PROMOTION AND ADOPTION OF CONSERVATION AGRICULTURE IN MOZAMBIQUE AND ZAMBIA

By

Philip Paul Grabowski

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ABSTRACT

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The development of improved agricultural technologies has tremendous potential for improving the livelihoods of smallholder farmers in sub-Saharan Africa. Conservation agriculture (CA) has been widely promoted to improve farmers' productivity and decrease their vulnerability to climate change. However, the benefits and challenges associated with reducing tillage vary by soil type and rainfall regime. Due to the complexity of both the livelihood strategies of resource-poor farmers and of their agro-ecological conditions, widespread adoption of any one form of CA is unlikely. Instead, technologies need to be adapted to specific agro-ecological and socio-economic contexts.

The first paper in this dissertation uses the case of conservation agriculture (CA) in Mozambique to obtain an in-depth perspective on the challenges researchers and development agencies face in using innovation networks that include farmers and input suppliers to improve the process of technology adaptation. The results show widespread agreement among researchers and program managers about the need to locally adapt CA due to the agro-ecological diversity of Mozambique. However, they also show that farmers' involvement in CA research is limited to simply managing researchers' experiments. In contrast some NGOs work collaboratively with farmers through Farmer Field Schools to adapt CA to the local context. There is widespread agreement about the importance of establishing links across the value-chain, and lessons from nascent efforts to accomplish this are documents. The results also indicate that effective

collaboration will require coming to terms with polarized disagreements on two key issues: the importance of emphasizing minimum tillage and the role of commercial inputs for CA.

The second and third papers combine quantitative and qualitative analysis of farmers' practices in Eastern Zambia. A survey was carried out with 245 farmers in 15 communities where CA adoption was expected to be relatively high. In-depth interviews were carried out with 63 farmers and cotton company representatives. Despite farmers' favorable opinions, adoption remains low and disadoption is common. The main reasons farmers use minimum tillage are to improve their yields and to reduce their vulnerability to droughts.

There are also a number of challenges preventing more widespread use of the technology. The increased effort needed for dry season land preparation is a key constraint. Households that have more available household labor were able to use MT on more of their land. Dry-season ripping is seen as too taxing for the oxen to make ripping services worthwhile. Farmers who use ripping tend to be better-off, enabling them to invest in the new equipment and take the risk of a new technology. Lack of adequate information also limits the number of farmers using MT. Farmers who have never tried MT tend to be poorer and have more diverse livelihood strategies.

The main conclusion is that farmers are not stuck in traditional practices but are carefully evaluating CA with the information they have available to them. Widespread adoption will require adapting existing technologies to overcome technical challenges and developing new ones to match a broader range of resource endowments. This process could be greatly improved by drawing on farmers' experiences and recognizing them as active learners with valuable insights on the constraints and possible adaptations for the technologies.

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CHAPTER 1: INTRODUCTION

Over the past 50 years agricultural yields have remained stagnant in Africa while the population has more than tripled (World Bank, 2007). Agricultural area has expanded in order to meet consumption needs at the national level (World Bank, 2007) but this has caused shortening of fallow periods and land degradation, which threatens the sustainability of production (Morris et al., 2007; Todaro and Smith, 2009). Improved agricultural technologies hold tremendous potential for national food security by increasing the productivity of smallholder farmers (Pretty et al., 2011). This would also reduce poverty by improving the livelihoods of some of the poorest people in the world (Barrett, 2010). Though agricultural technologies led to dramatic yield increases in Asia during the green revolution, in Africa the diversity of agro-ecological contexts across the continent has inhibited the benefits from technological transfers because specific technologies have limited domains where they are applicable (World Bank, 2007). Furthermore, the complex livelihood strategies of the rural poor make it difficult for agricultural researchers to develop appropriate technologies (Chambers, 1997). Developing effective agricultural technologies for smallholder farmers in Africa requires including farmers in a process of localized adaptation in order to overcome context-specific challenges (Pretty et al., 2011). This dissertation focuses on the need for adapting conservation agriculture technologies to overcome adoption constraints in southern Africa.

Conservation agriculture (CA) has been widely promoted to sustainably increase farmers' yields (Kassam et al., 2009). The combination of three principles (minimal soil disturbance, permanent soil cover, and incorporation of legumes through intercropping or rotations) has the potential to increase soil fertility (FAO, 2001), increase water infiltration (Thierfelder and Wall, 2009), and overcome labor bottlenecks through dry season land preparation (Haggblade et al., 2011). Minimal soil disturbance in Zambia is accomplished through three major forms of minimum tillage: digging basins with a hand hoe, using an ox-drawn Magoye ripper to open a rip line, or using a tractor drawn chisel plow to open a rip line. Despite promotion since 1996, adoption levels remain low and promotional efforts have been criticized for narrowly pushing technological packages that are not well aligned with smallholders' resource endowments (Giller et al., 2009; Andersson and Giller, 2012). Nevertheless, some farmers continue to use CA on small portions of their land (Arslan et al., 2014; Andersson and D'Souza, 2014), which suggests the possibility of adapting the technologies to overcome the constraints. This dissertation aims to contribute practical guidance for this adaptation process by linking empirical observations of CA research, promotion and use with lessons from the literature on smallholder agricultural development.

The second chapter, *"Using Farmer Participation and Innovation Networks for Conservation Agriculture Adaptation in Mozambique"*, analyzes the challenges researchers and development agencies face in using innovation networks that include the participation of farmers, input suppliers and other stakeholders to improve the process of CA technology adaptation. It is based on an inventory of the experiences with CA in Mozambique, an on-line survey of CA researchers and projects managers, and phone interviews with key informants who were implementing CA projects using Innovation Platforms (IPs) and Farmer Field Schools (FFS). With the aim of learning from history, the results are framed in the context of the broader literature of participatory technology development.

The results indicate widespread agreement about the need for adapting CA technologies to the local context within Mozambique because of the diversity of farmers and their conditions. Setting up client-oriented participatory research efforts requires collaboration at two levels: between researchers, extension and the private sector across the value chain and between researchers and resource-poor farmers. The results indicate that collaboration in Mozambique will require researchers to be aware of and either resolve, or learn to live with, polarized disagreements on two key issues: dedication to the CA components and the importance of commercial inputs. Furthermore, institutional arrangements for research management will have to shift so that researchers have the support and incentives to manage the complexity of an evolving research process that is tightly linked to non-research stakeholders. Researchers can more easily connect with farmers' realities if these collaborative efforts are decentralized, such as through regional CA working groups.

The third chapter *"Determinants of Adoption of Minimum Tillage by Cotton Farmers in Eastern Zambia"* analyzes the factors that cause some households to use, and others to disadopt or never have tried minimum tillage (MT), the principle of CA that is typically emphasized first. The study focuses on areas where promotion has been adequate, and where complementary inputs and equipment are available on credit, in order to identify constraints that may require adaptive research. It is based on a survey of 245 farmers in 15 communities and in-depth interviews with 63 farmers and cotton company buyers. The results indicate that there are four main reasons that keep farmers from using MT: the cost of equipment for ox-ripping, the increased effort for dry season labor, the high levels of uncertainty associated with a dramatic shift in farming and a lack of motivation by those who are satisfied with their current yields. The main reasons farmers use MT are to improve their yields and to reduce their vulnerability to droughts.

The fourth chapter, *"Understanding Partial Adoption of Minimum Tillage by Cotton Farmers in Eastern Zambia"* focuses on identifying constraints to MT use by analyzing farmers' reasons for partial adoption. This study combines quantitative analysis of the 445 plots farmed by 81 MT farmers and qualitative analysis of in-depth interviews with 43 MT farmers who explained why they chose to use MT on some plots but not others. The results show that the increased effort needed for dry season land preparation (for both hoe farmers and animal traction farmers) is a key constraint preventing many households from using MT on as much land as they would like. Households that have more available household labor and larger farm sizes were able to use MT on more of their land, showing an ability to overcome labor and investment constraints. Adaptive research is needed to overcome the challenges farmers face in using ox-ripping on large areas with an average team of oxen.

The results also show that farmers are rationally analyzing where they used MT based on the benefits, costs and risks they anticipate. Perceived benefits are greater with maize or cotton, and the perceived risks are less on flat plots (due to concerns about erosion with MT). MT can have large immediate benefits by making a degraded field productive (such as by breaking through hard pan or through the application of manure) so farmers selectively prefer those plots for MT. CA promotional efforts can be more effective by targeting areas where constraints are lowest and benefits are highest.

The papers from Zambia provide many examples of how farmers are not stuck in traditional land preparation methods but are carefully evaluating the benefits and costs of MT given the information they have available to them. Similarly, the Mozambique paper shows that development agencies are actively adapting CA technologies to better match farmers' constraints and priorities. There is potential for enhancing these adaptive efforts if agricultural researchers engage with farmers and development agencies to solve practical problems related to adapting existing technologies. Widespread adoption of CA in southern Africa requires making the principles beneficial under a broader range of conditions and resource endowments. The key message from all three studies is that the process of developing agricultural technologies suitable for African smallholders could be greatly improved by drawing on farmers' valuable insights on the constraints and possible adaptations. The on-going challenge is finding creative ways to organize research and development efforts to regularly incorporate farmers' feedback into planning and decision-making.

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CHAPTER 2: USING FARMER PARTICIPATION AND INNOVATION NETWORKS FOR CONSERVATION AGRICULTURE ADAPTATION IN MOZAMBIQUE

2.1. Introduction

The development of improved agricultural technologies has tremendous potential for improving the livelihoods of smallholder farmers in least developed countries (World Bank, 2007; Pretty et al., 2011). Sets of technologies such as conservation agriculture (minimum tillage, mulching and crop rotations) have the potential to sustainably increase yields and decrease farmers' vulnerability to climate change (Rockström et al., 2009; Hobbs, 2007). However, the linear technology transfer approach (from research stations to farmers via extension) has failed to produce technologies that most farmers can adopt where farming systems are integrated into complex livelihood systems and agro-ecological conditions are diverse (Bingen and Gibbon, 2012; Buhler et al., 2002; Ekboir, 2002). In contrast, there are cases where high levels of adoption have been achieved in complex contexts when innovation networks are used to locally adapt agricultural technologies (Ekboir, 2003; Klerkx et al., 2012). An innovation network allows interdependent actors (such as farmers, input suppliers, buyers, extensionists and agricultural researchers) who cannot meet their innovation objectives independently to come together to collectively facilitate the innovation process (Klerkx et al. 2010).

The need to adapt conservation agriculture (CA) to the local context of smallholder farmers has been well established in the literature (Erenstein et al., 2012; Giller et al., 2009; Wall, 2007). This is primarily because the benefits and challenges associated with reducing tillage are variable across soil types and rainfall regimes (Giller et al., 2009; Baudron et al., 2012, Ekboir, 2002). There are also a wide range of minimum tillage technologies (basins, jab-planters, ox-drawn rippers, tractor rippers), each with different labor, knowledge and financial requirements for effective use (Grabowski et al., 2014). Furthermore, CA adaptation requires integrated efforts across the value-chain to ensure the availability of commercial inputs, such as equipment for minimum tillage or herbicides, and secure markets for surplus production (Giller et al., 2011; Wall, 2007). A common feature of successful CA programs for smallholders is the use of participatory research approaches with linkages across the value-chain to adapt CA technologies to specific agro-ecological and socio-economic contexts (Ekboir, 2002). In contrast, CA promotion in southern Africa has been criticized as being overly prescriptive (Andersson and Giller, 2012) and lacking in the critical reflection of evidence that is needed for effective adaptation (Whitfield et al., 2015).

In this paper I use the case of CA in Mozambique to obtain an in-depth perspective on the challenges researchers and development agencies face in using innovation networks for improving local adaptation of CA. The experience from Mozambique is especially instructive because it has nearly 20 years of experience with CA but without the coordinated promotion of specific CA technologies seen in much of the rest of southern Africa. The study specifically aims to answer the following research questions: 1) To what extent do CA researchers and program managers perceive the need for adapting CA to the local context? 2) How are farmers currently involved in the process of adapting CA technologies to local conditions in Mozambique? 3) What obstacles hinder the use of innovation networks (including farmers, input suppliers and extensionists) in the technology adaptation process?

I used the following data collection activities to answer these questions: 1) an inventory of CA research and promotional projects, 2) a review of the literature on the performance of CA across the country, 3) a survey of CA researchers and program managers, and 4) in-depth interviews with key informants implementing CA projects that involved farmers and actors across the value-chain in local adaptation.

We take the need for participation as the starting point for the effective development of crop management technologies in contexts with high levels of complexity. I outline the evidence supporting the importance of participation and innovation networks by reviewing the literature in the next section. Next I present background information about agriculture in Mozambique followed by details about the research methods used. The results are organized in parallel to the four sections of the literature review.

2.2. Developing agricultural technologies in complex contexts

In this section I review the literature about how to effectively develop agricultural technologies in developing countries where smallholder farmers have complex livelihood strategies and typically live in diverse agro-ecological environments. First, I summarize literature on why the participation of farmers is needed in these contexts. Next I summarize how different levels of participation are appropriate for different types of technologies. In the third sub-section I focus on the innovation systems approach to agricultural change and the need for a holistic perspective that includes actors across the value-chain. Finally, I summarize what is known about the institutional challenges of implementing participatory agricultural research. Together this information from the literature provides a conceptual framework for the analysis of how CA is being adapted to local contexts in Mozambique and the challenges faced in using innovation networks for that purpose.

2.2.1. Effective innovation for smallholders requires farmer participation

The context-specific information about the agricultural problems of resource-poor farmers can be considered “sticky” information in that it is not easily transferred from the farmer to the researcher (von Hippel, 1994). Agricultural problem solving with resource-poor farmers is plagued by “sticky” information because: 1) in diverse agro-ecological environments farmers’ familiarity with their complex bio-physical context is typically implicit knowledge gained by observation and not easily communicated; 2) the livelihood strategies of resource-poor farmers tend to be diverse and complex (Chambers, 1997), which increases the amount of information that needs to be transferred; and 3) there tends to be a wide social and cultural gap between formal researchers and resource-poor farmers.

The top-down way in which CA has been researched and the inflexible way in which CA has been promoted in southern Africa (Andersson and Giller, 2012; Grabowski and Kerr, 2014) provides a perfect example of how researchers and development agencies who are actively engaged with farmers dominate the flow of information and fail to address the context-specific constraints to adoption.

Management research suggests that problem solving should be carried out where the “sticky” information is held so that effective solutions can be disseminated more widely (von Hippel, 1994). Since the mid-1970s a variety of agricultural research methods have aimed to accomplish this by increasing farmers’ participation in the technology development process (Merrill-Sands et al., 1991). The Farming Systems Research (FSR) movement was characterized by on-farm participatory trials and emphasized interdisciplinary research to address the complex interactions of the farming system (Bingen and Gibbon, 2012).

While FSR led to many important insights into the production constraints of smallholder farmers in Southern Africa, it did not lead to widespread adoption of the promoted technologies (Waddington, 1993). The disappointing performance of FSR is the direct result of three problems. First, most FSR projects were operating with low levels of farmer participation (Merrill-Sands et al., 1991). Second, FSR focused too narrowly on farm-level issues with little attention to the broader systems in which they were embedded (Bingen and Gibbon, 2012). Third, FSR projects did not have the institutional support needed for participatory research that was so drastically different from conventional research station-based approaches (Biggs, 1995; Merrill-Sands et al., 1991). The next section discusses the need for higher levels of participation, after which I turn to the need for a systems perspective on innovation followed by institutional support issues.

2.2.2. How participation is implemented affects the information flow

Participatory agricultural research has been implemented in very different ways. It is useful to characterize these approaches as a continuum (Table 1) based on the level of farmers' participation in research (Buhler et al., 2002; Biggs et al., 1989). At the low end, researchers carry out on-farm trials simply by contracting farmers to run their experiments. At the next level, researchers consult with farmers about their needs, run experiments on their land and then consult with them about their observations. At the collaborative level, farmers are involved with researchers through all phases of the research. Finally, at the collegial level the formal research system actively supports farmers' informal research systems recognizing the complementarities in knowledge and skills (Biggs et al., 1989).

Table 1: Continuum of farmers' participation in on-farm research

	Contractual	Consultative	Collaborative	Collegial
Description of roles	Researchers "hire" farmers to run experiments on their land	Researchers consult farmers about problems and develop solutions	Researchers and farmers collaborate as partners to design, implement and analyze research	Researchers strengthen farmers' informal research/problem solving systems
Level of interaction	Minimal	At beginning and end	High and continuous	Long term and sporadic
Conditions where approach is most appropriate	Technically complex technologies that are context sensitive but broadly used.	Minor adaptations to technologies with complex technical consequences.	Where both farmers' realities and the technical requirements are complex.	Where technical information needs are relatively low but farmers' realities are very diverse.
Examples	Plant breeding for high yields	Minimum tillage equipment	Crop management technologies	Trying out varieties, species or practices
Importance of farmers' "sticky" information	Low	Low	High	High
Importance of researchers' technical skills	High	High	High	Low

Source: Adapted from Buhler et al., 2002 Table 5.1 and Biggs et al., 1989

The level of participation that is most appropriate depends on the information needs of the problem addressed by the research. The contractual and consultative levels of participation are well suited to problems where the importance of farmers' "sticky" information is relatively low. Researchers can improve the effectiveness of their problem solving with minimal interactions with farmers. On the other end, the collegial level is best suited for problems that do not require much technical expertise but where farmers' in-depth knowledge of the context is essential.

The collaborative level is likely to be best when agricultural innovations require both intimate familiarity with the farmers' context and advanced technical knowledge from researchers. Examples of technologies requiring such collaboration include crop management technologies, natural resource management issues and improved germplasm for non-yield traits (Fujisaka, 1994). In contrast, plant breeding for high yields can be effective for addressing the needs of resource-poor farmers with low levels of participation, as long as the research is client-oriented and both consumers' and farmers' preferences are not too complex (Witcombe, 2006).

Conservation agriculture is a set of crop management technologies with complex interactions among the components of minimum tillage, rotation with legumes and covering the soil with residues or mulch. Due to these interactions CA has been described as knowledge-intensive (Kassam et al., 2009) and its effective implementation requires high levels of farmer participation and on-going adaptation through collaborations between researchers and farmers (Ekboir, 2002).

2.2.3. Many agricultural problems cannot be solved at the farm level

The scope of agricultural innovation has broadened over time as awareness of the importance of the wider system has increased (Table 2). This broader focus has been associated with a shift in boundaries starting with research being confined to single disciplines expanding to trans-disciplinary efforts that value non-academics as key contributors. With the focus on value-chains, partners such as input suppliers, output buyers and policy makers become part of the collaborative team for fostering CA innovation (Ekboir, 2003).

Table 2: The broadening focus for agricultural innovation research

	Transfer of Technology	Early Farming Systems Research	Farmer-first and AKIS [a]	Agricultural Innovation Systems
Time period	1960s on	1970s and 80s	1990s on	2000s on
Activities	Supply technologies	Learn farmers' constraints	Collaborate in research	Partner to foster innovation
Disciplines [b]	Single-discipline	Multi-disciplinary	Inter-disciplinary	Trans-disciplinary
Scope	Productivity increase	Efficiency gains	Livelihood system	Value chains, policies and organizations
Role of scientists	Innovator	Expert	Collaborator	One of many partners
Goals	Behavior change and technology adoption	Overcome constraints, better fit in farming system	Empowerment and better fit to livelihood system	Increased capacity to innovate and adapt

Source: Adapted from Klerkx et al., 2012 Table 20.1

[a] Agricultural Knowledge and Information Systems

[b] Multi-disciplinary research has separate disciplines working on the same issue relatively independently while inter-disciplinary research has several disciplines actively collaborating together and trans-disciplinary research includes non-professional researchers as part of the research team.

Innovation networks use this Agricultural Innovation Systems approach and have become operationalized in international agricultural research centers through what are called Innovation Platforms (IPs). The platform aims to provide space for collaboration by creating a new forum where all stakeholders can interact to collectively focus on solving a common problem (Klerkx et al., 2012). A researcher or extensionist typically takes the role of "innovation broker" to catalyze interactions among stakeholders by articulating the demand for innovation, strengthening and broadening the composition of the network, and managing conflicts (Klerkx et al., 2012).

However, unless farmers can effectively share information and truly set priorities, the innovation process will miss the potential benefits of their participation. Farmers that are better organized will be better able to articulate their needs to researchers and other partners (Rajalahti et al., 2008), which suggests community mobilization may be a necessary first step. Without farmers' participation IPs are simply a new name for coordinated development efforts. For example, a case study of an IP focusing on CA in Zambia documented benefits from coordination at the district level and harmonization of CA messages to farmers but no evidence that farmers' feedback on CA technologies led to localized adaptation (van der Lee et al., 2011).

2.2.4. Researcher involvement in innovation networks requires institutional support

Effectively fostering organizational change to meet the needs of a more client-oriented participatory approach to agricultural research is a key struggle in implementing the Agricultural Innovation Systems approach (Klerkx et al., 2012; Rajalahti et al., 2008) and was one of the major implementation challenges of the FSR approach (Merrill-Sand et al., 1991; Biggs 1995). For researchers to effectively implement the participatory and collaborative processes outlined above, research systems must support them to: 1) cross boundaries (interact with farmers, NGOs, the private sector, other scientists), 2) focus on practical problem solving, not just publications, and 3) implement an evolutionary research process.

First, agricultural researchers will need to spend significant time with farmers and actors across the value-chain as well as with scientists in other disciplines or working on different crops. Case studies from FSR projects show that these linkages are easier where regional centers facilitate researchers' frequent travel. Such collaborative efforts tended to be prioritized where research managers had firsthand experiences benefiting from crossing boundaries (Merrill-Sands et al., 1991). The commodity orientation of most agricultural research organization goes against the system perspective needed (Buhler et al., 2002), though interdisciplinary research planning can be used to ameliorate this challenge (Merrill-

Sands et al., 1991). Becoming boundary crossers will require scientists to have skills in understanding other's perspectives and effective communication across disciplines (Moore, 2009).

Next, researchers need incentives to engage in practical problem-solving, not just the production of peer-reviewed publications (Biggs, 1995; Klerkx et al., 2012). However, experience shows that employers and research funders are likely to continue using publications as their preferred performance indicator for scientists (Buhler et al., 2002). Nevertheless, this could be broadened to include indicators such as technical recommendations or new techniques. A study of agricultural research productivity in Mexico showed that increasing the number and intensity of interactions with farmers resulted in increases in both practical technical recommendations and publications (Rivera-Huerta et al., 2011).

Finally, researchers also need the flexibility to carry out an evolutionary research process to be able to respond to the needs of farmers and other partners. Facilitating innovation in complex systems requires skills in adaptive management where decisions are based on information from regularly scanning the environment (Klerkx et al., 2012). This flexibility can be facilitated through decentralized planning of research (Biggs, 1995).

2.3. Background on Mozambican agriculture

At the end of the 16-year civil war in 1992 Mozambique was considered one of the poorest countries in the world. Food aid was astronomical, national infrastructure was largely destroyed, the economy was at a standstill and it was nearly a failed state (Newitt, 2002). The UN and the World Bank supported the Mozambican government in pursuing free market economic policies with strong emphasis on international investment in large projects (Hanlon and Smart, 2008). These policies led to dramatic increases in Gross Domestic Product (GDP) and with a more stable economy and increased tax revenues, the Mozambican government was able to invest in highly needed rural development projects. The combination of a stable currency, improved roads and communication systems and foreign investment in cotton and tobacco production led to increases in the welfare of the rural poor through greater market inclusion (Hanlon and Smart, 2008). Poverty levels decreased from 69% in 1997 to 54% in 2008 (Feed the Future, 2009).

Nevertheless, Mozambique's Global Hunger Index is still among the worst in the world (von Grebmer et al., 2013) with 8.1 million people undernourished, which is 38% of the population (Bread for the World, 2011). It is estimated that 44% of children under 5 years old are stunted and 18% are moderately or severely underweight (UNICEF, 2011). The rise in food commodity prices since 2007 and 2008 has caused increased concern for national agricultural production and a renewed emphasis on achieving a "green revolution" in Mozambique (AGRA, 2009).

There is tremendous agricultural potential in Mozambique but very poor performance in terms of both yield and total production. Only 12% of the country's arable land is cultivated and only 4% of irrigable land is actually irrigated (Feed the Future, 2009). Maize is the largest staple food crop and it is largely grown for household consumption, with only 15% of production being marketed in 2011 (Benfica et al., 2014). Smallholder maize yields have stagnated since the 1960s at only 1.4 tons/ha on average, though yields as high as 5 or 6 tons/ha are possible (Zavale et al., 2006).

In 1996 Sasakawa Global 2000 introduced CA to Mozambique, in collaboration with the National Directorate of Agricultural Extension (DNEA), the Agricultural Research Institute of Mozambique (IIAM) and Monsanto (Nhancale, 2000). Early CA promotion was championed by the Projecto de Promoção Económica de Camponeses (PROMEC) in Sofala (Zandamela et al., 2006), as well as the FAO and DNEA who formed an extension-focused working group.

Since 2007, funding for CA has increased including substantial research projects for international agricultural research centers and promotional efforts of development agencies from by both government and non-governmental organizations (Nkala et al., 2011). In 2012 a CA working group was established, consisting of research, extension and NGO staff, with the mandate to develop a national program for increasing the impact of CA for smallholder farmers. The Mozambican government's strategic plan for agricultural development includes promoting conservation agriculture (CA) to improve smallholder productivity based on its potential to sustainably manage soil fertility and decrease vulnerability to climatic events and overall climate change (Mozambique Ministry of Agriculture, 2010).

