CONSTRAINTS TO ADOPTION OF CONSERVATION AGRICULTURE IN THE ANGONIA HIGHLANDS OF MOZAMBIQUE: PERSPECTIVES FROM SMALLHOLDER HAND-HOE FARMERS

By:

Philip Paul Grabowski

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ABSTRACT

CONSTRAINTS TO ADOPTION OF CONSERVATION AGRICULTURE IN THE ANGONIA HIGHLANDS OF MOZAMBIQUE: PERSPECTIVES FROM SMALLHOLDER HAND-HOE FARMERS

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Conservation agriculture (CA) is a set of practices widely promoted to increase productivity while conserving soil through reduced tillage, mulching and crop rotation. I explore the constraints to CA adoption through in-depth interviews with 18 CA farmers, four dis-adopters and 11 non-adopters in one community where two NGOs have been promoting CA. One NGO promotes the basin method with compost production while the other promotes direct seeding with herbicide use. Though the farmers described many benefits in using CA there was little sign of adoption beyond the plots where NGOs provided inputs.

Most farmers were adamant that CA could perform better than conventional agriculture only if they applied fertilizer (or large quantities of compost). This constraint can be explained by the nutrient immobilizing effect caused by both reduced tillage and the retention of mulch. With planting basins, adoption is also constrained by increased labor requirements for land preparation, compost production and weeding. The high input to output price ratio causes CA practices to be unprofitable except on small plots for farmers who have a low opportunity cost of household labor. These findings suggest that CA can improve maize yields but capital and labor constraints limit adoption to small plots in the absence of NGO-provided inputs. Given the current ranges of prices for grain and inputs CA will not be adopted at a large scale in Angonia. Nevertheless, the small CA plots can serve the purpose of reliably providing farmers with high yields where constraints are lowest.

DEDICATIONS

I would like to dedicate this work to the smallholder farmers in southern Africa. I am inspired by their courage and ingenuity in the face of tremendous challenges. I have been humbled by the hospitality and love they have shown me and my family as we have sought to work with them towards a brighter future. I would also like to thank God for the abundant blessings I have experienced through this work and throughout my life.

"You care for the land and water it;
you enrich it abundantly.
The streams of God are filled with water
to provide the people with grain,
for so you have ordained it.
You drench its furrows and level its ridges;
you soften it with showers and bless its crops.
You crown the year with your bounty,
and your carts overflow with abundance.
The grasslands of the desert overflow;
the hills are clothed with gladness.
The meadows are covered with flocks
and the valleys are mantled with grain;
They shout for joy and sing."

Psalm 65:9-13 New International Version

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1. Introduction

The goal of increasing agricultural productivity has gained renewed emphasis in developing countries since the 2007/08 food crisis. Africa lags behind compared with global agricultural productivity (Todaro and Smith, 2009) and there is long standing food insecurity across the continent (World Bank, 2008). The World Health Organization defines food security as “when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life” (World Health Organization, 2009).

Rural food insecurity is a key element of poverty throughout Africa and Mozambique is no exception. In a recent news article the deputy minister of agriculture said that according to the latest survey results 37% of Mozambican households experience hunger at some point throughout the year (Mozambique News Agency, 2011). Smallholder agriculture is the livelihood strategy of 98% of rural people with 79% of households producing maize as a staple food (Bias & Donovan, 2003). The average smallholder cultivates 1.2 ha using only hand tools and very few modern inputs (Hanlon & Smart, 2008).

Where most people are smallholder farmers, increasing agricultural productivity is a key strategy for achieving food security. Though Africa previously produced enough to meet its own food needs, the population has grown at a faster rate than the agricultural productivity over the last 100 years (Todaro & Smith, 2009). Increased rural population density has caused there to be less land available for shifting cultivation, and increased urban demand for food has created a need for intensifying the traditional farming systems (Todaro & Smith, 2009). Many government and market failures reduce farmers’ incentives to intensify their agriculture (for examples related to fertilizer use see Morris, Kelly, Kopicki, & Byerlee, 2007). Innovative farmers tend to have greater access to land, labor and capital (Tripp, 2006) so the barriers to resource accumulation through markets are also barriers to innovation.

Conservation agriculture (CA) is being promoted as a solution to increase agricultural productivity and food security while at the same time preventing erosion and maximizing the ecological functions of the soil (Hobbs, 2007). CA is a package of technologies that includes minimum tillage, mulching and crop rotation (IIRR & ACT, 2005). CA has potential to reduce labor needs for land preparation and improve soil fertility while also reducing water stress in crops (IIRR & ACT, 2005), which is critically important as southern Africa braces for the hotter and drier weather predicted by climate change models (Lobell *et al.,* 2008).

Governments, UN agencies, corporations and NGOs in sub-Saharan Africa are trying to convince farmers to adopt CA to improve their production and conserve soil and water (FAO, 2001; Giller, Witter, Corbeels, & Tittonell, 2009; Haggblade & Tembo, 2003; Ito, Matsumoto, & Quinones, 2007). Despite these efforts, adoption levels are low in southern Africa with less than 1% of arable land under CA (Hove, Kadzere, Sims, Ager, & Mulila-Miti, 2011). Even in Zambia, with the highest levels of adoption, most farmers use only certain components of CA on parts of their farm (Baudron, Mwanza, Triomphe, & Bwalya, 2007). In addition, the level of sustained change is doubtful where fertilizer and hybrid seed were used as incentives for initial adoption (Giller *et al*., 2009). Nevertheless, some believe that CA in southern Africa is at “an advanced stage of early adoption” and needs a coordinated approach and harmonized policy so that it can “really take off” (Friedrich & Kassam, 2011, p.1).

Researchers from the Mozambican Institute for Agricultural Research (IIAM) have identified CA as a technology that needs to be understood better in the various agro-ecological zones in Mozambique, especially in light of climate change dynamics. Through USAID funding, Michigan State University researchers are supporting IIAM's Center for Socio-Economic Studies (CESE), with two main goals: 1) to expand the availability of appropriate crop, livestock and natural-resource management technologies for smallholder farmers, and 2) to accelerate the uptake of those technologies by strengthening policy institutions and market information services (AFRE, 2010).

This research contributes to these goals by exploring the constraints to CA adoption in the Angonia highlands of Mozambique. The study seeks to support IIAM's work by analyzing the CA technology from the perspective of smallholders and generating hypotheses about the constraints limiting wide-scale adoption. I use a qualitative approach in one community to obtain an in-depth answer to the primary research question: Why are farmers not adopting conservation agriculture? The hypotheses I generate inform policy decisions about CA promotion and future quantitative studies about the constraints to adoption.

1.1. Conceptual framework

Farmers face a variety of decisions about what crops to grow, what inputs to use, and how much of each input to use on different parts of their land in order to fulfill their farming objectives. The field of agricultural economics provides a theoretical basis for understanding farmer decision making. One might think that because relatively few of the farmers' decisions involve monetary transactions economics might not be the best fit for analyzing developing country smallholder agriculture. While the other social sciences such as sociology and anthropology have much to offer, economics is particularly suited to analyzing rational resource allocation choices, regardless of whether cash is involved or not.

Economics assumes that farmers are rational and will seek to maximize their own well-being through their choices about crops and inputs given the land they have, the labor they can employ and the capital they can access. Their attitude about risk is also an important factor in their decision-making: how much are they willing to gamble with a failed harvest? All of these factors vary by individual, though general trends may exist which can be useful for policy makers and development practitioners interested in improving smallholder productivity.

The effective application of economic theory to smallholder agriculture in developing countries requires intimate familiarity with farmers' reality. It was often thought that poor smallholder farmers do not respond to price changes related to their crops. This conclusion was based on the lack of observed correlation between what farmers grow and the market prices but it ignored the transaction costs farmers face in getting their harvest to market (de Janvry, Fafchamps, & Sadoulet, 1991). Once the correct "shadow prices"[1] were used to reflect the actual price for the farmer then the rational allocation of land to different crops became clear.

Determining the shadow price of labor can be quite complicated but the key principle is to consider the opportunity cost by comparing how labor is used in the situation being analyzed and its next best alternative use (Gittinger, 1982). Gittinger (1982) emphasizes that economic analysts should have an intimate familiarity with the small farm as a family unit and as a business firm. Recent research has highlighted the key role of non-farm income for the majority of the world's smallholder farmers (Haggblade, Hazell, & Reardon, 2007) and for the labor bottlenecks that occur at peak times in the agricultural season.

There is a large body of literature in agricultural economics which analyzes agricultural technology adoption, mostly focusing on the use of modern inputs by smallholder farmers in

[1] An explanation of shadow prices provided by Boardman, Greenberg, Vining and Weimer (2006) is as follows: "When observed prices fail to reflect the social value of a good accurately or observed prices do not exist, an approach called *shadow pricing* is often used to measure benefits and costs. That is, analysts adjust observed prices or assign values when appropriate observed prices do not exist, thereby finding "in the shadows" needed values that are not readily observable." (p.75)

developing countries. Feder, Just, and Zilberman (1985) defined adoption as "the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential" (p.256). New technologies are constantly arising and, as Feder *et al.* recognized, equilibrium may never actually be achieved. Nevertheless, this definition of adoption is helpful in quantifying adoption, which permits statistical regressions with explanatory variables.

In the literature there is a wide range of variables that could reasonably be assumed to correlate with levels of adoption. In a review of empirical studies, Feder *et al.* (1985) listed farm size, risk, human capital, labor availability, credit constraints, land tenure, and input supply constraints as key variables influencing adoption. A thorough understanding of how these variables impact levels of adoption can help inform projects and policies aimed at promoting increased productivity. For example, if access to credit is the key constraint then development agencies can explore linking farmers with commercial credit providers, organizing farmers into savings and loan groups or even directly setting up a credit component of the project.

Focusing on the characteristics of the technology, Byerlee (1986) hypothesizes that adoption of a technology depends on its profitability, riskiness, divisibility, complexity and the availability of inputs. Profitability is simply the value of the outputs less the costs of the inputs. Risk includes climate risk, price risk, investment risk, etc. Divisibility refers to the initial capital requirements per unit of investment (i.e. the difference between purchasing a tractor for one large sum or purchasing fertilizer in small increments). Complexity refers to the change in management required; high complexity may require substantial training. Availability of inputs is a critical issue with any new technology, especially those that require specialized machinery or chemicals that were not previously used. Understanding what aspect of the technology is preventing adoption can allow adaptation of the technology (for example to make it less risky), adjustment of policies (for example reducing a tariff on an import to increase its supply), or even choosing a new technology with more favorable attributes.

Agricultural technologies can be complicated to evaluate because multiple changes may be required simultaneously in order to use the new technology. For example hybrid seeds perform best under higher levels of fertilizer than conventional varieties. At what fertilizer level should the yield benefit be compared with conventional varieties? Changes in technology can be evaluated using Binswanger's concept (1978) of comparing the costs of production when the old and new techniques operate at their optimum input levels. One implication of this definition is that a technology never inherently saves on any one factor of production (for example labor-saving) because when it is transferred from one context to another it must be compared with the conventional technique being used in that location.

The induced innovation model (Ruttan, 1998) suggests that successful technologies are those that use the primary factors of production (land, labor and capital) that are most abundant while saving on those that are most scarce. This model helps explain why extensive agriculture technologies (large tractors) suitable for areas with abundant land are used in the U.S., Canada and Australia while intensive agriculture technologies (growing melons up a trellis and supporting the fruit with a hammock) are used in Japan and Taiwan. In any particular location, variation in adoption levels may be explained by variation in the relative scarcities of these factors of production.

However, simply finding technologies that use the resources that farmers have most in abundance will not necessarily lead to adoption. In Fujisaka's article (1994) about reasons why farmers do not adopt seemingly beneficial soil conservation measures, he emphasizes understanding adoption from the farmer's perspective. This includes understanding their priorities, the alternatives available to them in addressing the same problem and the indirect consequences of the technology. For example, Kerr and Sanghi (1992) found that in India farmers did not choose soil conservation technologies simply based on how much soil could be conserved. The recommended practice of contour ridges across plot boundaries interfered with several aspects of local farming strategies, including farmers' ability to use soil conservation structures as boundary markers and places for growing fodder (Kerr & Sanghi, 1992). A thorough understanding of the farmers' perspectives is critical for evaluating any technology.

When a technology is spreading slowly, before discarding it as unsuitable it is worth questioning if it is simply in the early stages of adoption. It is often the case that it takes time for information to be shared and small adaptations to be made in the promotion strategy before rapid uptake of a new technology. Diffusion is the term used for the aggregation of adoption in a region over time. The S-shaped diffusion curve that Griliches (1957) developed is a common technology diffusion pattern. A slow gradual adoption process (by the early adopters) is followed by a rapid increase in adoption (by the majority) followed by a final period of slow adoption (by the late adopters). The factors influencing the specific shape of the diffusion pattern may vary by context but are generally related to the process of learning and information sharing (Feder *et al.,* 1985).

Levels and reasons for disadoption can provide clues to help distinguish between the early stages of adoption and a truly unsuitable technology. Moser and Barrett (2003) state that "failure to take disadoption seriously signals the implicit assumption that new technologies are unambiguously superior" (p.1090). Their study of Sustainable Rice Intensification (SRI) in Madagascar focused on the characteristics and perspectives of disadopters, non-adopters and adopters of SRI to understand barriers to initial adoption and features of the technology that were not appealing to farmers. Unfortunately, those who have spent their careers developing a technology or have developed what seems like an attractive plan to donors may resist critical analysis of the suitability of a technology and instead hide behind the claim that it is just a matter of time before it takes off.

If interventions are promoted as blanket solutions across a diversity of contexts, variable levels of adoption may be observed. Heterogeneity in farming systems, social norms, property rights and the costs of different factors of production may result in different costs and benefits for individual smallholders. In providing recommendations for agricultural projects carrying out farm investment analysis, Gittinger (1982) suggests that a separate farm level budget needs to be prepared for different farm types based on major groupings of soil and water conditions, size of holdings and cropping patterns. Easterly (2008) criticizes the promotion of comprehensive approaches by the group he labels as "planners" who "apply global blueprints…think they already know the answers … and determine what to supply" (p.1). He argues that improvements to African agriculture require more "searchers" who "find things that work,…find out the reality at the bottom… and find out what is in demand." (p.1)

This theoretical background about agricultural technology adoption provides a framework for analyzing the apparently slow spread of conservation agriculture in southern Africa. Specifically conservation agriculture should be compared with the conventional system used in each context with particular attention to the changes in costs and benefits experienced by different types of farmers. A qualitative approach allows for an open exploration of how the heterogeneity of smallholders may affect adoption.

1.2. Defining CA in this context

In assessing the adoption of any technology it is critically important to be specific about the technology and its alternative. Conservation agriculture is not actually a technology *per se* but a set of principles that have been incorporated into a diverse range of technologies from mechanized agriculture to hand-hoe land preparation. On one extreme of CA technologies is the traditional swidden (slash and burn) agriculture once common in many parts of the tropics where natural vegetation is cleared, crops are sown with little soil disturbance and "rotation" is achieved through long term fallows. On the other extreme, CA for mechanized agriculture in North and South America and Australia has led to adaptations in equipment allowing the injection of seeds into undisturbed soil and weed control through chemical herbicides. The prevalence of these different forms relate to the relative abundance of the factors of production (land, labor and capital). Swidden agriculture is only found in areas with abundant land but relatively low labor and capital. Mechanized CA has been adopted in places where there is abundant land and capital but labor is constrained.

Nearly the entire range of CA technologies can be found in southern Africa. Mechanized CA is used in parts of South Africa, Zimbabwe and Zambia among large-holder commercial farmers. Animal traction CA is used in parts of Zimbabwe and Zambia where there is a tradition of cattle ownership and plowing with oxen. In many other areas where manual land preparation is prevalent CA takes the form of planting basins and direct seeding with a jab-planter or dibble stick. Much of the literature from Zimbabwe and the southern province of Zambia combines the analysis of CA with animal traction and CA with hand-hoe basins though the costs and benefits are different (Haggblade & Tembo, 2003). Usually both forms of CA are compared with plowing done by animal traction since that is the most common form of conventional land preparation in those contexts.

This paper focuses on two different forms of manual CA land preparation for maize production: basins and direct seeding. Both of these CA methods are being promoted by NGOs with smallholder farmers on small plots. CA can be used on many other crops (cotton, sorghum and millet are grown with CA in the region) but maize is the staple food in most of the region and is therefore the focus of many CA projects. Both of the NGOs promoting CA in Angonia include mulching as a key component but neither promotes crop rotation or intercropping with CA. These forms of CA are being compared with intercropped ridges prepared by hand-hoe, which is the traditional agricultural system for maize in this part of Mozambique, much of Malawi and eastern Zambia.

The basin planting method was developed by Brian Oldreive in Zimbabwe and adapted for widespread promotion in Zambia by the Conservation Farming Unit (CFU) (Baudron *et al*., 2007). In theory a permanent grid of basins is established with precise measurements which allows for easy calculation of required inputs. In addition, the permanent basins allow for improving the soil in small pockets rather than improving the soil of the entire field. The basins are generally 15cm deep and 15cm long and the width of a hoe-blade. The basins are then filled with compost or animal manure if available. Shallower basins may be used if only fertilizer is being applied. Generally two or three maize plants are allowed to grow per basin depending on the space between basins. The exact spacing between basins can be adapted depending on the crops a farmer plans to use and the desired plant population (usually based on the fertilizer application rate and the expected amount of rainfall). However, once the basins are established, adapting the spacing requires additional work in measuring as well as losing any benefits from improving the soil in the old basins. Often NGOs promote a specific spacing and even provide farmers with "teren ropes" that have knots or bottle caps indicating where each basin should be dug (Baudron *et al*., 2007).

The direct seeding method is being researched by CIMMYT in southern Africa and promoted by NGOs as well. The maize seeds are planted individually and close together within the row much as would be done by a mechanical planter (for example 15cm between plants and 70cm between rows). The lines are carefully measured but this is done rather easily with any string or rope. There is no preparation of the seed bed; instead the planting is accomplished through a dibble stick, jab-planter or one shallow cut of the hoe. Compared to the basins this method allows much less disturbance of soil but it offers no opportunity for the addition of organic matter to improve the soil.

The most common farming system for maize in this part of Mozambique, most of Malawi and eastern Zambia is that of intercropped ridges. In this method farmers prepare for the next season by either burning the residues or laying them down in the troughs between ridges, which are generally around 1 meter apart (Chigowo, 2011). A hoe is then used to split the old ridge and cover any remaining residues so that a new ridge is formed where the trough once was (for photos illustrating this technique see Aagard, 2009). When this ridge-splitting is done in the dry season the new ridges may be mostly large clods (depending on the soil type) and further work may be needed to form the ridge once the rains soften the soil. Cow manure or compost can be applied by putting it in the trough before splitting the ridge or by the handful at the planting stations. Maize is usually planted in clusters of about five plants approximately a meter apart with one or two legume stations between the maize clusters. A variety of other non-leguminous crops may also be intercropped with the maize in a variety of configurations. Commonly the ridges are added to through "banking" part way through the agricultural season. In order to bank the ridge farmers go through the rows using their hoe to cut under the weeds growing in the troughs and inverting them onto the ridge so that the weeds become buried. The banking is also done to prevent lodging of the maize due to wind.

Conventional agriculture in Mozambique is contributing to land degradation through erosion and nutrient mining caused by the intensive cultivation of the soil without fertilizer application (Famba, 2010). This is especially acute in areas with sloping land and high amounts of rainfall which have the highest erosion levels in Mozambique (Folmer, Geurts & Francisco, 1998). As soils become degraded smallholder farmers face yield reductions and decreased welfare unless they are able to compensate with non-agricultural activities. Technological changes in agricultural practices can prevent land degradation by reducing erosion and nutrient mining.

