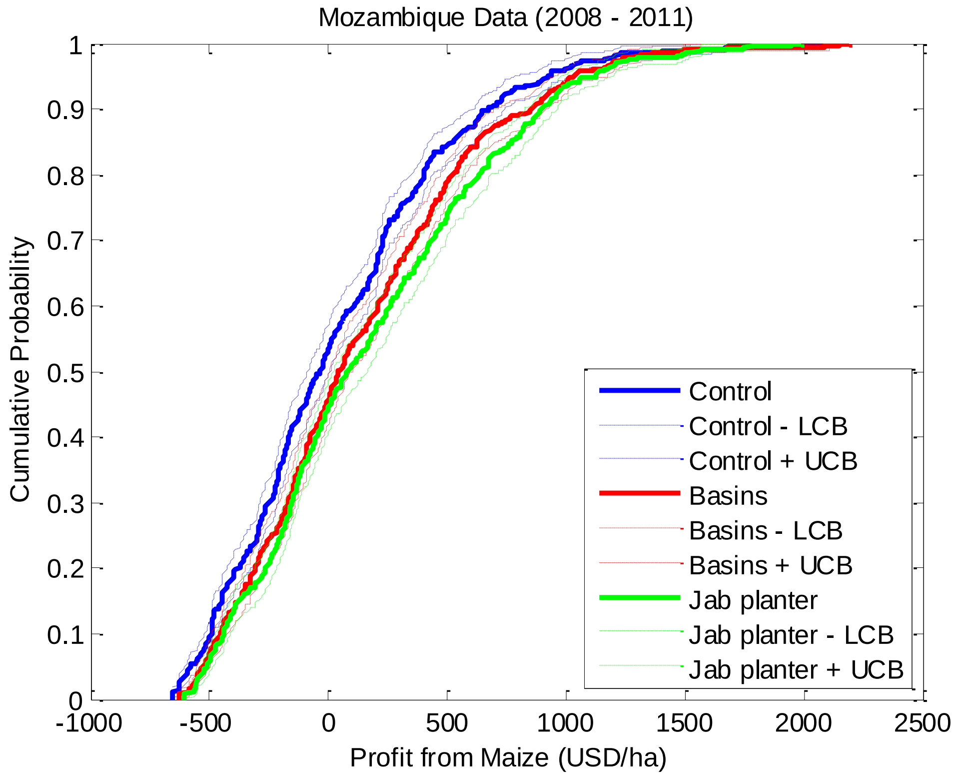

Figure 4. Empirical distribution of net returns for conventional tillage treatments and the CA planting technologies (basin and jab planter), Mozambique, 2008 – 2011.

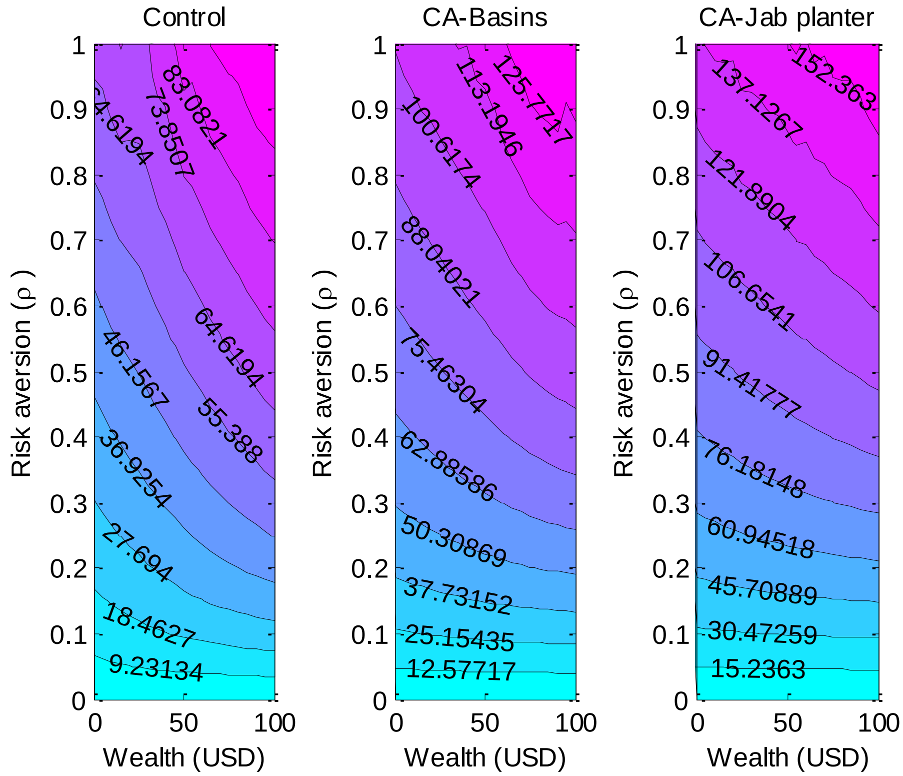

Figure 5. Sensitivity analysis of the risk premium associated with conventional ("control") and the conservation agriculture basing and jab planter planting methods. Data is from on-farm trials (N = 631) conducted in Mozambique (2008 – 2011) comparing the practices. Risk premium were calculated assuming a power utility function exhibiting constant relative risk aversion.

Table 1. Partial budget analysis comparing conventional, no-till, and basin maize planting

Plating/tillage practice	Break even yield (ha)	Labor cost as % of total cost
Basins ("likoti')		
Handweed and hired labor herbicide plus handweed	2.32	62
Hired labor	2.76	71
Family labor	0.8	0
Conventional		
Tractor + Animal hired labor	2.57	48
Animal + hired labor	2.33	60
Animal + family labor	0.93	0
Maize planted with no till planter		
Hired labor herbicide + hand weeding	2.11	48

Source: Eash et al., 2011.

Table 2. Maize yield response to N, P, K, and plant populating density under basin ("likoti") conservation agriculture method

	Nitrogen	Phosphorous	Potassium	Population
R^2	0.02	0.19	0.06	0.78
Constant (a)	10874	9639	11003	0
Linear	-11.1374	34.167	12.798	0.497
Quadratic		-0.103	-285.63	-4.00E-06
Square root	182.4886			
Cost/unit (b)	21	4.73	7.52	0.0075
Maize price (c)	2	2	2	2
BOR (d)	67.12	166.22	0.02	62,122
EOR (e)	17.78	154.71	0.02	60,184

Notes:

a. Restricted to be > 0 for population model.
b. Rand/kg or Rand/seed
c. Rand/kg
d. Biologically optimal rate; kg or seed ha^{-1}.
e. Economically optimal rate; kg or seed ha^{-1}.

Table 3. Summary statistics for on-farm trial net returns ($ ha^{-1}) for conventional planting, basin planting, and jab planting for maize; Mozambique, 2008 -2011 (N = 631 for each method).

Method	Mean	Std Dev	CV	Skewness	Minimum
Control	41.56	469.78	1,130.31	0.94	-659.02
Basin	136.25	496.75	364.57	0.87	-626.95
Jab planter	182.86	512.58	280.31	0.67	-608.44

-------Kolmogorov – Smirnoff Tests, H_0: the distribution are not different-------
[D statistic (p-value)]

	Basin	Jab planter
Control	0.1014 (0.0027)	0.1347 (0.0000)
Basin		0.0602 (0.1962)