2.4. Methods

2.4.1. Inventory of CA experiences in Mozambique

By contacting a large majority of CA researchers and managers of CA projects in the country, the combinations of CA principles and technologies that were being researched and promoted in each region were able to be identified. The inventory documented the efforts of 29 development organizations, 10 research organizations and 5 private sector organizations actively promoting CA. Respondents were identified using a combination of key informants, asking respondents to identify potential contacts and internet searches. Researchers and project managers filled out a form to provide details of what CA principles and technologies they were using in their projects and who they partner with. The results of the inventory were tabulated by region and research and development efforts were mapped by district.

2.4.2. Literature review of the performance of CA across Mozambique

A comprehensive review of CA literature in Mozambique was used to analyze the performance of CA technologies in each agro-ecological zone of the country. There is a limited amount of research published in scientific journals on conservation agriculture in Mozambique. To obtain a more complete understanding of the experiences with CA, the literature review also included gray literature including student theses, project reports and research presentations. The literature was analyzed by selecting the benefits and challenges of CA in each document and then summarizing that information by agro-ecological zone. The level of farmers' participation for each project was also noted. For further information see Grabowski and Mouzinho (2013a).

2.4.3. Survey of CA professionals

A two round on-line survey of researchers and project managers experienced with CA in Mozambique was used to obtain their perspectives on the importance of specific technologies for achieving each of the three CA principles with smallholder farmers. They were also asked about what was necessary to promote CA in a way that would result in wide-scale adoption by prioritizing lists of potential research, development and policy activities developed at a previous workshop.

A list of 43 individuals with a diversity of backgrounds was developed based on their experience with CA in Mozambique. Most of these individuals were researchers or development agency project managers, though a few were also from the private sector and educational organizations. Thirty-five of the 43 CA professionals responded to at least one round of the survey (30 in round 1 and 25 in round 2 with 20 responding to both rounds).

The survey was developed based on the Delphi methodology (Turoff, 2002) where respondents express their opinions about a topic and explain their reasons for that opinion in the first round. These results are then summarized so that respondents can see the opinions and arguments of others. In the second round questionnaire respondents can adjust their opinions or clarify their arguments. In theory the rounds can continue until the results have stabilized either in consensus or entrenched disagreement. In this case only two rounds were possible in the given timeframe. The questionnaires are available as supplemental files with this dissertation.

The closed ended questions were analyzed by tabulating responses and comparing differences between the first and second survey. Responses to open ended questions were compiled and summarized to represent the diversity of responses. Some quotes from these responses are used to illustrate a perspective in the respondent's own words. For further information see Grabowski and Mouzinho (2013b).

2.4.4. In-depth interviews

I presented the results of the expanded inventory of CA projects, literature review of CA evidence and the survey results to the CA working group in Maputo with participation from a variety of other CA stakeholders. At this meeting the group identified some of the themes emerging from the reports, including the need for local adaptation of CA technologies and better coordination between researchers and development practitioners. To pursue these ideas further, I carried out in-depth interviews with CA researchers and project managers involved in Farmer Field Schools or establishing linkages across the value chain. The interviews were recorded and transcribed. Summary statements were then developed on the theme of challenges faced in implementing a participatory and/or collaborative approach to CA adaptation.

2.5. Results

The results of this study are organized into four sections. First, I present evidence of the context-specificity of CA performance in Mozambique to highlight the need for farmers' participation in the CA adaptation process. Next, I summarize the level of famers' participation in current research and promotion. In the third section I present lessons from nascent efforts to link actors across the value-chain for CA adaptation. Finally, I present the anticipated challenges of using innovation networks for CA adaptation.

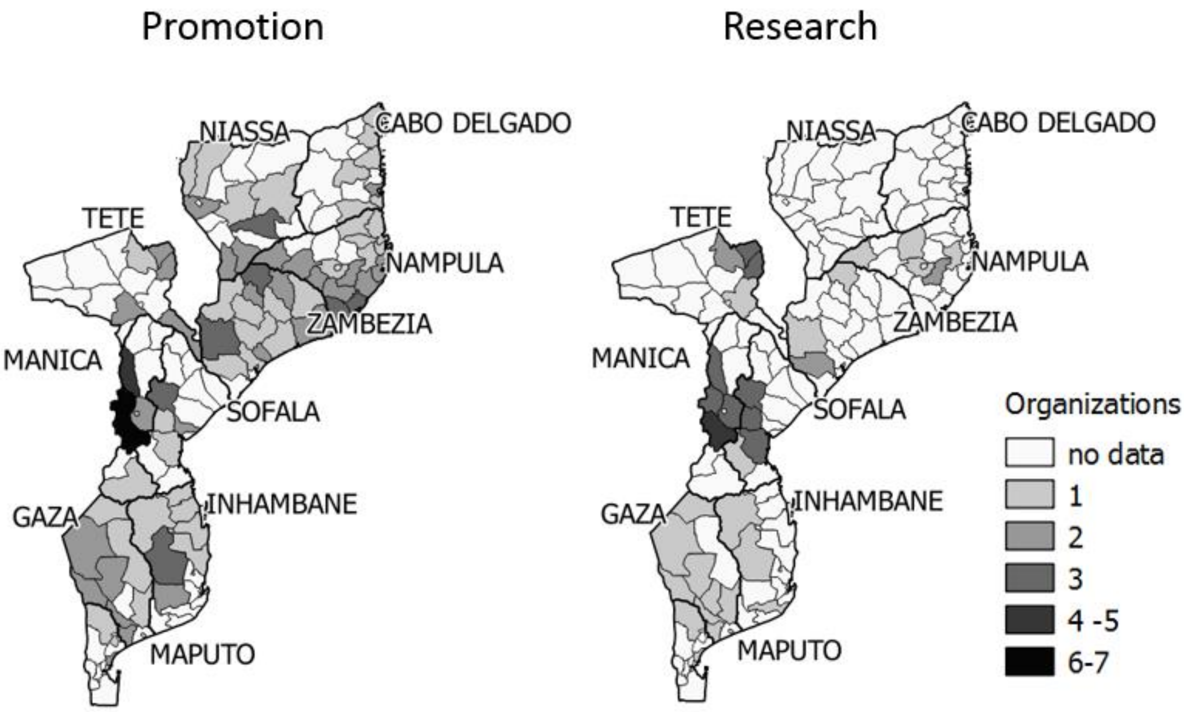
2.5.1 The need for farmers' participation in CA adaptation in Mozambique

2.5.1.1 Promotion and research of conservation agriculture

CA promotional and research efforts are widespread across Mozambique, with active programs in at least 84 of the 128 districts of Mozambique (81 districts with promotion and 33 districts with research, Figure 1). The largest concentration of organizations for both research and extension is in Manica province in the districts surrounding Sussendenga research station.

Most CA promotion in Mozambique emphasizes minimizing soil disturbance as the first and most essential component. Manual CA systems of reduced tillage predominate, including basins (a grid of holes dug in an otherwise undisturbed field) and direct seeding. Animal-based CA systems are only promoted in areas where cattle populations are large such as parts of Manica and Gaza provinces. Of the 29 development agencies promoting CA with farmers, 16 of them promote the use of herbicides and inorganic fertilizers while the other 13 promote CA without commercial inputs. All of the research organizations use commercial inputs for their experimental trials.

Figure 1: Number of organizations promoting and researching CA in Mozambique by district



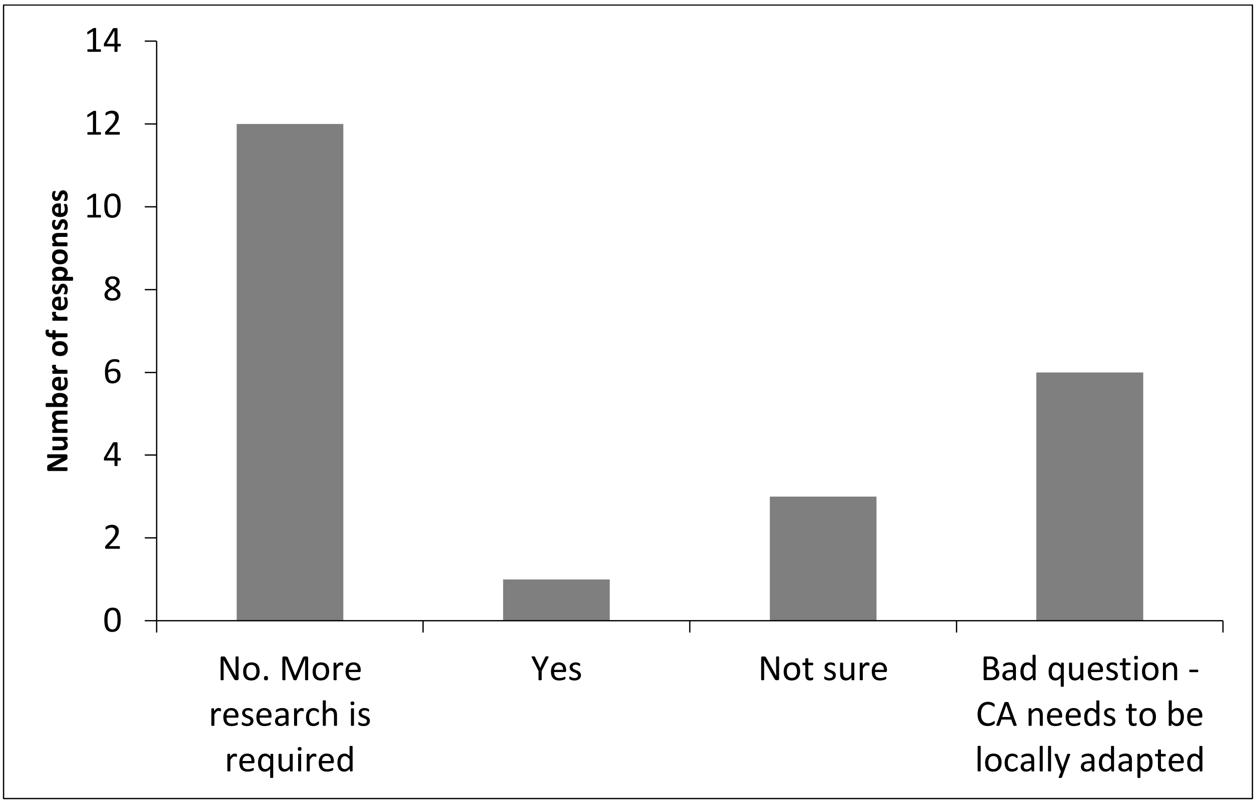
Source: Inventory of CA organization in Mozambique, 2011
Note: Does not include FAO and DNEA who report working in all provinces

2.5.1.2. The need to adapt CA to local conditions

Respondents generally agreed that the existing CA technologies are not ready for widespread dissemination but need significant local adaptation. In the first round I asked respondents their opinion about if a profitable form of CA had been identified that would lead to wide-scale farmer adoption given proper extension and minor local adaptation. Most respondents (67%) said “No” and that more research is needed, and 22% said they were not sure. One respondent commented that it is not possible to develop a single form of CA for the diverse agro-ecological zones, and that significant local adaptations were necessary. In the second round, I asked the same question but with an additional response category: “Bad question - CA needs to be locally adapted”. About a quarter of respondents (27%) chose this new response category with another 55% saying that more research was needed (Figure 2).

Only one respondent (5%) said “Yes,” being of the opinion that manual jab-planters with herbicides were ready for wide-scale promotion.

Figure 2: Researcher and program manager responses to the question: “In your opinion have CA researchers already succeeded in identifying a profitable form of CA that will lead to large-scale farmer adoption given proper extension efforts and minor adaptations to the local context?”



Source: Second round survey of CA researchers and professionals, 2012

The importance of adapting CA technologies to the local context is also highlighted in the responses to the importance of various minimum tillage technologies for CA. In both rounds, manual forms of minimum tillage were ranked as the most important, with respondents explaining that manual agriculture is predominant in Mozambique, so these are likely to be the ones that can lead to widespread adoption over the short term. There were mixed opinions about the importance of basins, as some saw basins as too labor intensive, and inappropriate for sandy soils. Respondents emphasized that context-specificity is important, and in certain areas animal traction, and even tractor power, can be useful for smallholder farmers in Mozambique.

Respondents' priorities for achieving wide-scale use of CA highlight the need for overcoming the "sticky" information associated with locally adapting CA technologies to meet the needs of resource-poor farmers. Priority research activities included adoption/disadoption studies in different agro-ecological zones and socio-economic studies. This suggests the importance of understanding context-specificity, as well as farmers' perspectives and motivations. Respondents also prioritized more farmer-led development initiatives and long-term projects (greater than 5 years), as are often necessary for participatory projects. Dissemination activities that were prioritized included the establishment of demonstration plots and training for extension workers (both public and private). Presumably these must come after appropriate CA technologies have been developed.

In addition, respondents also emphasized the need for long-term agronomic and soil science research to better understand the subtle and hard to measure effects of implementing CA principles. This combination of prioritizing both localized adaptation and long-term scientific research highlights the importance of a participatory approach that draws on both farmers' and scientists' expertise to effectively solve agricultural problems through adapting the existing CA technologies.

2.5.1.3. The context-specificity of CA performance

A wide range of CA technologies have been used across Mozambique's diverse agro-ecological zones. The performance of CA, and thus its relative utility for smallholder farmers, depends on the agro-ecological context and how it fits with the dominant cropping system (Table 3).

Across northern Mozambique many development agencies are promoting CA to increase yields of a diversity of crops. CARE is promoting CA with cassava in Nampula with an emphasis on mulching and intercropping with legumes as well as minimum tillage land preparation. The Aga Khan Development Network's CA promotion in Cabo Delgado is notable for its effective weed control by using grass cut from fallow lands for mulch (Dambiro et al., 2011), however, this is not possible in areas where livestock and fires dramatically reduce the availability of dry season biomass.

CA work in central Mozambique has focused on how to increase maize yields with researchers focusing on combining CA with fertilizer and herbicides, and NGOs promoting CA without these commercial inputs. One notable challenge is high termite activity on CA plots at Sussendenga research station (Famba, 2011). Despite high variability in rainfall between years, CIMMYT trials show long-term yield benefits from CA, except during poor rainfall years (Thierfelder and Nyagumbo, 2011). Research on maize-pigeon pea intercropping with CA found increased land productivity and reduced risk of crop failure (Rusinamhodzi et al., 2011). Nkala et al. (2011) emphasize how farmers in this region are actively redesigning CA packages to fit their needs and assert that a participatory approach to adapting the technologies is needed.

Southern Mozambique has lower rainfall than the rest of the country and CA has been promoted primarily as a strategy for water conservation. One project documented low adoption of basins due to the challenge of them collapsing too easily in the sandy soils near the coast (Sampath, 2011). Research on CA in the especially arid interior of the south has focused on mulch and basins to improve rainfed crop yields by increasing water availability, but the results are not conclusive. In this region, manual CA was resisted, in part because of farmers' investment in plowing and oxen (Midgely et al., 2012), which again shows how rigid promotion of specific technologies fails to result in adoption.

Table 3: CA experiences by province

Province	Region	Primary agriculture system targeted	Unique opportunities for CA	Unique challenges for CA
Cabo Delgado	North	Maize low input	Mulching with grass	
Nampula	North	Cassava		Lack of research on CA with cassava
Sofala	Central	Horticulture		
Manica	Central	Maize – high input	Adequate rainfall, Some animal traction	Termites, input pries
Tete	Central	Maize – high input		Input prices
Gaza	South	Maize and cowpea	Animal traction	Very arid
Inhambane	South	Maize – low input		Sandy soils, arid
Maputo	South	Horticulture		

Source: Inventory of CA projects in Mozambique, 2011
Note: There is no data for the northern provinces Niassa and Zambezia

2.5.2. Farmers' level of participation in CA adaptation

The on-farm research that was reviewed in the literature on CA in Mozambique is typically carried out at the consultative level. In most cases farmers are contracted to manager researcher-designed experiments on farmers' fields with feedback from farmers on the results. There were no cases of CA research implemented at the collaborative level of participation where farmers were involved with researchers in designing and implementing the research as well as interpreting the results. This likely stems from researchers' need to focus on producing peer-reviewed articles and from their lack of training in facilitating farmers' participation.

Nevertheless, collaborative levels of participation in the adaptation process were observed in some exceptional CA promotional efforts. These efforts used the Farmer Field School (FFS) approach to evaluate and improve the CA technologies promoted by their development projects. In the FFS methodology a group of about 20 to 30 farmers participate in regular meetings in a field with an outside facilitator to compare and adapt promising agricultural practices (Waddington et al. 2014). While the institutions using this approach (NGOs and extension) have expertise in working with farmers to adapt the technologies, their lack of formal agricultural research skills means they are generally lacking the ability to determine how such adaptations will affect long-term soil fertility.

Interviews with program managers from four institutions (the National Peasants' Union (UNAC) the National Agricultural Extension Directorate (DNEA), the Aga Khan Development Network (AKDN), and CARE) in Mozambique were used to document the challenges they face in implementing programs with higher levels of participation for CA adaptation.

UNAC uses FFS and farmer-to-farmer visits to provide training in a broad range of sustainable agriculture practices. Through the interview it was clear that UNAC shows strong commitment to working with farmers to find immediate solutions to agricultural problems but it is the least committed of the four institutions to CA technologies. The program manager who was interviewed explained that the focus instead is on farmer empowerment, combined with environmental sustainability. FFS provides the forum for fine-tuning the technologies to farmers' needs. Where the short term costs of CA are too high because of weed pressure, UNAC simply does not promote it.

After promoting CA with a technology transfer approach since the mid-1990s DNEA has shifted to making FFS the primary extension methodology for the nation. In the interview, it was explained that the goal is to have farmers decide on the curriculum. Farmers' participation appears to be at the consultative level because their input in decision making comes largely at the planning and evaluation stages. The emphasis on a set amount of material and “graduating” participants suggest that farmers have little input into how the FFS is run once the curriculum is chosen.

AKDN has been using FFS as its only methodology for agricultural training for over four years, with 7000 farmers in 248 groups learning about CA as well as basic agricultural concepts. The AKDN program manager explained that the farmers decide how to set up the experiments according to their own priorities and ownership of the process is emphasized. One of the key implementation challenges identified is the long timeframe required for developing the ownership of the group by its members and for training farmers in basic science.

CARE is actively using FFS to carefully evaluate and adapt specific CA packages that can fit into the farming system. Compared to AKDN there is less focus on farmers’ ownership of how the trials are designed. The experimental comparisons are the same for all communities and chosen by the project managers to be able to compare the performance of specific technologies - such as different types of cover crop or different varieties of cassava. The main challenge identified by the program managers in the interview was the increased amount of staff time required to implement FFS compared to their other agricultural training programs.

These four experiences using FFS with CA provide a number of lessons about the potential and the challenges of using participatory research at the collaborative level to develop CA technologies. First, it is clear that in order to adapt CA technologies effectively, there needs to be a balance between commitment to specific technologies and commitment to follow farmers’ priorities. UNAC’s lack of commitment to CA allows them to be highly responsive to farmers’ challenges but may not provide space for learning how to overcome CA implementation challenges. On the other hand, CARE’s guided approach to compare many specific CA practices can provide useful information for adapting CA but requires close monitoring of farmers' abilities to carry out the prescribed methods on their own farms and their motivations to do so.

Another lesson is that when FFS is established rapidly as a means of training it is less likely to provide the type of collaborative engagement with farmers needed in the early stages of technology development. Researchers would be better off working with a few groups, over a long timeframe, early on and then use larger numbers of groups for the fine-tuning of high potential technologies. Though it may seem that such an approach is not defensible when compared to the numbers that could be reached at the same cost using less intensive communication strategies, it is important to remember that once specific technologies are developed they can be spread with less focused effort to farmers in the same recommendation domain and these technologies would have a greater chance of being adopted.

2.5.3. Lessons from nascent efforts to link actors across the value chain

Researchers' and project managers' priorities indicate widespread recognition of the importance of an innovation systems perspective that links actors across the value-chain. One of the prioritized policy actions was ensuring that both input and output markets work better for smallholder farmers. In Mozambique value-chains are relatively weak and undeveloped. Many forms of CA require commercial inputs such as equipment, herbicides, improved seeds and chemical fertilizer. Even with low input forms of CA there is increasing evidence that farmers' motivation to invest in increasing productivity is contingent on reliable marketing systems so that farmers can respond to market demand (Benfica et al., 2014).

Nevertheless, most CA promotional efforts in Mozambique either focus only on the farmer or try to improve one link in the value-chain, such as helping farmers market their crops or tailoring fertilizer supply to smallholders' needs. Two organizations actively linking actors across the value-chain in association with CA. SIMLESA (Sustainable Intensification of Maize and Legumes in Southern Africa) is a research project that uses innovation platforms, and ECA (Empresa de Comercialização Agrícola) is a contract farming operation that links farmers with inputs, credit and markets.

While SIMLESA's agronomic research is at best consultative in terms of farmers' participation, the interviewee emphasized that the innovation platform aspect of the project is highly collaborative. Four active innovation platforms link farmers with agro-dealers, NGOs and grain buyers to reduce bottlenecks in production across the value-chain. Farmers have been enthusiastic about this, and in three of the IPs they have identified the high costs of inputs and the challenge of selling outputs as their main constraints. Information about prices was the key production constraint identified by farmers in the fourth IP.

As a result of the IPs, agro-dealers have been learning how to provide products demanded by farmers and over time they have become motivated to participate in the forum for their own benefit. The output buyers however have been less enthusiastic because the organized farmers have been trained to negotiate for higher prices. This highlights the key challenge of motivating participation across the value-chain. Traders of agricultural outputs may be more motivated where they benefit from farmers being organized, such as where monitoring quality is important or where the timing of bulk sales requires coordination.

The real potential for inducing innovation through improved coordination along the value-chain can be seen in the success of the contract farming firm ECA, which provides farmers with input loans at cost and coordinates linkages between input suppliers and groups of farmers. The interviewees explained that the input suppliers are becoming more sensitive to farmers' preferences for packages with smaller quantities, making input use more affordable. Because ECA has set up contracts with large-scale buyers of grain, it can provide farmers with a guaranteed price from the start of the season. This allows farmers to reduce the risk of investing in inputs. Variation in climate is a major production risk, and for this reason ECA has chosen to train all of its farmers in CA through demonstration plots. One of the technical challenges identified by the ECA interviewees has been the inability to retain mulch on fields through the dry season due to uncontrolled brush fires.

2.5.4. Challenges anticipated for collaborative research to adapt CA

Using an innovation systems perspective for developing CA technologies using participatory research will require collaboration at two levels: between researchers, extension and private sector actors across the value-chain and between researchers and resource-poor farmers. Any collaborative effort on CA in Mozambique will have to be aware of and either resolve, or learn to live with, polarized disagreements on two key issues: the importance of emphasizing minimum tillage and the role of commercial inputs for CA. Researchers will also need institutional support to carry out this collaborative effort.

2.5.4.1. Debating the emphasis on minimum tillage

During the inventory, it became clear that several NGOs promoting CA in Mozambique were not emphasizing minimum tillage, though it is clearly a defining feature of CA. To explore the range of opinions on this issues, in the first round survey I included the possibility of incorporating residues through tillage with the questions about the importance of various crop residue management practices. All respondents stated that maintaining residues on top of the soil was at least “somewhat important”, but opinions about incorporating residues (thus requiring full tillage) were polarized. Thirty four percent of respondents said incorporating residues was very important and explained that it is much better for the soil than burning the residues. Another 30% said incorporating residues was not important and argued that tillage is incompatible with CA and should not be practiced.

Because of this divergence, in the second round I asked respondents for their opinions regarding the benefits and challenges of promoting CA without emphasizing minimum tillage. In terms of benefits, respondents stated that these practices are more easily adopted because farmers can continue doing their familiar land preparation with tillage, but with the added benefit of mulch. Mulching helps control weeds, reduce erosion and retain moisture, though it may also require additional labor.

However, many respondents did not consider it to be “real” CA if minimizing soil disturbance is not emphasized. One explained it this way:

> *“CA is a system that allows the farmer to mimic a condition of fallow while using the land at the same time. It is about renewing and maintaining the soil structure. Minimal soil disturbance is key to this.”*

Respondents pointed out that promoting CA without emphasizing minimum tillage means ignoring the problems of erosion, loss of soil organic matter and the loss of soil structure associated with tillage. Others argued that the benefits from the other two principles (mulching and rotation with legumes) would be less than if minimum tillage were achieved as well. Furthermore, farmers would still have the work of tilling and have an additional task of adding mulch.

While minimum tillage need not be emphasized as the first CA principle (though it often is), completely neglecting it creates difficulty in defining the term “conservation agriculture”. Though there is a risk in being overly prescriptive if CA is defined too narrowly, there is also a risk of the term becoming meaningless if every improved agricultural practice can be labeled as CA (Andersson et al., 2014). Instead, where minimum tillage is not possible for farmers, technologies other than CA can be promoted, even if the theoretical benefits are less.

The disagreement on the importance of minimum tillage shows a divide between those researchers who focus on the hard system (sustainability of the soil) and NGOs, extension and some researchers who focus on the soft system (farmers’ priorities, markets and policies). The heart of the matter is the tension between what agronomic research suggests as the best way to manage the soil, and what farmers are willing and able to actually do, given their priorities and constraints.

Researchers that study the hard system tend to use positivist reductionist paradigms of science (where it is assumed there is one universal pool of knowledge and that reality is best understood one element at a time). Their research focuses on how to overcome specific technical challenges. Researchers that focus on the soft system tend to have a constructivist holistic paradigm of science (where problems are ill-defined and multiple types of knowing are valued). Simply recognizing these differences in scientific paradigms may help agronomists, social scientists, NGOs and extension collaborate more effectively (Eigenbrode et al., 2007). For example, promotion of reduced tillage with large-scale commercial farmers in Queensland, Australia failed to result in adoption even when the ideal agronomic practice had been developed using positivist science. Adoption followed only when scientists worked with extension to develop adult learning tools to help farmers understand why the technology was necessary for improving their production (Hamilton, 1998).