1.2.1. Benefits of CA

Conservation agriculture is thought to provide many benefits compared to the ridged farming system including reduced erosion. One of the most notable differences with CA is that there is little or no time spent on the physically demanding tasks of ridging and banking (Chigowo, 2011). Though basin making may be less physically demanding it may not be any faster because of the need to measure and align the grid of permanent basins (see reduced tillage constraints below). In addition, reduced tillage under certain soil conditions can improve the biological and physical properties of the soil, eventually resulting in increased production. Mulching provides further soil improvements as well as maintaining moisture by providing a cover for the bare soil. Rotations can help improve the soil and reduce crop diseases. See Table 1 for a summary of the positive and negative effects of CA.

Benefits from reduced tillage

CA has spread spontaneously among cotton farmers in the lower rainfall areas of Zambia because of the ability to plant with the first rains (Haggblade & Tembo, 2003). CA provides this advantage in places where farmers feel that the soil is too hard to make ridges until it is softened by the first rains. The long growing season requirement of cotton means farmers in drier regions with shorter seasons can experience significant yield losses from late planting. A further advantage of CA in this context (where most farmers use oxen to plow after the rains start) is that basin making can be done slowly throughout the dry season, thereby reducing labor during the labor bottleneck at planting. CA was shown to increase farmers' crop income in Zambia's cotton belt through both higher yields and the cultivation of larger fields. This result was true even for the poorest households though the magnitude of the income increase was greater for wealthier households who could afford chemical inputs (Haggblade, Kabwe, & Plerhoples, 2011).

Reduced tillage can improve soil in several ways. Under certain soil conditions, ridged agriculture that involves regularly hoeing to the same depth over several years may result in a hard pan or compacted layer of soil. A hard pan makes it difficult for water to penetrate beyond the top layer of soil, which can result in water logging and excess runoff. The basin method of CA can allow for punching through the compacted layer at each basin thereby allowing greater water infiltration (Baudron *et al*., 2007). Ridges of tilled soil have more surface area and dry out faster than undisturbed soil. On-station research with CA in southern Africa over a number of years indicates that CA can improve moisture retention and increase crop resilience to dry spells (Nyagumbo, Thierfelder, & Cheesman, 2011). Minimum soil disturbance prevents soil erosion, though on steep slopes contour bunds may be needed as well in order to slow down runoff (Giller *et al.,* 2009). The loose soil on ridges is prone to erosion and when unusually large quantities of rain fall in a short time, entire ridges may be washed away (Aagard, 2009).

Reduced tillage can prevent or slow down the loss of soil organic matter (SOM), a process which is accelerated by oxidizing the soil when it is tilled. SOM is a key component of soil fertility that affects the soil's ability to absorb water, store nutrients and sustain a diverse community of microorganisms. Soils with too little SOM are unresponsive to fertilizer applications (Marenya & Barrett, 2009). Reduced tillage can improve the effectiveness of fertilizer use both by increasing soil organic matter and by reducing the erosion of the fertilizer. Reduced SOM loss from minimum tillage is more significant on heavier clay soils (Chivenge, Murirwa, Giller, Mapfumo, & Six, 2007). Sandy soils do not provide a structure for stable SOM regardless of tillage system, so they require regular inputs of organic matter to maintain SOM levels (Chivenge *et al.,* 2007). Soil samples from within basins in Zimbabwe show a trend of increased soil organic carbon concentration (closely related to SOM) with longer CA use in some regions, though overall soil qualities were not statistically different between CA plots and non-CA plots (Nyamangara & Masvaya, 2011).

Benefits from mulch

Maintaining a thick layer of mulch can be beneficial in conserving soil moisture, reducing erosion and increasing soil organic matter (Locke & Bryson, 1997). When residues are burned nutrients are lost, soil microorganisms are destroyed and the loss of biomass means less SOM is added to the soil. Maintaining the residues on top of the soil and/or adding a layer of mulch to cover the soil can reduce erosion by reducing the impact of the rain on the soil and slowing down runoff across the field. The mulch also conserves moisture by absorbing water and protecting the soil from direct exposure to sunlight. Mulch is also beneficial in preventing weed growth either by physically preventing weed emergence or by blocking direct sunlight that some weed seeds require for germination.

Benefits from rotation

Crop rotation can improve soil nutrient management and reduce the prevalence of crop pests and diseases. Rotation with a legume can result in some increase in nitrogen from the nitrogen-fixing bacteria present in the legume's root nodules. Similar benefits can be gained by combining agroforestry practices using leguminous trees or shrubs with CA (Akinnifesi, Sileshi, Ajayi, & Beedy, 2011). Intercropping with legumes is another option that may help soil nutrient management. Even rotations with non-legumes can result in relative yield increases, possibly because of increased water infiltration caused by higher levels of soil organisms such as earthworms (Thierfelder & Cheesman, 2011).

When benefits occur

While some of these benefits from CA are immediate many of them do not occur until the system has been used for many years. This may make adoption difficult for risk-averse farmers with short planning horizons, especially if there are short term costs (such as yield penalties) in obtaining the long term benefits. Some conservation agriculture case studies suggest evidence of a gradual intensification of adoption (in both area and number of components) over time by some smallholder farmers in Zambia and Zimbabwe (Haggblade & Tembo, 2003; Mazvimavi & Twomlow, 2009).

1.2.2. Constraints to adoption of hand-hoe CA technologies

The components of CA are complementary in that under certain conditions the benefits increase dramatically if more components are used (Gama & Thierfelder, 2011). This explains why it is usually promoted as a package. In southern Africa however, free range cattle make it challenging to maintain permanent soil cover through a layer of mulch (Aagard, 2009). Furthermore, rotating every third year with a legume is constrained by low prices for legumes (Haggblade & Tembo, 2003). In most cases less than half of the farmers using CA are implementing all three principles (Baudron *et al.,* 2007; Mutsindikwa, Dumba, Munguri, &

Mvumi, 2011). Perhaps because of these challenges most organizations promoting CA emphasize minimum soil disturbance (Baudron *et al.,* 2007) and accept that many will not be able to follow the other two principles. The lack of rotation and the lack of additional fertility gained from permanent mulch cover theoretically increase the need for fertilizer in order for CA to achieve high yields.

Fertilizer constraints

Organizations promoting CA often promote the technology with subsidized or free chemical inputs (especially fertilizer and herbicides) so that farmers give the technology a try. This has led to confusion about what benefits come from the inputs and what benefits come from the CA principles (Giller *et al.*, 2009). The promotion of CA with cheap or free inputs also complicates adoption studies since adoption may not continue once the inputs are no longer provided.

CA with higher levels of fertilizer than conventional maize production has the potential to raise yields, (Ito *et al*., 2007) but cash constraints are a barrier to widespread fertilizer use (regardless of tillage method). Most farmers in Mozambique grow maize without fertilizer (Bias & Donovan, 2003). The benefits from fertilizer use depend on soil conditions (see above). Fertilizer use in Africa is generally low because of both demand side and supply side factors. Demand is often weak because of "the low-levels and high variability of crop yields on the one hand and the high level of fertilizer prices relative to crop prices on the other." (Morris *et al.,* 2007, p.5). The supply side is constrained by the high transportation costs and excessive regulations for businesses (Morris *et al*., 2007). These issues have caused corporations for tobacco and cotton production to set up contract farming schemes in southern Africa where smallholder farmers get fertilizer directly from the company on loan, which is automatically deducted from their payment when they bring their harvest for sale.

Reduced tillage constraints

Without fertilizer minimum tillage may lead to nutrient immobility causing farmers to experience reduced yields (Giller *et al*., 2009). The decomposition of crop residues, which have high carbon to nitrogen ratios, can lead to short term nitrogen immobilization because of increased biological activity by organisms that lock up nitrogen in their bodies (Verhulst *et al*., 2010). Tilling allows the incorporation of the residues, which speeds up the decomposition process, which allows the nutrients to be available to plants for the next cropping season. Leaving the crop residues on top of the soil slows the decomposition rate and may lead to short-term losses in nitrogen availability (Verhulst *et al.,* 2010). Over the long term greater nutrient availability may be achieved if SOM content increases.

Baudron *et al.* (2007) reported that perceived increased labor costs in the first years were a major disincentive for CA adoption in Zambia. Minimum tillage may require additional labor for land preparation and weeding though under certain conditions these may decrease after the first two or three seasons (Haggblade & Tembo, 2003). It is unclear from the literature whether basins require more or less time for land preparation than conventional ridge splitting. One estimate suggests that farmers need 320 hours per hectare of dry season land preparation to dig basins (Baudron *et al*., 2007). The CFU in Zambia recognizes that it may take that long the first year but asserts that with time farmers can learn to efficiently dig the basins in 180 hours (Aagard, 2009) or even 138 hours (Nkatiko, 2011). Though most of these studies are based on farmer recall, one study in Zimbabwe actually observed the labor required for CA with a sample of 38 farmers and found that basin digging requires 25 days per hectare or 200 hours (Tshuma, Mazvimavi, Murendo, Kunzekweguta, & Mutsvangwa*,* 2011).

The amount of labor required for land preparation with ridges in Malawi was estimated to be 79 days per hectare or 632 hours (Takane, 2008), though this includes time spent clearing or knocking down residues which CA farmers would also need to do but was not considered in the basin digging measurements above. In contrast to this high estimate the CFU estimates ridge-splitting would require 184 hours per hectare while overall digging (for example for potatoes) requires 450 hours per hectare (Aagard, 2009; Nkatiko, 2011), though no sample size is given for these estimates.

Theoretically the labor for basin making can be spread throughout the dry season but this option may not be attractive where farmers practice irrigation, migrate for work or prioritize cultural events after harvest. Furthermore, in Zambia there were complaints about livestock ruining the basins between digging and planting (Baudron *et al.*, 2007), requiring additional digging shortly before the rains. With conventional tillage, on the other hand, residues become buried supposedly decreasing livestock time spent on ridged plots.

One of the primary motivations for tillage is weed control (Wall, 2007); reduced tillage greatly increases weed pressure (Baudron *et al.,* 2007). Zambia's conservation farming unit recommends six weedings in order to manage the increased weed pressure but farmers rarely achieve this (Baudron *et al.,* 2007). CA plots in Zimbabwe showed greater weed density than tilled plots early in the season (Mavunganidze & Madakadze, 2011) though another study found no difference in weed biomass between CA and tilled plots at the end of the season (Mashingaidze *et al.,* 2011). Increased labor for weed control with CA has been recognized as a constraint that can be overcome with herbicides (Baudron *et al*., 2007). Minimum tillage without herbicides faces the challenge of controlling perennial weeds (Vogel, 1995) because of the need to remove their deep roots.

In addition, reduced tillage can lead to soil and water management problems. The same properties of minimum tillage that increase infiltration and reduce water loss can lead to water logging in wetter areas or in dry areas that experience high rainfall events. When direct seeding is used on heavy soils germination may be impaired because of the hardness and density of the soil around the seed. Sandy soils may be more likely to become compacted which leads to increased runoff and decreased infiltration (Giller *et al.*, 2009).

Mulch constraints

The challenge of maintaining mulch is mostly caused by conflicts with livestock (Baudron *et al.,* 2007; Nyathi *et al.,* 2011). Most of the regions where manual land preparation through ridge splitting is common have a mixed crop-livestock system with free range livestock able to graze on crop residues, which become a communal resource after harvest (Baudron *et al.*, 2007). Competition for crop residue prevented full adoption in case studies in Tanzania (Shetto & Owenya, 2007). Cattle ownership is usually concentrated in the higher income groups who benefit from these existing cultural norms and few development agencies even attempt to change this property rights regime (Baudron *et al*., 2007). In addition, investments in maintaining crop residue (including the cost of foregoing other uses) may be lost because of uncontrolled fires. Mulching may also lead to an increase in crop pests, especially termites (Nyathi *et al.,* 2011). Furthermore, maintaining mulch may lock up nitrogen (see above), requiring increased fertilization in the short term (IIRR & ACT, 2005).

Rotation constraints

The key challenges for crop rotation are the lack of a reliable markets for many leguminous crops and the shortage of improved legume seeds (Baudron *et al.*, 2007; Haggblade & Tembo, 2003). One analysis of the gross margin earned by different combinations of rotating maize, cotton, and sunhemp showed that the greatest profits were earned from growing maize only (Thierfelder & Cheesman, 2011) despite yield increases from rotation. Much of the experimentation with rotations has been done on experiment stations and there is little evidence of fertility benefits in on-farm trials (Snapp, Rohrbach, Simtowe, & Freeman, 2002). Intercropping with pigeon peas may have potential but one study in central Mozambique shows that this practice results in increased weeding time and has the risk of losing the pigeon pea harvest due to free range cattle after the maize harvest is complete (Rusinamhodzi *et al*., 2011). Farmers are also hesitant to plant legumes in the permanent planting basins because of the spacing (Baudron *et al.*, 2007). The grid of planting stations is usually set up for the conventional spacing for maize or cotton, which is different from the conventional practice of planting peanuts and soybeans very close to each other in a line.

Table 1: Positive and negative short and long term effects of the three components of conservation agriculture cited in the literature[1]

Short term positive effects	Minimum tillage	Mulch	Rotation	Conditions for this effect to occur
Facilitates early planting	X			Where conventional system does not prepare land until the rains have softened it and where a short rainy season limits yields
Reduced labor bottle neck at planting time	X			Where CA basins can be prepared throughout the dry season and where the conventional system does not
Reduced labor for land preparation	X			Where ripping is faster than plowing and where direct seeding is used
Increased soil water availability				Benefit only where water shortages frequently limit crop yields (see waterlogging below for the other side of this effect)
- reduced evaporation	X	X		Generally occurs
- reduced runoff		X		Minimum tillage increases runoff on "clay-poor structurally weak" soils (Giller *et al.*, 2009) but mulch may correct for this.
- increased infiltration	X	X	X	Minimum tillage decreases infiltration on "clay-poor structurally weak" soils (Giller *et al.*, 2009) though it could increase infiltration where a hard pan problem is corrected by basins or deep ripping.
Breaks through hard pan	X			Only where hard pan is a problem; requires deep basins, deep ripping or sub-soiling before using CA to have this benefit immediately. Or it is possible to wait several years for root systems to break up hard pan.
Reduced soil temperature oscillations		X		Generally occurs
Long term positive effects	**Minimum tillage**	**Mulch**	**Rotation**	**Conditions for this effect to occur**
Reduced erosion	X	X		On gently sloping fields or in combination with contour bunds or vegetation strips
Increased soil organic matter	X	X	X	Larger effect on clay soils; on sand it depends on what is added each year; effect occurs faster with basins using manure or compost

Table 1 (cont'd)

Increased N mineralization	X	X	X	Benefit where soil N is limited, which is very common
Increased soil aggregation (improved soil structure)	X	X	X	Generally occurs
Short term negative effects	**Minimum tillage**	**Mulch**	**Rotation**	**Conditions for this effect to occur**
Nitrogen immobilization	X			When soil N is limited and when residues with high C:N ratio are used, both of which are very common
Increased weed pressure	X			Under most conditions, magnitude depends on weed seed stock
Water logging	X			Higher rainfall areas or during high rainfall events in dry areas, more common with heavier soils
Poor germination	X			Heavy soils with direct planting
Stimulation of crop pests		X		Where termites and other insects that benefit from the mulch are already a problem
Occurrence of residue borne diseases		X		Depending on the conditions for each particular disease
Long Term negative effects	**Minimum tillage**	**Mulch**	**Rotation**	**Conditions for this effect to occur**
Increased soil compaction	X			Especially in sandy soils
Increased soil acidity in top layer	X			Not ubiquitous and unclear causation

[1]Sources: Baudron *et al.*, 2007; Haggblade & Tembo, 2003; Giller *et al.,* 2009; Verhulst *et al.*, 2010

1.3. Summary of potential benefits and constraints

Changes from ridged agriculture to CA may result in a variety of positive and negative effects that vary with the specific context. The specific combination of positive and negative effects in any given area will affect the yield difference and labor requirement differences between CA and conventional agriculture. The general attractiveness of CA to smallholder farmers, therefore, may be very context specific. Even in areas where CA is generally not beneficial there may be niches where the constraints are low and the benefits are adequate for farmers to use CA on a small scale. If the principles of CA are taught broadly and farmers innovate and adapt then it is more likely that they will be able to maximize the benefits and minimize the negative effects of CA using the resources most available to them.

2. Data and Methods

In this study I explored CA adoption through semi-structured interviews with CA farmers, dis-adopters and non-adopters. By gathering qualitative and quantitative data from farmers who are using CA on small plots I was able to explore the constraints to farm-wide adoption from the farmers' perspective. During the interviews I visited farmers' CA plots where I gathered labor data for every task in the last season based on farmer recall, measured field size with a GPS and obtained the farmer's estimate on the harvest. I developed partial budgets by using the labor, input and yield data in order to assess farmers' incentives for adoption of CA maize. Interviews with non-adopters and dis-adopters provided further detail on the constraints of CA adoption. I also interviewed agricultural professionals to check what I was learning from the farmers with the local technical experts. Some of these professionals were involved in CA projects and through the interviews I was able to understand how CA was being promoted in the region. All interviews were recorded and transcribed. Thematic analysis was used to process the text data.

2.1. Case description

The majority of data was collected from one community where two NGOs have been promoting CA for the past three years. By focusing on one community I was able to obtain a rich understanding of the farmers' perspectives by interviewing most participants in a similar context. The community makes an interesting study because two NGOs promoting very different CA technologies have been working there for several years with a reasonable number of participants in each program. The Angonia highlands are an interesting place to study CA because they are a highly productive zone of Mozambique. While CA practices are often used in more arid environments than the high rainfall Angonia highlands, this area does experience significant mid-season dry spells. Though farmers in this agroclimatic region may not need to conserve moisture as dramatically as other parts of the country they also may have fewer challenges to intensification because of the high agricultural potential.

2.1.1. Geographic setting

The Angonia highlands of Tete province Mozambique are a productive zone on the western border of Malawi with high rainfall (900-1200mm) and high population density. The altitude for this region is over 1000 meters with average temperatures between 18 and 24 degrees Celsius (Amane & Mlay, 2002). The most common soil types are Lixisols and Luvisols (see soil maps in Geurts, 1997; Amane & Mlay, 2002), both of which are considered decent soils for agriculture though possibly rather nutrient depleted (Geurts, 1997). Soil fertility is a key constraint to smallholder production in Mozambique in general (Bias, Donovan, 2003). A low population density means land is generally abundant in Mozambique but farmland is constrained in the most productive areas (Bias & Donovan, 2003) including in most of the study area of Angonia and Tsangano districts. The range of landholdings for smallholders in these areas varies roughly from five hectares down to one hectare.

2.1.2. Non-governmental organizations

In the Angonia highlands the Igreja Reformada em Moçambique (IRM) is a NGO promoting CA with basins and compost (Table 2). IRM has been promoting CA in Tete province for four years and in 2009 it had 1307 farmers using some form of CA in 12 catchment areas. Total Land Care (TLC) is a NGO promoting CA with direct seeding, herbicides and fertilizers (Table 2). TLC has 248 farmers participating in 30 communities in its CA program in Angonia, Tsangano and Macanga districts, which have been growing steadily over the past three years.

Table 2: Details of CA as promoted by two NGOs

Organization	IRM[1]	TLC[2]	
Plot size	.04 ha (20mX20m)	0.1 ha (50mX20m)	0.3 ha (50mX60m)
Planting method	Basins	Direct seeding	Direct Seeding
Plant spacing	2 plants/basin 60cm between basins and 75 cm between rows	1 plant every 25cm and 75cm between rows	1 plant every 25cm and 75cm between rows
Plant population	44,443 plants/ha	53,320 plants/ha	53,320 plants/ha
Fertilizer	6kg NPK, 6kg Urea 2 oxcarts of compost	25kg NPK 25kg Urea	50kg NPK 50kg Urea
Fertilizer application rate	.15 tons/ha of each	0.25 tons/ha of each	.167 tons/ha of each
Herbicide	None	0.5L Glyphosate, 0.5L Alachlor/Atrazine	1 L Glyphosate, 1 L Alachlor/Atrazine

[1]Igreja Reformada em Moçambique
[2]Total Land Care (TLC) provides different farmers with two different levels of inputs for different plot sizes depending on which project is funding their participation in CA production.