2.5.4.2. The role of inputs in CA promotion

Divergent opinions about the importance of commercial input use with CA is another area of tension that can constrain collaboration. Most scientists and some development practitioners see fertilizer, herbicides and improved seeds (such as hybrid maize) as key tools for modernizing the smallholder sector. But other development practitioners see them as problematic because of farmers' lack of access to these inputs, and because of concerns for environmental sustainability and social equity.

One third of the respondents (eight out of 24 in the second round) stated that CA without these inputs was not even feasible. A few explained that the high C:N ratio of cereal mulch requires increased nitrogen fertilizer. Others pointed out that herbicides were needed at the beginning to effectively control weeds without tillage. One stated that without chemical inputs:

> *"Yields will remain low, or will even go down and farmers will soon revert back to conventional tillage, which controls weeds and improves decomposition of crop residues and release of nutrients leading to higher yield".*

Another five of the 24 respondents stated that low-input CA was feasible, pointing out that farmers do not have access to inputs so this is the only option available for most in Mozambique. Other respondents emphasized that they have observed CA benefits even without purchased inputs.

Fertilizer, herbicide and hybrid seed were all seen as "somewhat important" by nearly half the respondents, with a quarter saying they were very important, and another quarter saying they were not important at all (Table 4). While the average rating is neutral, the wide spread of opinions is the primary concern.

Table 4: CA program managers' and researchers' perspectives on the importance of commercial inputs

	Fertilizer	Herbicide	Seed
1. Not Important	5	4	6
2.	1	2	1
3. Somewhat Important	8	9	9
4.	5	3	0
5. Very Important	4	4	5
Rating Average	3.09	3.05	2.86
Response Count	23	22	21

Source: First round survey of CA researchers and professionals, 2012

Arguments against chemical fertilizers were that they are expensive or unavailable and there is some risk in not seeing the benefit on a bad rainfall year. Arguments for chemical fertilizers emphasized how they work together with CA to show greater benefits (yields) for all the effort the farmer has put in to improving soil quality.

Arguments against herbicides included the need for training and the fear of health and environmental problems. As one respondent put it, herbicides are "*not available and better left out of the equation. It can only harm the environment*." Others argue that they are highly beneficial for increasing labor productivity.

Hybrid seeds were seen by some as irrelevant because of the good quality of open pollinated varieties (OPVs), though access to these seeds is not necessarily reliable. Others were more emphatic about their disapproval:

> "*Under no circumstances will this benefit anyone except the seed companies. Seed supply is probably one of the least developed links in Mozambican agriculture. It is CERTAINLY NOT TO THE POINT that farmers should be encouraged to rely upon it for their annual seed supply.*"

Some who rated hybrid seed as unimportant clarified that it is not relevant to crops like cassava, though they did point out that improved varieties are needed there too. Those who ranked hybrid seed as "very important" pointed out how beneficial the high yields would be for food-insecure smallholder farmers. This divergence of opinions is especially noticed in maize-based systems where fertilizers can dramatically boost yields, though inputs such as herbicides are relevant to cotton and cassava systems as well.

There are many biological and economic arguments that can be made on both sides of this debate. Those who favor commercial inputs tend to focus on yield potential and the subsequent profits from marketing that production. In contrast, those who favor low-input CA emphasize self-sufficiency and environmental integrity. While there is growing recognition of the importance of agro-ecological approaches (IAASTD, 2008), biotechnology and commercial interests have dominated agricultural research in developed countries (Vanloqueren and Baret, 2009).

It is important to recognize that these divergent opinions do not necessarily stem from scientific uncertainty, but reflect differences in values, priorities and worldviews. A good first step for collaboration is helping all sides to listen and understand each other, realizing that effective collaboration does not require consensus on these issues, but rather respecting each other's perspectives.

From a pragmatic perspective low-input CA technologies have the short-term advantage as long as weeds can be effectively controlled. In Mozambique, where commercial input use is low because it is largely unavailable and unaffordable, it is logical to start with technologies that only require inputs that can reasonably be made available at an affordable price. Nevertheless, the value-chain perspective emphasizes that input availability and prices are not fixed, and collaboration can reduce the barriers to their use.

2.5.4.3. Institutional support for collaborative CA adaptation

For the Mozambican Ministry of Agriculture to support a process of participatory collaborative agricultural innovation, it will have to face the institutional challenges of managing evolving research processes that are tightly linked to non-research stakeholders. Organizational change from a hierarchical bureaucracy to an egalitarian learning-focused institution is essential but will require courageous leadership (Matta et al., 2005). The national CA working group is a good start at effective collaboration linking researchers, NGOs and extension together. This group has made the first steps in developing regional working groups that can foster local collaborative efforts that are closer to farmers' realities.

Collaborative efforts to locally adapt agricultural innovations would also be assisted by bringing the research and extension branches (IIAM and DNEA) into closer coordination. The challenges of achieving such coordination in other countries suggest that patience and perseverance will be needed (Merrill-Sands et al., 1991; Biggs, 1995). Establishing effective two-way communication between research and extension requires creativity to join these efforts in their common goal of rural poverty alleviation (Biggs 1995). One of the barriers experienced in other countries is that of valuing extension less than research rather than recognizing the complementarity and interdependence of the two institutions (Buhler et al., 2002). One promising development is that the Platform for Agricultural Research and Technological Innovation in Mozambique is considering how to be jointly managed by both the extension and research branches of the Ministry of Agriculture.

2.6. Conclusion

There is widespread agreement that agro-ecological diversity of Mozambique, and the context specificity of CA technologies, make it especially important to develop suitable CA technologies through local adaptation. However, farmer involvement in CA research in Mozambique is minimal as most on-farm research simply contracts smallholders to manage and provide feedback on experiments. The benefits of farmers' participation will only be realized if their involvement in the research process utilizes their implicit knowledge to develop technologies relevant to their needs and priorities. The richest benefits of farmers' participation come through closer information sharing as when professional researchers collaboratively engage with the clients who will use the technologies.

The Farmer Field School methodology appears to be an appropriate forum for this type of intensive collaborative engagement between farmers and researchers. The FFS methodology has been used in several CA promotional efforts in Mozambique, which provides an opportunity to combine the technical skills of researchers with the skills of extension and NGOs to facilitate farmers' participation. It is timely that the national extension directorate (DNEA) is up-scaling FFS as its primary extension methodology. However, for Farmer Field Schools to effectively function for participatory research on CA technologies they must be implemented in a bottom-up manner that facilitates farmers' meaningful contribution to decision-making.

Including innovation networks to integrate efforts across the value-chain is especially important for adapting CA technologies in Mozambique where commercial inputs are largely unavailable. Locally adapting CA technologies will be more likely to result in widespread adoption if linkages across the value-chain can increase farmers' access to input and output markets. For researchers to effectively play the role of "innovation broker" they will need to have skills in facilitating group processes, understanding multiple perspectives and resolving conflicts.

Innovation networks offer the potential to accelerate the innovation process by integrating the efforts of researchers, development agencies, farmers and actors across the value-chain. However, effectively using innovation networks for CA adaptation in Mozambique will require coming to terms with polarized disagreements on two key issues: the importance of emphasizing minimum tillage and the role of commercial inputs for CA. It will also require overcoming the institutional challenges of managing evolving research processes that are tightly linked to non-research stakeholders.

Collaboration takes effort and the returns to this investment in developing specific technologies can be maximized if areas with relatively large recommendation domains are targeted. Researchers must develop strong links with advisory support organizations (NGOs and extension) from the beginning so that dissemination strategies become part and parcel of the technology development process.

History shows that farmers around the world continuously innovate and adapt technologies as well as they are able. Research and development agencies have the opportunity to support this process of adaptation with CA in Mozambique and improve the livelihoods of some of the poorest people in the world.

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CHAPTER 3: DETERMINANTS OF ADOPTION OF MINIMUM TILLAGE BY COTTON FARMERS IN EASTERN ZAMBIA

3.1. Introduction

There is increasing concern about the food security of smallholder farmers as southern Africa experiences unpredictable rainfall patterns and is expected to experience declining rainfall due to global climate change (Lobell et al., 2008; Boko et al., 2007). Growing demographic pressure on farmland and the resulting reduced fallow periods are also causing land degradation, soil erosion and nutrient mining (Todaro and Smith, 2009; Morris et al., 2007; World Bank, 2007).

As efforts proceed to develop and introduce new agricultural technologies to help mitigate the effects of climate change and land degradation in sub-Saharan Africa, much of the discourse focuses on conservation agriculture (CA) – a set of management practices including minimal soil disturbance, permanent soil cover and rotation with legumes (FAO, 2001). CA has demonstrated the potential to increase agricultural productivity and food security while preventing erosion and maximizing ecological functions of the soil (Kassam et al., 2009). Proponents argue that it is the best means of sustainably managing the soil and reversing land degradation (Rockström et al., 2009; Kassam et al., 2009). They point to widespread adoption throughout the world – 106 million ha worldwide according to Kassam et al. (2009) – as evidence of its promise.

However, adoption in southern Africa is still at less than 1% of arable land after 20 years of promotion (Hove et al., 2011), causing many to question its suitability to smallholder farmers (Giller et al., 2009). This has led to a polarized debate with CA advocates asserting that low adoption levels are to be expected during the initial phase of an S-shaped diffusion process (FAO, 2001), and that the “take off” phase will start when promotion efforts are coordinated and policies are supportive (Friedrich and Kassam, 2011). Critics point out the challenges farmers face in using CA, such as increased weed pressure, competing demands for crop residues and a lack of markets for legumes (Giller et al., 2009).

CA adoption studies in southern Africa tend to focus on minimum tillage (MT), which is the component of CA that is typically emphasized during promotion. Some adoption studies evaluate program interventions (for example in Zambia – Nyanga, 2012; Kasanga and Daka, 2013) but these types of studies are typically biased by focusing on adoption and ignoring the possibility of subsequent disadoption (Andersson and D'Souza, 2014). Other studies analyze the determinants of adoption using econometric analysis of multi-purpose household surveys (Arslan et al., 2014; Ngoma, Mulenga and Jayne, 2014), but they tend to lack a detailed understanding of the underlying reasoning shaping farmers' adoption decisions (Andersson and D'Souza, 2014). Giller et al. (2011) highlight the need for mixed methods research to understand farmers' reasons for adoption or disadoption of CA.

In this study, this gap in the literature is addressed by combining econometric analysis of the determinants of adoption with qualitative data on the motivations behind farmers' decisions to use or not use MT. The focus of this study is on cotton farmers in Zambia's Eastern Province, the country with the highest number of CA farmers in southern Africa and is often seen as the exemplar for CA adoption (Hove et al., 2011; Haggblade et al., 2010). Cotton farmers in Eastern Province provide a sub-population where MT has been successfully promoted and adopted without heavy use of incentives. This allows for analysis of farmers' perceptions of the performance of MT and the constraints to its use where it is known that promotion has been adequate, the environment is reasonably suitable and adoption is more than a temporary response to material incentives. The study does not aim to estimate national or even provincial adoption levels.

Assuming farmers make rational decisions about MT given their individual objectives and constraints, I hypothesize that labor, wealth, experience, and technical challenges with the technology may all constrain farmers' use of MT. The goal is to determine the perceived benefits and limitations of the MT technologies in order to focus innovation and adaptation. The results provide guidance on how to overcome challenges related to CA adoption and have implications for sustainable intensification efforts more generally.

3.2. Conservation agriculture

3.2.1. Minimum tillage

The three principles of conservation agriculture (minimal soil disturbance, permanent soil cover and rotating or intercropping with legumes) are complementary in that the overall benefits are greatest when they are all used together (Thierfelder et al., 2013b). In practice, however, farmers prefer to adopt technological packages in a step-wise fashion starting with those that are most beneficial for their own specific situations (Byerlee and de Polanco, 1986; Kasanga and Daka, 2013). In southern Africa the principle of minimizing tillage has received the most attention, often with some neglect of the other two principles (Andersson and D'Souza, 2014; Baudron et al., 2007).

In Zambia three specific MT technologies have been promoted - hand hoe basins, ox-drawn ripping and tractor ripping (Grabowski et al., 2014; Nyanga, 2012). Basins are dug in a precise grid and each hole is 20 centimeters (cm) deep, 30 cm long, and the width of a hoe blade. Farmers with animal traction can use a the locally engineered Magoye ripper to open up a trench 5 cm wide and 15 cm deep where the seeds can be sown (Kabwe, Donovan, and Samazaka, 2007). Where tractors are available, tractor-drawn rippers can be used.

Minimizing soil disturbance offers two types of important benefits to farmers: improved soil fertility and increased water-use efficiency. Improvements to the soil tend to be long-term and are the result of reducing the decomposition of soil organic matter and preventing erosion (Rockström et al., 2009; Verhulst et al., 2010; Thierfelder, Cheesman, and Rusinamhodzi, 2013a). MT can increase water-use efficiency by improving water infiltration, especially with mulch (Thierfelder and Wall, 2009) or by breaking through a compacted layer of soil (Haggblade and Tembo, 2003). In addition, MT takes place during the dry season, enabling earlier planting than with plowing which only begins once the rains start. Cotton and maize yields tend to increase with earlier planting on the order of 100 to 200 kg per week (Haggblade and Tembo, 2003; Haggblade, Kabwe, and Plerhoples, 2011).

Some of the most commonly identified constraints for minimum tillage include increased labor requirements for basins (Grabowski and Kerr, 2014) and the challenge of weed control without soil inversion (Giller et al., 2009; Wall 2007; Gatere et al., 2013). The retention of dry season biomass is problematic due to uncontrolled fires and grazing by free range livestock (Giller et al., 2009; Baudron et al., 2007). Rotation or intercropping with legumes tend to be low at least in part due to low prices, high seed costs, high labor requirements and poor access to improved varieties (Snapp et al., 2002).

3.2.2. Conservation agriculture promotion among cotton farmers in Zambia

Cotton farmers are the largest group of spontaneous CA adopters among smallholder farmers in Zambia (Haggblade and Tembo, 2003). Private sector cotton companies, which provide inputs on contract to smallholder growers, have actively promoted CA since the late 1990s to increase yields and reduce losses from dry spells (Kabwe, Donovan, and Samazaka, 2007). The initial emphasis was on basins, in part because cattle corridor disease had reduced the availability of animal traction at that time (Haggblade and Tembo, 2003). Starting in the early 2000s the Magoye ripper was increasingly promoted with cotton farmers (Kabwe, Donovan, and Samazaka, 2007).

NWK Agri-services (previously known as Dunavant) and Cargill are the largest cotton companies and strongest private sector promoters of MT (Haggblade et al., 2010). NWK uses a system of distributors who are lead farmers that provide training, distribute seed and chemicals, monitor fields and buy the harvest for 50 to 100 cotton farmers. They earn a commission from their farmers with bonuses for high volume, yields, and loan repayment rates. Cargill on the other hand employs buyers who may or may not be farmers to carry out similar functions but oversee 200 to 500 farmers.

NWK encourages each of its distributors to have a CA demonstration plot to use for training in the communities. Cargill buyers hold what are called cotton schools to train farmers on CA and cotton production practices. Both companies have increased their efforts over the last few seasons as herbicides and equipment have become more available to farmers on credit (Grabowski et al., 2014).

Approximately 64% of small- and medium-scale farmers in Eastern Province grow cotton (Tembo and Sitko, 2013). Cotton is a demanding crop in terms of labor and management with regular pest monitoring and pesticide sprays. On average cotton farming households have larger cultivated areas, own less cattle and earn a larger portion of their income through agriculture than households that do not grow cotton (Haggblade, Kabwe, and Plerhoples, 2011). In addition to the cotton companies, numerous development agencies have promoted CA in Eastern Province since the mid-1990s (Baudron et al., 2007; Arslan et al., 2014).

3.2.3. Agriculture in Eastern Zambia

Eastern Province is a high agricultural potential region where 24% of all households are smallholders (the highest rate in the country), many of whom are food insecure (Siegel, 2008). The province has a unimodal rainfall pattern with annual precipitation varying between 600 and 1200 millimeters between November and May. Though overall population density is relatively low, localized land scarcity exists, especially around large villages. Eastern Province can be divided into two major agro-ecological zones. The lower elevation *valley* zone has lower rainfall, higher temperatures and lower cattle populations because of tsetse fly infestation. The upland *plateau* regions have greater population density and higher rainfall. This study focuses only on the plateau portion of the province.

3.2.4. Minimum tillage adoption in Zambia

Despite at least 10 years of heavy promotion of CA in Zambia's moderate-rainfall zones, national adoption rates remain low (Arslan et al., 2014; Grabowski et al., 2014). Two separate surveys suggest that MT use in Eastern Zambia has been expanding gradually, though remaining below 15% of households (Arslan et al., 2014; Ngoma, Mulenga, and Jayne, 2014). Data from cotton farmers in Eastern Province also showed an overall increase in MT use, most of which came from the uptake of ox-ripping while basin use rates were relatively unchanged (Grabowski et al., submitted). Both promotion and adoption of CA are clustered geographically (Grabowski et al., 2014; Kasanga and Daka, 2013), which make it more difficult to precisely estimate province-level MT use (Grabowski et al., submitted).

MT adoption correlates with promotion and higher rainfall variability, suggesting that farmers use MT to reduce their vulnerability to an unpredictable climate (Arslan et al., 2014; Ngoma, Mulenga, and Jayne, 2014). For communities where cotton is grown, adoption correlates with greater herbicide availability, longer promotion and better demonstrations by lead farmers (Grabowski et al., 2014).

Adoption is often temporary, particularly when development agencies provide material incentives to adopters. Arslan et al. (2014) report that in Eastern Province 88% of the 78 MT users in the sample in 2004 disadopted by 2008. The authors attribute disadoption to the expectation of free inputs to use CA and the discontinuation of those incentives, as has been documented elsewhere in Zambia (Ngoma, Mulenga, and Jayne, 2014; Baudron et al., 2007; Haggblade and Tembo, 2003).

3.3. Data and methods

I used a mixed methods approach to gain an in-depth understanding of the factors affecting farmers' decision to use MT or not. I used qualitative interviews to both document farmers' motivations and to guide the subsequent development of a survey instrument to analyze the determinants of adoption. I carried out the survey with 245 farmers in 15 communities where CA adoption was expected to be relatively high. I carried out in-depth interviews in the local language, Chinyanja, with 63 farmers and cotton buyers in 10 communities with varying levels of adoption. I used thematic analysis to analyze the qualitative data and econometric analysis to analyze the survey data.

3.3.1. Selection of respondents

3.3.1.1. Community selection

Communities were specifically chosen with relatively high levels of adoption by randomly selecting locations where lead cotton farmers reported MT use rates greater than the overall average where MT was practiced (census of lead cotton farmers described in Grabowski et al. (2014)). This stratification was done to enable analysis of the determinants of adoption where it was known that non-adoption was not simply the result of lack of promotion or the unsuitability of the environment (Table 5). All communities in this study are in plateau areas of Eastern Province.

Table 5: Community stratification by company and adoption level

	NWK		Cargill	
Strata	**Total**	**Surveyed**	**Total**	**Surveyed**
High tractor ripping	5	4	0	0
High ox ripping	61	2	22	5
High basins	38	1	16	1
Medium MT	116	2	35	0
Low/Zero MT	408	0	102	0
Total number of groups	628	9	175	6

Source: Author's calculations using Survey data from NWK distributors and Cargill buyers, 2011
Note: Communities were stratified by MT use rate based on a census of lead cotton farmers. "High" rates of use are defined as twice the mean use rate (from the mean of communities where MT was used by at least one farmer), "Medium" rates are defined as rates between half and twice the mean use rate. "Low" rates are defined as less than half the mean use rate.

3.3.1.2. Respondent selection for in-depth interviews

I carried out in-depth interviews with 34 farmers, 18 distributors from NWK and 11 buyers and chairpersons from Cargill. In addition, I conducted three group interviews with a total of 122 farmers (69 males and 53 females) and ad hoc interviews with seven survey respondents.

For all randomly selected communities I interviewed the distributor, buyer or chairperson who linked me to the farmers. I conducted most in-depth interviews with farmers in five communities from the full range of adoption levels (high tractor ripping, high ox-ripping, high basins, and low adoption). In each community I selected farmers for in-depth interviews from each category of land preparation (plow, ox-ripper, hoe, basin user, tractor ripper or disadopter). I used group interviews during impromptu data collection opportunities where farmers had assembled to observe the survey process. The participants in the ad hoc interviews were identified as disadopters during the survey and I asked them to explain their experience and motivation for disadopting.

3.3.1.3. Farmer selection for the survey

Distributors and buyers at the community level were used as key informants to categorize farmers by their most distinctive (unique) land preparation method. Most farmers hoe some of their land so only those who exclusively hoe were categorized as hoe farmers. If farmers used any type of MT they were categorized by the MT technology used. If they used ox-ripping and basins they were categorized as ox-rippers and if they used tractor ripping with any other type of MT they were categorized as tractor rippers. I then randomly selected up to eight farmers in each category from each community and invited them to participate in the survey.

Table 6: Response rates of farmers by stratification category

Stratum	Selected	Surveyed	Response Rate	Analyzed	Actual Practice [a]
Chairman	4	4	100%	4	-
Hoe Farmer	52	35	67%	34	34
Plow farmer	62	40	65%	39	118
Basin farmer	22	14	64%	15	33
Ox-ripper	73	62	85%	56	45
Tractor plower	9	6	67%	6	2
Tractor ripper	31	17	53%	17	4
Disadopter	5	4	80%	4	-
Unknown	83	63	76%	61	-
Total	342	245	72%	236	236

Source: Survey of NWK and Cargill farmers, 2013

[a] This is how the farmers in the sample are categorized based on their actual responses

3.3.2. Data collection

3.3.2.1. Qualitative data collection

Interviews with farmers focused on their farming practices for the previous season before asking about their experiences and perspectives on MT. I asked farmers who used MT about how they learned about it, what they had done previously, their motivation for using MT and their assessment of how MT performs compared to conventional tillage. Farmers who had disadopted MT were asked to explain their reasoning for disadoption. I asked distributors, buyers and community leaders about community-level issues related to inputs, production and CA promotion in the area. These key informants also provided their perspective on farmers' motivations for using, not using and disadopting MT in the area. I recorded and transcribed all interviews. The in-depth interview guides can be found in Appendices B and C.

3.3.2.2. Survey data collection

Four enumerators were hired to assist in conducting the survey using the local language, Chinyanja. Distributors and buyers invited the selected farmers to meet in a central location and those who did not attend were visited at their home as time allowed. The survey response rate was 72%.

The questionnaire included questions about farming practices for every plot cultivated during the 2012/13 rainy season. Household-level questions were used to understand the household composition, education level of the adults, total landholding, years of cotton experience, crops sold, sources of non-agricultural income, livestock ownership, and ownership of agricultural and household items. Farmers also were asked their opinions comparing hoeing to basins and ripping to plowing. The survey instrument can be found in Appendix A.

The total value of equipment at the time of deciding whether or not to use MT was calculated by including only equipment that had been owned since before the decision to adopt or disadopt was made. For those who never had used MT only equipment owned over three years was included, which is the average amount of time adopters have used MT.

3.3.2.3. Community-level data collection

Community-level data were collected from several sources. Distributors and buyers provided information about how long CA had been promoted and about their own farming practices. To examine the influence of distributors' and buyers' use of MT, I multiplied the percent of area they farmed with MT by the years they have used MT. The percent of farmers using animal traction was obtained from the census of lead cotton farmers (Grabowski et al. 2014). I obtained population density from the 2010 census information at the ward level and measured elevation using GPS. Some variables were generated by aggregating household-level responses in the community, such as average fertilizer application rate for maize and the percent of plots whose residues had been heavily grazed the previous dry season.

3.3.3. Data analysis

3.3.3.1. Qualitative data analysis

The qualitative data includes transcripts, researcher notes and comments written on surveys. I coded this data using thematic analysis to facilitate retrieval of similar information across the data. In thematic analysis the researcher systematically examines textual data for each code and develops summary statements to concisely represent the diversity of responses (Miles and Huberman, 1994; Rubin and Rubin, 2005). I use quotes from respondents where possible to succinctly represent the perspectives presented in the data. In addition, numerical tabulations are used to clarify the level of agreement or disagreement about an issue.

3.3.3.2. Statistical data analysis

While other adoption studies typically explore adoption as a binomial variable (Arslan et al. 2014; Ngoma, Mulenga, and Jayne 2014; Nyanga 2012) this analysis allows for greater insight by differentiating adopters into those who use basins and ox-ripping and differentiating non-adopters into those who disadopted and those who never used MT.

I used a multinomial logistic regression to estimate how marginal changes in household characteristics affect the probability of being in one of four categories: 1) ox-ripper farmers (who may also use basins), 2) basin farmers (who do not use ox-ripping), 3) disadopters (anyone who previously used MT before the 2012/13 season) and 4) farmers who have never used any type of MT. Tractor farmers were excluded from the analysis because tractor use among sampled farmers was too low (see Grabowski et al. (submitted) for more details).

A multinomial logistic regression estimates how a marginal change in the independent variables will affect the probabilities of fitting into any one category relative to another. The multinomial logistic model can be presented formally as:

$$\ln \Omega_{m|b}(x) = \ln \frac{\Pr(y = m \mid x)}{\Pr(y = b \mid x)} = x\beta_{m|b} \qquad \text{(equation 1)}$$

for land preparation categories m = 1 to J where b is the base category (Long and Freese 2001).

3.3.3.3. Sampling weights

To estimate the parameters of the population (cotton farmers in communities with relatively high adoption), I weighted the observations by the inverse sampling probability. Using weights in the analysis reduces bias when generalizing to the broader population and cannot be ignored when observations are stratified by the dependent variable (Elliott 2008) as was done here. Outlier weights in this study were trimmed to five times the median weight (following Pedlow et al. 2003). This ad-hoc way of trimming has been shown to be just as effective as more advanced trimming methods that use simulation and modeling (Chowdhury, Khare, and Wolter 2007).