2.2. Overview of the study design

The research presented here is a case study focused on one community using qualitative interview data and quantitative partial budget data in order to obtain an in-depth analysis of the constraints to CA adoption by smallholder farmers. This section provides background for the qualitative research methodology that may be less familiar to many of the readers than survey based research methodology or agronomic experimental methodology.

The term "qualitative research" can refer to a variety of different research types which differ from quantitative research in that they depend less on numbers, categories and/or statistical analysis. In this paper I use the term "qualitative research" to refer to text data analyzed qualitatively using thematic analysis (see below). While quantitative data is used in this study for an in-depth understanding of farmers' incentives for CA adoption, that data was gathered during the qualitative interviews which do not arise from a random sample.

Qualitative methods differ from survey-based statistical analysis in that they are less structured, allow for iterative interactions with participants and do not rely on random sampling (Chung, 2000). Frequently semi-structured interviews are used in qualitative studies to provide a framework for interacting with research participants and categorizing their responses while still being easily adapted mid-course in order to include new categories or refine previously defined categories (see Rubin and Rubin, 2005, Ch.6 for an overview of qualitative interviewing). Iterative interactions with research participants enable the researcher to check back with earlier participants in order to gain their perspective on concepts or relationships that were only seen to be important after their first contact or to clarify their responses in light of what was learned from other interviews.

While quantitative research is usually associated with positivist or post-positivist epistemologies, qualitative approaches are often promoted by those with constructivist and critical theory epistemological perspectives (Guba & Lincoln, 1994). In reflecting on my own epistemological assumptions I seem to hover between post-positivism and constructivism. I think that this tension comes from my ontological assumptions that there exists one "true" reality but that reality is only partially comprehensible by humans because we are inherently biased by our socially constructed perspectives. Qualitative research allows for carefully discerning a complex reality by intentionally recognizing one's own bias and explicitly aiming to understand the perspectives of research participants, including their categorization and explanation of the phenomenon.

Much of the debate between proponents of qualitative and quantitative research methods have been around these epistemological and ontological issues. However the either/or dichotomy ignores the complementarities between the two approaches (Chung, 2000).

Qualitative research and surveys are not mutually exclusive and, in fact, they are becoming increasingly popular together (Patton, 2002). Qualitative research can be instrumental before survey design to ensure that the right questions are asked in the right way in order to gather as much information as possible (Chung, 2000). Sometimes it might be desirable to include a few open-ended questions in a survey to be analyzed qualitatively to allow research participants more freedom to share their own perspectives (see the case of the Kalamazoo school system in Patton, 2002). In addition, qualitative research methods can be utilized after surveys have been analyzed in order to facilitate the interpretation of the results. For example, quantitative surveys in Thailand in the 1970s detected a dramatic change in average family size but provided little evidence about why this phenomenon occurred (Knodel, Havanon & Pramualratana, 1984). Knodel's qualitative research on the fertility transition in Thailand provided missing information about what motivated people to have smaller families thus facilitating the interpretation of the quantitative results (Knodel *et al.*, 1984).

Tashakkori and Teddlie (1998) "stress the importance of the research question over the paradigm" (p.10) and suggest that "for most applications… research questions are best answered with mixed method … research designs" (p.10). Though this study is primarily a qualitative exploration of the research question, I had originally hoped to follow it up with a quantitative survey. Time and resource constraints prevented me from doing so.

Qualitative research was appropriate for the final scope of this study because it focuses on why farmers are not adopting CA on more of their land. Qualitative research has a number of advantages over traditional survey methodology for addressing social science research questions aiming to understand how or why a phenomenon occurs. Research on how a social phenomenon happens requires exploring many different possibilities that may be difficult to thoroughly categorize *a priori* but may become apparent in the middle of the data collection, thereby requiring a less structured or more flexible approach. Research on why a social phenomenon occurs often requires subtle questioning to tease out research participants' motivations and/or a less rigid research design that is able to include unanticipated variables.

In addition, this qualitative study provides a unique contribution to the CA literature as a community-focused case study grounded in data from in-depth interviews with individual farmers. This is different than other CA case studies (such as Baudron *et al.* 2007 for Zambia and Shetto & Owenya, 2007 for Tanzania), which depended more on grey literature from NGOs and focus groups facilitated by CA promoters which may be biased towards the benefits of CA. While those studies provide significant insights into the advantages and constraints of CA from a large scale perspective, they risk missing important factors faced by individual farmers. This study on the other hand aims to present in-depth analysis of the perspectives of individual farmers in a specific community in order to generate hypotheses about the constraints to adoption from their perspective.

Qualitative research methods are ideally suited for initial efforts to answer the research question of this study: why are farmers not adopting conservation agriculture? By answering this question in-depth in one specific community this study aims to generate hypotheses that will inform both policy decisions about CA promotion and further research examining the constraints to CA adoption. By providing details about the critical categories of benefits and constraints in this context, this study aims to facilitate future quantitative studies about CA adoption.

2.3. Sampling and Data collection

2.3.1. Community selection

The community, Bwaila (a pseudonym[2]), was purposively selected after visiting 13 of the communities where at least one of the two NGOs are promoting CA (see Table 8 in Appendix A for the community selection table). Bwaila was chosen for three reasons: CA had been promoted there for three seasons, both NGOs were operating there, and it had more CA participants than other communities. Visits to other communities helped put the results in a broader context.

Bwaila is a large concentrated village of over 800 households with agricultural lands in a 3 km radius around it. Nearly all of the land is cultivated each year except the steepest parts of the hills, which are used for grazing. Three creeks run through the village enabling small-scale irrigation. A 2 km path leads from the village to a well-maintained dirt road leading to the nearest administrative centers. Most farmers sell their potatoes either at Vila Ulongue (25km away) or at Tsangano turn-off (17km away) in Malawi situated along the Lilongwe-Blantyre highway.

Two other communities are specifically mentioned in the analysis below for how they contrast with Bwaila. Mulingo is a small community (about 100 households) a few kilometers from the border with Malawi, about 15km east of Vila Ulongue, where only IRM is working. The landscape there is a deforested rolling plain with lower population density and large tracts of uncultivated grasses. The area may have higher rainfall and the community is crossed by a large stream used for irrigation. Kawale is a community about 30km west of Domue with low

[2] All of the communities in this study are given pseudonyms to protect the identity of individuals who participated in this research. This decision was made *a priori* and was communicated as part of the consent process, partly in order to encourage greater disclosure by participants. In the end there is hardly any information in this study that could be considered sensitive but pseudonyms are retained since confidentiality was promised to all participants.

population density and many large trees and large tracts of woodlands between fields and houses. Irrigation is also practiced in the small streams that run through this community. (Note that Kawale is not listed in the community selection table (Table 8) because it was not visited before Bwaila was selected.)

2.3.2. Respondent selection

I interviewed 18 CA farmers, four dis-adopters and 11 non-adopters in the focus community, Bwaila. In addition, I gathered some additional information from visits to 16 other communities where the two NGOs work and from interviews with eight agricultural professionals (see Appendix A for a list of data collections).

I identified CA farmers in the communities with the help of the IRM and TLC staff responsible for the communities I visited. The staff of each NGO organized a meeting to present me to the CA participants in Bwaila during which I introduced my research to them, gathered some general information about their use of CA and scheduled interviews. Some CA participants did not attend this initial meeting. Time prevented me from interviewing every adopter but the majority of TLC participants (11 out of 15) and many of the most active IRM participants (10 out of 45) took part in the study. The CA farmers who did participate in my study tended to be the most active participants as evidenced by their attendance at the initial meetings and their willingness to spend time with me in an interview. This selection bias towards the leading edge of CA farmers does not threaten my results since it can safely be assumed that the less active participants would not generally have had more success with CA.

The NGO staff only accompanied me to Bwaila in the first weeks to introduce me to the participants and the local authorities. I interviewed every dis-adopter in Bwaila that I learned of during the data collection. Non-adopters were interviewed opportunistically as I met people in the focus community (for example the daughter of one older CA farmer, the brother-in-law of another and the sub-chief near the church). Professionals were purposively chosen who could provide information on either the specifics of the CA projects or general information about agriculture in the area. (See Appendix A for a list of interviews.)

2.3.3. Data collection

Semi-structured interviews with CA participants focused on the following main topics: the specific practices used on the CA plot visited, benefits and challenges of minimum tillage, mulch and crop rotation, land tenure security, perception of rainfall patterns, how they learned about CA, household characteristics, labor use and general agriculture practices. During these interviews the CA participants shared their detailed labor data for every task, their estimated yield, the inputs used and the prices of inputs if they purchased any themselves. I measured CA plots at the same time as the interviews. Interviews with professionals focused on how their organization promotes CA and what benefits and challenges they perceive in its use. (Please see the semi-structured interview guides in Appendix A for details). In addition, I was able to check what I was learning about CA from the participants with the NGO professionals. The NGOs provided me with information about the prices they paid for inputs provided to CA participants which was used for the partial budget analysis for TLC.

I carried out my interviews over two months during the dry season. I spent about 5 hours interviewing and visiting the fields of each CA farmer, though this time was usually broken up over two or three days. By visiting their CA plots I was able to directly observe the size of the plots that were farmed without ridges relative to other fields, the level of mulch on the ground and weeds in the plot. Since I was visiting the plots shortly after harvest it was possible to observe the size of the maize stalks.

Interviews were conducted in Chichewa with farmers and in Portuguese with professionals. All interviews with farmers and most with professionals were recorded and transcribed. Two interviews with professionals were not recorded but my detailed notes were expanded into an interview summary document within 24 hours of the interview. During the interviews with farmers I took some notes that I later typed. In addition, after most days of data collection I recorded my own reflections on the process and my otherwise unrecorded observations from the day. These recordings were also transcribed. Occasionally I typed my observations after carrying out interviews.

At the end of conducting the interviews I had three group interviews in order to check my initial findings with CA participants. Two of these group interviews were conducted in one community with the participants of each NGO while the other was conducted in another community with CA participants from IRM. During this final interaction I was able to ask each group some of my remaining questions and get their feedback about my initial conclusions. These group interviews also gave me an opportunity to observe the level of consensus on certain issues in a group setting and compare how individuals' responses compared to the private interviews. The group interviews were recorded and transcribed though it was not always possible to determine specifically who was speaking from the recording.

2.4. Data Analysis

2.4.1. Thematic analysis

Thematic analysis was used to code and summarize the transcripts and notes from the data collections. Thematic analysis is an on-going process of developing and reformulating hypotheses that starts in the field while the data is being recorded and continues until the research is written up (Rubin & Rubin, 2005). In thematic analysis the researcher systematically examines the transcripts for themes and concepts that address the research question and then develops a coding system for labeling all of the text data that relates to each theme or concept (Rubin & Rubin, 2005). The themes and concepts may be based on the literature or may emerge from the data (Rubin & Rubin, 2005). Coded data facilitates the systematic retrieval and analysis of the data into meaningful and manageable "chunks" (Miles & Huberman, 1994).

The interview data were coded into 19 themes using the definitions and rules detailed in Table 10 in Appendix B. I initially developed these themes before I started collecting data considering the categories of information I expected to hear from participants based on my previous experience and the literature on CA. This list of categories was then refined and formalized during the data collection based on the information I was collecting. When I had transcribed about one third of the interviews I started coding and by using the codes I was able to make some adjustments in the definitions and add to gaps in the coding system. At this point I finalized the codes and definitions presented in Appendix B. I was open to further adjustments on the coding system in case new categories emerged but none were necessary. I was already familiar with the content of all of the interview data because I collected it and had been reflecting on it throughout the collection process. In addition, I made the decision to apply the code whenever I was in doubt so as to ensure that no meaningful data was left out of the coding scheme.

I used the Nvivo computer program to facilitate the analysis by electronically coding the text and gathering the categorized data into groups for extraction and analysis. Once all the data for a particular code was in one place I read through it carefully making marginal notes on paper. I then summarized the information for each code into a set of condensed statements that highlight the main points from that data regarding the research question. I revised these summary statements by systematically re-reading the categorized data and my marginal notes to make sure that the diversity of responses were represented.

Throughout the analysis I processed the data with a focus on answering the key research question: what are the constraints to CA adoption? Information that was not relevant to this question was not fully analyzed (for example, the codes on livestock and irrigation). I started by processing the codes for benefits and challenges of CA use. This information gave me a general picture of how to continue the analysis: by focusing on fertilizer use and labor changes. The tension between the positive and negative perspectives on CA by the same individuals caused me to look for greater depth of meaning through the quantitative details about labor, yields and costs of inputs. The importance of fertilizer for CA led me to develop displays comparing participants' levels of fertilizer use and the resulting yields. I also created a display about compost production with details from each IRM participant in order to summarize their perspectives on compost. The themes and displays were then organized into groups related to soil fertility (mulching, rotations, compost, fertilizer) and labor changes (herbicide, labor shortages, wage labor). The results below address these two categories and the qualitative information comes directly from the summary statements and displays generated in the thematic analysis.

2.4.2. Quantitative data analysis

I analyzed the quantitative data (gathered during the in-depth interviews) on plot size, labor by task, quantities and prices of inputs and estimated yields in order to assess labor changes and CA profitability. Labor data is based on farmer recall of all tasks carried out on a given plot in the previous season. Farmers shared how many people did each task for how many days including approximate start and end times for the different tasks. The data were entered into a labor data table (see Table 9 in Appendix A) and the information was separated by gender and age. Household labor was recorded separately from paid labor.

Total man hours were calculated by adjusting female labor by a factor 0.75 for the heavy tasks of basin making, ridge making and banking. This factor was based on interviews with women who supplied agricultural labor and were asked to compare what they were able to accomplish on those tasks in one day compared to men. Labor from children under 15 was adjusted by a factor 0.5 except for planting and fertilizing where it was only adjusted down by 0.75. The difference is based on how farmers seemed to value their children's efforts more for the tasks of fertilizing and planting. (Note: Uaiene (2008) used a similar adjustment (0.75 for women and 0.5 for children) for calculating labor based on number or people in the household; Mupanda (2009) valued men and women equally and excluded children under 15).

I used the transcripts for checking and correcting the labor data tables that I filled out during the interview process. Labor data was collected disaggregating by gender and age (see Table 9 in Appendix A for the data collection instrument). The mean labor requirements and standard deviations were calculated for each set of agricultural tasks. I collected data on field size using a measuring tape and GPS for each CA plot visited and for some non-CA plots.

In addition, I analyzed the quantitative data using partial budget analysis to assess the profitability of CA use. This analysis required putting a cash value on the yield and subtracting the cash costs and a monetized value of household labor. These calculations were made under different assumptions of maize prices and household labor opportunity costs. Valuing the TLC inputs can be done either by valuing the grain the farmers actually return to the NGO or by estimating the market value of the inputs. In the first case the monetized value was calculated using the low maize price, which is appropriate for when the grain was to be collected. To estimate the market value of the inputs (MZN 2640 on average for the farmers receiving higher input levels) I used the prices provided by TLC and the quantities the farmers said they actually applied to that plot. Participants receiving the larger quantity of inputs were expected to repay 3 sacks of maize (50kg each), which had a value of 600 MZN during the harvest period, indicating that NGO was effectively subsidizing over 75% of the input costs.

I analyzed CA profitability for three different groups of CA farmers (IRM and the two TLC groups). The TLC participants were separated into two groups based on the amount of inputs they were provided with (see Table 2 for details). The participants who received two 50kg bags of fertilizer were supposed to use it on 0.3 ha but on average applied it only over 0.25 ha thereby increasing the fertilizer application rate from the recommended 0.334 tons/ha to 0.4 tons/ha.

It is also possible to construct an approximation of the total costs and benefits of using CA under different field sizes by making a few assumptions about the opportunity cost of labor. For large fields (over 0.5 ha) the opportunity cost of labor can be assumed to be equal to the market agricultural wage rate (40 MZN/day) because a household would either be able to sell their labor at that rate (for example if they decided to leave it fallow) or would have to pay for labor at that rate if their own supply was inadequate.

However, as the field size gets smaller this assumption seems less realistic for many households since it may not be necessary to spend a full working day at a time in the small plot. It seems likely that small farmers in this context have some surplus time (during non-peak labor seasons) that cannot reasonably be used for wage labor since it is only a few hours a day. This "spare" time would have very low opportunity cost and could be used for agricultural activities (such as making one pile of compost or weeding a very small plot). Stated conversely, as more hours are needed the opportunity cost increases since the farmer would otherwise be doing something else (weeding another field for example).

2.5. Validity issues

Qualitative data collection deals with threats to validity in a very different manner than quantitative studies (Maxwell, 2005). Quantitative studies use control groups, random sampling and other methods to generically control for rival hypotheses in advance. Qualitative studies, on the other hand, frequently use non-random (purposeful) sampling to allow researchers to select participants based on the information they can provide (Patton, 2002). By focusing on where rich information can be found the researcher avoids wasting time interviewing, transcribing and analyzing irrelevant or redundant information. The key criterion for participant selection is their potential to provide a deeper understanding of the research question.

In the absence of random sampling as a check against the subjectivity of the researcher, qualitative researchers cannot simply draw conclusions from the data without explicitly providing evidence against alternative conclusions (Maxwell, 2005). During the data collection process therefore, researchers must actively seek evidence that could challenge their conclusions. This requires consciously developing alternative hypotheses and considering what information would be needed to support or discredit each hypothesis.

Qualitative researchers have a variety of strategies that can be used to improve the validity of their findings. Long-term involvement with participants through multiple interviews and multiple visits to each site can "help rule out spurious associations and premature theories" (Maxwell, 2005, p.110). Intensive interviews rich in detail which are recorded and transcribed reduce the chances of producing "data that uniformly support a mistaken conclusion" (Becker, 1970, quoted in Maxwell, 2005, p. 110). Researchers can also systematically solicit feedback from participants about the data and their conclusions to avoid misinterpretation, a process which is often referred to as “member checks” (Maxwell, 2005). Researchers can avoid systematic bias through triangulation: a process of “collecting information from a diverse range of individuals and settings, using a variety of methods” (Maxwell, 2005, p.112). For example, interviews with farmers can be combined with observation of their fields and interviews with extensionists in order to verify what farmers self report.

In addition, qualitative researchers reduce threats to the validity of their study by systematically mitigating the negative effects their own bias may have on how the research is conducted and the conclusions drawn (Maxwell, 2005). During the data collection researchers must be aware of their own bias and of how they influence the responses of participants. In conducting semi-structured interviews it is critical for researchers to avoid using leading questions and to be aware of how their reactions to participants’ responses (through both words and body language) affect the information participants share (Rubin & Rubin, 2005).

Rubin and Rubin (2005) argue that “interviewing is more than learning how to word and ask questions. …an interview is part of a developing relationship in which issues of mutual interest are explored in depth” (p.128). In the context of personal relationships it is impossible to imagine eliminating researcher bias or reactivity to the researcher. Because of this, in analyzing the interview data, qualitative researchers must reflect critically on how the participant came to share some evidence towards a hypothesis. For example, evidence that is shared voluntarily with rich detail can carry more weight than a short response prompted by a leading question.

This study incorporates many of these principles in order to maximize the validity of the findings. Though many of these strategies were described throughout the methods section they are listed again to document the care that was taken to ensure that the results are as valid as possible. This study's design aimed to reduce the chance of coming to the wrong conclusions by carrying out iterative in-depth interviews in one location which allowed for longer term relationships with the respondents and a greater understanding of their context. Furthermore the triangulation of findings by observing fields, interviewing farmers and the NGO staff responsible for those communities helped ensure that the data was robust in supporting the conclusions drawn. Member checks by the farmers at the end of the data collection period were used to verify that the conclusions drawn were supported by the participants. Finally the research design supports that the conclusions are valid by explicitly pursuing evidence for alternative hypotheses as explained in the results below.

The study design also aimed to minimize researcher bias by transcribing the interviews and using open-ended questions. Furthermore, I attempted to reflect critically on how my actions may be influencing responses and made every effort to avoid reacting to what seemed surprising or indirectly leading respondents to answer in the way I expected.

2.6. Description of participants

The 19 NGO participants that I interviewed were a heterogeneous group with varying levels of assets, education and experience with CA. The IRM participants were mostly members of the local Reformed Church since the NGO uses that local institution as the starting place for its community outreach. The most active members from IRM were composed of five men and seven women and I interviewed 10 of these 12 and came to know seven quite well by visiting their fields and some of their homes. Though the IRM staff person responsible for Bwaila gave me a list of 45 CA participants, it was these 12 who managed the CA demonstration garden next to the church and attended both the initial meeting and final meeting I had with them.

Of the seven participants I came to know well, two of the best off IRM participants were older men who had metal roofed homes and adequate maize harvests despite low education levels. One man and one woman (both in their 30s) had higher education levels (3rd and 6th grade respectively), metal roofed housing, and higher levels of fertilizer use. At the low end of the asset spectrum was a man in his 30s and a woman in her 50s who were both illiterate, had homes that were small and thatched and expressed frustration about low agricultural productivity. A woman in her 50s was at the lowest asset level judging by her inability to buy any fertilizer and the shortage of labor in her household (abandoned by her husband but supported by her three married daughters). All of these participants had landholdings of at least one hectare, often divided over multiple fields. They each had a small CA mono-crop maize plot (on average 0.08 ha) that had been under minimum tillage for 2 or 3 years without rotation. None of them were actively employed in non-farm income earning activities and only one of them earned the potentially high return cash crop tobacco.

There are 15 TLC participants in Bwaila who are using CA and receiving subsidized fertilizer, herbicide and seed from the NGO. I interviewed 11 of them and I visited 9 of their CA fields and many of their homes. Two of these TLC participants are also IRM participants – both of them men in their 30s described above. Of the remaining nine, four of them are older men who seemed to be well off compared to most of the IRM participants with three having significant non-agricultural earning and the other one being the only tobacco farmer of the group. One man and one woman (both in their 30s) had limited outside employment, some fertilizer use but poor housing. Two older women had low levels of fertilizer use and low education levels. One young woman who had been left by her husband to care for two small children never used fertilizer unless it was given to her and regularly sold her labor to meet her cash needs.

As with IRM participants all of these farmers had landholding of over one hectare spread over several fields. Five of the TLC participants I interviewed were trying CA for the first time this year, three had done it for two years and three participants had three years of CA experience. All but one were only using CA on a single plot, for which TLC provided all of the inputs. The chairman of the TLC group had an additional CA plot that he added the previous season using the fertilizer he received at a subsidized price from the Mozambican government.

3. Results

This study explores the constraints to CA adoption by smallholder hand hoe maize farmers in the Angonia highlands of Mozambique. I explored the constraints to farm-wide adoption by interviewing farmers who were using CA on small plots because of their participation in NGO programs that were promoting CA. I also interviewed farmers in the same community who had never used CA in order to understand the constraints to initial CA adoption. The first step in analyzing the constraints to adoption was to understand the participants' perceptions of the technology.

Most farmers in this study state that they like practicing conservation agriculture, mostly because it addresses one of their key priorities: increased maize yields. One lady said, "I never expected to get an oxcart of maize from that area." The CA farmers explained in the interviews that the key reasons for yield increases are fertility supplements and a greater planting density. The combination of higher yields for less effort was also a frequently mentioned benefit as succinctly summarized by one farmer: "The difference is that we don't work them (the fields) with much power but we harvest for real." For another farmer the change in work requirements was the key benefit: "Here (in a CA plot) you don't cry, it is different than that type (conventional agriculture)." Another added, "It doesn't get your blood running, this no-till farming." Additional benefits that were mentioned are that CA is more drought-tolerant and is better for long-term soil fertility.

However, in contrast to all the positive opinions about CA there is little sign of CA adoption beyond the plots where NGOs have provided inputs. By visiting the fields of CA participants and inquiring about their tillage methods I came to understand that CA practices were limited to small plots and that most land was still being farmed with conventional ridges. In Bwaila only one farmer had one plot where he expanded CA use beyond where the NGOs had ever provided inputs. Many of the IRM participants had reduced the area under CA because the NGO failed to provide inputs during the last agricultural season. These findings suggest that farmers were convinced of the benefits of CA but something about the technology was preventing them from using it on more of their land. This seeming contradiction between the opinions of the farmers and their actions is what motivated the in-depth analysis of this study. The remainder of this section focuses on three constraints to CA adoption that emerged from analyzing the data: reduced nutrient availability, increased labor requirements and low profitability.

3.1. Soil fertility and CA

Most of the farmers explained during the interviews that because they could not afford fertilizer they were not able to use CA on more of their land and reap the benefits of what they had seen on the small plots where NGOs had provided the inputs. The nutrient immobilizing effect of reduced tillage appears to be preventing farmers from using CA on their unfertilized maize fields.

Most farmers in Bwaila see burying crop residues as a strategy to make low fertility fields produce some maize by making "compost" right in the field. One of the TLC chairmen in the village said, "If I just dig a hole and plant, the roots quickly reach infertile soil, so the maize doesn't grow much, but on a ridge it will grow well because it is only on good soil." An IRM dis-adopter added that, "where there is minimum tillage the roots quickly find un-dug places that are too dry so it (maize) gets weak quickly. But where you have made ridges they (the maize plants) all do well."

When interviewed, most CA farmers said they wanted to expand CA but they were adamant that they need fertilizer to make CA perform better than ridges. The IRM participants showed me their group demonstration garden with three CA plots – one with fertilizer only, one with compost only and one with nothing added. They explained that the portion with no added fertility grew maize that was only about one meter tall and produced almost no grain. The small stalks were still visible in the plot when I visited in June. Another IRM participant in another community, Mulingo, showed me her CA field which she had divided into three portions – one with compost and fertilizer, one with compost only and one without anything added. The maize in the last section was less than a meter tall and produced no harvest at all. Both of these farmer trials were surrounded by ridged maize that grew tall and presumably was not fertilized. Though there are many imperfections to these "experiments" they convinced most of the farmers that CA without added fertility would not produce anything.

Not everyone agreed that farmers would experience better yields with ridges than with CA absent of fertility amendments. Many professionals and some of the participants asserted that it would make no difference if you make ridges or not; the yield simply depends on soil fertility. The head TLC chairman said, "If there is no fertility even if you make ridges it won't do well and without ridges it won't do well."

Interviews with farmers revealed mixed opinions on the performance of unfertilized ridged maize. While some farmers expressed their satisfaction and pride, others said that the ridges were hardly producing. One of the IRM dis-adopters explained that he had a fertile field that he had cleared a few years earlier that consistently produced several oxcarts of maize without fertilizer, which was more than he expected for its size. In contrast, a young couple that participated with TLC explained that they have to add fertilizer to produce acceptable maize yields on their family plot. I collected detailed labor and yield information for two conventional maize plots (see the last column of Table 4) and it was striking that almost twice as much labor was used on the plot that had nearly half the yield of the other plot. It is likely that this variation has much to do with the existing soil fertility of the field and the timeliness of the management practices of the farmers. This heterogeneity in conventional agriculture may be critical for understanding CA adoption since farmers are directly comparing how CA performs relative to their other fields.

Farmers believe that they need increased fertility to use CA and there are two ways they commonly meet this need: compost and fertilizer. The next section discusses compost production and its potential as an alternative to fertilizer. After that I examine farmers' fertilizer use patterns in order to explore if access to fertilizer relates to CA adoption.

3.1.1. Compost production

IRM professionals explained that compost production is their strategy for helping cash-constrained farmers to supplement the fertility in their soil. During the interviews these professionals pointed out that compost production uses farmers' labor and saves their cash while still improving the soil structure and adding nutrients. In the interviews with many of the farmers who used compost, they mentioned benefiting by needing less fertilizer and improving drought resistance. The key complaint that compost-using farmers shared was the problem of transporting the compost to their fields by head or oxcart. IRM CA participants explained to me that they apply one can of compost per basin which may weigh about 150 grams (IIRR & ACT, 2005) coming to a total of about 3,330 kg per hectare. Some of the farmers I interviewed who used compost also complained that obtaining the ingredients was too difficult and time consuming.

During the interviews the majority of compost-using farmers complained that compost was not as effective as fertilizer and that it made the maize grow well but then it "ran out of power" at tasseling. Many IRM participants described how their harvests were radically reduced this year compared to last year when IRM gave them 12kg of fertilizer for 0.04 ha plots (20m by 20m). Farmers use about one oxcart or less of compost for a 0.03 ha plot (10m by 30m). IRM suggests that farmers apply at least an oxcart on 0.02 ha plots (10m by 20m). The low application rate by IRM participants probably explains much of the poor results they perceive from production with compost only. In contrast, one farmer at Kawale had increased harvests because he increased his compost application and kept his fertilizer rate the same.

Many of the farmers I interviewed say that minimum tillage with compost is better than minimum tillage with no fertility amendments. In the "experiments" mentioned above compost did better than CA without adding any sort of fertility. One joint TLC and IRM participant stated his opinion about compost this way:

> We have seen that it is a very good method, making compost, because the field is going back to old times; because that soil had run out with our parents. So, if we just hoe, the maize does not come. But if we add compost we can see a difference with how things were (interview with BM8).

Despite challenges all of the IRM farmers interviewed in Bwaila made compost in small batches. One farmer in Mulingo said that making compost was much easier than finding money to buy fertilizer suggesting that, for him, labor is more abundant than cash for small-scale CA investment. All IRM participants were using compost either for CA or for irrigation agriculture but it would probably improve conventional maize production as well.

One of the lead IRM participants explained to me that he minimizes the constraints to compost production by locating his CA plot close to home. Another explained that last season he made compost little by little, which he found less inconvenient than making it all at once as he did previously. The IRM participants in Mulingo found that group work helped reduce labor because “every hand grabs something” as they produce compost on a rotating basis. Nevertheless, in the individual and group interviews every IRM participant agreed that it would not be possible for each farmer to have enough compost even for one entire field.

The labor data results from this study indicate that on average it takes 24 hours to make one compost pit (1 cubic meter) and transport it to the field. The cost of this labor (at the agricultural wage rate of MZN40/day) is MZN120. Making two compost pits plus renting one oxcart can be valued at MZN340 and this amount can be used on the same area where NGOs would recommend applying 6kg of fertilizer (MZN120). Therefore the monetized price of compost is greater than the cost of fertilizer.

This means that it is not profitable to make compost at a large scale since time would be better spent earning agricultural wages and buying fertilizer. However, the opportunity cost of labor is negligible for small batches of compost for many households with surplus labor (see discussion below in the profitability sections 3.3 and 3.3.1). Theoretically, having the materials close by, owning an oxcart, applying it at a nearby field and having extra family labor would all make composting more profitable. This monetary comparison with fertilizer ignores the benefits unique to compost (drought resistance and long-term soil improvement).

Poor land quality constrains the effectiveness of minimum tillage and compost is a labor-intensive way of addressing this issue. With the current range of prices for labor and fertilizer, profitable compost production is limited to small batches where the opportunity cost of labor is minimal.

3.1.2. Fertilizer use

The lack of fertilizer experienced by most smallholder farmers in sub-Saharan Africa is indicative of a cash constraint on agricultural productivity (Morris *et al.*, 2007). Most CA farmers that I interviewed are adamant that they need fertilizer for CA to perform better than ridges. One logical supposition is that CA adoption is constrained by access to fertilizer, but is that the key constraint?

There are two ways to explore whether fertilizer is the key constraint preventing farmers from adopting CA in the Angonia highlands. The first is by looking at what happens to CA adherence when the NGO stops subsidizing fertilizer. The second is to see if CA farmers who use their own fertilizer on maize make ridges or use CA. If it is true that CA is desirable but fertilizer is the key constraint, then farmers will dis-adopt when the inputs stop coming in (unless they can buy their own fertilizer). In addition, if farmers think CA is the best system for fertilized maize then they will not put fertilizer on ridged maize.

The first test was observed in this community since IRM's project had limited funding and decided to provide inputs only for demonstration plots. At least three farmers in Bwaila dis-adopted CA with IRM once the fertilizer did not appear last season. Two others explained in their interviews that they reduced the area to match what fertilizer they could afford on their own (see the last column of Table 3). In fact, the only other dis-adopters I found out about were two TLC participants who no longer received inputs (one because of her inability to repay some grain to the NGO and the other because she stopped attending TLC meetings and work days). These cases show that the decision for some farmers of how much area to plant using CA practices was highly influenced by NGO input provision.

The interviews with IRM participants indicate that fertilizer provision motivated CA use but the data does not suggest that fertilizer was the single most important constraint. All three dis-adopters of IRM CA purchased fertilizer for other uses. The two who reduced area because of lack of fertilizer used fertilizer on their cash crops. In addition, there is some evidence that input provision also affected how farmers managed their CA plots. Two IRM participants said that the lack of fertilizer from the NGO induced them not to mulch their CA plot because they were less motivated to ensure good production. Interestingly neither of them used fertilizer on their CA maize, though both purchased fertilizer for their potatoes suggesting that access to fertilizer was not the key constraint. To summarize, fertilizer motivates CA use by IRM participants but its presence does not guarantee continued adoption. IRM's system of CA must have other challenges that make it to not be the priority for fertilizer use.

Fertilizer use in general is low with the highest levels being a few hundred kg per farmer (based on the interviews with CA participants). Most participants (13 out of 18) buy fertilizer for potatoes or tobacco (Table 3) and usually in larger quantities than for maize. Five of the 13 farmers growing cash crops used all of their own fertilizer on cash crops (though three of these received some from TLC for CA maize). It is interesting to note that farmers 1, 3, and 4 in Table 3 had outside income from either small business or earning wages but no other farmers except 13 indicated significant non-farm income. On the other extreme farmers 16, 17, 18 and 19 are female-headed households who either currently or until recently sell their labor in agriculture. High levels of fertilizer use therefore seem to be partly correlated with non-agricultural income.

Fertilized maize on ridges is usually grown as a monocrop at a higher plant population than the traditional intercrop. Farmers often refer to this approach of monocropped maize with ridges as the Sasakawa method. Only two out of 10 non-adopters applied any fertilizer on maize. On the other hand nine out of 18 CA farmers purchased fertilizer to use on maize and five of these nine used it on non-CA maize as well (Table 3). Non-adopters expressed interest in CA but many said they had never been trained how to do it. Most also pointed out that farmers received fertilizer to use CA and that they were very interested in that and felt left out by the NGO.

Table 3: Fertilizer use by conservation agriculture (CA) farmers and dis-adopters in Bwaila

Crop type:		CA maize	CA maize	CA maize	Conventional Maize	Potatoes or Tobacco	
Fertilizer source:		Purchase	NGO	Gov. subsidy[4]	Purchase or Gov. subsidy	Purchase or loan	
NGO:		IRM[2]	TLC[3]	-	-	-	Change in IRM CA:
Category[1]	Farmer #						
1	1	-	X	X	X	X	Disadopted
	2	X	X	-	X	X	Same area
	3	-	X	-	X	X	n.a.
	4	-	X	-	X	X	n.a.
2	5	X	-	-	-	X	Same area
	6	X	-	-	-	X	Reduced
	7	X	-	-	-	X	Reduced
	8	X	-	-	-	X	Same area
	9	Compost	X	-	-	X	Same area
	10	-	X	-	-	X	Disadopted
	11	-	X	-	-	X	n.a.
	12	-	X	-	-	X	n.a.
3	13	-	X	-	X	-	n.a.
4	14	-	-	-	-	X	Disadopted
	15	Compost	-	-	-	X	Same area
5	16	-	X	-	-	-	n.a.
	17	-	X	-	-	-	n.a.
6	18	Compost	-	-	-	-	Same area
	19	Compost	-	-	-	-	Same area

Source: author's survey, 2010.

[1] Category of fertilizer use:

Category 1: Fertilizer used on CA maize, other maize, and cash crop
Category 2: Fertilizer used on CA maize and cash crop only
Category 3: Fertilizer used on CA maize and other maize only
Category 4: Fertilizer used on cash crop only
Category 5: Fertilizer used on CA maize only and all of it provided by the NGO
Category 6: No fertilizer used on any crop

[2] For Igreja Reformada em Moçambique (IRM), X indicates fertilizer purchased by farmers. "Compost" means the use of compost only. All other participants did not have any plots using IRM's method of CA.

[3] All Total Land Care (TLC) CA participants received fertilizer from the NGO.

[4] The Mozambican government subsidized fertilizer for the 2009/10 season. One participant used it on his own CA plot, mimicking what he does with TLC but without herbicide. Another used it on ridged maize.

By analyzing how farmers use their own fertilizer, the second means of exploring whether fertilizer is the key constraint can be done. One IRM and TLC dual participant (number 2 in Table 3) used his own fertilizer on non-CA maize as well as CA maize, showing that CA was at best tied as his first choice for fertilized maize production. Though he liked CA enough not to dis-adopt, he used more fertilizer on a larger Sasakawa plot.

Of the five TLC participants who bought their own fertilizer and used it on maize, only one of them used the CA system for land preparation on the plots where they applied their own fertilizer. Three of the five used the Sasakawa method and two used fertilizer to top-dress ridged intercropped maize on those plots. Two of these five participants who used their own fertilizer on non-CA maize were using CA for the first time this season, so they might not be expected to adopt CA immediately for all fertilized maize.

In conclusion, it appears that CA adoption is not simply limited by a cash constraint for fertilizer. Even if the fertilizer constraint is overcome it is not certain that CA would expand. The fact that many farmers were able to purchase fertilizer for potatoes suggests that the key constraint is not access to fertilizer but rather the profitability of applying fertilizer to maize fields. I return to a discussion of profitability in section 3.3 below after discussing other constraints.

3.1.3. Rotation with legumes and permanent mulch cover

In addition to analyzing the capital and labor constraints affecting soil fertility supplements, it is necessary to consider how farmers perceive basic agronomic practices. Understanding farmers' perceptions about crop rotation and residue management provides a more complete picture of the challenges related to soil fertility management. During the in-depth interviews I asked the farmers about each of their fields and what crops they previously grew on each field in order to get a history of any rotations that were practiced.

The farmers I interviewed explained that year after year most of their fields were planted to conventional maize on ridges intercropped with a diverse set of legumes. As I visited their fields and measured them with a GPS I was able to observe the ridges and the residues of the maize and intercrops. The primary goal of intercropping seems to be food production since most farmers did not state any soil fertility benefit from the practice. When asked about planting pure stands of legumes, the farmers in Bwaila explained that they are not accustomed to that in this area but in other areas with more land they do that. The CA participants that I interviewed explained that they prefer not to produce legume monocultures because it is either too risky (unreliable bean varieties and fluctuating soy prices) or because it is "too much work" (implying too little profit). As they explained the history of crops grown on their fields I came to understand that a few years ago many of the farmers in Bwaila planted pure stands of soya. They told me that they were promised high prices and this induced them to try it as a new crop. Though a few continue to grow soya as a monoculture many explained that they now intercrop it with maize or do not plant it all. The farmers explained that this change was caused by their disappointment in the low prices for soya. This evidence suggests that these farmers are aware of the markets for legumes and respond to higher prices with increased production.