3.3.3.4. Cluster analysis to control for community fixed effects

To control for unobserved heterogeneity across communities, I used cluster analysis drawing on key indicators of economic and environmental variation. I employed the k-means method of clustering to group communities into four groups according to five variables: population density, elevation, the percent of farmers using animal traction, the average fertilizer application rate to maize and the percent of plots where residues were heavily grazed (Table 7). K-means is the most commonly used method for data clustering due to its easy implementation and empirical evidence of its effectiveness (Jain, 2010). Dummy variables for the clusters were then used in the regression to control for fixed effects at the community level.

Table 7: Mean values of the characteristics used to cluster communities

	Population Density (people/square kilometer)	Elevation (meters)	Percent of farmers using animal traction	Average fertilizer application rate to maize (kg/ha)	Percent of plots where residues were heavily grazed
Cluster 1	48.96	1006	76.6%	99.6	34.9%
Cluster 2	140.53	1106	67.2%	308.0	29.6%
Cluster 3	83.3	833	41.8%	273.6	32.0%
Cluster 4	50.1	1012	65.6%	187.4	31.8%

Source: Survey of NWK and Cargill farmers, 2013

3.4. Results and discussion

The results are organized to specifically draw on the strengths of both the qualitative and quantitative research methods. First I present quantitative data on the level of adoption to provide a clear idea of how farmers are using MT. Next, I summarize the qualitative analysis to show the primary motivations of farmers' decisions to use or not use MT. Finally I present econometric analysis of the characteristics of those who use MT, disadopt MT and have never used MT, which provides statistical information about the relative importance of the constraints and motivations identified through the qualitative analysis.

3.4.1. Adoption rates

Even in the surveyed areas where relatively high adoption was expected, 52% of the farmers have never tried any form of MT and another 24% tried it previously but did not use it during the 2012/13 season (Table 8). Of the 24% of farmers who are using MT, about half are using ripping and half are using basins with a few using both.[1] Only an estimated 12% of cotton area and 20% of hybrid maize area were prepared using MT (Figure 3). Groundnuts

[1] For details on how farmers in this dataset combine MT with the other principles of CA as well as other agronomic practices see Chapter 4.

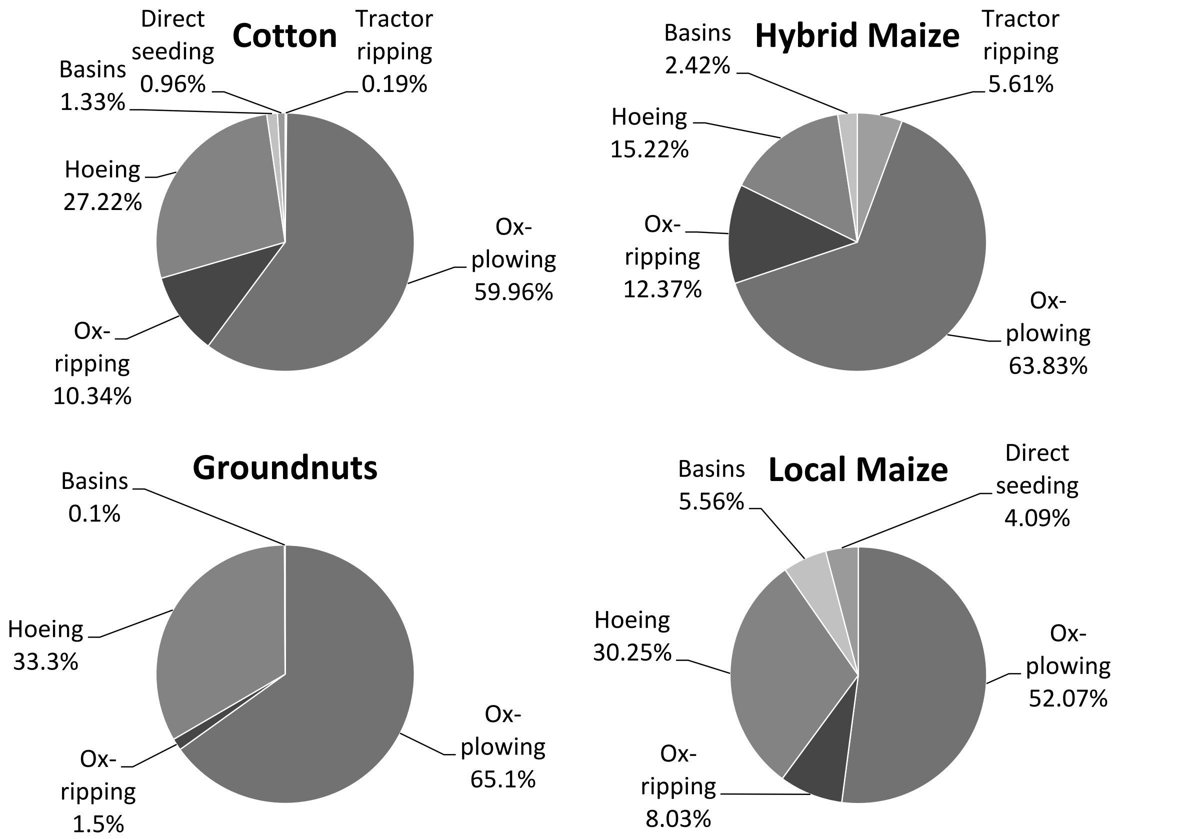
and other crops are only rarely planted on MT plots, which contrasts with another study that found over 20% of MT users with one fifth of their MT plots being planted to legumes (Kasanga and Daka, 2013).

Table 8: Land preparation method use rates and rates of disadoption for cotton farmers in areas of medium and high adoption in Eastern Province

	Proportion of households		**95% confidence interval**
Basins as only form of MT	12.8%		(4.3% - 21.3%)
Ox-ripping with or without basins	11.8%		(6.1% - 17.5%)
Both basins and ox-ripping		*2.0%*	*(0.1% - 4.9%)*
Disadopted all MT	23.7%		(15.3% - 32.0%)
Now only hoes		*5.3%*	*(0.6% - 10.0%)*
Now plows		*18.4%*	*(8.5% - 28.3%)*
Never used MT	51.7%		(27.3% - 76.2%)
Only hoes; never used MT		*17.1%*	*(10.5% - 23.7%)*
Plows; never used MT		*34.6%*	*(13.4% - 55.9%)*
Total	100%		

Source: Survey of NWK and Cargill farmers, 2013.
Note: The rows in italics are additional ways of grouping the data.

Figure 3: Percent of area under each land preparation method for the four largest crops



Source: Survey of NWK and Cargill farmers, 2013

3.4.2. Farmers' motivations for adopting MT

Farmers' main reasons for using MT are to improve their yields and reduce their vulnerability to drought. Fifteen out of 20 key informants (distributors or buyers) specifically mentioned drought tolerance as a motivating factor.

> *"Now these days the rains are less and with MT*[2]*, even if the rains are less they harvest well… like our other fields the maize wilts but now with MT, it looks like the rains were still falling."* (Key informant 3)

[2] *Gamphani* is the Chinyanja word commonly used for minimum and it is translated as MT for all quotes in this study. *Gamphani ya maenje* (MT with holes) and *gamphani ya ng'ombe* (MT with cattle) are translated as basins and ripping respectively.

One NWK farmer explained his recent adoption saying,

"My friends were harvesting very well despite drought, it was resistant and it still grew very well and thrived, good maize, healthy maize. So I thought, let me take it as well." (Key informant 14)

Early planting is a key aspect of MT that helps farmers achieve the goals of higher yields and drought tolerance (Haggblade and Tembo, 2003). Seven out of 20 key informants specifically mentioned early planting as a motivation for using CA. As one Cargill buyer put it:

"Those who have rippers and use this method, they recommend it because they plant early. Because for them by the time the rains come they have already done the ground work. So they can plant early, the weeding is done early. The production is higher than those who do plant after the rains. ... Those who ripped, they capture a lot of moisture. So their crops, despite the dry spell, they still look very good." (Key informant 26)

Several farmers explained that when they saw their yields declining with conventional agriculture they switched to MT to redress the situation. For example one farmer said,

"So what made me start using MT, for many years I had been making ridges [by hoe], but I was not finding food well enough. Harvests were down. So I tried MT and I found it. I harvested two ox-carts." (Farmer 33)

From the survey data it is clear that cotton farmers in general believe that basins and ox-ripping result in higher yields, better soil fertility, better crop performance during drought years and reduced erosion (Grabowski et al., submitted).

3.4.3. Understanding farmers' reasons for not using MT

3.4.3.1. Incentives

It is important to note that among respondents current MT use is not closely associated with receiving material incentives (such as cash, fertilizer, or food), though some farmers did receive these for using MT in the past. Only two farmers who were interviewed were receiving incentives from an NGO and in both cases this was for teaching about MT, not simply for using it. Both of them identified jealousy of the incentives as a reason for others to decide not to adopt MT. One farmer explained his reasoning not as jealousy but as a perceived injustice:

> *"What has made me not try MT, is that those leaders who are in front, they can write your name but then later they take the fertilizer. That makes it so that I would be lacking wisdom to do that work with them. …So we refuse to do it. For me to dig those basins, there is nothing for me to put in them."* (Farmer 1)

In three communities distributors explained how disadoption was widespread once incentives stopped. One distributor explained, "So they [farmers] concentrate just for the purpose of getting a bike. Then after that thing, that funding goes, they will forget" (Key informant 29).

3.4.3.2. Labor as the primary constraint for basins

Farmers identified labor as the key constraint for more widespread use of basins. Of the 20 farmers who stated their reasons for disadopting basins, 12 of them said it was the hard work of digging the basins that made them stop. They described digging basins as "heavy work", "painful" and "too hard to dig". Three of those 12 stopped using basins when they started using animal traction. Another farmer stopped when his wife passed away. A fourth farmer stopped when he started having regular employment. A fifth stopped when she moved from the village to a farm where she had larger fields, explaining, "It needs too much power to do basins on a large area" (Farmer 2). All of these show how changes in circumstances that alter the value of household labor directly impact the relative utility of using that labor to dig basins. Furthermore, the perceived increased effort needed for manual MT has kept many people from trying basins.

3.4.3.3. Equipment costs as a key constraint to ox-ripping

Many farmers expressed a desire to use ox-ripping but they said they were unable to afford the equipment and/or were unable to obtain oxen. Most current basin users previously hoed and most current ripper farmers previously used oxen for plowing and making ridges. This suggests that oxen ownership and animal traction experience are likely to determine if a household uses ripping or not. Altogether the total cash outlay required for the equipment is either $150 for the full set or $55 for the ripper attachment and chain if the farmer has an extra plow frame. With a mean per capita gross household income of only $390 for smallholders in Eastern Province (Tembo and Sitko, 2013) such an investment would require significant tradeoffs in other expenditures.

Of the 11 farmers interviewed who disadopted ripping, six of them had borrowed the ripper. They explained that the lack of availability of the ripper led them to not rip in the 2012/13 season. As one farmer put it, "the owner is busy using it. The time may go by when you are supposed to use it. That is the main problem" (Farmer 24). Another explained that the loss of one of his oxen prevented him from ripping in 2012/13.

Of the 50 ripping farmers surveyed, 30 of them own a ripper. Most of them bought their ripper on credit from the cotton companies but with low cotton prices it can be difficult for farmers to repay. Low cotton prices resulted in loan defaults on 20% of the 40 ripper loans provided in three Cargill depots in 2011, causing the company to reclaim the equipment. For this reason many farmers were cautious about taking on too large of a loan during the 2012/13 season.

While many farmers are interested in getting rippers on credit, they must be willing to take the risk of a relatively large loan and their distributor or buyer must deem them creditworthy. The other ways farmers obtained a ripper was to pay cash or receive a ripper from an NGO. Many farmers without oxen made requests for oxen loans so that they too could start ripping.

3.4.3.4. Fear of over-exerting oxen as a barrier to widespread use of ox-ripping

Because ripping can be done throughout the dry season one would expect a well-developed rental market by those who own the equipment. However, ripping rental service provision is not common. One of the main reasons why those who own the equipment do not extensively rip for others with their oxen (as is common for plowing at the start of the rains) is that dry-season ripping is seen as too taxing for the oxen. As one distributor put it, “Well, ripping, you know, it ruins the oxen... It is very dry below so they need to be strong” (Key informant 21). Feed for oxen also tends to be running out in the dry season as the grasses and crop residues largely disappear due to burning, tilling and grazing, so the oxen are at their weakest (Wall, 2007).

The concern for oxen health has even kept some people from using ripping at all. A farmer who uses ox-ripping explained his friends’ resistance this way:

> *“They think it is causing problems to their oxen; to make them dig deep like that is to cause problems for their oxen. They prefer to do it during the rainy season…. But they say, ‘Ah during the dry season, my oxen can’t manage that!’”* (Farmer 19)

3.4.3.5. Information needs as a barrier to adoption of ox-ripping

While most farmers were aware of basins, ripping is a newer and less familiar technology to farmers. Training on ripping was commonly requested and the need for training, over and above equipment, is shown by the surprising fact that 13% of those who invested in a ripper had never used it, despite owning it for over a year. One of these was a distributor who explained that he needed more support in learning how to use the ripper effectively.

Five of the fifteen farmers (33%) who explained their motivation for adoption said that what persuaded them to use ripping or basins was the combination of receiving training and observing the benefits of MT in the fields of earlier adopters. These comments suggest that the uncertainty of a new technology and the perception that MT is too challenging can be reduced through training that is accompanied by real life observation.

3.4.3.6. Lack of motivation as a reason for non-adoption

Because farmers are primarily motivated to use MT because of concerns with drought or soil fertility it is logical then that those who are satisfied with their harvests are less likely to adopt MT. An NWK distributor identified this as one of the key differences between MT users and non-MT users:

> *"What helps them do ripping is to be searching, and wanting to improve… [They say,] 'Maybe we can do better than ridging with oxen, maybe the yields can go up.'"* (Key informant 21)

When asked why he had never tried MT, a hoe farmer responded,

> *"Because we don't really believe what we have heard. I am still interested in hoeing. When I plant on the ridge I see that the maize grows well and if the fertilizer D [compound] and Urea are there it will do well."* (Farmer 16)

Similar ideas were communicated by the non-adopting farmers who participated in the three group interviews.

3.4.3.7. Other reasons for disadopting ripping

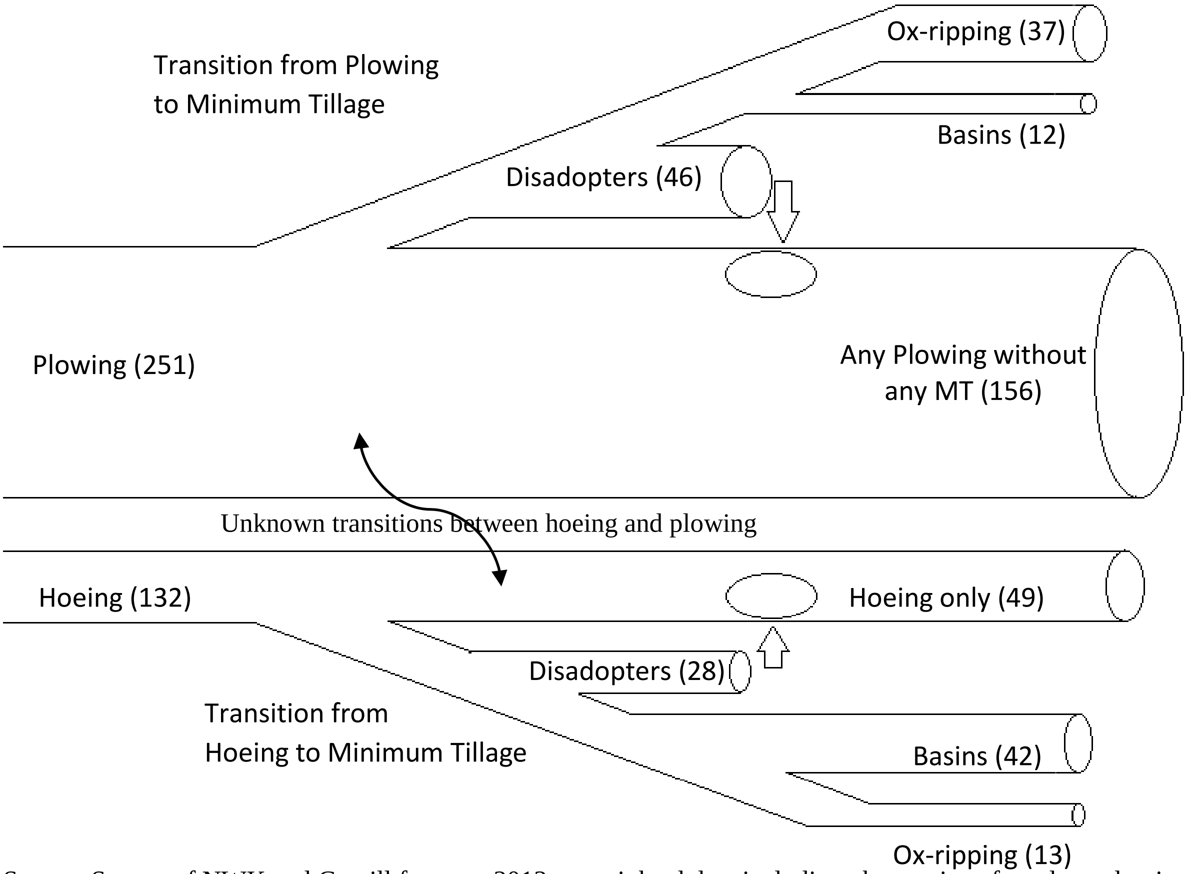
The five farmers interviewed who disadopted ox-ripping though they were ripper owners had various reasons for stopping. One explained that he could not use ripping without herbicides so he stopped when he was unable to obtain herbicides on credit. "If you use the ripper, the weeds are many. But if we make ridges the weeds stay small. So that is why I used the ripper one year and then stopped and kept making ridges" (Farmer 34). Another said that he only used the ripper with fertilizer, which he could not afford last year. He asserted that unless fertilizer was added he saw no difference between plowing and ripping. Two other farmers said that they failed to rip in 2012/13 because the trained household member was busy during land preparation months.

These reasons for discontinuing use of ripping show that disadoption can be an active rejection of the technology due to challenges such as labor, weeds and erosion or a more passive and temporary change brought on by the unavailability of equipment or trained household members. This range of reasons behind disadoption needs to be kept in mind in interpreting the characteristics of disadopters in the statistical analysis below.

3.4.4. Transitions in land preparation methods

Analyzing the frequency of transitions in land preparation methods (including disadoption) allows for a greater understanding of who is using each type of MT and why, what they were doing previously, and what future adoption trajectories may be. In this study all MT users and disadopters were asked if they used oxen or hoed before they started using MT. The results show that most current basin users previously hoed and most current ripper farmers previously used oxen for plowing and making ridges (Figure 4). This suggests that oxen ownership and animal traction experience are likely to determine if a household uses ripping or not. It is also striking that a larger proportion of disadopters previously plowed with their own oxen before they tried using MT. Many of these disadopters received incentives to dig basins, which suggests that they used MT primarily for the incentives.

Figure 4: Illustration of farmers' transitions to MT



Source: Survey of NWK and Cargill farmers, 2013, unweighted data including observations from low adoption communities.

Notes: Pipe diameters are proportional to the number in each category with that number provided in parentheses. For simplicity, disadoption is not disaggregated into basins and ripping in the figure. Of the 46 disadopters who previously plowed, 38 used basins and 15 ripped (seven did both). Of the 28 disadopters who previously hoed, 24 used basins and seven ripped (three did both).

3.4.5. Household-level regression results

I used multinomial logistic model to determine how explanatory variables affected the probability of households being categorized as follows: those who use ripping, use basins, disadopt all MT or never use any MT. In the final regression 215 observations had no missing values. The means, standard deviation and range of the explanatory variables are presented in Table 9. The results are presented in Table 10.

Table 9: Description of variables used in the household-level regression on MT use

	Mean	Standard Deviation	Minimum	Maximum
Household Level Variables				
Household Composition				
Female Headed HH (Y/N)	0.083	0.276	0.00	1.00
Age of head	42.44	14.03	17	81
Age squared	1997.4	1314.4	289	6561
Economic qualities of household				
Adults in hh / Operated Area	1.11	0.80	0.178	6.294
Total Operated Area	3.91	2.43	.98	16
Number of non-ag. income sources	1.00	1.00	0	5
Total fertilizer used (1000 kg)	0.26	0.35	0	2.6
Equipment value ($) at time of adoption/disadoption				
Oxen	1.50	1.77	0	8
Total Livestock (TLU)[a]	3.70	4.06	0	23.27
Capacity qualities of household				
Trained in CA (Y/N)	0.73	0.44	0	1
Ever received incentives for CA (Y/N)	0.10	0.31	0	1
Years of schooling	5.18	3.08	0	12
Cotton experience (years)	10.54	6.95	1	40
Community Level Variables				
Years CA has been promoted	5.23	2.81	2	13
Buyer CA practice	1.33	1.70	0	6.48
Cluster 1	0.22	0.42	0	1
Cluster 2	0.23	0.42	0	1
Cluster 4	0.25	0.44	0	1

Source: Survey of NWK and Cargill farmers, 2013

[a] Tropical Livestock Units - cattle have a value of 0.7, goats and sheep 0.1, pigs 0.2, poultry 0.01 and donkeys 0.5 (Jahnke, 1982).

Table 10: Factors affecting household use of MT, multinomial logistic regression results with robust standard errors

Explanatory Variables	Rip vs. Never			Rip vs. Disadopt			Basins vs. Never			Basins vs. Disadopt		
Household Level												
Female Headed HH (Y/N)	-2.29	**	(1.04)	-1.30		(1.12)	0.17		(1.09)	1.17		(1.17)
Age of head	0.35	**	(0.15)	0.26	*	(0.15)	0.13		(0.14)	0.04		(0.14)
Age squared	-0.004	***	(0.00)	-0.004	**	(0.00)	-0.002		(0.00)	-0.002		(0.00)
Economic variables												
Adults in hh / Operated Area	1.21	**	(0.51)	0.73		(0.52)	1.46	***	(0.45)	0.98	**	(0.44)
Total Operated Area	0.46	*	(0.27)	0.08		(0.23)	0.64	**	(0.27)	0.26		(0.23)
Sources of non-ag. income	-0.81	*	(0.48)	-0.92	*	(0.50)	-0.68	**	(0.33)	-0.79	**	(0.35)
Total fertilizer (1000 kg)	3.41	***	(1.17)	0.99		(0.68)	1.96		(1.35)	-0.46		(0.92)
Equipment value ($)	8.99	***	(2.83)	5.58	***	(1.82)	5.62	**	(2.58)	2.21		(1.74)
Oxen	-0.29		(0.30)	-0.48		(0.30)	0.01		(0.26)	-0.18		(0.25)
Total Livestock (TLU)[a]	-0.12		(0.12)	0.06		(0.13)	-0.24	**	(0.12)	-0.06		(0.11)
Capacity variables												
Trained in CA (Y/N)	4.39	***	(0.98)	3.50	***	(1.10)	1.14		(1.15)	0.26		(1.12)
Years of schooling	0.07		(0.12)	-0.06		(0.12)	0.38	***	(0.13)	0.26	*	(0.14)
Cotton experience (years)	0.05		(0.08)	-0.04		(0.07)	0.19	***	(0.07)	0.10		(0.07)
Received incentives (Y/N)	0.79		(1.76)	-2.31		(1.74)	5.36	***	(1.05)	2.26	**	(0.90)
Community Level												
Years CA promoted	0.20		(0.17)	0.06		(0.16)	0.06		(0.22)	-0.08		(0.24)
Buyer CA practice	0.23		(0.43)	0.37		(0.44)	-0.57		(0.39)	-0.43		(0.38)
Cluster 1	-0.39		(1.12)	-0.05		(1.07)	-0.50		(1.36)	-0.16		(1.30)
Cluster 2	0.74		(0.91)	1.60	*	(0.85)	-0.29		(1.06)	0.57		(1.00)
Cluster 4	-1.78		(1.38)	-0.71		(1.24)	-0.83		(1.16)	0.24		(1.17)
Constant	-17.07	***	(4.64)	-9.38	**	(4.41)	-10.82	***	(3.41)	-3.13		(3.48)

Observations 215 Wald Chi^2 (57) = 177.00 Pseudo R^2 = 0.3903

Prob > chi^2 = 0.0000 Log pseudolikelihood = -12,661.594

Source: Survey of NWK and Cargill farmers, 2013

[a] Tropical Livestock Units - cattle have a value of 0.7, goats and sheep 0.1, pigs 0.2, poultry 0.01 and donkeys 0.5 (Jahnke, 1982).