In contrast, based on the interview data the cash crops potatoes and tobacco are grown as monocultures and then rotated with maize. The farmers explained that they were very aware of the risk of losing a crop of potatoes or tobacco to diseases and this motivated them to practice rotation with those crops. It seems logical then that if there was a benefit to the farmer of rotating maize with a legume, they would practice it, even if the benefit did not come until the following year. According to the interview data the low and unreliable prices for legumes and the lack of improved varieties are what keep farmers from deciding to rotate their maize with legumes.

During my interviews with the professionals from both NGOs I inquired about rotation since it is one of the three key principles of CA. While they acknowledge the benefits of rotations they promote CA as a maize monoculture year after year. They explained that the farmers refuse to plant pure stands of legumes because they prefer intercropping. Staff from both NGOs recognized the possibility of intercropping with CA during the interviews but neither actively promotes CA intercrops. In addition, TLC's choice of Bullet (Alachlor and Atrazine) as a non-selective pre-emergent herbicide prevents intercropping with a legume. For these reasons none of the CA farmers in Bwaila are benefiting from the potential agro-ecological benefits of incorporating legumes with their maize production.

The CA farmers I interviewed see mulch as a beneficial means of controlling weeds and conserving soil moisture. During the group interviews farmers from both organizations explained that they are unable to maintain mulch on their fields through the dry season primarily because of free-range livestock and people gathering residues for fuel but also because of termites. In other communities, TLC participants mentioned that they would gather their maize residues from their CA plot and store them at home through the dry season. CA farmers explained that they add mulch by gathering residues from neighboring plots and by carrying old thatching from the village to their CA plot. Though farmers recognized that CA is more drought-tolerant because of the mulch, this did not seem to be a key motivation for adoption, in contrast to what is described for the Southern Province of Zambia (Haggblade &Tembo, 2003, Baudron *et al*., 2007).

To summarize, CA as practiced is not benefiting from the agro-ecological principles of rotations or intercrops because of poor legume varieties and unreliable markets. CA is also missing the advantages that come from permanent soil cover because of livestock and fuel pressure, both of which are challenging in many areas throughout southern Africa. These missing components of CA exacerbate the need for fertility supplements.

3.2. Labor changes with CA

In the interviews with CA professionals, staff from both IRM and TLC were quick to point out that CA saves labor because farmers do not need to make ridges. However, minimum tillage makes weed control more challenging and for this reason CA is often promoted with herbicide use (Baudron *et al*. 2007). This section explores how CA farmers perceive labor requirements for CA with emphasis on land preparation and weed control.

3.2.1. Land preparation and planting

By reducing the amount of tillage CA moves less soil which should reduce the amount of heavy labor needed for land preparation. However, if farmers are applying compost they will still need to use some heavy labor for digging basins. TLC's system of direct seeding avoids the labor of basin making but offers no opportunity for fertilizing with manure or compost.

IRM participants explained that CA was impossible on a large scale because of the tedious work of measuring and digging basins. Though ridges are laborious to make, the farmers claim that they facilitate fast planting of a large field because they have perfected a system where they "just plant (a seed) and step on it, plant and step on it." During the field visits and interviews I observed that few farmers could not remember the measurements for setting up the basins, which suggests that the complexity of establishing a precise grid may considerably slow them down.

On average it took IRM farmers 349 hours/ha to dig basins (Table 4) which is higher than estimates from Zambia (between 138 and 330 hours/ha) (Aagard, 2009, Baudron *et al.* 2007, Nkatiko, 2011). In addition, during the first year IRM recommended that farmers level their old ridges requiring even more labor. No IRM participants leveled fields in the last season because all of them had been using CA for at least 2 seasons so this task is not reflected in the labor data.

Many of the TLC farmers state that CA is easier work but the data does not indicate a general reduction in hours per hectare. Instead their comment could imply greater returns for their effort or less time on the demanding tasks of ridging and banking, both of which are supported by the data in Table 4. The labor requirement for land preparation and planting with TLC's direct planting method is slightly lower than the conventional tillage data gathered in Bwaila and dramatically lower than Takane's (2008) conventional tillage estimate in Malawi (Table 4). Planting time is generally the most critical labor bottleneck but further analysis would be needed to understand the seasonality of the CA labor changes in the Angonia context.

3.2.2. Weed Control

Not moving the soil results in increased weed pressure thereby requiring either more labor or more herbicides. IRM farmers complained about the weeding labor required by CA without an effective herbicide. On average IRM weeding requires more labor than conventional according to the labor data gathered in the interviews, though it varied from 1400 hours/ha to 200 hours/ha. Conventionally farmers weed twice in the season, the second is done through banking. Though requiring heavy physical exertion, banking a ridge is a task that does not need to be repeated in a given season, while weeding a CA plot requires 2 to 4 total weedings. Farmers mentioned several cases when illness in their family prevented them from weeding. Banking therefore has less risk than many weedings with CA.

Table 4: Maize yield and labor requirements[1] by task for conservation agriculture (CA) and conventional systems

	TLC –CA	IRM-CA	Conventional (Malawi)	Conventional Intercrop
Number of plots	9	6	186	2
Yield (ton/ha)	1.66 (.67)[2]	1.45 (1.01)[2]	0.90 (.47)[3]	0.7 (.93, .46)[2]
Plot size (ha)	0.18	0.08 (.03)	-	0.72 (0.72, 0.71)
Land preparation and planting (hours/ha)	295(110)	527 (328)	704[4]	341 (269,414)
Weeding (hours/ha)	292 (131)	587 (431)	520	440 (438, 443)
Fertilizing (hours/ha)	225 (131)	200 (137)	56	0
Mulching (hours/ha)	248 (200)	286 (204)	0[3]	122 (0, 246)
Harvesting (hours/ha)	226 (119)	157 (92)	136	77 (56, 99)
Total (hours/ha)	**1534 (781)**	**1756 (793)**	**1416 (256)[3]**	**980 (762, 1202)**
Power tasks (hours/ha)[5]	0	200 (162)	712	404 (270, 308)
Labor per ton (hours/ton)	1128 (1022)	3048 (1572)	1564	1395 (813, 2586)

Sources: TLC and IRM conservation agriculture data are from author's fieldwork, 2010.
Conventional agriculture data for Malawi ridged maize are from Takane (2008).

[1]Weighted averages based on plot size to correct for error in small plot sizes

[2]Parentheses indicate standard deviations for the two forms of conservation agriculture. For the conventional intercrop, n=2 so both data points are given in parentheses.

[3]Takane's study presents the average labor needed for maize in man days (converted to hours by multiplying by 8) from 6 villages broken down by task without any information about the variability in the data. The yields and total labor by village are also presented without any variability information but I estimated the variability in the yield and total labor needed for maize by calculating the standard deviation of the village averages.

[4]Note that Takane's study did not separate clearing residues from ridgemaking so the land preparation figure includes clearing residues, which would fit under mulch in this table.

[5]Ridgemaking, banking and digging basins were regarded as tasks requiring greater physical exertion.

Based on CA experience in Zambia herbicides can provide 70% saving on weeding labor (Aagard, 2009). Both the comments from the participants and the figures in Table 4 show that herbicide with TLC failed to reduce time spent weeding to that extent (292 hours/ha by TLC is a 43% reduction from 520 hours/ha). Farmers said that the herbicide failed to work well this season because of heavy rains shortly after application.

Aagard asserts that weeding is costly ($100-$120/ha) compared to herbicides ($60-$70/ha). In Bwaila, CA farmers who did not use herbicides spent between 320 and 800 hours/ha weeding (Table 4) which would cost between $45 and $114/ha in paid labor. TLC uses 1 liter of herbicide (which costs MZN 450 or $12.86) for 0.1 ha which comes to $129/ha. In order to cost the same as paying agricultural laborers for 450 hours of weeding the herbicide price would need to be reduced to half its price (or even lower if we assume that many households' opportunity cost of labor is less than the agricultural wage). TLC provides the herbicide in exchange for 26kg of grain which has a value of $5.93 if it were to be sold at the time it was collected. Though herbicide use may not be profitable it does require less physical effort than banking. It is interesting to note that the cost of herbicide in neighboring Zimbabwe is only about $6 per liter (Thierfelder, personal communication, February 9, 2011) which, if achievable in Mozambique, would increase the profitability of herbicide use.

During the visits to CA plots I observed high variation in weed levels after harvest but this may be related more to cattle pressure than weeding effort. In the interviews TLC professionals said that they hope weed seed stocks will decrease after a few years of herbicide use. However, this does not seem plausible based on the abundance of weeds going to seed after the crop was mature and the small plot size surrounded by weed filled conventional fields. Many CA promoters urge farmers to carry out late season weeding to reduce the weed seed levels but this is rarely done (Baudron *et al*., 2007). Other complications with herbicide use include the lack of any safety equipment and the lack of locally available herbicide (TLC buys it in Malawi).

3.2.3. Mulching

In conventional agriculture farmers do not mulch so time spent mulching is an additional task for CA compared to conventional tillage. The clearing of crop residue (one of the tasks included in the mulch total) is also done with ridging but would normally be included under land preparation. The amount of mulch put on the field this season varied from zero to full coverage according to interviews with the farmers and my own observations. Through the interviews several farmers explained that they noted a difference in weed growth caused by different levels of mulch cover. The inability to maintain mulch throughout the dry season and the general shortage of mulch probably led to increased labor in weeding.

3.2.4. Summary

IRM farmers using basins say that labor is a constraint limiting their use of CA to a small plot. In order to prepare their fields quickly they say they need to make ridges. IRM participants found CA to be more work in weeding and in measuring and digging basins.

TLC farmers using direct seeding and herbicides said CA was less work than ridging. The labor data gathered does not provide enough evidence to suggest a significant reduction in the number of hours per hectare. However, time spent on physically demanding tasks (ridge-making and banking) was eliminated with TLC's form of CA. Based on this the farmers' statements that CA is "less work" can be interpreted as the need for less exertion with CA or that CA work that has greater returns.

3.3. Profitability of using inputs with CA

Smallholder participation in staple grain markets in southern and eastern Africa is low (Barrett, 2008). Most smallholders in the region are net buyers of grain and in Mozambique data show that only 30% of maize producers are net sellers (Boughton *et al.*, 2007). Most grain is produced for household consumption or sold at harvest not because of an annual grain surplus but because of the need for immediate cash (Barrett, 2008). Because of this smallholders face severe constraints on the cash that they invest in grain production and need to choose wisely what inputs they purchase and how they use them. This qualitative research allows for a limited analysis of the profitability of CA because of the small sample size but it will allow for some indicative findings requiring more detailed research before they can be made conclusive.

The profitability of CA can be assessed in various ways: with or without valuing labor, with different output prices, using the actual cost charged to the farmer by the NGO for the inputs or the market value paid by the NGO. For further details of how labor, inputs and outputs were valued, see Appendix C. In this section I first examine the profitability of TLC's method of CA and then analyze IRM's method of CA. Because I used purposive sampling the data cannot be analyzed statistically to infer similarities with the larger population of CA participants. For this reason I present the proportion of CA participants interviewed who had positive net profit under different conditions for valuing labor, inputs and maize. The average profitability figures for TLC are presented in Appendix C.

The results show that for the TLC participants interviewed the application of inputs is profitable primarily when the inputs are subsidized and when the value of labor is not considered (Table 5). When the full value of labor is included, the system is only profitable when the price of maize is high and inputs are subsidized for the 0.4 tons/ha fertilizer regime (three plots). When the market value of the inputs is used, farmers may break even if they sell maize at the high price, but they lose money if they sell at the low harvest price. This suggests that few farmers would be able to afford the inputs or would choose to apply them on maize given the possibility of making greater profits on potatoes.

Many TLC participants explained in the interviews that they experienced crop losses due to the cobs rotting caused by heavy rains after the crop was mature, which impacts these profitability calculations. The signs for net profitability using an ideal harvest of 2.7 tons per hectare (based on the best CA yields reported by farmers) are presented in Table 6 which has the same trends as Table 5. For the ideal harvest with high maize prices the TLC system is profitable except when the full labor value and market value of inputs are used in the calculation for the 0.5 tons/ha fertilizer regime. With low maize prices it is only profitable if subsidized and even then it is not profitable when the full labor value is used on the 0.5 tons/ha fertilizer regime.

The same profitability calculations were carried out on the data from IRM and the proportion of farmers with positive net profit are reported in Table 7. The results indicate that the profitability of IRM's CA system suffers from high labor requirements. IRM participants paid the full market value for low levels of fertilizer. When the value of labor is not included then IRM's CA is profitable with the high maize price but is near the breakeven point with the low maize price. When the opportunity cost of labor is included at the market wage rate (40MZN/day) IRM's CA was not profitable (last row of Table 7). This suggests that labor is the key constraint for making the basin system of CA profitable at a large scale. The same relationship held for data from four IRM participants in other communities (three in Mulingo and one in Kawale) though farmers in those communities experienced higher yields and therefore slightly greater profitability (see Table 14 in Appendix C).

IRM CA with higher fertilizer use may be profitable based on yields described for the previous year though respondents likely exaggerated them in order to convince me that IRM should keep giving out fertilizer. Still it does make sense that medium range fertilizer application rates (around 0.25 tons/ha) complemented by compost could profitably increase maize yields.

Table 5: Proportion of Total Land Care (TLC) participants with positive net profit for conservation agriculture for two input application rates under different conditions for valuing labor, maize and inputs.[1]

	TLC one plot[2]				TLC three plots[3]			
	Inputs subsidized[4]		Inputs at mkt. value[5]		Inputs subsidized		Inputs at mkt. value	
	Low Maize Price[6] (4/kg)	High Maize Price[7] (8/kg)	Low Maize Price (4/kg)	High Maize Price (8/kg)	Low Maize Price (4/kg)	High Maize Price (8/kg)	Low Maize Price (4/kg)	High Maize Price (8/kg)
Labor free[8]	4/4	4/4	0/4	1/4	5/5	5/5	0/5	3/5
Labor at 20/day[9]	1/4	¾	0/4	1/4	3/5	5/5	0/5	3/5
Labor at 40/day[10]	0/4	2/4	0/4	1/4	1/5	4/5	0/5	2/5

Source: author's fieldwork, 2010

[1] All prices in Mozambican Meticais (35 MZN = 1 USD)

[2] 0.5 tons/ha fertilizer application rate; average field size = 0.1ha; average yield = 1.05 tons/ha; n=4

[3] 0.4 tons/ha fertilizer application rate; average field size = 0.25 ha; average yield = 1.85 tons/ha; n=5

[4] TLC inputs were provided in return for grain after harvest (75kg for the 0.1 ha plots and 150kg for the 0.25 ha plots). The calculation was done by counting the low maize price value of this grain as a cash input. The inputs were provided following the TLC guidelines in Table 1.

[5] The market value of the actual inputs used was calculated using prices from TLC

[6] The low maize price is the farm-gate price at harvest time.

[7] The high maize price is the high nominal retail value in Tete for a 5 year average (USAID FEWS Net, 2010).

[8] No household labor costs were included. Paid labor costs are included. This row is a cash analysis of cash costs compared to the value of the grain produced

[9] Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age

[10] Includes the cost of labor valued at MZN 40 per 8 hour day for all household labor adjusted by gender and age

Table 6: Estimated signs for net profit of Total Land Care (TLC) promoted conservation agriculture based on ideal yields (2.7 tons/ha) for two input application rates under different conditions for valuing labor, maize and inputs.[1]

	TLC (0.5 tons/ha fertilizer, 0.1 ha)				TLC (0.4 tons/ha fertilizer, 0.25 ha)			
	Inputs subsidized[2]		Inputs at mkt value[3]		Inputs subsidized		Inputs at mkt value	
	Low Maize Price[4] (4/kg)	High Maize Price[5] (8/kg)	Low Maize Price (4/kg)	High Maize Price (8/kg)	Low Maize Price (4/kg)	High Maize Price (8/kg)	Low Maize Price (4/kg)	High Maize Price (8/kg)
Labor free[6]	+	+	-	+	+	+	-	+
Labor at 20/day[7]	+	+	-	+	+	+	-	+
Labor at 40/day[8]	-	+	-	-	+	+	-	+

Source: author's fieldwork, 2010

[1] All prices in Mozambican Meticais (MZN35 = 1 USD).

[2] TLC inputs were provided in return for grain after harvest (75kg for the 0.1 ha plots and 150kg for the 0.25 ha plots). The calculation was done by counting the low maize price value of this grain as a cash input.

[3] The market value of the actual inputs used was calculated using prices from TLC

[4] The low maize price is the farm-gate price at harvest time.

[5] The high maize price is the high nominal retail value in Tete for a 5 year average (USAID FEWS Net, 2010).

[6] No household labor costs were included. Paid labor costs are included. This row is a cash analysis of cash costs compared to the value of the grain produced

[7] Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age (see Appendix C)

[8] Includes the cost of labor valued at MZN 40 per 8 hour day for all household labor adjusted by gender and age (see Appendix C)

Table 7: Profitability of conservation agriculture use by Igreja Reformada em Moçambique participants under different conditions for valuing labor and maize.[1, 2]

	Low Maize Price (4/kg)[3]			High Maize Price (8/kg)[4]		
	Proportion with positive net profit	Mean	Median	Proportion with positive net profit	Mean	Median
Labor free[5]	5/6	108	210	5/6	482	420
Labor at 20/day[6]	1/6	-519	-305	2/6	-146	119
Labor at 40/day[7]	0/6	-1146	-801	1/6	-773	-559

Source: author's fieldwork, 2010

[1]All prices in Mozambican Meticais (MZN 35 = 1 USD).

[2]Actual input purchase prices used, no herbicides were used, hybrid seed was not purchased; average yield = 1.45 tons/ha; average plot size = 0.08 ha; average fertilizer use was 0.085 tons/ha; average compost use was 1.5 oxcarts per plot; (n=6).

[3]The low maize price is the farm-gate price at harvest time.

[4]The high maize price is the high nominal retail value in Tete for a 5 year average (USAID FEWS Net, 2010).

[5]No household labor costs were included. This row is a cash analysis of cash costs compared to the value of the grain produced

[6]Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age (see Appendix C)

[7]Includes the cost of labor valued at MZN 40 per 8 hour day for all household labor adjusted by gender and age (see Appendix C)

3.3.1. Profitability by area

Figures 1 and 3 present the estimated total costs and benefits for TLC farmers and IRM farmers respectively for different field sizes by making the following assumptions about the opportunity cost of labor: I assume that labor requirement has a linear relationship with the field size and that the opportunity cost of labor for 0.5 ha or above is the market wage rate but the marginal wage decreases linearly to half the market wage rate at 0.25 ha and on to a very low value at 0.01ha. In reality, the exact relationship would be household and season-specific based on the opportunities each household has for using its labor productively at different times of the year.

The yields, hours required and input costs used to generate the curves in Figure 1 are based on the average data from the 5 farmers with TLC using the 0.4 tons/ha fertilizer application rate. The change in slope in the total cost of production at 0.25 ha is caused by the fact that the inputs are subsidized by TLC only up to 0.25 ha but for larger areas farmers would have to pay the full market price. The total cost of production also includes the actual cost of paid labor which was used by several farmers to enable planting the 0.25 ha plot in one day. Some of the farmers used a system of labor sharing to accomplish the same goal. The cost for the paid labor was retained as a cost apart from household labor because it reflects the high labor cost for peak season activities such as planting.

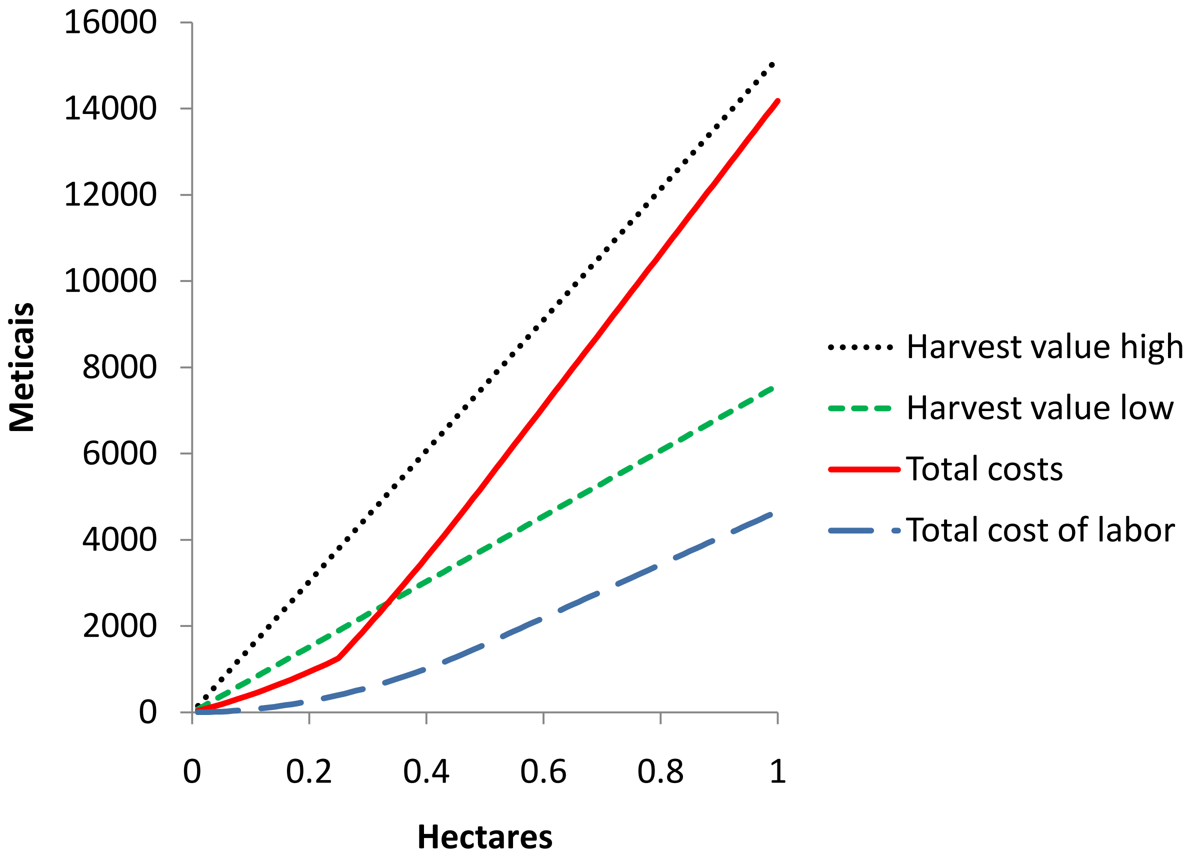
The difference between the harvest value and the total cost of production is the profitability at any given point. In order to maximize profit a farmer would want to use CA only up to the point where the cost of increasing area by one more unit equals the benefit of one more unit. This point is easily identified by finding where the marginal cost curve and the marginal benefit curve intersect (Figure 2 for TLC and Figure 4 for IRM). At a high maize price the optimal TLC CA area under these assumptions is 0.29 ha, just after the full price of inputs needs to be paid. At a low maize price the optimal CA area is 0.25 ha just before the full price of inputs needs to be paid. Though it would be possible to achieve positive net returns using CA on a larger area than these points, it would not be as profitable as where the curves intersect.

A larger scale farmer who regularly employs labor is assumed to have an opportunity cost of labor equal to the market wage rate regardless of the area cultivated. Such a farmer would never find the TLC system of CA profitable even with high maize prices, as represented by the horizontal portion of the marginal cost curve to the right of 0.5 ha which is above the marginal benefit curves. With a subsidy on the inputs they would find it profitable to use CA if they could get the higher maize price for their output (see figure 6 in Appendix C for the marginal cost curve of a farmer whose opportunity cost of labor equals the market wage rate).

For the IRM data the average total cost of production is higher and the average yield is lower thereby reducing the marginal benefit and causing a reduction in the area where CA is profitable (Figure 3). The level of inputs used is lower than with TLC and the relative amount of labor is higher which causes the labor cost curve to be closer to the total cost curve than for TLC. The optimal IRM CA area for maximizing profitability under these assumptions (where the marginal costs equal the marginal benefits) is at .04 ha for a low maize price and .19 ha for a high maize price (Figure 4).

These figures for both IRM and TLC are illustrative of the relationships indicated by the qualitative results. The results are based on a very small sample size and need to be tested with a much larger sample size to establish the finer details of the relationships. Nevertheless, the figures help to demonstrate how the profitability of CA depends on the opportunity cost of labor, which varies significantly from one farmer to the next.

Figure 1: Total cost of production[1,2] and total benefits under two output price scenarios[3] for Total Land Care (TLC) plots with 0.4 tons/ha fertilizer application rate.[4]



Source: author's fieldwork 2010

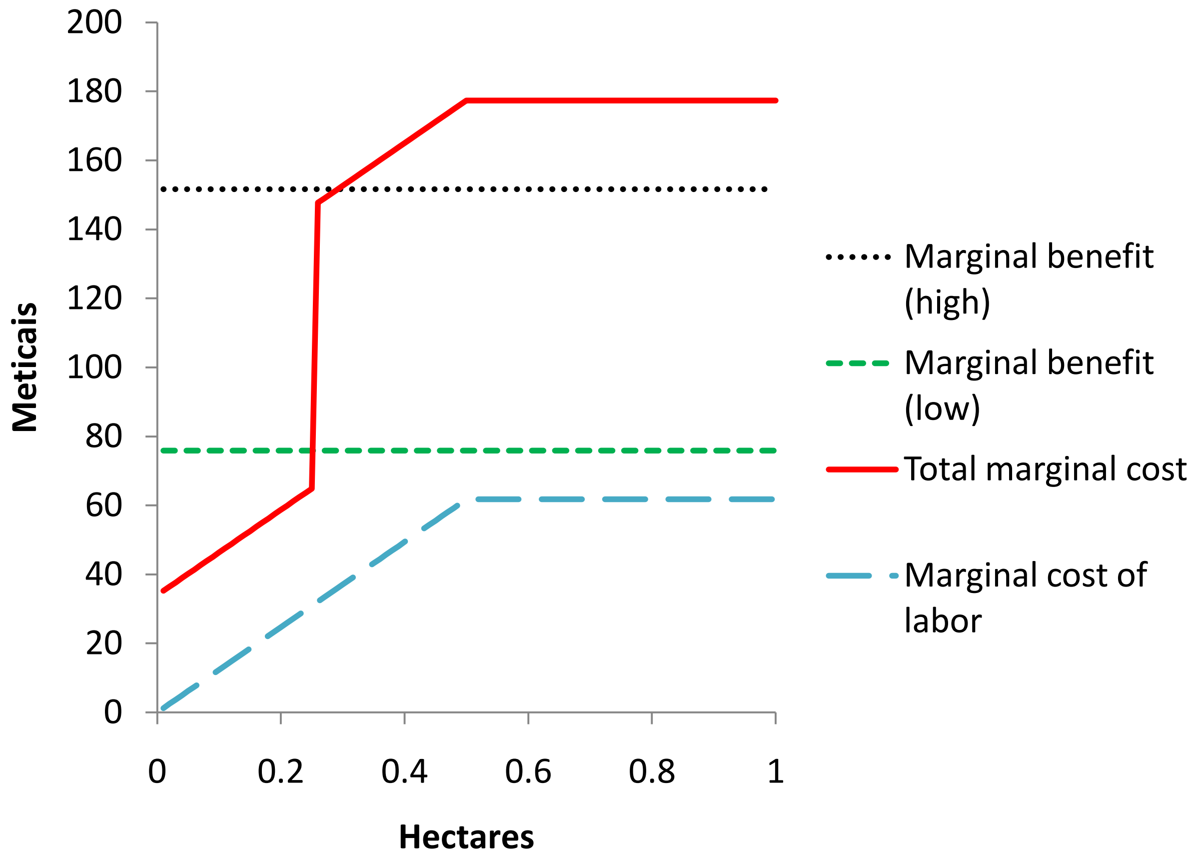
[1]The total cost of production is estimated by adding the cost of purchased inputs, the cost of paid labor and the opportunity cost of household labor.

[2]For this figure the opportunity cost of household labor was valued at the agricultural wage rate (40 MZN/day) for all areas beyond 0.5 ha. The opportunity cost of labor was calculated by using a marginal wage rate which was assumed to decrease linearly passing through a point where half the agricultural wage rate (20 MZN/day) is the value at 0.25 ha.

[3]"Harvest value high" has a maize price of 8 MZN/kg and "Harvest value low" has maize price of 4 MZN/kg.

[4]For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

Figure 2: Marginal cost of production[1,2,3] and marginal benefits under two output price scenarios[4] for Total Land Care (TLC) plots with 0.4 tons/ha fertilizer application rate.



Source: author's fieldwork, 2010

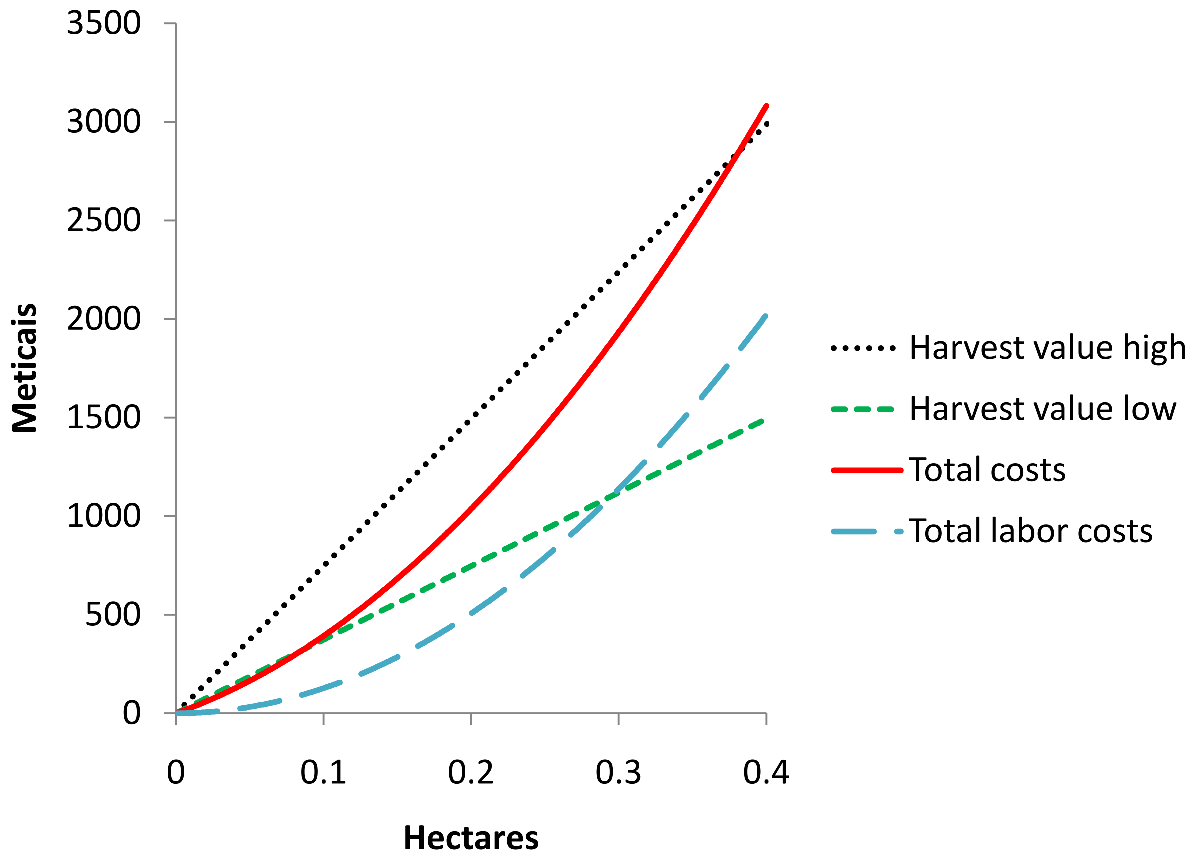
[1]Marginal costs and benefits were calculated for increments of 0.01 ha.

[2]The marginal cost of production is estimated by adding the marginal cost of purchased inputs, the marginal cost of paid labor and the marginal opportunity cost of household labor.

[3]For this figure the marginal opportunity cost of household labor was valued at the agricultural wage rate (40 MZN/day) for all areas beyond 0.5 ha. The marginal opportunity cost of labor was assumed to decrease linearly passing through a point where half the agricultural wage rate (20 MZN/day) is the value at 0.25 ha.

[4]"Harvest value high" has a maize price of 8 MZN/kg and "Harvest value low" has maize price of 4 MZN/kg.

Figure 3: Total cost of production[1,2] and total benefits under two output price scenarios[3] for Igreja Reformada em Moçambique (IRM) plots with 0.085 tons/ha fertilizer application rate



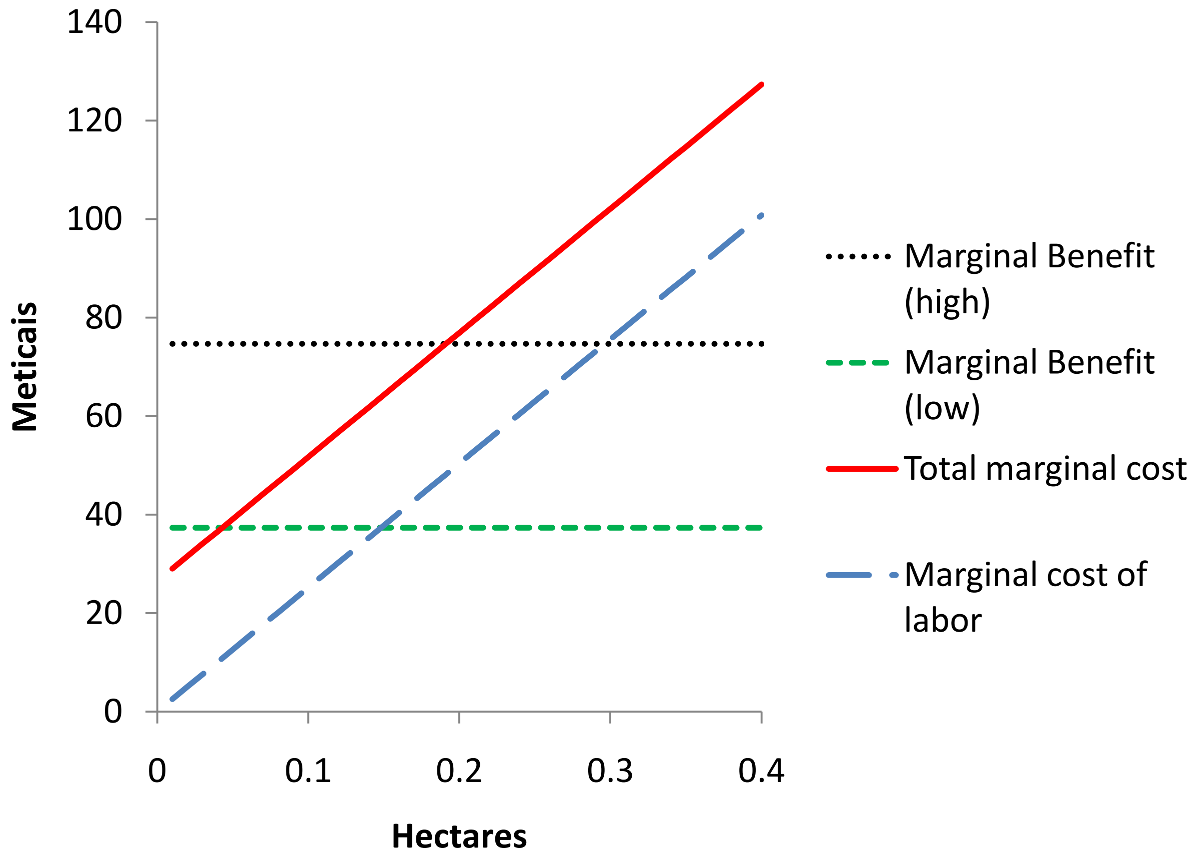
Source: author's fieldwork 2010

[1]The total cost of production is estimated by adding the cost of purchased inputs, the cost of paid labor and the opportunity cost of household labor.

[2]For this figure the opportunity cost of household labor was valued at the agricultural wage rate (40 MZN/day) for all areas beyond 0.5 ha. The opportunity cost of labor was calculated by using a marginal wage rate which was assumed to decrease linearly passing through a point where half the agricultural wage rate (20 MZN/day) is the value at 0.25 ha.

[3]"Harvest value high" has a maize price of 8 MZN/kg and "Harvest value low" has maize price of 4 MZN/kg.

Figure 4: Marginal cost of production[1,2,3] and marginal benefits under two output price scenarios[4] for Igreja Reformada em Moçambique (IRM) plots with 0.085 tons/ha fertilizer application rate



Source: author's fieldwork 2010

[1]Marginal costs and benefits were calculated for increments of 0.01 ha.

[2]The marginal cost of production is estimated by adding the marginal cost of purchased inputs, the marginal cost of paid labor and the marginal opportunity cost of household labor.

[3]For this figure the marginal opportunity cost of household labor was valued at the agricultural wage rate (40 MZN/day) for all areas beyond 0.5 ha. The marginal opportunity cost of labor was assumed to decrease linearly passing through a point where half the agricultural wage rate (20 MZN/day) is the value at 0.25 ha.

[4]"Harvest value high" has a maize price of 8 MZN/kg and "Harvest value low" has maize price of 4 MZN/kg.

3.3.2. Summary

The high ratio of input cost to output price means that if TLC farmers had to pay the full market price for inputs they would only cover their costs if they were able to store their maize until its price rose to MZN 8/kg (the annual high based on a 5-year average (USAID FEWS Net, 2010)). Though farmers under these conditions could cover their costs by using CA they would not be maximizing their profits. This implies that CA with high inputs is not profitable at a large scale unless subsidized. At a small scale CA is profitable for households with a low opportunity cost of labor.

According to the data from the interviews IRM's system of CA with basins is too labor-intensive to be profitable when the opportunity cost of labor is at least equivalent to the lowest agricultural wage. This implies that unless labor requirements can somehow be reduced IRM's CA system is only profitable on small plots where the opportunity cost of labor is negligible.

3.4. Missing benefits of CA

It is worth noting here that some of the possible benefits of CA were not mentioned or hinted at by the farmers in Bwaila. They did not view early planting and reducing a labor bottleneck at planting time as benefits of the CA system. In this community all farmers prepare land for conventional agriculture months before the rains start, enabling planting with the first rains. In addition, there is high dry season labor opportunity cost because of irrigation. There was no mention of the benefit of breaking through hard pan, nor any description of reduced water logging. The soil type may be one that is not easily compacted, though I did not test the compaction of the soil, nor did I observe the fields during the rainy season to check if this is the case. Farmers in Bwaila also did not mention any benefit from reduced erosion, and many of them even felt that the lack of ridges may increase erosion, leading them to only use CA on relatively flat fields.

4. Discussion and Conclusion

This qualitative assessment of farmers' perspectives on CA provides depth and detail from the farmers' perspectives which is often lacking in quantitative studies and which can inform CA research about constraints to adoption. Through the analysis I developed a number of hypotheses regarding constraints to the adoption of CA for maize by smallholder hand-hoe farmers. The results are potentially generalizable to similar agro-ecological and socio-economic conditions. The partial budget analysis is based on a small sample size and is not meant to be conclusive. Instead the profitability data illustrate the challenges in wide-scale adoption in this specific context and for this specific form of CA.