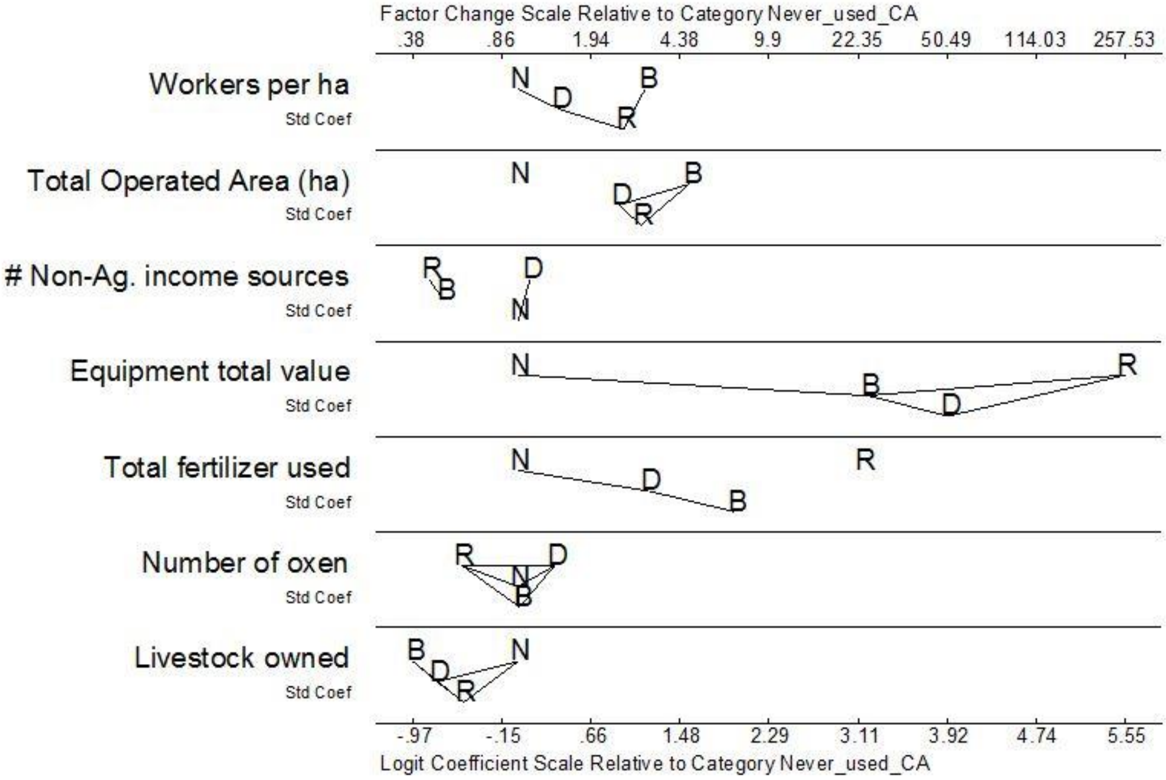
One of the challenges with interpreting the results of this multinomial regression on four categories is that marginal effects for each explanatory variable must be considered for all pairs of comparisons. In Table 9 I present the coefficients for only the four most relevant comparisons. An odds ratio plot (also known as a factor change plot) makes it easy to visualize how a change in each variable (holding the others constant) affects the probability that a household will fall into any category relative to the others (Figures 5 and 6).

For dummy variables the odds ratio between a pair of choices *m* and *n* can be calculated as $Z = e^\beta$. The interpretation of the odds ratio for a dummy variable is that when X=1 the odds of a household being in category *m* versus *n* are expected to change by a factor of Z, holding all other variables constant.

For continuous variables the odds ratio plots below show standard deviation changes. The odds ratio for a standard deviation change can be calculated as $Z = e^{(\beta * s.d)}$. The interpretation for continuous variables is that when there is a standard deviation change in X the odds of a household being in category *m* versus *n* are expected to change by a factor of Z, holding all other variables constant.

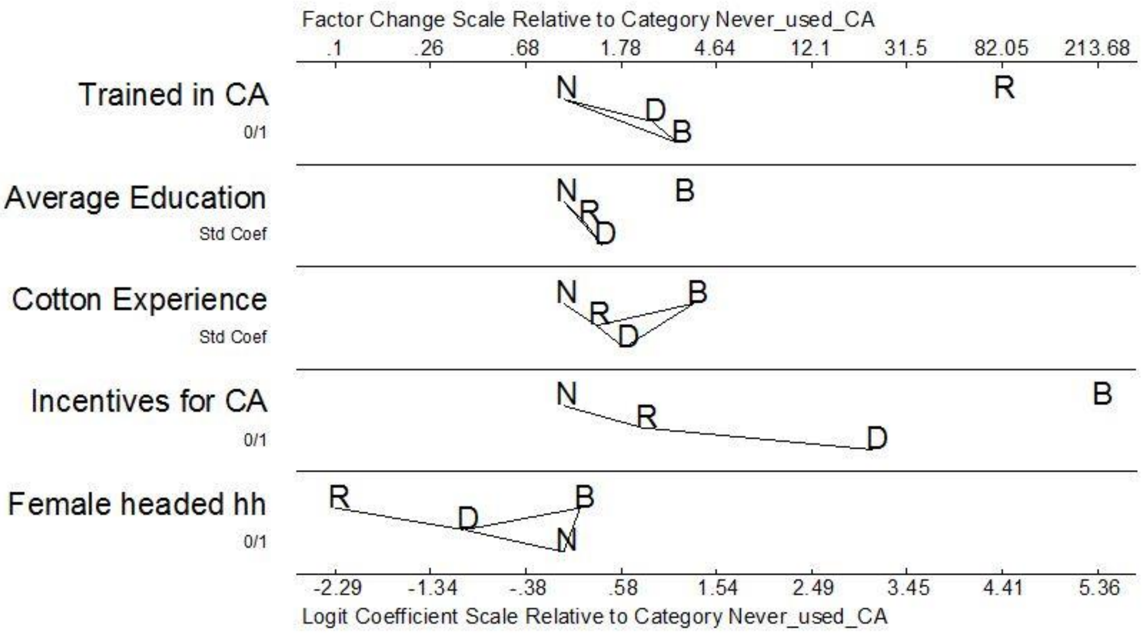
In the following figures the household categories are represented by their first letter (B = Basins, R = Ripping, D = Disadopter, N = Never used MT). When there is a line between two letters there is no statistically significant difference in the probabilities of being in either category ($p=0.1$). The category of "Never used MT" is the base category so all the N's are lined up at the value of 1 on the top axis (which shows the odds ratio) and 0 on the bottom axis (which shows the β's from the regression results). When a category is to the left of the base category it means that an increase in the explanatory variable leads to reduced probability of a household being in that category, thus requiring the odds ratio to be inverted. So when a category is at 0.1 on the top axis it means it is 10 times less likely than the base category.

Figure 5: Odds ratio plot for economic indicator variables



Source: Survey of NWK and Cargill farmers, 2013
Note: Household categories are represented by their first letter (B = Basins, R = Ripping, D = Disadopter, N = Never used MT).

Figure 6: Odds ratio plot for capacity indicators and other variables



Source: Survey of NWK and Cargill farmers, 2013
Notes: Household categories are represented by their first letter (B = Basins, R = Ripping, D = Disadopter, N = Never used MT).

3.4.5.1. Labor availability as a determinant of adoption

The statistical analysis supports the qualitative finding that labor is a key constraint to MT use. In addition to the challenge for land preparation with basins, labor is also higher for weeding in the absence of herbicides for any MT. A standard deviation increase in the number of adult workers per hectare of land farmed makes a household 4.3 times more likely to use basins and 3.3 times more likely to use ripping than to have never tried MT (Figure 5). Surprisingly, a standard deviation increase in oxen has no effect on the probability of a household falling into any of these categories (Figure 5). The fact that half the basin users also plow with oxen indicates that basin use is not mutually exclusive with oxen ownership. While hand-hoe farmers may be the best candidates to adopt basins (since plowing and ripping are not easy options for them), they also have limited labor.

3.4.5.2. Wealth indicators as determinants of adoption

A variety of wealth indicators were used in this analysis and several were significantly associated with MT adoption. Wealth allows farmers to invest in ox-ripping equipment, a major constraint identified in the qualitative analysis. Wealth also makes the household better able to risk trying out a new technology. Households with more farmed area are more likely to use basins and ripping than to have never tried MT. Similarly, households with higher values of equipment at the time of adoption are more likely to use ripping or become a disadopter than to never try MT. Households that apply more fertilizer are also more likely to use ripping and, to a lesser degree, basins (Figure 5). Total fertilizer use reflects a household's ability to find cash at the beginning of the season, which is a major challenge for smallholders (Andersson and D'Souza, 2014).

The characteristics of the head of the household play an important role in the MT adoption decision and are directly related to the ability to invest and take risks. Female-headed households are 10 times less likely to use ripping than to have never tried using MT and 12 times more likely to use basins than ripping (Figure 6). Age of household head has a positive non-linear effect on the probability of a household using ripping. The combined marginal effect of age and age-squared is positive over the entire range (being older makes one more likely to use ripping) and peaks at age 41. The interpretation is that older household heads have greater ability to invest in equipment, which is supported by the insignificance of age for explaining adoption of basins.

3.4.5.3. Livelihood strategy as a determinant of adoption

Households without much land may not be able to focus on making it more productive if their small farmed area forces them to have diverse livelihood strategies. Households with more non-agricultural income sources are less likely to use ripping or basins. Households with more diverse livelihood strategies may have too many non-farm responsibilities to focus attention on learning and implementing complex management practices such as MT.

3.4.5.4. Knowledge as a determinant of adoption

Conservation agriculture has been described as a knowledge-intensive technology (Kassam et al., 2009) and as such training is expected to be important for adoption. These results show this to be especially true for ox-ripping. Most households in the sampled communities (64%) have received some training, though not necessarily in ripping, which is more technical and has been promoted less than basins. Nearly all households using ripping (97%) have received training, suggesting that without it adoption is highly unlikely. Farming experience and formal schooling are more important for explaining adoption of basins than training.

3.4.5.5. Incentives as a determinant of basin use and disadoption

While most farmers in this study did not receive incentives, those who did were typically basin farmers. If a household has ever received incentives for doing MT it is more likely to use basins or disadopted than to have never tried MT. The effect on ripping is smaller, which fits with the history of MT promotion - basins have been promoted longer and by more NGOs than ripping. The effect of incentives on disadoption matches well with the qualitative data, suggesting that once incentives are removed disadoption is common. Only 10% of disadopters said they received incentives, so the other challenges merit attention as well.

3.4.6. Summary

Cotton farmers in Eastern Zambia are generally aware of minimum tillage and think highly of its potential for improved yields, especially due to earlier planting, increased drought tolerance and efficient nutrient application. Despite farmers' favorable opinions about MT, farmers' explanations and the statistical analysis both suggest that technical and economic problems significantly limit the use of both basins and ripping.

Significant labor limitations suggest that the use of basins by hand-hoe farmers is unlikely to take off exponentially. However, this does not mean that basins are not worth promoting as many farmers persist in using basins on small plots. Furthermore, as Zambian smallholders face increasing land scarcity in pockets of higher population density there will be less opportunity to fallow and greater need to make land more productive, such as through the labor-intensive method of basins.

For ripping the primary constraints relate to the cost of investment in the equipment and the associated risks of investing in a new (to the farmer) technology. Ox-ripping rental services are not widely available, primarily because of concerns for the health of oxen while they are laboring to do dry season minimum tillage when feed is scarce. Improving the health of oxen may help reduce this challenge and the promotion of forage crops may aid in this while simultaneously reducing the competition between using residues for mulch or for feed (Giller et al., 2011). The lack of effective demonstration and training on how to rip limits its use among those who can afford the equipment. Training and personal observation of ripping appear to help farmers overcome the challenges of learning a new land preparation technique.

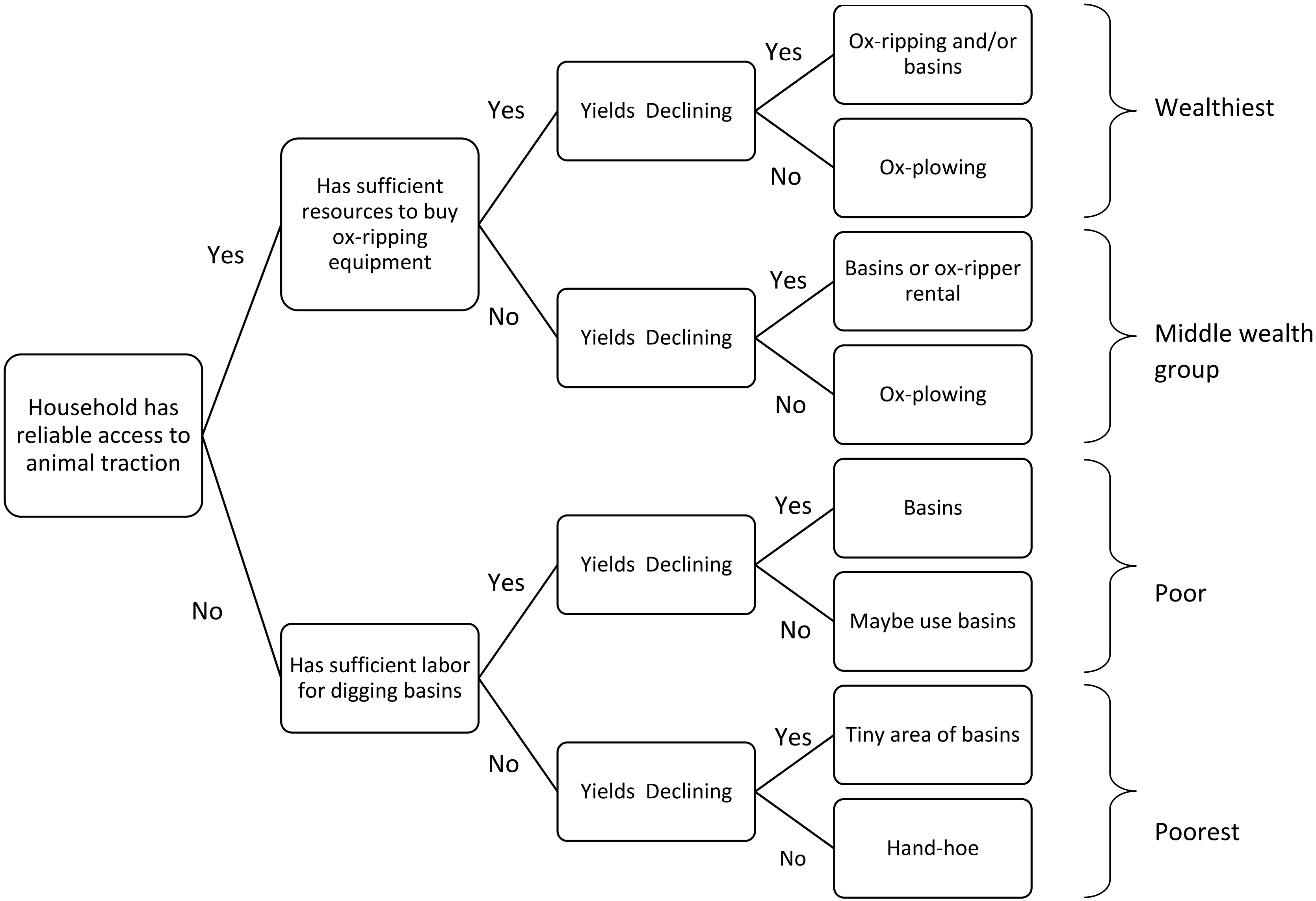
Farmers who have never tried MT have less land, use less fertilizer and have more non-agricultural income sources, which suggest they may be poorer and have more diverse livelihood strategies. Disadopters tend to be better off than those who never tried MT. They are also less educated and have less labor than basin users and use less fertilizer than ripper users. These relationships and constraints are summarized in Figure 7.

3.5. Conclusion

The results of this study highlight three key lessons that can improve efforts to help smallholder farmers mitigate the problems of climate change and land degradation through improved agricultural technologies. First, the diversity of smallholder farmers observed in this study should give caution to those seeking simple technological solutions to low productivity. Any particular technology is likely to be a good match for some farmers and bad match for many others because of the variation in their skills, assets, livelihoods strategies and agro-ecological conditions. Providing a basket of choices (Chambers, 1997) to farmers is much more likely to yield long-term change than promoting one or two narrow solutions.

Second, adaptation of technologies should draw on farmers' experiences to expand the range of conditions where the technology can be used. The clear reasoning that farmers provided in this study about their decisions show that they are not stuck in tradition but wrestling with a complex set of potential benefits and challenges associated with MT. Including farmers in the technology development process can make the most of what they have learned through their experiences and makes it more likely that technologies can be adapted to match with their actual needs and constraints.

Figure 7: Decision tree summarizing the interactions between farmers' resources and priorities and land preparation decisions



Finally, promotion of new technologies should not be based on top-down behavior change messages but rather should follow adult education principles of facilitating experiential learning in a respectful way and drawing on farmers' lived experiences. Farmers using MT highlighted the importance of combining training with real life observations where their peers benefited from using the technologies. Also, policy makers considering subsidizing the use of technologies should be aware of the perverse effects this may have on adoption. Those providing incentives may be hoping to get the ball rolling but may actually be distracting farmers from evaluating the technology.

For sustainable intensification efforts to find effective solutions for smallholder farmers they will have to consider their diversity, include their participation in the technology development process, and promote change in a way that builds on farmers' experiences.

APPENDICES

Appendix A: Survey instrument

Company___________ Distributor/Buyer: _______________________ Survey Number:________

Survey of cotton farmer practices **Date:_____________** **Enumerator: _____________**

A. Introduction **Strata: ____________** **Checked By: _____________**

Introduce yourself by saying your name and that you are doing research for Michigan State University. Next read the consent script.

B. Getting to know the respondent

Name:_________________________ ________ **Village/Section:____________ _______________**

NRC#: _________________________________ **Cell phone: _____________________________**

1. How old are you? _____________ 2. How many people live in your household? ____

3. How many of them work in the field?____ 4. How many of them work like adults?_________

5. Did you go to school? ☐ Yes ☐ No

6. What is the highest grade level that you completed in school? ______

7. Did your wife/husband go to school? ☐ Yes ☐ No

8. What is the highest grade level that your spouse completed in school? ______

C. Understanding their farming practices

9. Do you live in a village or on a farm? □ Village □ Farm □ Other: Please describe ____________

10. What crops do you grow? *Prompt with:* Any others? Any others? (*Check boxes column1)*
11. On how much area did you plant _____ this year? *(Each crop, column 2, if small: write < ¼ lima)*
12. This year how did you prepare your fields? *Prompt with:* Do you plow or hoe? Do you rip or use basins? (*Check all that are used)*

□ Ox-plow □ Ox-ripping □ Hoeing □ Basins □ Tractor Plowing □ Tractor Ripping

13. How much of your cotton area did you use each land preparation method on this year?

(Continue to for all crops, columns 3-6)

10. Crop	11. Total Area 12/13	13.Ox Plowed Area	13.OX Ripped Area	13.Hoed Area	13.Basin Area	13.Tractor Plowed Area	13.Tractor Ripped Area
□ cotton							
□ hybrid maize							
□ local maize							
□ groundnuts							
□ sunflower							
□ soya							
□ tobacco							
□ sweet potato							
□ cassava							
□ beans							
□ other _____							
TOTALS:							

14. On how many plots did you plant _________ (crop) using _________ (land prep method)?

For example: On how many plots did you plant cotton and plow?

Continue for each cell in Table 1 writing the crop and land prep type into the first two rows of the plot table - a column for each plot.

	Plot 1	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**
Crop (2012/2013)							
Land Preparation Method							
15. What size is that plot? (hectares, acres or lima)							
16. How much did you harvest from that plot?							
17. Are there other crops that you planted with __________? (*Indicate which crop, If NO skip to 19)*							
18. How much did you harvest from those other crops?							
19. *If the plot was ripped or had basins:* How many consecutive years have you done ripping (or basins) on that plot?							
20. What month was the last land preparation before planting that field? *Or:* What month did you plow/rip/dig basins/ hoe ridges?							
21. How much seed did you use to plant that field? (kg)							
22. How was the weed pressure on that plot?							
23. How many times did you weed that plot? (including banking)							
24. Did you bank (kupantira/kufochera) that plot?							
25. What did you plant on that plot the previous season? (2011/2012)							
26. What happened to the crop residues on that plot before planting this crop?							
27. *If it was grazed:* How much of the residues were consumed?							
28. What is the soil type on that plot? Sand, stones, loam,							

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7
Crop (2012/2013)							
Land Preparation Method							
clay (soil type)							
29. What color is the soil on that plot? Red, Black, Brown, White (soil color)							
30. What is the slope on that plot? *OR:* How does the water run off of it?							
31. Do you do anything to reduce soil erosion on that plot?							
32. What do you do (if anything) to reduce erosion?							
33. Did you use fertilizer or manure on that plot?							
34.*If Yes:* How much fertilizer did you apply to that plot?							
35. Did you use herbicide (weedkiller) on that plot?							
36a. *If Yes:* How much herbicide? (liters or kg)							
36b. What type of herbicide did you apply on that plot?							
37. Are there any “msangu” (*Faidherbia albida)* on that plot? (fertilizer trees) Yes or No							
38. Do you own, rent or borrow that plot?							
39. Do you think you will continue farming that plot 5 years from now?							
40. *If No:* What makes you think that you may not be farming that plot in the future?							
41. Which plot is your best plot? Which one is the next best? *(Rank all plots)*							

96. Have you ever used CA on that plot? Yes or No							
97. *If Yes:* How many total years have you ever used CA on that plot?							

42. Do you have a wetland garden? ☐ Yes ☐ No

43. *If Yes:* What is the total area of your dimba? ________

44. How much area of land did you leave fallow during the previous season? ____

45. How much land do you have with trees on it? ______

46. Do you have any fields that you rented out last year? ☐ Yes ☐ No

47. How much area (if any) did you rent out to others during the previous season? ________

Animal traction ***If they plow or rip with oxen. Otherwise skip to 52***

48. How many oxen do you own?______ *If zero skip to 50*

49. *If they own any oxen:* For how long have you owned oxen?________ Go to 52

50. *If they don't own any oxen:* How do you obtain oxen for plowing/ripping?

☐ pay/barter to rent them ☐ relative does it for me ☐ borrow from friend or relative

51. *If they rent oxen:* Do you pay the full price up front? Or can you pay some after harvest?

☐ pay all up front ☐ pay all at harvest ☐ pay part up front, part at harvest ☐ other____

Cotton production

52. How many times did you spray pesticides on cotton during this season? _______________

53. How do you decide when you need to spray?

☐ Scouting ☐ Every Two Weeks ☐ Not sure

54. Do you own a sprayer? ☐ Yes ☐ No *(If no go to 57)*

55. What type of sprayer? ☐ Ovaplus (battery) ☐ Jacto (knapsack) ☐ Other ________

56. For how long have you owned it? _____________ (Go to 58)

57. *If they don't own a sprayer:* How do you get your fields sprayed?

☐ Pay/barter to rent ☐ Relative does it for me ☐ Borrow without paying

58. How long have you been growing cotton? __________ years

59. How many 15kg packets of seed did you plant last season? ________

60. How much seed was left over last season?

☐ more than half ☐ about half ☐ about a quarter ☐ less than quarter ☐ none

61. How much cotton did you produce last season? ___________ (woolpacks or kg - *circle*)

Crop marketing

62. What crops do you sell?

☐ cotton ☐ maize ☐ groundnuts ☐ sunflower ☐ soya ☐ tobacco
☐ sweet potato ☐ cassava ☐ beans ☐ other __________________

63. Did you buy maize this year for home consumption? ☐ Yes ☐ No

64. *If yes AND they sold maize:*
Which was larger, the total maize you sold or the total maize you bought?
☐ total maize sold was larger ☐ total maize bought was larger ☐ equal

Agricultural wage Labor

65. Did you hire any laborers for your fields last year? ☐ Yes ☐ No

66. Did you work as an agricultural laborer for others last year? ☐ Yes ☐ No

67. *If No:* Did your spouse work as an agricultural laborer for others last year? ☐ Yes ☐ No

Non-agricultural economic activities

68. In addition to crop and animal production how else do you earn money for school supplies, soap, salt, etc.

☐ Processing food (cooking scones, fritters, etc.) ☐ Making or selling beverages (including alcohol)
☐ Small business trading (groceries) ☐ Wage labor not in agriculture
☐ Building/masonry ☐ Carpentry
☐ Basket weaving / mat making ☐ Sewing/Tailoring
☐ Brick molding ☐ Charcoal making
☐ Bicycle repair/other repairs ☐ NGO work
☐ other (please specify _________________)

69. Were you or your spouse ever employed previously? ☐ Yes ☐ No

70. *If Yes:* What occupation did you have? __________________

71. For how many years did you do that work? _______________________

Sellable assets

72-77. How many ___________(livestock) do you own?

72.Cattle	73. Goats	74. Pigs	75. Poultry	76. Donkeys	77. Sheep

78. Do you own any of the following agricultural equipment? If yes, for how many years have you owned them?

☐ Ox-cart (Years owned _________) ☐ Cultivator (Years owned _________)
☐ Plow (Years owned _________) ☐ Ripper (Years owned _________)
☐ Ridger (Years owned _________) ☐ Treadle Pump (Years owned _________)
☐ Engine to pump water (Years owned _________)

79. How many working bicycles do you own? ________

80. How many working radios do you own? ________

81. How many working cell phones do you own?___________

82. Do you own any of the following items? If yes, for how many years have you owned them?

☐ Motorbike (Years owned _________) ☐ Vehicle (Years owned _________)
☐ Solar panel (Years owned _________) ☐ Generator (Years owned _________)
☐ Maize mill (Years owned _________) ☐ Television (Years owned _________)

83. What type of house do you live in?

 Metal roof OR grass roof

 Fired bricks/cement block OR unfired bricks OR Other ___________________

D. Conservation Agriculture

(*If they already stated that they are using CA skip to 85)*

84. Have you ever heard of farming without tilling the soil such as basins or ripping? Yes No

If NO then SKIP to 109- but really make sure they have never heard of it.