Hypothesis 1: In order to attain yields from CA higher than conventional tillage, fertilizer or compost is required which in turn requires either cash or labor, so adoption is difficult for both cash- and labor-constrained farmers.

Farmers in Bwaila use tillage as a means of in-field compost making and nutrient release. CA only performs better than ridges in the short term if fertilizer or compost is added. Compost is labor intensive and therefore can only be applied to small areas. Fertilizer is expensive and farmers prefer using it on cash crops which have a higher profit than maize. Some farmers used their own fertilizer on small plots of maize but not all of them used CA. The current constraints preventing permanent mulch cover and rotations with a legume exacerbate the need for fertility supplements with CA.

Implications: If CA requires fertility supplements then mulching, rotations, intercrops and green manures all need more attention so that chemical fertilizer use can be minimized and its benefit maximized. NGOs or governments may subsidize fertilizer and this can be used to persuade CA adoption. Agro-ecological practices can help maximize the cost effectiveness of fertilizer use.

Mulching continues to remain a challenge but allowing farmers to choose fields with the least biomass pressure may help.

The policy of subsidizing inputs has been both highly praised and highly criticized. These results suggest that input subsidies affect CA utilization in the short term. Despite increased production and possibly reduced erosion from CA use, more information is needed to really analyze the net effect of a subsidy.

<u>Hypothesis 2:</u> CA eliminates the work of making ridges but requires more labor for land preparation (for basin making) as well as more labor or money for weed control.

Labor constraints in basin making and weeding for IRM participants limit the widespread use of CA. TLC participants save time and effort in land preparation but herbicides are too expensive to justify their use.

<u>Implications:</u> Those promoting CA with planting basins should train farmers how to dig basins as quickly and efficiently as possible to reduce the labor needed in land preparation. In addition, IRM should explore the possibility of not requiring participants to level their ridges so that first year land preparation labor can be reduced. Those promoting CA with herbicides should carefully consider the cost of weeding relative to herbicide use.

<u>Hypothesis 3:</u> Under the current price ranges for labor, maize and chemical inputs CA is not profitable for maize production except on a small scale where the opportunity cost of labor is lower.

The small scale allows farmers with some surplus labor to implement CA without much cost while providing them with an “insurance plot” for reliable maize production. As long as these constraints exist, small CA maize plots will operate side-by-side with larger conventional maize plots.

Implications: Promoters of CA should be more aware of the labor and capital limitations farmers face in CA adoption and understand that these are likely to vary by household. They should work with farmers to find the niches where CA costs can be minimized and its benefits maximized. They should understand that in the Angonia highlands CA and conventional agriculture are likely to continue to exist side-by-side and understand that promoting sustainable agriculture in that region means more than promoting CA. Development agencies interested in sustainable agriculture in Angonia need to work with farmers on their non-CA plots as well to reduce erosion, increase production and reduce labor requirements.

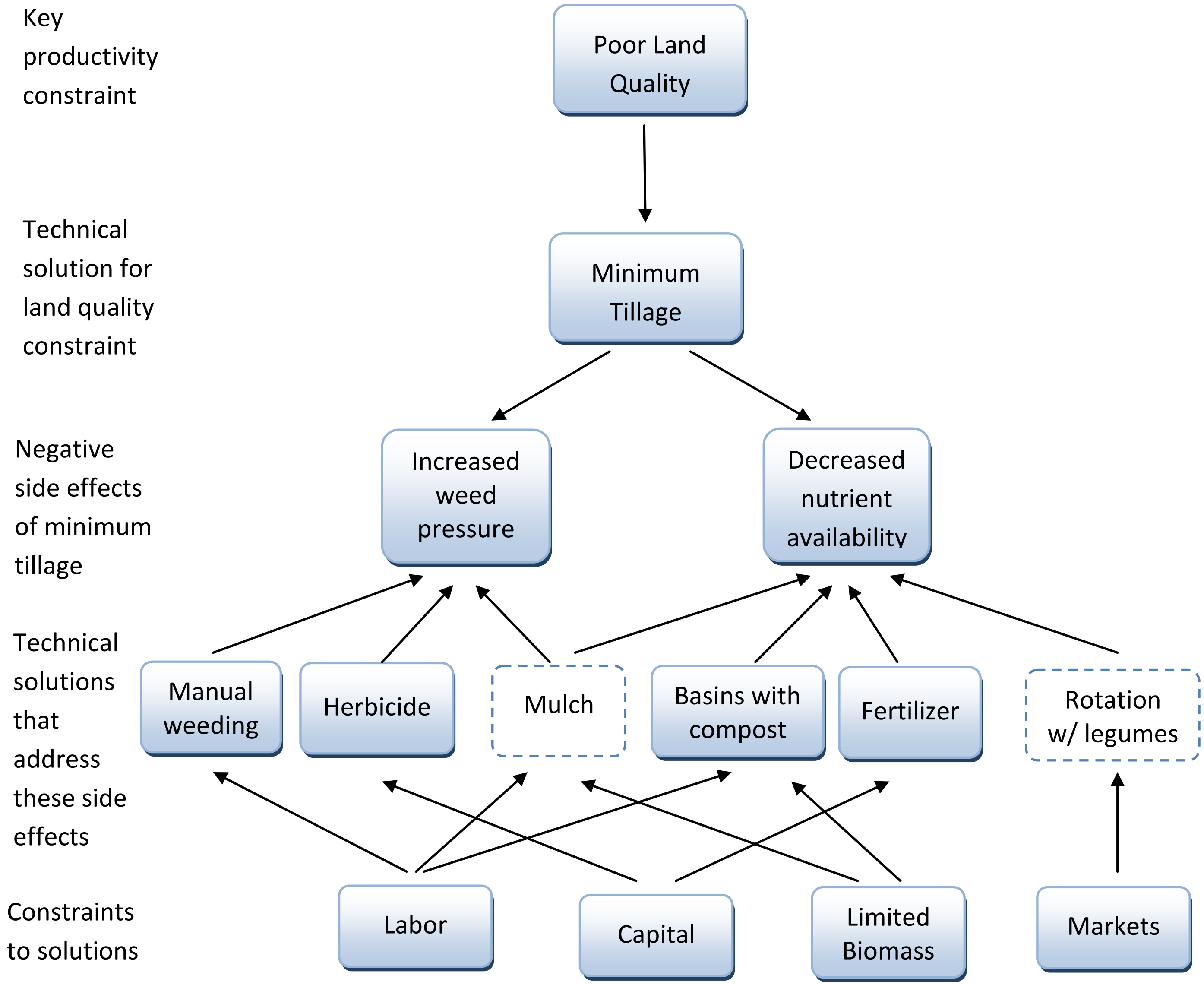
Figure 5 summarizes these hypotheses about constraints conceptually. Poor land quality is being addressed through minimum tillage which results in a need for more fertility amendments and weeding. Weed control requires either herbicides (which is constrained by capital) or more weeding (which is constrained by labor). Decreased nutrient availability requires either fertilizer (which is constrained by capital) or compost (which is constrained by labor and by the scarcity of biomass). If compost is used then basins are needed (which also requires more labor). Mulch permanence would reduce the amount of weeds and increase the fertility in the long term but it is not feasible under the current conditions of dry season biomass demand. Rotations with a legume would reduce the need for fertility amendment but requires sufficient output market.

It is important to remember that the results of this study are for hand-hoe CA methods for maize production without rotation in a high rainfall area. Under different conditions most of the constraints identified would still exist but new benefits or constraints may exist as well. This study focuses on CA in a high rainfall agro-ecological zone and so its moisture conserving benefits may not be as noticeable as in drier regions. However, in drier areas it is likely that farmers would face even greater challenges for maintaining an adequate cover of mulch. CA with animal traction has potential for reducing the labor costs to smallholders but would require higher initial investment in equipment.

Further research is needed to guide policy makers about CA promotion decisions. First of all the hypotheses developed in this study can be tested quantitatively in the same context. Now that I have analyzed the qualitative data I am in a position to embark on a much better survey research process than if I had attempted the two methods simultaneously. Similar studies could be carried out in different agro-ecological and socio-economic contexts with a larger, randomly selected sample in order to discern where CA has the most promise and where it might not be worth promoting. The results of this study specifically compare two forms of CA for hand-hoe farmers with the conventional ridge-making system for maize but other crops and other forms of CA are being used and would require their own analysis.

The positive and negative effects of CA broadly described in Table 1 should be explored in different agro-ecological zones of southern Africa. For example, areas with shorter seasons and less rainfall than Angonia may find the drought tolerance of CA more attractive but those contexts may have other constraints, perhaps even greater demand for biomass from livestock and for fuel. A more thorough understanding of the conditions where the different costs and benefits of CA are present would allow NGOs, policy makers and other development agencies to be more effective in how they promote sustainable agriculture. In addition, a comparative study of CA in contexts with varying socio-economic conditions could facilitate a discussion about how changes in factors such as market access or animal traction would affect CA adoption.

Figure 5: Conceptual diagram of how labor and capital are constraints to conservation agriculture adoption by small holder farmers in Mozambique



APPENDICES

Appendix A: Data collection instruments

A.1. Interview guide

This guide indicates the key topics for an unstructured interview with farmers at their home or in their fields. The main questions are listed first in each section with possible follow up questions listed beneath them.

Introduction

Can you describe for me the different agricultural activities you carried out over the last year?

- What did you grow on this plot last year?
- When did you start land preparation for this plot? How much time did it take?
- When were you able to plant? What inputs did you use? Did you use any animal manure or compost? How did you apply it?
- What activities do you do and what activities are done by your spouse or children? What activities do you hire laborers to complete?
- How were the rains?
- How did the crop perform?
- (See plot level data collection sheet below)

Minimum tillage

Can you explain to me how you learned about planting in basins instead of ridges?

- How long have you been using basins on part of your farm?
    - How many basins did you have each year since you started?
- What technical support have you had in learning how to use basins?
- What have you heard about basins from outside organizations supporting your community's agriculture?
- What motivated you to try this method of land preparation?
    - How did you decide on which plot to try using basins on?
    - What was your attitude about CA when you first tried it? Did you think it would work?
    - What made it difficult? What parts were easy?
    - Who approved of you trying CA? Who disapproved?
    - What prevented you from using basins on more area?
- What is your general opinion about the benefits of the basins?
- What are your plans for land preparation for the coming year? When will you start? What method will you use?

Please describe to me how to use basins for agriculture?

- How do you go from a ridged field to a field with basins?
- Do you need any special tools?
- How do you decide where to dig the basins? Do you measure?

What do you put in the basins?
How do you weed without turning over the soil?
How does weeding compare with traditional ridge tilling? Who has been most affected by any changes in weeding?
How do you bank your maize?
Do you have to dig the basins every year? Do you measure every year?
Do you do anything differently depending on the type of soil in the field? Please explain.

Do the basins affect the water in your field? How?
When it rains hard how is a plot with basins different from a plot with ridges?
When there is a dry spell how is a plot with basins different from a plot with ridges?
Can you share examples from the last few seasons about any noted differences between basins and ridges?
Do you have any concerns about erosion in any of your fields?
What do you do if you are concerned about erosion?

Crop Rotation

How do you decide where you will plant your maize?

What is your experience growing maize in a field that previously had legumes?

What would make it easier to grow more legumes?

Mulching

What do you do with what is left in the field after you harvest?

For those not using mulch:
What do you think would happen if you left the crop residue in the field?

For those using mulch:
What happens to the crop residue when it is left on the field?
Do termites remove it? Do cattle eat it?

What difference do you see between a plot where you have left crop residue and one where the crop residue has been removed or burned?
How does the crop residue affect weeding if at all?
How does the crop residue affect soil fertility if at all?

Animal Traction

What livestock do you own?
Is there anyone you know who uses livestock for land preparation?
Have you ever used livestock for land preparation (either your own or someone else's)? Please explain.

For those who have livestock but have not used them for land preparation
What prevents you from using your livestock for land preparation?
For those who have livestock and used them for land preparation
How did you learn about animal traction?
What equipment do you use?
How much area do you prepare using animal traction?
How long does it take to prepare one hectare of land? What method do you use?
Are you aware of ripping lines as an effective land preparation method?
Do you let others borrow your animals for land preparation?
Do you rent your animals for land preparation?

<u>Labor</u>
How many people are in your household? How many of them work in the fields? What other types of work does each person in your household do? How many children are in your household?

What activities do you do between the start of the harvest and when the rains start again? How much time do you spend on the different activities? Which ones are most important?

(Possible answers may include: Processing the harvest, Irrigation, Buying and selling agricultural products, Buying and selling manufactured goods, Wage Labor, Land Preparation for rain fed plots, Cultural activities such as weddings, funerals, and other ceremonies, Home improvements / construction, Community projects)

<u>Land Tenure Security</u>
Do you think you will be farming this same plot next year? What about two years from now? What about five years from now? (If applicable: What makes you think that you may not be farming this plot in the future?)

<u>Perceptions about rainfall patterns</u>
Did your crops experience any dry spells over the last three seasons? How severe were they (mild, severe, very severe)? Which plots were affected?

Did your fields have any flooding or damage from excess water over the last three seasons? How severe were they (mild, severe, very severe)? Which plots were affected?

A.2. Professional Interview Guide – for use with NGO workers or extension staff

Please explain for me the history of your organizations involvement in promoting conservation agriculture?

How did you first hear about it?

Please explain for me the process your organization has used for promoting conservation agriculture?

What methods do you use to motivate farmers to try a new tillage method?

Can you share with me any training manuals or lesson plans you use?

Where did they come from?

What adaptations have you made?

How do you interact with farmers in the communities? Groups? Individually? How regularly?

Has your organization been involved in the formation of groups of farmers? How is that done?

How are the skills of groups built by your organization (if at all)?

What are the results that you see so far in farmers adopting conservation agriculture?

How many farmers? What locations? What benefits?

How long have you been promoting it?

What challenges do farmers share with you about conservation agriculture?

What challenges do you see for the widespread adoption of conservation agriculture?

What do you think should be done to address these challenges?

How does your organization feel about farmers who adopt only portions of conservation agriculture or do not implement it the way that you trained them to?

A.3. Community selection table

Table 8: Community selection table with details of conservation agriculture (CA) participation and promotion by Total Land Care (TLC) and Igreja Reformada em Moçambique (IRM)

Village	Farmers Practicing CA		Years promoted		Distance	Characteristics
	TLC	IRM	TLC	IRM	km	
1 (Bwaila)	16	35	3	4	40	hilly, densely populated in parts, large village
2	6	8	2	3	10	near main road and close to town
3	23		3 (6 ppt.s)		25	on main road
4		8 to 13		2 (3 aware)	45	on border, low pop. Levels, not too far from main roads
5 (Mulingo)		20+		3	65	bad road, 1 hour or more, low pop. levels, strong group, water - irrigation, not ver far from Malawi main road
6	30+6		2		30	TLC model village, hilly, lots of trees planted, tecnico says high unity
7	15		3		50	Near posto administrativo, rolling hills
8	5		2		5	
9	1?				10?	1km off main road
10	demo plot		1		12?	off main road
11	demo plot		1		15?	off main road
12	3		2		35	right next to Domue road
13	12 to 20	some	1	4	60	
14	55		1		130	
15		?		4	45	

A.4. Labor data collection sheet

Table 9: Sample labor data collection sheet

Community: Mulingo ID: MF 3 Field: IRM Date: 23 July

			Men				Women				Children						Paid labor		
Task description	Timing (dates)	Method/ notes	workers	# days	hours/day	**Total hours**	workers	# days	hours/day	**Total hours**	workers	# days	hours/day	**Total hours**	**Total person hours**	**Adjusted man hours**	How paid	Value per day	Other payment
Dig basins	Nov	before rain				0	1	3	6	18				0	18	13.5			
Compost	Nov					0	1	3	6	18				0	18	18			
Residues	Oct					0	1	2	6	12				0	12	12			
Add grass	Oct					0	1	5	6	30				0	30	30			
Plant	Dec	3/basin				0	1	3	6	18	1	3	6	18	36	31.5			
Weed	Jan					0	1	4	6	24	1	4	6	24	48	36			
Weed	Feb					0	1	2	6	12	1	2	6	12	24	18			
Weed	Feb					0	1	2	6	12	1	2	6	12	24	18			
Harvest	Jun					0	1	1	9	9				0	9	9			
Total						**0**				**153**				**66**	**219**	**186**			

Other notes: this year 3 sacks harvested
last year one oxcart
child age 11

Summary	Hr. s	%
Planting	45	24%
Weeding	72	39%
Fertilizing	18	10%
Mulching	42	23%
Harvesting	9	5%

A.5. Record of interviews and community meetings

Day 1 – TLC professional Lilongwe

Day 3 – TLC visit to Bwaila – quite brief – meeting at house of BM9

Day 11 – Mulingo visit

Day 14 – IRM group meeting at church, demo garden visit to fields of BF1, BF2 and BF3

Day 16 – Meeting with village chief with IRM Bwaila staff

Day 19 – TLC professional Vila

Day 22 – Meeting with village chief and area chief with IRM staff. IRM group meeting – consent and basic info. at house of BM13

Day 23 – (funeral) TLC group meeting – consent and basic info – at Store

Day 26 – IRM professional Bwaila

Day 27 – (funeral) BM4 at field, BM5 at field, BM4 at home

Day 28 – (funeral) BF1 home (short), BM6 TLC field, Bf8 (home short)

Day 29 – BM9 home, BF26 home, BM10 home and TLC field

Day 30 – BF26 TLC field

Day 33 – BM8 TLC and IRM field, BM10 home (not recorded)

Day 35 – BM2 home Bf2 TLC field, Bf3 TLC field BM5 home

Day 37 – BM9 (TLC field) BF9 home IRM disadopter, BF58 TLC non participation

Day 40 – BM13 home and IRM field, BM11 at wetland - disadopter

Day 42 – BF 45 (TLC field was IRM field - disadopted) and BM9 (own CA field) BF1 at house

Day 48 – BM6 (follow up at home and field), BF59, BM5 (about selection of BF59)

Day 49 – P4

Day 50 – BM7, BF60 (dis-adopter), BM9 (at wetland regarding inputs). Non-adopters: BM61b and BM61f, BM62, BM63, BM64, BF65

Day 51 – P5

Day 52 – Met BF61 at home with BF61g and BM61bro (non-adopters), set up visit for 21 July with BM68. Followed up with BM2 about labor for IRM plot, arranged to meet BM11 on 21 to finalize plans for IRM meeting. Interviewed his two daughters BF66 and BF67 (non-adopters). Tried to meet some non-adopters in field on way out but they declined to participate.

Day 55 – meeting with IRM agricultural staff about CA and IRM and general soil fertility discussions

Day 56 – BM68 (animal traction) and neighbor – BM69, confirmed meetings for next week Monday and Tuesday with BM11 and BM9. Tried to meet relative of BM8 with cattle but did not find the person. P6 at Fonte Boa and P7 in Vila Ulongue. Also spoke with P2 (not recorded) to get information on costs of inputs for CA and printed copies of protocols for CIMMYT/CIAT and CIMMYT/USAID.