85. Who have you heard about basins or ripping from? (*Check all that are mentioned)*

 Dunavant Cargill CFU (Conservation Farming Unit)

 Agricultural extension officer

 Some other NGO (please specify ____)

 Radio Written material Other _______________________________________

86. How many of your friends and relatives are using basins? ____________

87. How many of your friends and relatives are using ripping (both ox and tractor)? ______________

88. Have you ever been trained to do basins or ripping? Yes No

89. Have you ever received incentives for digging basins or using ripping? Yes No

(*If they already stated that they are using Gamphani skip to 92)*

90. Have you ever tried using basins or ripping on your own land? Yes No *(If "No" SKIP to 106)*

91.*If Yes:* How many years has it been since you last used basins or ripping? ____________

92. How many agricultural seasons have you used basins? ________

93. How many agricultural seasons have you used ox ripping? ____________

94. How many agricultural seasons have you used tractor ripping? __________

95. On how much total area did you use basins/ripping each year since you started?

Year 1 ____________ Year 2 ___________ Year 3 ___________ (*Indicate units)*

96. On which plots have you ever used CA? (*Record on PAGE 5!)*

97. For how many years did you use it on each plot? (*Record on PAGE 5!)*

98. What land preparation practices did you use before using basins/ripping? *(Check all that were used)*

 Hoeing Plowing with own oxen Plowing with hired oxen Other ________

99. Which person was most influential in helping you learn about basins/ripping?

Name: ______________________

Relation: Friend Relative Distributor/Buyer/Chairman

 Extension officer NGO field worker Other: ___________________

100. *If they have ever used basins:* Do you have a Chaka hoe? ☐ Yes ☐ No

If they have never used ripping SKIP to 106

101. If you want to rip a field that has ridges, do you rip on the ridge or in the furrow?
☐ Ridge ☐ Furrow ☐ I have never done that ☐ I don't know

102. Where you rip, do you weed with oxen or tractor, such as by using a cultivator or plow?

☐ Yes ☐ No

103. Where you rip, do you bank the crop mid-season? ☐ Yes ☐ No (*If No skip to 106)*

104. *If yes:* Do you always bank the crop when ripping? ☐ Yes ☐ No (*If Yes skip to 106)*

105. *If no:* Why do you sometimes bank the crop when ripping?
☐ Only when there is excessive rainfall
☐ I only bank for particular crops (*List:* ___________________)
☐ Other: ____

106. How would you compare a field with one half under ox ripping and one half ox plowed?

	Ox Ripping	Ox Plowing	No difference	I don't know
a. Which one would be more work?	☐	☐	☐	☐
b. Which one would give you more trouble with weeds?	☐	☐	☐	☐
c. Which one would produce more harvest?	☐	☐	☐	☐
d. Which one would have better soil?	☐	☐	☐	☐
e. Which one would do better on a dry year?	☐	☐	☐	☐
f. Which one would do better on a wet year?	☐	☐	☐	☐
g. Which one would have more erosion?	☐	☐	☐	☐

107. How would you compare a field with one half with basins and one half hoed?

	Basins	Hoeing	No difference	I don't know
a. Which one would be more work?	☐	☐	☐	☐
b. Which one would give you more trouble with weeds?	☐	☐	☐	☐
c. Which one would produce more harvest?	☐	☐	☐	☐
d. Which one would have better soil?	☐	☐	☐	☐
e. Which one would do better on a dry year?	☐	☐	☐	☐
f. Which one would do better on a wet year?	☐	☐	☐	☐
g. Which one would have more erosion?	☐	☐	☐	☐

For tractor ripping communities only - otherwise skip to 109

108. How would you compare a field with one half under tractor ripping and one half tractor plowed?

	Tractor Ripping	Tractor Plowing	No difference	I don't know
a. Which one would be more work?	☐	☐	☐	☐
b. Which one would give you more trouble with weeds?	☐	☐	☐	☐
c. Which one would produce more harvest?	☐	☐	☐	☐
d. Which one would have better soil?	☐	☐	☐	☐
e. Which one would do better on a dry year?	☐	☐	☐	☐
f. Which one would do better on a wet year?	☐	☐	☐	☐
g. Which one would have more erosion?	☐	☐	☐	☐

109. Thank you so much for your time. You have answered many questions. Do you have any questions for me or have anything else you would like to say? *(Take notes on questions and comments in the box below)*

Appendix B: Qualitative interview guide for distributors or buyers

1. How many years have you worked as a buyer/distributor?________

If they work for Dunavant:

2. Are you a Yield Coordinator Distributor (YCD)? Y/N
   a. If No, are you a Yield Group Leader (YGL)?
   b. If Yes, How many YGLs do you have among your farmers? ______
3. Are you a buyer for Dunavant? Y/N

If they work for Cargill:

4. Do you over see cotton schools? Y/N How many are active? ________
5. Do you oversee women's clubs? Y/N How many are active? ___________

For all respondents:

6. How many farmers do you oversee? ___________
   a. How many packets of seed did they receive last season?____________
7. What is the largest number of farmers you have ever overseen? ___________
   a. What is the largest number of seed packets you provided in a single season? ________

Spray service provision and herbicides

8. Have your farmers been trained as spray service providers? Y/N
   a. How many of your farmers are providing the service of spraying? _________
9. Were herbicides available to your farmers on credit last season? Y/N
   a. If yes, was there enough herbicide supplied to meet farmers' demands? Y/N
   b. How many farmers received herbicides on credit last season? ____________

Tillage service provision and ox-ripper availability

10. Have your farmers been trained as tillage service providers? Y/N
    a. How many of your farmers are providing tillage services? ________ (total)
       i. Plowing __________ Ripping _____________
11. Were ox-rippers available on credit to your farmers last season? Y/N
    a. How many farmers have ever received ox-rippers on credit? _________
    b. How many farmers have bought their own ox-rippers? __________
    c. Cost to rent a plow and oxen _______________
    d. Cost to rent a ripper and oxen______________

Farmer density

12. How often do you visit each farmer in a season? __________
13. How far do you have to travel to find the furthest farmer? _____________
14. How many villages or clusters are the farmers you oversee grouped into? _________

Community level context

15. What are the economic opportunities for people in these areas other than agriculture?
16. What is the travel cost a farmer would have to pay to obtain fertilizer?_____________
17. How much does an average male earn working 8 hours of ganyu in this community?_________
18. Do most farmers that you oversee live on farms or are they primarily in villages?
19. What are the main challenges your farmers face in getting higher cotton yields?

Conservation agriculture

20. How many years has conservation agriculture been promoted in these areas? ___________
21. What other organizations are promoting CA in these areas?
    a. For how long has each been operating?
22. What do you see as the primary motivation for your farmers to use CA?
23. What has made it possible for those farmers to use CA?
24. What are the main challenges your farmers face in using CA?
25. What do you think can be done to overcome those challenges?

Work as a Buyer/Distributor

26. Can you describe for me your work responsibilities?
27. What are the main challenges you face in completing your work as a buyer/distributor?

Appendix C: Qualitative interview guide for farmers

Name:_________________________ Village:__________________ Date:_____________

A. Introduction

Consent process - not a test, what they are actually doing

B. Getting to know the respondent

1. How many people live in your household? ____
2. How many of them are 15 years or older? ______
3. Did you go to school (Y/N)? What is the highest grade level that you completed in school? __
4. Did your wife/husband go to school (Y/N)? What is the highest grade level that your spouse completed in school? ______
5. In what village and district were you born? ______ (here, close by, far away)
6. How many years have you lived in this village? _______

C. Understanding their farming practices

7: Can you describe for me the different agricultural activities you carry out on your farm?

8. What is the total area that you farmed last season/this year? _____

    9. How much of that area was planted to maize? ___________
    10. How much of that area was planted to cotton? __________
    11. How much of that area was planted to groundnuts? ________
    12. How much land was planted to sunflowers? ________
    13. How much land was planted to beans or other legumes (cowpea, pigeon pea, soya)? _
    14. How much of that area was planted to other crops (cassava, tobacco, paprika, etc.)? _
    15a. How many wetland gardens do you have? _________
        15b.What is the total area of your dimba? ________
        15c. What crops do you grow there? _______
    16a. Did you intercrop your maize with legumes or other crops like sorghum or pumpkin? (Y/N)
        16b. How much area was intercropped? _______

Other land use questions

    17. How much area of land did you leave fallow during the previous season? ____
        17b. For how many years has it been fallow? ________
        18. How much of that fallow land was an improved fallow with leguminous shrubs? ____
    19. How much area (if any) did you rent in during the previous season? _____
    20. How much area (if any) did you rent out to others during the previous season? ____

Inputs

21. How much fertilizer (if any) did you use on your maize during the previous season? ______

    22. What types of fertilizer did you apply?
        ____D-compound
        ____Urea
        ____ Other ________________
        ____ Other ________________
    23. What price did you pay for that fertilizer? _____
    24. What distance did you travel to obtain that fertilizer? ________

24b. What was the travel cost?_______

25. Did you use any herbicide on your crops last year? Y/N

26. What type of herbicides did you use?

__ Round up (Glyphosate, systemic)
__ Pantera (Quizalofop - selective for grasses)
__ Paraquat (contact burning)
__Metalachlor (pre-emergent - seed dormancy)
__ Other (please specify _______________)

27. How much did you apply on each crop?_______________________________

Plots

28. How many plots of land did you farm? If it is all together, how is it divided? (See Table for recording)

29. On each plot/division - What size is it?
30. What crops did you plant this year? The previous year?
31. What inputs did you use? (kg and liters)
32. What land prep method?
33. Distance to home?
34. Ranking compared to other plots?

Crop Rotation and legumes

35. How do you decide which field you will plant each crop in?
36. Do you practice crop rotation? Y/N
37. What is your experience growing maize in a field that previously had legumes?
37b. How does that compare with maize after cotton? ________________________
38. What would make it easier to grow more legumes? ___________________________
39. Have you ever tried growing an improved fallow (tephrosia, gliricidia or sesbania)? Y/N
40. What results?
41. Have you ever planted Msangu trees (Faidherbia albida)?
42. What results?

Erosion

43. Do you have any concerns about erosion in any of your fields? Y/N
44. What do you do if you are concerned about erosion?

Mulching

45. What do you do with the maize stalks and the cotton stems in the field after you harvest?

Cotton production

46. How long have you been growing cotton? __________
47. With what company? ______________ Have you ever changed companies? Y/N
48. How are your yields this season? ___________ Last Season? _______________
How many packets of seed did you plant this season? __________ Last season? ____
How much seed was leftover this season? ________ Last season? ___________
49. How many times did you spray pesticides during this season? _______________
50. Do you spray pesticides on cotton yourself? Y/N
Or do you hire someone to do it? Y/N
51. Do you own a sprayer? Y/N
52. If Yes: Do you provide spraying services to others? Y/N

53. What fee do you charge? _____________
54. If No: Do you pay others to spray your fields? Y/N
54b. Or do you pay them to use their sprayer? Y/N
55. If Yes: How much do you pay? _____________
56. If No: How do you get your fields sprayed? ____

Agricultural innovation

57. How have your farming practices changed over the past few years?
58. What new varieties or crops have you tried?
59. What new soil conservation measure have you tried?
60. What new pest management strategies have you tried?
61. What new weed control methods have you tried?

Future Plans

62. How will you prepare your fields for the coming year? When will you start?

Land Tenure Security:

63. Do you think you will be farming the same plots next year? Y/N
64. What about two years from now? Y/N
65. Five years from now? Y/N
66. (If No: What makes you think that you may not be farming these plots in the future?)

Crop marketing

67. What crops do you sell?
68. Where do you sell them?
69. What price did you receive last year?

Animal production

70-73. How many cattle/goats/pigs/poultry do you own?

Cattle	Goats	Pigs	Poultry

74. Do you use your cattle forPlowing? Y/N
75. Ripping? Y/N
76. Pulling a cart? Y/N
77. How many oxen are currently able to work in these tasks? _______________
78. Do you ever rent out your cattle so that others can use them to plow? Y/N
79. How much do you charge? ___________________
80. Do you ever rent out your cattle so that others can use them for ripping? Y/N
81. How much do you charge? ____________________
82. How long have you been using them for land preparation? ______________

Agricultural wage Labor

83. Did you hire any laborers for your fields last year? Y/N
84. How did you pay them?
85. Did you work as an agricultural laborer for others last year? Y/N
86. How much does an average male earn working 8 hours of ganyu in this community?__________

Non-agricultural economic activities

87. In addition to crop and animal production how else do you earn money for school supplies, soap, salt, etc.
   __ processing food and beverages (including alcohol)
   __ petty trading
   __ wage labor not in agriculture
   __ building/masonry
   __ carpentry
   __ basket weaving / mat making
   __ bicycle repair/other repairs
   __ NGO work
   __ other (please specify ________________)
88. What activities do you do between the start of the harvest and when the rains start again?
   89. How much time do you spend on the different activities?
   90. Which ones are most important?

D. Knowledge about CA (for non-CA users)

1. Have you ever heard of farming without tilling the soil? Y/N
2. *If yes:* What have you heard about it?
   a. Who did you hear about it from?
   b. What is your opinion about these ideas?
      i. What do you think the benefits would be?
      ii. What would be the challenges?
      iii. How do you think it would affect your yields?
      iv. How do you think it would affect the work you can carry out?
   c. Do you know anyone who uses these land preparation methods?
      i. What have you observed from these people?
      ii. How are they similar or different from you?
      iii. How is their land similar or different from yours?
      iv. Who approves of their use of basins/ripping? Who disapproves?
      v. Would anyone disapprove if you started using basins/ripping?
   d. Do you think you know enough about it that you could try it if you wanted to?
      i. If not, who would you talk to in order to learn more?
   e. What would need to change for you to use basins or ripping?
      i. What would motivate you to try it out?

3. What do you think the effects of farming without tilling the soil would be? (check all that are mentioned)

Less erosion	More erosion
Wetter soil	Drier soil
Softer soil	Harder soil
Higher yields	Lower yields
More weeds	Less weeds
More work (digging basins/ripping)	Less work (not having to make ridges or plow)

E. Minimum tillage (for CA users)

1. How many agricultural seasons (if any) have you used basins/ripping? ____
   a. On how much area did you use basins/ripping each year since you started?

2. What land preparation practices did you use before using basins/ripping? (*skip if not using CA)*
    a. How much area of each? Hoeing _____ Plowing ________
3. Can you explain to me how you learned about planting in basins/ripping?
4. Who is the first person you knew who used CA?
    a. Name: ______________________ Relation: ________________________
5. Which person was most influential in helping you learn about basins/ripping?
    a. Name: ______________________ Relation: ________________________
6. Where did you first learn about basins/ripping?
   __Cotton company (specify which one ___________)
   __CFU (Conservation Farming Unit)
   __Some other NGO (please specify ______)
   __ Agricultural extension officer
   __ Radio
   __Written material
7. What have you heard about basins/ripping from outside organizations supporting your community's agriculture?
8. What motivated you to try this method of land preparation?
9. How did you decide on which plot to try using basins/ripping on?
10. What was your attitude about basins/ripping when you first tried it? Did you think it would work?
11. What made it difficult? What parts were easy?
12. Who approved of you trying basins/ripping? Who disapproved?
13. What prevents you from using basins/ripping on more area?
14. What is your general opinion about the benefits of the basins/ripping?
15. Please describe to me how to use basins/ripping for agriculture?
    a. How do you go from a ridged field to a field with basins/ripping?
    b. Do you need any special tools?
    c. How do you decide where to dig the basins (or place the rip lines)? Do you measure?
    d. Do you have to dig the basins every year? Do you measure every year?
    e. What do you put in the basins/rip lines?
    f. Do you do anything differently depending on the type of soil in the field? Please explain.
16. How do you weed without turning over the soil?
17. How does weeding compare with traditional ridge tilling?
18. Who in your household has been most affected by any changes in weeding?
19. How do you bank your maize?
20. Do the basins/rip lines affect the water in your field? How?
21. When it rains hard how is a plot with basins/ripping different from a plot with ridges?
22. When there is a dry spell how is a plot with basins/ripping different from a plot with ridges?
23. Can you share examples from the last few seasons about any noted differences between basins/ripping and other land preparation methods?

If they use ox-ripping (All the questions above and the following):

24. What maintenance do you need to carry out on your ripper?

25. How frequently do you sharpen it?
    a. Where do you get it sharpened? How much does that cost?
26. Where do you buy spare nuts and bolts? How much do they cost in a season?
27. Have you had to replace the beam or the tine since you started?
28. Do you rent your ripper to others? How much do they pay?
    a. Do you carry out the ripping or do they do it themselves?
    b. Do they rent your animals as well?
29. Have you ever rented a ripper from someone else?
    a. Did you rent their animals as well?
    b. How much did you have to pay?

If they use tractor ripping

30. Do you own or rent the tractor?
31. What is the cost of renting a tractor for ripping?

If they own the tractor:

32. How did you obtain the tractor? How long have you had it?
33. What other uses do you have for the tractor other than ripping?
34. How do you pay for the maintenance and cost of the tractor?
35. What do you do when it breaks down?

If they use multiple CA land preparation methods:

36. How do these reduced tillage methods compare?
    a. What are the benefits of each?
    b. What are the challenges of each?
    c. Are there fields, crops or seasons where one was notably better or worse than the others?
    d. Which one would you like to use more of? What would you need to do that?

F. Minimum tillage (disadopters)

I hear that you have experience using basins or ripping and I would like to learn from you about that.

1. Please describe to me how you used basins/ripping for agriculture?
2. How many seasons did you use basins/ripping on part of your farm?
3. What land preparation method were you using before you started using basins/ripping?
4. Can you explain to me how you learned about planting in basins/ripping?
5. What technical support have you had in learning how to use basins/ripping?
    a. Who did that information come from?
6. Who is the first person you knew who used CA?
7. Which person was most influential in helping you learn about basins/ripping?
8. What have you heard about basins/ripping from outside organizations supporting your community's agriculture?
9. What motivated you to try this method of land preparation?
10. How did you decide on which plot to try using basins/ripping on?
11. What was your attitude about basins/ripping when you first tried it? Did you think it would work?
12. What made it difficult? What parts were easy?
13. Who approved of you trying basins/ripping? Who disapproved?
14. What made you decide to stop using this method of land preparation?

15. What has changed since you stopped?
    a. Are yields different?
    b. Is your labor in agriculture different?
    c. The total cultivated area?
16. What, if anything, would be needed for you to try it again?
17. What advice would you give to someone who is thinking about starting to use basins/ripping?

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CHAPTER 4: UNDERSTANDING PARTIAL ADOPTION OF MINIMUM TILLAGE BY COTTON FARMERS IN EASTERN ZAMBIA

4.1. Introduction

Currently Sub-Saharan Africa is home to 76% of the world's ultra-poor (121 million people) who live on less than 50 cents a day (Barrett, 2010). Most of these people live in rural areas and agriculture is their primary livelihood strategy (Barrett, 2010). The inadequacy of conventional farming practices for long term food security can be seen both by the alarming levels of land degradation (World Bank, 2007) as well as the frequency of crop failures in an increasingly erratic climate (Boko et al., 2007; Lobell et al., 2008).

As smallholder farmers in Africa face the dual challenge of responding to climate change and mitigating land degradation there is increased attention to the potential for improved agricultural technologies to increase smallholders' productivity and improve their quality of lives (Pretty et al., 2011; World Bank, 2007). However, resource-poor farmers typically have diverse livelihood strategies and live in complex agro-ecological environments, making it especially challenging to find technologies that fit the needs and priorities of most farmers (Conway and Barbier, 1990; Chambers, 1997). For this reason farmers' participation in the innovation process is essential for sustainable intensification efforts to effectively deliver technologies that can be used by the diverse types of smallholders (Pretty et al., 2011).

Conservation agriculture is a set of technologies that holds tremendous potential for reversing land degradation and making smallholder farmers less vulnerable to climatic variability (Rockström et al., 2009; Kassam et al., 2009; Hobbs, 2007). The three principles of conservation agriculture – minimal soil disturbance, permanent soil cover, and either crop rotation or intercropping with nitrogen fixing legumes (FAO, 2001) – have been widely promoted across southern Africa for well over a decade. However, adoption levels remain low, with less than 6% of cultivated area under CA in most areas (Andersson and D'Souza, 2014). Agencies promoting CA claim that adherence to the three principles is non-negotiable for sustainable land management (for example CFU, 2007). That position has drawn criticism for being overly prescriptive and counter-productive to participatory problem-solving (Andersson and Giller, 2012). The risk of promoting a strict set of principles embodied in specific technologies is that by ignoring farmers' practical challenges in implementing them, it may achieve only limited adoption while missing opportunities to adapt the available technologies to better match farmers' resources and priorities.

This paper uses empirical observation of the conditions under which farmers used MT on at least some of their land to identify the constraints farmers face in using it on more of their land. The goal is to assist CA promoters and agricultural researchers in identifying possible ways to overcome those constraints by providing detailed feedback from the farmers on the performance of the technologies. The research focuses on smallholder cotton farmers in Zambia's Eastern Province, a population and location with significant levels of promotion, training and adoption. It complements Chapter 3, which analyzes household level determinants of MT use and disadoption. This chapter combines quantitative analysis of 445 plots farmed by 81 MT farmers, and qualitative analysis of in-depth interviews with 43 farmers who have used MT to understand why they chose to use MT on some plots but not others and to gain insight on what prevents them from using MT on more of their land.

4.2. Conservation agriculture in Zambia

4.2.1. Conservation agriculture and minimum tillage

There is experimental agronomic evidence from on-station research that the CA principles are complementary and additive in that the benefits are greatest when the three principles are implemented together (Thierfelder et al., 2013a). However, in on-farm situations most smallholder farmers in southern Africa find it extremely difficult to retain crop residues due to free-range cattle and uncontrolled burning (Umar et al., 2011; Thierfelder et al., 2013b). In addition, the area under legumes tends to be much lower than the recommended 30% of cropland, and uptake of agroforestry (as an alternative means of integrating legumes into the farming system) remains a challenge (Umar et al., 2011; Umar, 2012). For these reasons in Zambia minimal soil disturbance is the principle of CA that is often promoted first and emphasized most.

In Zambia, three specific MT technologies are being promoted to allow farmers to prepare the land while minimizing soil disturbance - hand hoe basins, ox-drawn ripping and tractor ripping (Grabowski et al., 2014; Nyanga, 2012). Basins require only a hoe and promoters recommend digging a precise grid of holes 20 centimeters (cm) deep, 30 cm long, and the width of a hoe blade. Ox-ripping requires specialized equipment and promoters recommend using the locally engineered Magoye ripper to open a trench 5 cm wide and 15 cm deep where the seeds can be sown (Kabwe, Donovan, and Samazaka, 2007). Tractor ripping also requires specialized equipment, which in Zambia is usually a two-tined ripper. Due to the limited availability, tractor ripping is rarely used and so is not part of this analysis. A fourth technology for minimizing soil disturbance is that of simply cutting into the previous year’s ridge with a hoe and planting. This farmer-led innovation, which I call *direct seeding*, was observed but is not the focus of this analysis. Direct seeding with jab-planters, sticks or specialized hoes has been promoted for CA in Southern Africa, especially for maize (Grabowski and Kerr, 2014), but it is not common among cotton farmers in Zambia and was not observed in this study.

4.2.2. Conservation agriculture and cotton farmers

CA promotion in Zambia began in the mid-1990s with the creation of the Conservation Farming Unit (CFU) as branch of the Zambian National Farmers' Union. From the start private sector cotton companies have collaborated with CFU to actively promote CA with smallholders. NWK Agri-services (previously known as Dunavant) and Cargill are the largest cotton companies and strongest private sector promoters of MT (Haggblade et al., 2010). NWK has been promoting basins since the 1990s and both companies were involved in promoting Magoye rippers in Eastern Province as early as 2002 (Kabwe, Donovan, and Samazaka, 2007). Efforts have increased since 2011 as herbicides and equipment have become more available to farmers on credit (Grabowski et al., 2014).

Smallholder farmers access the inputs to grow cotton on credit through contracts, with the costs deducted from payment at harvest time (Haggblade, Kabwe, and Plerhoples, 2011). NWK uses a system of distributors, who are lead farmers that link 50 to 100 farmers with the company by providing training, distributing seed and chemicals, monitoring fields and buying the harvest. They earn a commission on the production from their farmers with bonuses for high volume, yields, and loan repayment rates. Cargill on the other hand employs buyers who may or may not be farmers to carry out similar functions but overseeing 200 to 500 farmers.

4.2.3. Cotton farmers in eastern province

Eastern Province has a unimodal rainfall pattern with annual precipitation varying between 600 and 1200 millimeters between November and May. Though overall population density is relatively low, localized land scarcity exists, especially around some large villages.

Eastern Province can be divided into two major agro-ecological zones. The lower elevation *valley* zone has lower rainfall, higher temperatures and lower cattle populations because of tsetse fly infestation. The upland *plateau* regions have greater population density and higher rainfall. This study focuses only on the plateau regions.

Of the 257,000 small- and medium-scale farming households in Eastern Province in 2012, 97% grow maize and 64% grow cotton (Tembo and Sitko, 2013). Cotton is a demanding crop in terms of labor and management with regular pest monitoring and pesticide sprays. On average cotton farming households have larger cultivated areas, own less cattle, and earn a larger portion of their income through agriculture than households that do not grow cotton (Haggblade, Kabwe, and Plerhoples, 2011).

4.2.4. Adoption of MT in Eastern Province

Despite the general lack of residues and rotations, adoption of MT has been expanding gradually in Eastern Province over the last decade (Arslan et al., 2014; Grabowski et al., 2014; Ngoma et al., 2014). The persistent use of MT suggests that the benefits outweigh the costs for certain farmers under certain conditions. MT adoption correlates with promotion and higher rainfall variability, suggesting that farmers use MT to reduce their vulnerability to an unpredictable climate (Arslan et al., 2014; Ngoma, Mulenga, and Jayne, 2014). For communities where farmers grow cotton, adoption correlates with greater herbicide availability, longer promotion and better demonstrations by lead farmers (Grabowski et al., 2014).

Smallholder farmers in southern Africa typically adopt MT on only a portion of their land and use conventional tillage on the rest of their plots. Data from Eastern Province shows that adopters used MT on 54% of their land in 2008 (Arslan et al., 2014). One of the key problems with MT is that weed control is difficult without soil inversion (Giller et al., 2009; Wall, 2007;

Gatere et al., 2013), especially in the absence of a thick layer of mulch. Another commonly identified constraint to using MT on larger areas is the increased labor requirements for basins (Grabowski and Kerr, 2014).

The analysis of multi-purpose household survey data provides some statistical evidence for the reasons for partial adoption in Zambia. Households tend to use MT on more of their land where soils are depleted of nutrients, (Arslan et al., 2014) if they are male headed, and if they are in areas where CFU operated (Ngoma et al., 2014). In one analysis, farmers with more land used MT on a smaller proportion of their land (Arslan et al., 2014) but another study found that those who farm more land use MT on more area in absolute terms (Ngoma et al., 2014). Together these suggest that environmental and economic conditions combine to affect the relative benefit of using MT on more land, though training may serve to reduce some of the constraints.

4.3. Methods and data

This research combines qualitative and quantitative methods to understand partial adoption of MT. The statistical relationships among economic and agronomic variables are supplemented by qualitative analysis of farmers' explanations about why they chose to use MT on some plots but not others. I used results of a nationwide census of lead cotton farmers (as described in Grabowski et al., 2014) to stratify communities in Eastern Province by MT adoption levels. I then randomly selected 15 communities where CA adoption was expected to be relatively high. Next I stratified farmers within each community by their use of various tillage technologies and randomly selected some from each group. The complete data includes 1178 plots from 245 farmers, of which 81 farmers use some form of MT. The complete survey methodology is detailed in Chapter 3.

4.3.1 Data collection

4.3.1.1. Qualitative data

The first author conducted in-depth interviews in the local language, Chinyanja, with 34 farmers, 18 distributors from NWK and 11 buyers from Cargill. Of the 69 individuals interviewed, 43 had experience using MT on their own fields for at least one season. For each of the communities that were randomly selected I interviewed the associated distributor, buyer or chairperson that links the farmers to the cotton company. I carried out most in-depth interviews in five communities purposively chosen to represent the range of experiences with MT technologies (high tractor ripping, high ox-ripping (one each for Cargill and NWK), high basins, and low adoption). Similarly, in each community I selected farmers for in-depth interviews from each category of land preparation (plow, ox-ripper, hoe, basin user, tractor ripper or disadopter) to understand the perspectives of all groups.

The interview process was carefully crafted to obtain farmers' honest opinions about the performance of MT. Because of the cultural tendency to please outsiders and the dominant narrative from the cotton companies that CA is the best way to farm, there was a risk that farmers would withhold criticism of CA, even when directly asked. To avoid this bias the lead researcher operated independently from cotton company staff, emphasized the confidentiality of responses and presented the research goal in general terms of learning from farmers about how to improve production. Interviews with farmers initially focused on their farming practices for the previous season before asking about their experiences and perspectives on MT with the goal of building rapport and starting with questions about facts before asking for opinions.

In the course of the interview I asked farmers who used MT how they learned about it, what they had done previously, their motivation for using MT, their assessment of how MT performs compared to conventional tillage and the factors that prevented them from using MT on more land. I asked distributors, buyers and community leaders about general community-level issues related to inputs and production as well as the constraints to more widespread MT use in the area. I recorded and transcribed all interviews. The in-depth interview guides can be found in Appendices B and C of Chapter 3.

4.3.1.2. Survey data

Surveys were carried out with 245 cotton farmers across Eastern Province and detailed information was provided for the 1178 plots of land they cultivate (Table 11). For this study plots were defined as portions of fields with one land preparation method and planted to one primary crop. I excluded plots with tubers as the primary crop (cassava and sweet potato) from the analysis because all of them were prepared with conventional hoeing.

Table 11: Tabulation of land preparation methods for all plots in the dataset

Land preparation method	Conventional farmers' plots	MT farmers' plots	All farmers' plots
Ox-plowing	483	230	713
Ox-ripping	0	80	80
Hoeing	210	85	295
Basins	0	54	54
Direct seeding	16	1	17
Total plots	693	449	1142
Farmers	160	85	245

Source: Survey of NWK and Cargill Farmers, 2013

I asked each farmer to provide details about the characteristics of all plots cultivated and their management practices on each plot. I also asked about household characteristics such as educational attainment, total landholding size, types of non-agricultural income sources, livestock owned and ownership of a variety of agricultural and household items. I also asked farmers' opinions about how they compare hoeing to basins and ripping to plowing. Distributors and buyers at each location provided quantitative information about how long CA has been promoted and about their own farming practices.

For each plot farmers provided details about soil type (sand, clay or other) and soil color (black, brown, red, or white). In general, white sand and red clay soils are lower in fertility than brown or black soils. Sandy soils tend to be easier to work and can be planted quickly with moderate rainfall but do not hold nutrients or moisture as well. Clay soils hold nutrients and moisture but are harder to work and require more rainfall before they are ready to be planted. A wide range of textures lay between sandy and clay soil (i.e. clay-loam, sandy-loam, etc.) but I categorize these intermediate textures together as "loam" in this analysis. The complete survey instrument can be found in Appendix A of Chapter 3.

4.3.2. Data analysis

4.3.2.1. Qualitative data analysis

I systematically examined the qualitative data (interview transcripts, researcher notes and comments written on surveys) using thematic analysis. In thematic analysis the researcher categorizes the textual data using codes to facilitate retrieval of similar information across the data and then develops summary statements to concisely represent the diversity of responses (Miles and Huberman, 1994; Rubin and Rubin, 2005). I use quotes from respondents where possible to succinctly represent the perspectives in the data. In addition, I use numeric tabulation of responses to clarify the level of agreement or disagreement in the data.

4.3.2.2. Statistical analysis

To focus on understanding partial adoption, the statistical analysis includes only data from the 81 respondents who used some MT in 2012/13. To be able to generalize to the wider population (cotton farmers using MT in medium to high adopting communities) sampling weights were used for both regressions as outlined in Chapter 3. I included dummy variables for community clusters to control for unobserved heterogeneity across communities (see Chapter 3 for details and Table 12 for characteristics of clusters).

Table 12: **Characteristics of clusters used in regression analyses**

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Crop area with sandy soil	4.7%	16.9%	10.5%	18.7%
Crop area with red loam soil	3.7%	6.3%	7.9%	5.9%
Crop area with clay soil	45.2%	17.2%	57.0%	48.7%
Crop area on flat plots	37.2%	66.0%	41.2%	63.8%
Crop area with plan to rest soil	1.6%	9.4%	0.0%	2.4%
Crop area under a cash crop	77.7%	81.0%	81.9%	81.8%
Crop area with secure tenure	100.0%	95.7%	99.5%	98.7%
Percent of crop area planted to hybrid maize	42.0%	19.7%	29.4%	28.9%
Percent of crop area planted to local maize	11.5%	19.1%	15.2%	18.5%
Percent of crop area planted to cotton	30.6%	30.5%	36.6%	26.6%
Population Density (people/square kilometer)	48.96	140.53	83.3	50.1
Elevation (meters)	1006	1106	833	1012
Percent of farmers using animal traction	76.6%	67.2%	41.8%	65.6%
Average fertilizer application rate to maize (kg/ha)	99.6	308	273.6	187.4
Percent of plots where residues were heavily grazed	34.9%	29.6%	32.0%	31.8%

Source: Survey of NWK and Cargill farmers, 2013

4.3.2.2.1. Modeling choice of land preparation method for each plot

Most farmers use more than one land preparation method in any given season. The 81 farmers using MT had a total of 449 plots prepared with one of the four primary land preparation methods (plowing, ripping, hoeing or basins). I used dummy variables for soil types with loam soils that are not red colored as the base case. A multinomial logistic model estimates how a marginal change in plot characteristics affects the probability of using any given land preparation method to the others.

The multinomial logistic model can be presented formally as:

$$\ln \Omega_{m|b}(x) = \ln \frac{\Pr(y = m \mid x)}{\Pr(y = b \mid x)} = x\beta_{m|b} \quad \text{(equation 2)}$$

for land preparation categories m = 1 to J where b is the base category (Long and Freese, 2001).

4.3.2.2.2. Modeling intensity of adoption of minimum tillage

Modeling farmers' decisions about how much land they decide to have under MT can be facilitated by defining intensity of adoption as the proportion of their land under MT. I used a quasi-maximum likelihood fractional logit estimator (Papke and Wooldridge, 1996) to model the partial effects of explanatory variables on the proportion of a farmers' land under MT. This is the best choice for proportional responses that include the extreme values of zero and one. It is more appropriate than a Tobit model, which assumes that there is a continuous latent variable for which negative values are being censored (Baum, 2008). For simplicity this model combines basin and ripping area. The average partial effects are presented after multiplying by 100 so that they can be interpreted as the effect on the percent of land under MT.

4.4. Results

In the results I first provide a brief summary of how farmers are using MT. Next I present analysis of how crop and plot characteristics determine the conditions where farmers prefer MT over conventional tillage. In the third section I analyze the household-level constraints to more widespread use of MT. For both the plot-level and household-level analyses, I first present the qualitative analysis of farmers' stated reasons for their decisions and then the regression analysis results.

4.4.1. How farmers are using basins and ox-ripping

Among farmers who use some form of MT, 30% of their area was ox-ripped, 8% was in basins and the other 62% was prepared with conventional tillage (Table 13). Farmers use MT on all types of crops except tubers, but the overwhelming majority (84%) of MT area is planted to maize and cotton. Partial adoption of MT is the norm (Figure 8). Only one farmer used basins on all plots, totaling just one hectare. Another farmer used ox-ripping on 97% of the farm (9.5 ha), hoeing only a 0.25 hectare plot of sweet potatoes.

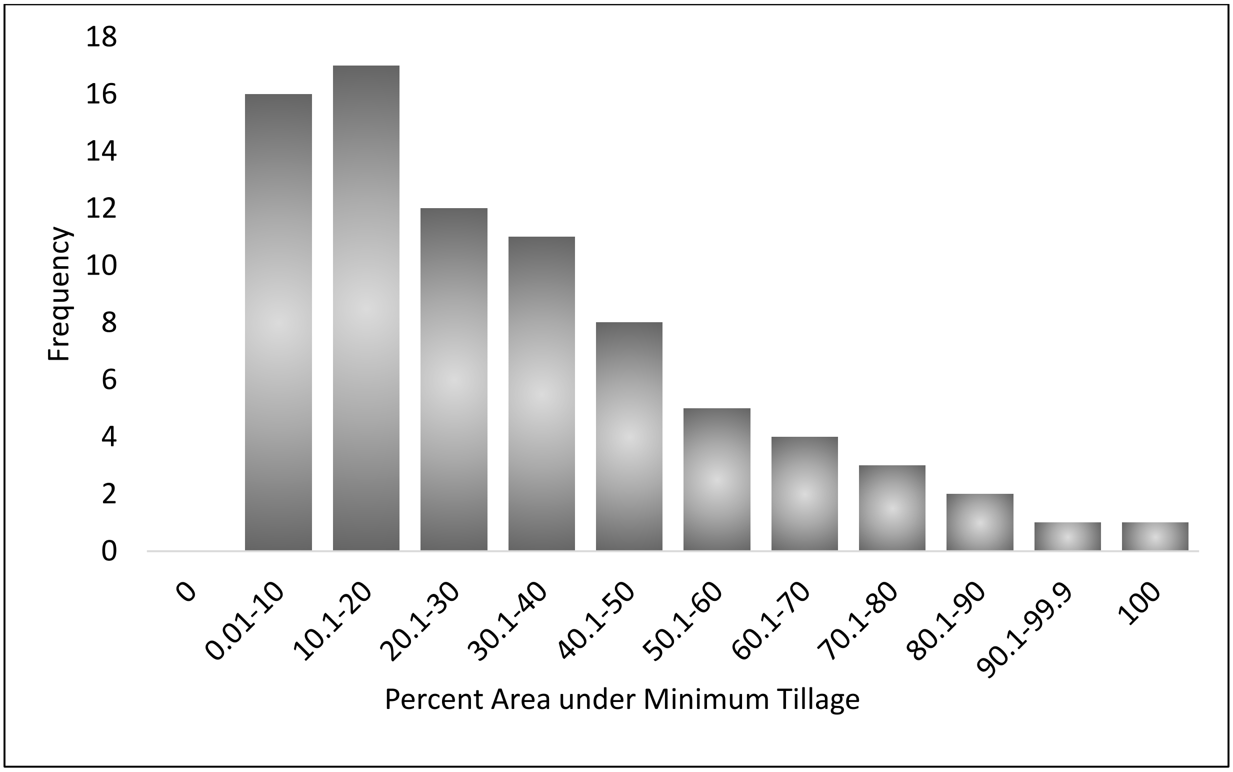
Table 13: Percent of overall area under minimum tillage by crop for farmers who use some MT

	All crops	Cotton	Hybrid Maize	Local Maize	Ground-nuts	Other crops
Percent crop area[a] with ox-ripping	30.1%	35.3%	31.0%	31.2%	14.2%	24.0%
Percent crop area with basins	7.8%	4.5%	6.1%	21.6%	0.01%	4.8%
Percent crop area conventional	62.1%	60.2%	62.9%	47.2%	85.8%	71.2%
Total	100%	100%	100%	100%	100%	100%

Source: Survey of NWK and Cargill farmers, 2013

[a] Percent crop areas are calculated using data from all farmers using some MT

Figure 8: Percent of area under minimum tillage (MT) by cotton farmers who use some MT



Source: Survey of NWK and Cargill farmers, 2013

Farmers' management of their cotton and maize differs according to the land preparation method that they used. Basin plots are smaller than hoed plots on average (Table 14), which suggests a labor constraint (see 4.4.3 below). Plots prepared with ox-ripping and ox-plowing tend to be larger since the human labor constraint is overcome with animal traction. Fertilizer use is lower on hoed plots than plowed plots, which is likely indicative of cash constraints that limit both the hiring of oxen and purchasing of fertilizer. Basin plots tend to receive more manure and less herbicides than ox-ripped plots, which again is likely related to the limited cash resources available to farmers using basins. Ox-ripped plots are twice as likely to have herbicides applied than ox-plowed plots, which is understandable given the lack of physical weed control from tillage.

Table 14: Differences in plot size, preparation date and inputs by land preparation method for cotton and maize plots of farmers who use minimum tillage on some part of their land

	Basin plots	Hoed plots	Ox-ripped plots	Plowed plots
Number of plots	47	37	63	121
Mean plot size (ha)	0.46 ^{A}	0.66 ^{B}	1.43 ^{C}	1.03 ^{C}
Percent of plots fertilized	42.3% ^{AB}	33.4% ^{A}	49.8% ^{AB}	49.3% ^{B}
Percent of plots with manure added	30.6% ^{A}	16.7% ^{AB}	3.8% ^{C}	7.0% ^{BC}
Percent of plots with herbicides	0.3% ^{A}	3.9% ^{A}	47.6% ^{B}	17.2% ^{C}
Percent of plots prepared before December	99.9% ^{A}	59.3% ^{BC}	86.8% ^{AB}	40.9% ^{C}

Source: Survey of NWK and Cargill farmers, 2013

Notes: Values are calculated using sampling weights in order to estimate the true population values.Values in a row that do not share a capital letter superscript are significantly different ($p < 0.1$) from each other using a Wald Chi-squared test and linearized standard errors that incorporate the survey design

4.4.2. Conditions where farmers prefer using MT

Understanding farmers' perceptions of the conditions where MT is preferred over conventional tillage provides insight into the constraints that must be overcome. Whether farmers' perceptions match with those of agronomists or not, their perceived concerns with MT will need to be addressed before more widespread adoption is likely. I first present the results of the qualitative analysis to understand common concerns with MT in farmers' own words. Then in section 4.4.2.3 I quantitatively analyze to what degree these stated concerns affect how farmers use MT on their fields.

4.4.2.1. Crop-specific MT benefits

Groundnuts are the most commonly grown legume in Eastern Province but MT farmers planted them primarily on conventionally tilled plots. Several farmers explained in the interviews that they believed groundnuts would not produce well without adequate tillage. This concern stems from how groundnuts need to penetrate the soil with the fertilized ovary when pegging. In contrast, several farmers said they had good success with groundnuts on MT plots. One of the key challenges with using MT on groundnuts, and other less prioritized crops, is that they tend to be planted later, once the maize and cotton has been planted. Farmers explained that if they do not plant a MT plot soon after the first rains they will have to till the soil or the weeds will take over. Unless MT becomes more widely used with groundnuts and other legumes, farmers will not be able to practice both crop rotation and minimal soil disturbance on most of their land.

One of the primary reasons farmers provided for adopting MT was to increase their yields through early planting. This benefit is especially important for cotton and local maize varieties, which take the full length of the rainy season to mature. For this reason most farmers use MT with cotton and maize and carry out the land preparation before December so that they can plant with the first rains and avoid yield losses associated with late planting.

4.4.2.2. Plot-specific benefits and challenges of MT identified by farmers

By asking farmers how they decided on which plot to use MT, a number of location-specific issues came to light. Farmers considered the slope of the field, the soil type and the fertility of the soil in their decision.

<u>4.4.2.2.1. Farmers' concerns that ripping leads to erosion</u>

Several farmers who use ripping expressed concern about erosion on plots that are not flat, even though they rip across the slope. One farmer expressed this concern as a request for technical advice: "When the rains come I am getting gullies so now I need knowledge for using my ripping; how should I do it?" (Key informant 28). Another farmer who used tractor ripping even completely disadopted MT because his seed eroded out of the rip lines. Similarly, several farmers found plowing preferable on sloped fields, saying for example, "If I rip there [on the slope], the water just goes but if I make ridges the water starts to stop" (Key informant 24). The lack of residue retention on most MT plots increases the potential for erosion. Residues on the surface reduce the impact of rain on the soil and can increase infiltration of water by preventing crusting of the soil.

However, this concern about erosion was not shared by all respondents. Most farmers surveyed think erosion is greater with conventional tillage than with MT. Several farmers who use ox-ripping explained how they made contour ridges in their ripped fields to prevent erosion. “Some areas where it is really sloping, we still do ripping, but we also come quickly and make some small ridges with oxen, just on top, to break the water from running” (Key informant 25). This adaptation obviously creates an additional task for the farmer and disturbs the soil, thus reducing some benefits from MT.

4.4.2.2.2. Soil type affects the costs and benefits of MT

Most farmers said that ripping and basins could be used on any soil. However, two ripper farmers with sandy soil said that they could not use ripping because the furrow made by the ripper would not be stable. If the rip line collapses before planting, the work of ripping was in vain. One of these farmers, who also had a red loam and a black loam soil, explained that ripping was more difficult in the red soil because it became so hard in the dry season.

4.4.2.2.3. Soil fertility affects the magnitude of the benefits

Of the eight farmers who specified why they chose to use MT on a particular plot, seven of them mentioned declining soil fertility on the plot as a reason for using MT there. For example, one farmer said, “[I decided to ripn that field] to protect the soil. I saw the soil was not great. I thought I should just do ripping. The cotton was not doing well” (Farmer 27). Similarly another farmer reported successful remediation of a degraded plot as follows:

"I chose that one [plot] because it was going down but I learned about ripping and that it could do well, so I thought let me do that plot. So, even though that plot was without fertility, the crop did well." (Key informant 4)

One of the mechanisms by which MT can significantly improve crop performance over the short term is by breaking through a compacted layer of soil. One respondent described his experience with basins as follows, "If you dig it [basins], the roots are happy, because it is porous, it is nice. So I thought I should dig there deep" (Key informant 14).

4.4.2.3. Plot characteristics associated with MT

The statistical relationships among plot-level characteristics and land preparation method largely support the reasons farmers provided (Tables 15 and 16). The plot characteristics affect the decision to use MT independent of what crop is planted on the plot, as these are controlled for. A simple way to visualize these results is a table of the predicted probabilities that each land preparation method will be used on a plot given the plot's characteristics and the crop planted on it (Table 17).

Flat plots are not statistically more likely to have MT than sloping plots, so the concern some farmers have about erosion does not seem to widely impact behavior. The strong contrast between predicted rates of basin use and ox-ripping use by soil type (Table 17) shows how they are being used very differently. Ox-ripping is less likely on sandy soils and red loam soils, though not at a statistically significant different rate from ox-plowing (Table 16). Thus there is some evidence that ox-ripping is used preferentially on plots with soil types that are neither too soft nor too hard. Basins are used more on sandy soils, which are easier to dig in the dry season than clay soils, which is logical given the effort required for manual dry season land preparation. However, it is also likely that sandy soils are lower in fertility and that basins are being used with the intention of improving their productivity through the precise addition of manure. This interpretation support the qualitative results and is confirmed by the coefficient on the dummy variable for degraded plots, which is negative and significant for basins, showing that farmers do not consider a plot to be degraded once basins have been used there.

Table 15: Description of variables used in the plot-level regression of determinants of land preparation method for MT users

	Mean	Standard Deviation	Minimum	Maximum
Soil Type				
Sand (Y/N)	0.176	0.381	0.00	1.00
Clay (Y/N)	0.374	0.484	0.00	1.00
Red Loam (Y/N)	0.065	0.246	0.00	1.00
Plot Characteristics				
Flat (Y/N)	0.608	0.489	0.00	1.00
Soil Degraded (Y/N)	0.031	0.174	0.00	1.00
Secure Tenure (Y/N)	0.980	0.140	0.00	1.00
Crop Characteristics				
Crop is sold (Y/N)	0.706	0.456	0.00	1.00
Cotton Plot (Y/N)	0.247	0.432	0.00	1.00
Hybrid Maize Plot (Y/N)	0.203	0.402	0.00	1.00
Local Maize Plot (Y/N)	0.151	0.359	0.00	1.00
Community Level Variables				
Cluster 1	0.174	0.379	0.00	1.00
Cluster 2	0.241	0.428	0.00	1.00
Cluster 4	0.285	0.452	0.00	1.00

Source: Survey of NWK and Cargill farmers, 2013

Table 16: Factors affecting plot-level use of MT, multinomial logistic regression results with robust standard errors

Explanatory Variables	Plowing vs. Hoeing			Basins vs. Hoeing			Ripping vs. Plowing		
Soil Type									
Sand (Y/N)	-0.408		(0.789)	1.04	*	(0.557)	-0.297		(0.492)
Clay (Y/N)	-1.652	*	(0.958)	1.204		(0.827)	-0.762		(0.749)
Red Loam (Y/N)	-0.432		(0.678)	-0.428		(0.485)	0.392		(0.627)
Plot Characteristics									
Flat (Y/N)	0.662		(0.440)	0.0816		(0.449)	-0.306		(0.427)
Soil Degraded (Y/N)	1.328		(1.279)	-18.05	***	(1.035)	-0.579		(0.693)
Secure Tenure (Y/N)	-2.412		(1.629)	-0.886		(1.563)	-2.356	*	(1.334)
Crop Characteristics									
Crop is sold (Y/N)	1.151	**	(0.448)	0.451		(0.726)	0.464		(0.574)
Cotton Plot (Y/N)	0.0343		(0.452)	0.533		(0.745)	0.66		(0.723)
Hybrid Maize Plot (Y/N)	1.177	**	(0.575)	2.007	***	(0.619)	0.425		(0.605)
Local Maize Plot (Y/N)	0.888		(0.542)	3.111	***	(1.015)	1.247	**	(0.487)
Community Level									
Cluster 1	-1.327		(0.999)	-1.234	**	(0.495)	0.802		(0.547)
Cluster 2	-1.654	*	(0.957)	-0.0733		(0.504)	0.914		(0.565)
Cluster 4	-0.169		(0.826)	-0.548		(0.585)	0.909		(0.893)
Constant	2.394		(1.922)	-1.215		(1.575)	-0.105		(1.543)
Observations 449		Wald Chi^2 (39) =	5,585.65				Pseudo R^2 =	0.1620	
		Prob > chi^2 =	0.0000				Log pseudolikelihood =	-27,800.9	

Source: Survey of NWK and Cargill farmers, 2013

Table 17: Predicted probabilities of land preparation method from the results of the multinomial logistic regression.

	Probability of:	Sand				Clay			
		Plow	Hoe	Rip	Basins	Plow	Hoe	Rip	Basins
Flat	Cotton	49%	21%	12%	17%	49%	23%	25%	3%
Flat	Hybrid Maize	54%	9%	11%	26%	62%	10%	22%	6%
Flat	Local Maize	29%	8%	9%	54%	38%	12%	29%	21%
Flat	Other	46%	37%	5%	12%	51%	35%	11%	3%
Sloped	Cotton	36%	29%	12%	23%	37%	33%	26%	4%
Sloped	Hybrid Maize	40%	14%	11%	35%	51%	16%	24%	9%
Sloped	Local Maize	19%	10%	8%	63%	28%	17%	28%	28%
Sloped	Other	32%	49%	5%	15%	37%	49%	11%	4%

	Probability of:	Red Loam				Other Loam			
		Plow	Hoe	Rip	Basins	Plow	Hoe	Rip	Basins
Flat	Cotton	27%	41%	5%	27%	55%	20%	20%	5%
Flat	Hybrid Maize	30%	13%	3%	54%	63%	12%	15%	10%
Flat	Local Maize	7%	12%	2%	79%	43%	9%	23%	25%
Flat	Other	20%	58%	1%	21%	53%	34%	9%	4%
Sloped	Cotton	17%	49%	5%	30%	43%	29%	21%	7%
Sloped	Hybrid Maize	19%	16%	2%	62%	51%	19%	16%	14%
Sloped	Local Maize	4%	14%	1%	81%	31%	13%	23%	33%
Sloped	Other	11%	65%	1%	22%	39%	48%	9%	5%

Key to colors

>50	(50-35]	(35-20]	(20-5]	<5

Source: Survey of NWK and Cargill farmers, 2013
Notes: Probabilities calculated assuming secure tenure and plot not degraded and holding cash crop and community variables at the mean

4.4.3. Constraints to increased MT use

In addition to these crop- and plot-specific factors that affect the performance of MT, there are household-level factors that affect farmers' willingness and ability to use MT on more area. From the in-depth interviews, farmers' explanations of their partial use of MT fall into three categories of constraints: informational constraints, investment constraints, and labor constraints. In this section I start by summarizing the qualitative results for each of these constraints. Next I quantitatively analyze the degree to which these constraints explain partial adoption.