Day 58 – Mulingo field visit

Day 61 – Neighboring TLC community, BM9, BF25, TLC group meeting

Day 62 – BF 19 and 20, IRM group meeting, BM12 and11, BF13 history, took village chief to area chief

Day 63 – Kawale with P8

Appendix B: Details on Thematic analysis

Table 10: Coding rules, definitions and examples

Name	Definition	Rule	Example (my words in italics)
Benefits of CA	Benefits from conservation agriculture which may be referred to as Farming God's Way or farming without tilling	Apply to any data where the interviewee expresses a positive opinion of the agricultural methods learned from Total Land Care or the Igreja Reformada.	*How did you first react the first time when you heard let's try no till farming?* I just heard that and thought let's see it and how it worked. I saw it and the herbicide sprayed and saw that it doesn't need a lot of work, in our farming we have to ridge and hoe and this one you just have to arrange the cornstalks which is easy and saves a person. It doesn't get your blood running this no till farming.
Challenges of CA and reasons for disadoption	Both directly stated problems as well as reasons why farmers do not expand no till farming or reasons why they have stopped using no till methods	Apply to any data where the interviewee describes problems with the agricultural methods learned from the NGOs, reasons they cannot expand it or reasons they have reduced area or stopped altogether.	That other way of planting stations produced a lot of maize but when there was a lot of rain it seemed like a lot of maize rotted. We only pala (lightly weed) the power of the holes. But this way of cutting the ridges and adding manure the roots develop better, they find the food faster but without till they dry faster. Where there is minimum tillage the roots quickly find undug places that are too dry so it gets weak quickly. But where you have made ridges they all do well.
Compost making	Producing organic compost in a pit or a heap	Apply to any data discussing compost making, transport, its application and its effectiveness. Include even simple statements about not knowing how to make compost.	*Have you learned to make compost?* Yes we make it. *What do you use?* To make compost we dig out that hole and then we go around get cow manure, leaves, to mix it all up, different leaves of fertility and we mix it all together and add water and wait a few days until it is ripe.
Conversions for units measuring maize	The local measures of the volume of grain or cobs of maize	Apply to any data indicating how the different measures relate to each other	*How many baskets fit in an oxcart?* It depends on the oxcart – some are bigger and some are smaller. I use my parents' oxcart and it has 17 baskets. You fill the oxcart by nailing the cobs in.

Table 10 (Cont'd)

Name	**Definition**	**Rule**	**Example (my words in italics)**
Day labor use and wages	Agricultural wage labor in cash or in kind. Not family labor.	Apply to any data discussing the use of wage labor or participation in wage labor for agriculture including availability, wages and quantity of wage labor used or provided.	*So you have these 4 fields, do you pay day laborers?* Yes, we have to pay day laborers, sometimes when hunger is a problem, instead of eating enough ourselves we use some maize in the rainy season and find some friends who can help us a little, and we give them maize. *How much do you pay them per day? Do you count out a plate?* We count out. We find people who can work 4 days and we pay them one bucket of maize . One person 4 days we give them a bucket of maize.
Decisions about CA plot location	The explanation about why a specific plot was chosen for conservation agriculture compared to other options.	Apply to any data stating reasons for the choice of the plot for CA use or any guidance from the NGO about plot location	He said that if they have visitors they want to be able to visit quickly so fields should be close to the road. That's what he said. That's why I chose field three because even though it is a bit away it is right on the road and my other fields, hey they are on the other side of the hills. Indeed. That's what happened, they want close fields so that they can take visitors there. *But if it wasn't like that what would you do on your own, which field would you choose?* Ohh… I would rather have the TLC farming be on field 2. *The one on the other side of the hill?* Yes. *Why is that?* Because it has a lot of space and it is level. If I could have I would have chosen that one.
Erosion	The loss of soil due to runoff and the resulting soil degradation	Apply to any data talking about erosion - it's prevention, prevalence or how CA affects it	*What about regarding soil erosion?* Regarding soil erosion it is better here in TLC plot because we put the crop residues, they help keep the water from running very fast, when the rain comes and it hits the residues, it is caught up a little bit.

Table 10 (Cont'd)

Name	**Definition**	**Rule**	**Example (my words in italics)**
Fertilizer use	Chemical fertilizer use in general	Apply to any data relating to fertilizer use, benefits, challenges and its effectiveness. Leave out isolated requests for fertilizer that do not have any further discussion about fertilizer.	*Where have you used fertilizer?* I used it in three fields. The TLC plot, the IRM plot and the small one with only maize. *And that third plot, how much fertilizer?* I added 25kg of Chitowe. *As a basal dressing?* Yes. *Are there other field where you used compost?* No, only the IRM plot.
Herbicide	Herbicide use in general	Apply to any data discussing herbicide application and its effectiveness	In the first year I used herbicide – roundup and bullet applied before planting and before the rains came. We mix the two herbicides at once in the backpack sprayer. The sprayer came from TLC and stays with the chairman.
Interactions with NGO	Total Land Care and the Igreja Reformada (also referred to as CCAP and Bwaila) are non governmental organizations actively promoting CA	Apply to any data where the interviewee describes how they interact with either NGO including any reference to their selection, provision of inputs, the timing of those inputs, and the need to return harvest to the NGO as well as the influence of the NGO on field selection.	I saw others farming like that and I was admiring/jealous and thought I should try my own farming God's way field. *Whose field did you see?* Fulana's. She is the one who… I saw her and said, so that's how you do it? She said yes and then I said when your facilitator comes tell him that I am also interested. So then when the facilitator came and told me how to do it. I entered that church and learned about agriculture, they were training about compost making and they said here is a visitor and I said I don't want to be a visitor I want to be one of you.
Irrigation	Any discussion of any type of irrigation	Apply to any data referring to irrigation	*You have two dimba gardens?* Yes, this one and the other over there. We are harvesting potatoes now and will plant beans. *Only beans?* We will put a few maize plants in there. We have a well and we carry it with a can and our hands hurt – we need a treadle pump.

Table 10 (Cont'd)

Name	**Definition**	**Rule**	**Example (my words in italics)**
Labor Shortage	Expression of not being able to complete a task for any reason indicating a shortage of labor	Apply to any data where the interviewee specifically mentions a labor shortage related to agriculture	I used a hoe to weed once here. My wife got sick and so I was not able to do a second weeding with a hoe and you would have seen much less weeds than you see now. It takes my wife and two kids and I four days to weed this field. But this is less work than weeding in conventional ridging.
Land Tenure	Any mention of the expectation of staying or being kicked off the land. Discussions about inheritance or renting	Apply to any data where land tenure is discussed or alluded to.	*And all the fields are yours or do you have to pay for them?* No they are mine, I am the owner. *And do you expect to continue farming those fields for many years?* Yes. Those fields are the end of my life. Really the end of my life. I will leave them to my children and they are the ones I received from my parents. They are not borrowed.
Legumes and Rotations	Legumes in this area are peanuts, cowpeas, beans, pigeon peas and soya. Rotation refers to any description of changing the crop in a given field from one year to the next.	Apply to any data relating to legume production or describing any type of rotation.	We plant peanuts, beans but they did not stay, the weather – they dried up. These (cowpeas) do not dry quickly though, they grew without drying up even when the rains came back then these still grew.
Livestock	Any discussion of any livestock	Apply to any data referring to livestock	*How do you protect your cassava from livestock this time of year?* The field where we have cassava livestock do not come. *Why? Is it far?* Yes it is far and it is near the wetland gardens and people don't want the cattle to ruin their potatoes and beans so there is protection for my cassava.

Table 10 (Cont'd)

Name	**Definition**	**Rule**	**Example (my words in italics)**
Mulching	Maintaining crop residues on the surface or adding plant material as a soil cover	Apply to any data discussing mulch and any data describing how crop residues are used.	I brought some grass after I had already planted and the maize was about 6 inches tall. I wasn't able to add more because of the transport challenge of an oxcart. Last year I left the corn stalks. Others come by and take them for fuel for cooking. I sometimes use the cornstalks near my home for cooking but I try to use wood, cut a mango tree for the year.
Personal Characteristics	Household information, education levels, other ways they make a living, personal history	Apply to any data revealing details about the basic characteristics or history of the individual or household.	During the war I was here and we left for Malawi. I went to school there but it was a school for us who were refugees in Malawi – I learned 1-3 there. Grades 4-6 I did here when I got back. I was in Malawi 7 years.
Planting method	How the maize is planted - can be direct planted through "stabbing" with a stick, or direct planted by cutting with a hoe or by making planting stations in either a no-till field or a ridge.	Apply to any data referring to the planting method used.	The next job was digging the planting stations with a hoe. Last year I measured but this year I just left the stumps of maize and planted where I saw them – in places where I couldn't see them I just guessed.
Tillage-Fertility connection	The connection between tillage and fertility of the soil	Apply only to data directly stating a connection between tilling and having better production or no till requiring fertilizer	If you plant maize in those basins without compost or fertilizer you can see that it doesn't grow well but in the ridges it grows. *Why is that?* It is because you have mixed the dirt, what was on top is now below and what was on top gives moisture and compost to the ridge, because we take all the residues from the field and knock it down between the ridges and bury it under the ridges and it is like having a bit of fertilizer because of all that residue is in the ridge; whereas the other way we clear the field and leave it all on top, and that is the big difference.

Appendix C: Processing labor and profitability data

Values for profitability assessment

To estimate the market value of the inputs I used the following prices which were supplied by TLC: NPK-MZN20/kg, Urea-MZN16/kg, hybrid seed-MZN35/kg, herbicide-MZN450/liter. The amounts of inputs used on each IRM plot and the prices paid for these inputs were given by the farmers.

The low maize price of MZN4/kg is based on what farmers and professionals mentioned as a farm gate price during the research around harvest time. The high value of MZN8/kg is a high nominal retail value for Tete using the 5 year average (USAID FEWS Net, 2010). Harvests were based on farmer estimates using local units of measure (oxcarts, baskets, buckets and sacks). Conversions for these local units of measure into kg were established by consulting the farmers individually and in their groups by NGO. In general it was estimated that an ox-cart of maize in this area is approximately 270kg of maize grain and a basket is about 15kg of grain (making 18 baskets per oxcart). These measures are not precise since oxcarts are not all of equal sizes and baskets vary greatly in size.

Excluding labor cost allows a simple actual cash input vs. hypothetical monetized output comparison but valuing labor in some way is more realistic. Family labor can be valued at MZN40 per 8 hour day (based on the most common agricultural wage used in Bwaila). Alternatively a value of MZN20 per 8 hour day can be used which is the lowest agricultural wage mentioned or half the most common agricultural wage. The hours worked were based on farmer recall for that plot and adjusted by gender and age (see above for details). Plot areas were measured using a GPS after verifying its accuracy with a tape measure (see Appendix D).

The following tables present additional profitability information for TLC and IRM under different assumptions.

Table 11: Mean net profit for Total Land Care conservation agriculture farmers who received inputs for one plot under different conditions for valuing labor, grain and inputs.[1]

	Inputs subsidized[2]		Inputs at market value[3]	
	Low Maize Price[4] (4/kg)	High Maize Price[5] (8/kg)	Low Maize Price[4] (4/kg)	High Maize Price[5] (8/kg)
Labor free[6]	225	750	-869	-344
Labor at 20/day[7]	-167	358	-1261	-736
Labor at 40/day[8]	-558	-33	-1652	-1127

Source: author's fieldwork 2010

[1]All prices in Mozambican Meticais (MZN35 = 1 USD). Average field size = 0.1ha; average yield = 1.5 tons/ha; n=4

[2] TLC inputs were provided in return for grain after harvest (75kg for the 0.1 ha plots). The calculation was done by counting the low maize price value of this grain as a cash input. The inputs were provided follow the TLC guidelines in Table 1.

[3] The market value of the actual inputs used was calculated using prices from TLC

[4] The low maize price is the farm gate price at harvest time.

[5] The high maize price is the high nominal retail value in Tete for a 5 year average (USAID FEWS Net, 2010).

[6] No household labor costs were included. Paid labor costs are included. This row is a cash analysis of cash costs compared to the value of the grain produced

[7] Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age (see above)

[8] Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age (see above)

Table 12: Mean net profit for Total Land Care conservation agriculture farmers who received inputs for three plots under different conditions for valuing labor, grain and inputs. [1]

	Inputs subsidized[2]		Inputs at market value[3]	
	Low Maize Price[4] (4/kg)	High Maize Price[5] (8/kg)	Low Maize Price[4] (4/kg)	High Maize Price[5] (8/kg)
Labor free[6]	1046	2942	-994	902 (1372)
Labor at 20/day[7]	274	2170	-1766	130 (1375)
Labor at 40/day[8]	-498	1398	-2538	-642 (1395)

Source: author's fieldwork 2010.

[1] All prices in Mozambican Meticais (MZN35 = 1 USD). Average field size = 0.25 ha; average yield = 1.85 tons/ha; n=5

[2] TLC inputs were provided in return for grain after harvest (150kg for the 0.3 ha plots). The calculation was done by counting the low maize price value of this grain as a cash input. The inputs were provided follow the TLC guidelines in Table 1.

[3] The market value of the actual inputs used was calculated using prices from TLC

[4] The low maize price is the farm gate price at harvest time.

[5] The high maize price is the high nominal retail value in Tete for a 5 year average (USAID FEWS Net, 2010).

[6] No household labor costs were included. Paid labor costs are included. This row is a cash analysis of cash costs compared to the value of the grain produced

[7] Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age (see above)

[8] Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age (see above)

Table 13: Profitability of conservation agriculture for Igreja Reformada em Moçambique farmers in Mulingo and Kawale under different conditions for valuing labor and grain. [1, 2]

	Low Maize Price (4/kg)[3]			High Maize Price (8/kg)[4]		
	Proportion with positive net profit	Mean	Median	Proportion with positive net profit	Mean	Median
Labor free[5]	4/4	787	576	4/4	1957	1206
Labor at 20/day[6]	3/4	115	143	4/4	1285	803
Labor at 40/day[7]	0/4	-558	-332	3/4	612	418

Source: author's fieldwork 2010

[1]All prices in Mozambican Meticais (MZN 35 = 1 USD).

[2]Actual input purchase prices used, no herbicides were used, hybrid seed was not purchased; average yield = 1.45 tons/ha; average plot size = 0.08 ha; average fertilizer use was 0.085 tons/ha; average compost use was 1.5 oxcarts per plot; (n=4).

[3]The low maize price is the farmgate price at harvest time.

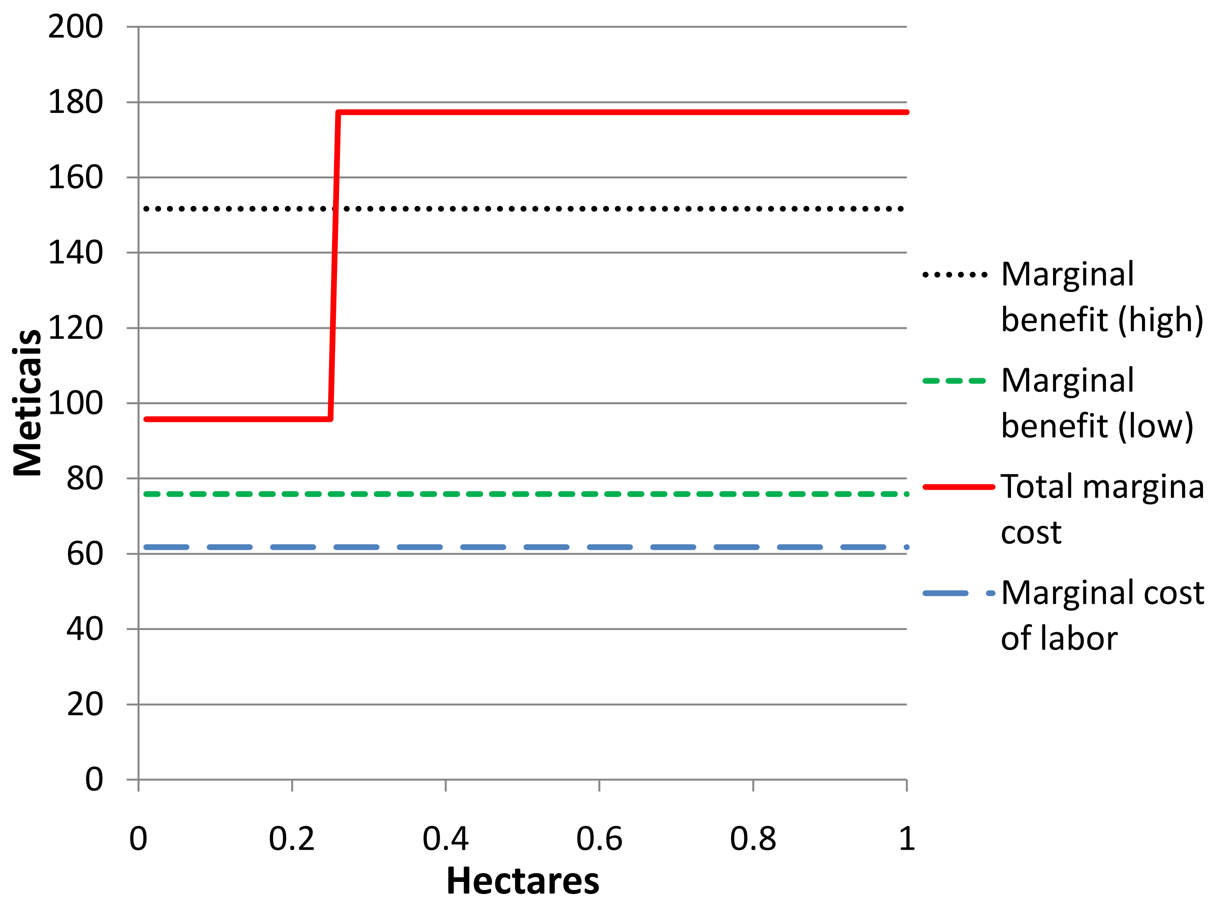
[4]The high maize price is the high nominal retail value in Tete for a 5 year average (USAID FEWS Net, 2010).

[5]No household labor costs were included. Paid labor costs are included. This row is a cash analysis of cash costs compared to the value of the grain produced

[6]Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age

[7]Includes the cost of labor valued at MZN 20 per 8 hour day for all household labor adjusted by gender and age

Figure 6: Marginal cost of production[1,2,3] and marginal benefits for a farmer whose opportunity cost of labor is equal to the market wage rate under two output price scenarios[4] for Total Land Care (TLC) plots with 0.4 tons/ha fertilizer application rate.



Source: author's fieldwork 2010

[1]Marginal costs and benefits were calculated for increments of 0.01 ha.

[2]The marginal cost of production is estimated by adding the marginal cost of purchased inputs, the marginal cost of paid labor and the marginal opportunity cost of household labor.

[3]For this figure the marginal opportunity cost of household labor was valued at the agricultural wage rate (40 MZN/day) for all areas.

[4]"Harvest value high" has a maize price of 8 MZN/kg and "Harvest value low" has maize price of 4 MZN/kg.

Appendix D: Plot area data

Table 14: Plot measurements by tape measure and GPS in Bwaila including limited information about the time required to make the measurements

	Participant	Field type	Measurements				Calculated area (square meters)	Time (2 people)	GPS area (ha)	Time (1 person)	Notes
1	Bm7	TLC							0.12		
2	Bm9	Own							0.31		
3	Bf45	TLC	53.4	31.1			1661	5 min	0.14		
4	Bm13	IRM	25	30.5	13.5	30.8	590		0.06		Corner angled off
5	Bm9	TLC	56.4	47.8			2696		0.24		Forgot to start watch
6	Bf3	IRM	26	53.2			1383	4m27s	0.12		
7	Bf2	IRM	27.2	43.2	27.2	39.5	1081	8m30s	0.11	3min	2 m of ridges along 22m of the 39.5m lenth
8	Bm8	IRM	26.3	9.2		13.9	304	8m	0.03		
9	Bm8	TLC	59.9	22.5			1348		0.1		
10	Bf26	TLC	40.8	50.3	40.1	54	2109	18m56s	0.2	4m4s	
11	Bm10	TLC	62.4	66.1			4125	10m50s	0.33		irregular shape - makes sense GPS calculates smaller
12	Bm6	TLC	103.7	20.7			2147		0.2		Forgot watch
13	Bm5	TLC	51.6	39.3	52.4	41.8	2109		0.21		
14	Bm4	IRM	22.8	29	21	25.9	601		0.06		
15	Bm4	TLC	50	24.5	53	26.6	1316		0.14		
16	Bf1	IRM	33.3	25.3	33	29.3	905	6m4s	0.08	2m25s	

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