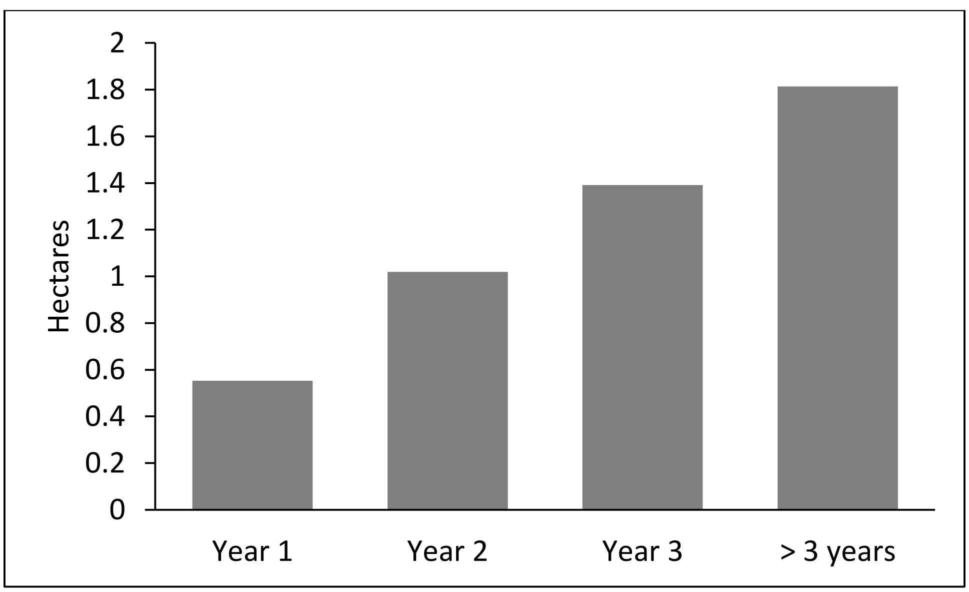
4.4.3.1. Information constraints: Incremental testing of MT as a reason for partial adoption

Farmers who are new to MT typically test the technology on a small portion of their cotton or maize. One farmer explained,

> *"The ripper training I received just last year, so I was just trying it out to really learn it. So I saw that ripping is good and this year I will rip on a large area, pretty much all crops I will rip. It does very well."* (Key informant 4)

Experienced MT farmers described how they went through a similar process of testing before using MT on most of their area. One farmer and CFU trainer who was in his eighth year using ox-ripping explained that he incrementally increased his ripped area from 0.25 ha in the first year to 2.65 ha in 2012/13. Surveyed farmers' average area under MT doubles from the first to the second year and increases by another 36% in the third year, after which the mean area plateaus at just under 2 hectares (Figure 9).

Figure 9: Average area under minimum tillage



Source: Survey of NWK and Cargill farmers, 2013
Note: Mean of 71 farmers for years 1 to 3; Mean of 22 farmers for >3 years

The stories shared by veteran MT users about their early challenges with MT show the wisdom of this incremental approach. Several farmers mentioned their frustrations learning to effectively apply herbicides – either killing some of their crop or not killing the weeds, resulting in heavy competition before they managed to weed manually. Others described how, when they first started using MT, they watched their waterlogged crop suffer before seeking advice. They then learned the importance of quickly adding soil to the base of the plant so that yields are not affected. Some farmers decided to use both MT and conventional tillage to ensure that at least one plot does well regardless of the rainfall pattern.

4.4.3.2. Investment constraints -challenges obtaining rippers and oxen

For those farmers who rent ripping services, their MT area is limited by the time they can access the oxen and equipment. Several farmers who borrowed rippers and rented oxen explained that the challenge of coordinating these services limited the areas they could manage. One older man and ripper owner explained that he and his sons were unable to rip all of their maize because they shared the ripper among 6 households. Though the dry season is a long period (May through October), farmers typically only rip part of the day to avoid tiring their oxen. This also contributes to a reluctance to lend or rent out the equipment.

4.4.3.3. Labor constraint – the increased effort needed for MT as a reason for partial adoption

<u>4.4.3.3.1. Dry season labor issues</u>

Dry season land preparation with MT is labor intensive, causing many farmers to be unable to implement it on all of their area. Many farmers recognize that the effort needed for preparing the land with MT is lower soon after harvest, before the soil has had a chance to dry out. However, they explain that this is a busy time for marketing and processing their harvest. As one distributor said, "basins require digging when it is soft underneath and that is the same time when I am going all around buying cotton. So now I just did one acre of maize with basins" (Key informant 16). Another basin farmer who also does wetland gardening in the dry season said that his area was limited because of other activities early in the dry season.

> *"There are a lot of things we normally do. So the time we are busy preparing fields, we could have started that a while ago but we haven't yet picked* cotton, *whereby, it takes more time do that. So we are busy with other things. But MT*[3] *is better."* (Key informant 14)

Due to these issues many cannot focus on dry season land preparation until October when the soil is drier and harder.

While the labor-intensive nature of digging basins is well documented, the increased effort needed for oxen relative to plowing is less well known. Several farmers who rip explained that they manage their ripping in small portions each day so as not to wear out their oxen:

> *"Ripping you can't do it twelve hours, no they [the oxen] would get too tired. We don't do it in the hot times. We do it first in the morning and then we do 10 lines, tomorrow 15 lines; that is all. Then we give them [the oxen] some time [to rest]."* (Farmer 19)

> *"One day we can do 1 lima, or a half acre [0.2 to 0.25 ha], so that the cattle have enough time to get food; forage is difficult at this time. It is also the time when we are harvesting when we rip, so we do it little by little. Harvesting some, ripping some."* (Farmer 10)

> *"Dry preparation is very difficult, the soil is very hard, we do it bit by bit. It may take a month or so."* (Key informant 20)

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[3] The Chinyanja word "gamphani" is translated here as minimum tillage (MT) as it can refer to both basins and ox-ripping.

This concern for oxen health limits the area a farmer may rip on his own land. A careful oxen owner will not risk hurting the oxen by ripping a large area. One farmer explains this challenge as follows:

> *"When we do ripping we have to do it like it is now, when it is dry. … now to rip 10 acres, the oxen tire quickly. Because it is dry below. … When I had done 5 acres the health of my oxen was low from all of that work. So I was forced to stop so that I store up enough power to be able to plow well the other 10 acres. So this is only half a bread better than none, so that is why I plowed."* (Key informant 18)

The concern for oxen health also limits the availability of ripping rental markets, which prevents those who cannot afford the equipment from even trying ox-ripping (Chapter 3).

Once the rains come, ripping is no longer recommended and most farmers do not attempt it. Likewise, digging basins after the start of the rains is not recommended, though it is occasionally practiced. There is some risk that digging basins in wet soils with high clay may actually compact the soil, thereby increasing waterlogging and reducing root growth.

<u>4.4.3.3.2. Weeding labor issues</u>

One of the primary functions of tillage is weed control and weed pressure is greater on MT plots (Wall, 2007; Giller et al., 2009). Farmers may therefore limit their areas under MT so as to make sure they will not have to abandon plots that become overrun with weeds. This quote from a ripper farmer summarizes a perspective shared by many MT farmers – that herbicides are a requirement:

> *"The challenge for using a ripper is that weeds, weeds do attack very fast, since you have just ripped in that furrow you will find the weeds attack you very much there. Once you delay, you delay to take those weeds away, that crop won't do anything. So it needs,*

where you are doing ripping you need to have herbicides, somewhere somehow." (Key informant 20)

One farmer stopped using ripping when he could not get herbicides on loan from the cotton company. Another farmer said that if the cotton company rejected his requests for herbicides on credit he would not be able to do ripping, saying, "the work would be too much for me" (Key informant 28). One farmer explained that he plows the fields where he notices the weed pressure is greatest and only rips on the one hectare where weeds are a bit less. Others explained that they are managing to use MT without herbicides but they have to put extra effort into weeding.

One of the complementarities between CA principles is that substantial crop residue retention can provide a layer of mulch that will suppress weed growth. Unfortunately, in Eastern Zambia the frequency of free range cattle and uncontrolled fires make it extremely difficult for farmers to retain their residues. Over 80% of MT plots recorded in the survey had lost more than half of the residues to grazing and over 25% to burning.

One reason why some farmers did not find weeds a challenge with MT is that they used conventional mid-season tillage to control weeds. Many ripper farmers (26 out of 49 responses) use banking (moving soil from the inter-row with a hoe or plow) on MT plots to control weeds. Others use an ox-drawn cultivator or hand hoe to weed between the rows. This mid-season tillage reduces the long-term potential benefits of minimizing soil disturbance.

Furthermore, fields that are banked are difficult to rip the next year. Over half the farmers rip between ridges the year after banking. Farmers explained that ripping in the inter-row is easier than ripping on a ridge and is necessary to cut sufficiently deep for improved infiltration of water. Unfortunately ripping the inter-row makes the oxen have to exert more effort than if the rip lines stayed in the same place year after year. This contributes to the dry season labor constraint.

4.4.3.4. Quantitative analysis of household-level constraints

To examine the statistical significance of these constraints I used a fractional response model to estimate the average partial effects of household- and community-level variables on the proportion of cotton and maize area a farmer has under. The means, standard deviations and ranges for the variables in the regression are in Table 18.

The results generally support the importance of the constraints identified through the qualitative analysis (Table 19). Farmers use MT on more of their cotton where the distributor or buyer also uses MT on more cotton area, indicating that their example reduces the informational constraints. The lack of significance for the coefficient on years of experience with MT could be due to this variable only being important for the first three years, after which farmers reach an upper limit on MT (Figure 2).

Farmers who have more adult household members per area farmed tend to use MT on more area, which shows the importance of labor as a constraint. Also, farmers who operate larger areas use MT on a larger proportion of their cotton and maize. Total operated area is a wealth indicator (due to higher income from producing on more area). Wealth is generally associated with higher risk tolerance and also enables farmers to purchase herbicides and equipment.

In addition, the regression results highlight a number of interesting issues that did not arise from the qualitative analysis. Farmers who sell more crops use MT on less maize area. This suggests that farmers who are less commercialized (i.e. producing primarily for their own consumption) are using more MT on more of their maize. These farmers may have lower opportunity costs of labor and greater need to produce sufficient food on their own land, thus making MT relatively more attractive. Farmers who own more livestock use MT on less of their cotton and those who own more equipment use less MT overall. These may be related in that farmers who have more oxen and more plowing equipment may face fewer challenges preparing all their land soon after the rains, thus decreasing the need to use MT to achieve dry season land preparation.

Farmers who live in dispersed settlements (i.e. not in villages) use MT on 32% less of their cotton area. Living in a dispersed settlement could potentially increase all three of the constraints identified above: information constraints are greater due to less opportunities to observe neighbors' fields; equipment constraints are higher due to greater challenges borrowing equipment; and weeding labor costs tend to be higher in areas with lower population density. Further research is needed to understand the relative importance of these factors in dispersed settlements. Another reason for lower percent of area under MT in dispersed settlements is that those farmers tend not to use MT on cotton, which may simply be caused by lack of extension by cotton companies in these areas (see Appendix for details).

The percent of cotton area under MT is lower in cluster 1 which has the least sand and red loam (where MT tends to be used) and the most clay soils (where MT is used less). Cluster 2 and 3 have larger proportions of cotton area under MT, possibly because they have the most flat area (see Table 12 for more details on cluster characteristics).

Table 18: Description of variables used in the household-level regression

	Mean	Standard deviation	Minimum	Maximum
Dispersed settlement (Y/N)	0.58	0.50	0	1
Buyer's area under MT (%)	33.4	24.6	0	81.5
Years using MT	3.20	3.07	1	25
Number of crops sold	3.15	1.69	1	9
Total Fertilizer (kg)	410	426	0	2600
Total Livestock (TLU)[a]	4.80	4.91	0	23.27
Total Value of Equipment ($)	1226	2419	0	15,945
Adult HH members per ha	1.09	0.94	0.29	6.29
Total Operated Area (ha)	4.83	3.18	1.05	18.4
Cluster 1 dummy	0.19	0.39	0	1
Cluster 2 dummy	0.22	0.42	0	1
Cluster 4 dummy	0.26	0.44	0	1

Source: Survey of NWK and Cargill farmers, 2013

[a] Tropical Livestock Units - cattle have a value of 0.7, goats and sheep 0.1, pigs 0.2, poultry 0.01 and donkeys 0.5 (Jahnke, 1982)

Table 19: Average partial effects of household- and community-level factors influencing intensity of adoption of minimum tillage (MT).

	Percent Maize Area under MT			Percent Cotton Area under MT			Percent of All Area under MT		
Explanatory variable	APE		Std. Error	APE		Std. Error	APE		Std. Error
Dispersed settlement (Y/N)	-1.38		(12.33)	-32.18	***	(6.15)	-13.61	*	(7.88)
Buyer's area under MT (%)	-13.99		(27.05)	58.86	***	(11.71)	11.09		(18.16)
Years using MT	-2.09		(1.94)	0.36		(0.74)	-0.69		(0.95)
Number of crops sold	-7.10	***	(2.60)	1.31		(1.29)	-1.74		(1.27)
Total Fertilizer (kg)	-0.001		(0.02)	0.004		(0.013)	-0.01		(0.02)
Total Livestock (TLU)[a]	0.36		(1.37)	-3.37	***	(0.94)	-0.50		(0.94)
Total Value of Equipment ($)	-0.004		(0.004)	-0.004		(0.003)	-0.005	*	(0.003)
Adult HH members per ha	13.59		(9.55)	11.38	***	(3.27)	7.35	**	(3.47)
Total Operated Area (ha)	4.78	*	(2.87)	10.82	***	(3.21)	5.07	***	(1.85)
Cluster 1 dummy	-20.68		(13.55)	-83.05	***	(26.90)	-13.56		(8.65)
Cluster 2 dummy	-9.76		(13.78)	29.30	***	(10.59)	-0.18		(9.28)
Cluster 4 dummy	-5.23		(13.47)	19.16	**	(8.45)	1.44		(7.91)
Observations	79			77			79		
Log pseudo-likelihood	-2,294.56			-1148.05			-1827.55		
Wald Chi-squared	Chi^2 (12) = 13.82		p=0.3122	Chi^2 (12) = 31.77		p=0.0015	Chi^2 (12) = 30.83		p=0.0021

Robust delta-method standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: Quasi-maximum likelihood fractional logit estimator (multiplied by 100 for easier interpretation) using data from survey of NWK and Cargill farmers, 2013

[a] Tropical Livestock Units - cattle have a value of 0.7, goats and sheep 0.1, pigs 0.2, poultry 0.01 and donkeys 0.5 (Jahnke, 1982)

4.5. Implications for CA promotion

Farmers' concerns about erosion with MT on sloped fields suggest that agricultural extension services (from any source) that provide training on how to reduce erosion may support more widespread use of MT. Instructing farmers to use contour bunds between rip lines to prevent erosion may require training as well as overcoming negative associations with being forced to carry out soil conservation during colonial times. Achieving residue retention will require controlling free-range cattle and wildfires.

The identification of three primary constraints to farmers using MT on more of their land (informational, investment and labor constraints) helps guide how CA needs to be adapted and promoted so that farmers can experience the yield benefits on more of their land.

First, increased adoption will require reducing farmers' uncertainty about the available technologies. Awareness of CA is widespread in Zambia so mass campaigns are likely to be ineffective. Education about CA will be more likely to help farmers use MT on more area in a shorter time if it addresses farmers' key concerns, such as how to effectively manage weeds, what to do on MT plots in wet years and how to use MT on sloping land. Personal experience using MT and the presence of local opinion leaders using MT are important determinants of farmers using MT on more land. This suggests that CA promotional efforts should combine situated experiential learning-by-doing with efforts to link participants with MT veterans who can help farmers overcome their practical concerns with how to benefit from using more MT.

In addition, effective learning about MT must be accompanied by increased ability to access ox-ripping equipment through rental services or credit to purchase one's own equipment. Equipment subsidies or longer-term loans may help reduce the investment constraint by making the equipment more available. The concerns of oxen owners for oxen health indicate that the dry-season labor issue must be addressed together with the equipment availability issue.

Finally, current MT technologies need to be adapted to overcome labor constraints. Farmers minimize dry season labor costs by using MT on plots where the dry-season labor requirement is less but where MT is still effective: basins tend to be dug on sandy soils and ripping tends to be done on soils that are not too hard for the oxen but also not sandy (so the furrow does not collapse). Improving farmers' ability to control weeds (through herbicides or mulch) has the potential to not only reduce weeding labor but also to reduce the ox-labor constraint associated with dry season ripping by reducing the need for banking, and thus enabling ripping in the same line each year. Improvements to livestock health and dry season forage availability could help an average team of oxen be able to rip through the dry season without over-exertion. Easing this labor constraint is also likely to increase the availability of ripping rental services, which would help more farmers have access to the rippers and avoid the investment constraint.

While technologies are being adapted, targeting areas with lower constraints would make sense. Due to the unavoidable labor constraint of digging basins with a hoe, promotion may be more effective if it is targeted at labor-abundant, land-constrained households. Also the short-term benefits of basins tend to outweigh the costs on plots that are degraded or where compacted soil has significantly affected yields. Targeting basin promotion at areas with land degradation may therefore be another logical approach.

4.6. Conclusion

Conservation agriculture holds great potential for helping farmers become less vulnerable to rainfall variability. Theoretically CA would be adopted as a package of complementary principles that can be used permanently on a plot to sustainably increase the land's productivity. Over time the labor costs would decrease while the benefits to crop production increase. However in Eastern Zambia, where CA has been promoted for over a decade, the farming system of free-range cattle and widespread burning make residue retention extremely difficult, which increases the challenges of weeds and erosion on MT plots. Furthermore, even where MT land preparation methods are used, the benefits of minimizing soil disturbance are lost due to the widespread use of tillage for weed control.

The fact that many farmers are using MT despite these challenges, and without any expectation of direct incentives, shows that the short-term benefits of MT outweigh the costs – at least for certain farmers and under certain conditions. Farmers' stated reasons for partial adoption and empirical observation of the factors associated with increased use of MT reveal three challenges that need to be addressed for making the benefits of CA available to more farmers on more of their land: 1) reducing uncertainty about the technology through experiential learning, 2) reducing barriers to entry by making equipment more available and more effective, and 3) adapting technologies or identifying new technologies that can improve production despite difficult to change constraints.

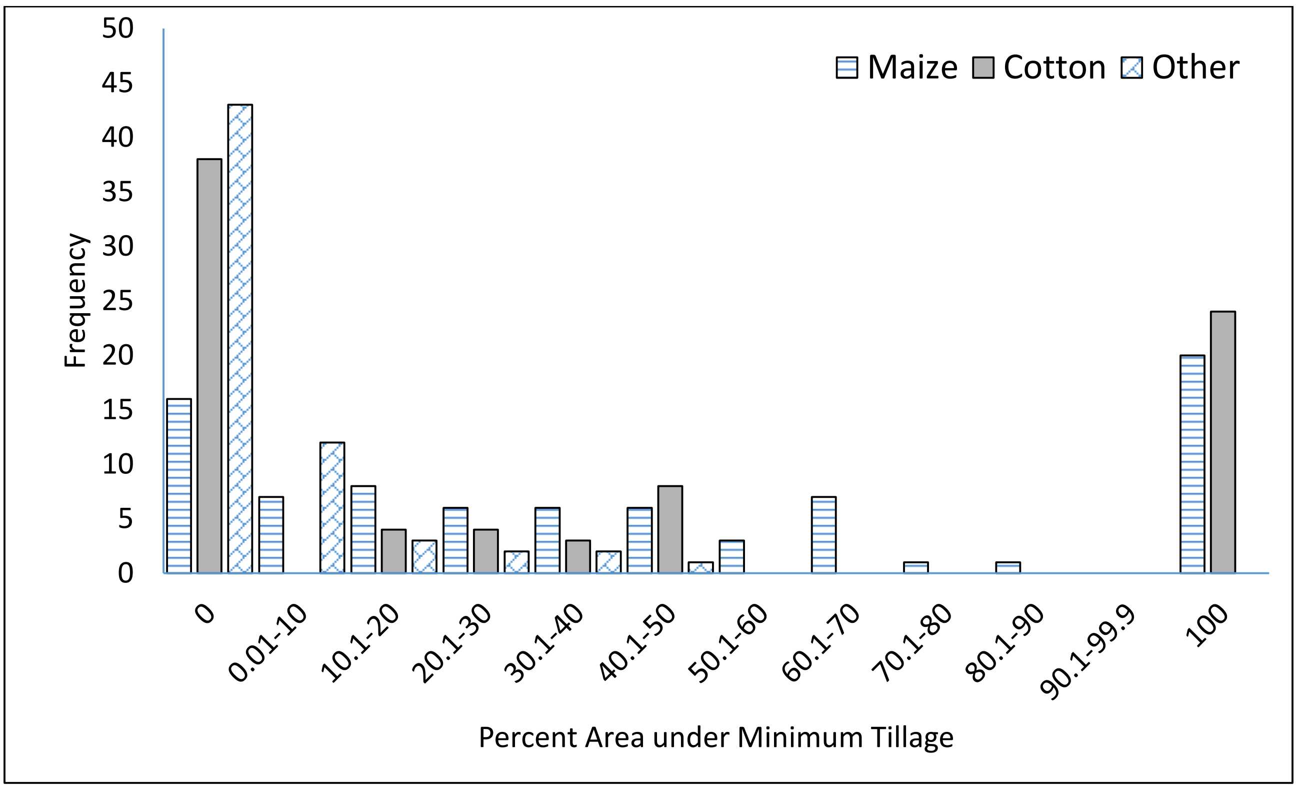
Similar challenges are likely to be applicable to a wide range of agricultural technologies across many contexts. Realizing improvements in smallholder production through agricultural technologies will require systematically identifying and addressing these challenges. The results of this study indicate that careful analysis of farmers' experiences with technologies is essential for guiding the efforts of development agencies and researchers.

APPENDIX

Appendix: Intensity of MT use by crop

This section provides details of the differences between farmers who use MT on cotton and those who do not use MT on cotton. When the area under MT for each farmer is separated by crop, a striking result is a bimodal distribution with high peaks at complete adoption and complete non-adoption for cotton and maize (Figure 11). Twenty farmers used MT on all of their cotton, while 39 used it on none of their cotton. A similar distribution of many farmers using MT on 100% or 0% of their maize area was also observed. Eight farmers (10%) used MT on 100% of their cotton and maize area.

Figure 10: Percent of area under minimum tillage (MT) for maize, cotton and other crops by cotton farmers who use some MT on any crop



Source: Survey of NWK and Cargill farmers, 2013

A simple comparison of means with a t-test shows some important differences. There is statistically significant difference in the percent of the distributor/buyer's MT area between farmers who use MT on cotton and those who do not (42% compared to 23%). There is also a statistically significant difference in the proportion of farmers living in dispersed settlements (as opposed to villages) between those who use MT on cotton and those who do not. 76% of those who do not use MT on cotton live in dispersed settlements, compared to 42% of those who use MT on cotton (57.6% live on farms on average). Also a larger proportion of farmers who do not use MT on cotton are basin users (66% over 44%), which is statistically significant. There is not a statistical difference in the size or proportion of maize area under MT between those who use MT on cotton and those who do not.

However, this comparison of means across those with and without MT on cotton and those with and without MT on maize can be misleading. There are really three distinct groups: those using it on cotton but not maize (14 farmers), those using it on both cotton and maize (29 farmers), and those using it on maize but not cotton (36 farmers).

When these variables are combined in a multinomial logistic regression (for the three groups mentioned above) it becomes clear that source of information about MT is the primary determinant of whether farmers use MT on cotton only or maize only (Table 20). The influence of the buyer or distributor's example has the largest effect on the probability of using MT on cotton. Living in a dispersed settlement and owning more livestock also having significant negative relationships with MT use on cotton.

Table 20: Multinomial logisitic regression results of household characteristics and community characteristics associated with whether MT is used on cotton or maize or both.

	MT on cotton only vs. MT on cotton and maize			MT on maize only vs. MT on cotton and maize		
Dispersed Settlement (Y/N)	1.034		(1.03)	4.004	***	(1.14)
Buyer's area under MT (%)	-0.367		(2.15)	-11.3	**	(4.39)
Received Incentives (Y/N)	-4.439	***	(1.48)	2.65	**	(1.35)
Total Operated Area (ha)	0.131		(0.32)	-0.675	**	(0.32)
Total Fertilizer (1000kg)	-0.473		(0.00)	-2.43		(0.00)
Total Livestock (TLU)[a]	-0.0999		(0.17)	0.419	*	(0.23)
Cotton Experience (years)	-0.0205		(0.13)	0.0513		(0.08)
Community Level Variables						
Years CA Promoted	0.41		(0.27)	0.625	*	(0.37)
Cluster1	-5.29		(4.06)	1.587		(1.98)
Cluster2	-2.144		(1.76)	-6.769	**	(2.92)
Cluster4	-1.546		(1.60)	-3.157		(1.98)
Constant	-1.399		(2.52)	1.943		(2.17)
Observations	77			77		

[a] Tropical Livestock Units - cattle have a value of 0.7, goats and sheep 0.1, pigs 0.2, poultry 0.01 and donkeys 0.5 (Jahnke, 1982).

Farmers using MT on maize but not cotton tend to live in communities where the buyer or distributor uses MT on a smaller proportion of land, there is a longer history of CA promotion, and where that promotion included the use of incentives. Incentives were previously used by NGOs and government CA promotional programs but not by the cotton companies. In areas where buyers or distributors are not providing strong examples of MT use, it is likely that the primary source of information is from extension services (whether government or NGOs), which tend to emphasize MT for maize production. Farmers in such communities may not have enough information or encouragement to try using MT with cotton. In contrast, farmers using MT on cotton but not maize were significantly less likely to have ever received incentives for doing CA, which suggests their primary information source is the cotton company.

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