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A Prospective Analysis of Participatory Research on Conservation Agriculture in Mozambique

by

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A Prospective Analysis of Participatory Research on Conservation Agriculture in Mozambique

EXECUTIVE SUMMARY

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 and the different minimum tillage technologies (basins, jab-planters, ox-drawn rippers, and tractor rippers) have unique labor, knowledge and financial requirements for effective use. 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, adoption of CA technologies will require a process of innovation, whereby technologies are adapted to specific agro-ecological and socio-economic contexts. The development and adaptation of appropriate CA technologies requires a highly participatory approach that can bring together scientific problem solving with farmers' context-specific knowledge.

The aim of this paper is to analyze the specific challenges and opportunities facing the Mozambican Ministry of Agriculture and its partners as they consider how to effectively invest in adapting CA technologies for Mozambican smallholders. Four data collection exercises were used to systematically analyze the practical experiences with CA in Mozambique. First, an inventory of CA projects was carried out using data provided by CA researchers and project managers. The focus of the inventory was to identify how the principles of CA were being combined in each region. A review of the scientific literature and project documents was also carried out to analyze the performance of CA across the country. Next, research and development priorities for up-scaling CA were explored using a survey of CA program managers, with an emphasis on understanding the level of agreement about the potential of specific types of CA and how to reach that potential. Finally, in-depth interviews were carried out with key informants who were implementing participatory CA projects using Farmer Field Schools (FFS) and Innovation Platforms (IPs). The focus of the interviews was to identify the challenges that can be expected in pursuing a participatory approach to CA research and how those challenges can be addressed.

The results indicate widespread agreement about the need for adapting CA technologies to the local context. Much of the research on CA focuses on the agronomic performance of predetermined sets of technologies, with little role for the farmers except as custodians of on-farm research plots. Even where farmers participate in the research, it is typically not at a level that gives farmers the opportunity to design or interpret the research. This is problematic because the limited interactions reduce researchers' ability to benefit from farmers' implicit knowledge about their complex bio-physical socio-economic context. The diversity of farmers and their conditions in Mozambique make farmers' participation in the design and interpretation of research essential for the CA innovation process. In contrast, CA promotional programs are using high levels of

farmers' participation to carry out localized adaptation to overcome constraints to adoption, but without the ability to determine how such adaptations will affect long-term soil fertility.

The logical way forward with the development of appropriate CA technologies in Mozambique is to set up participatory research efforts with two levels of collaboration: 1) combining the scientific expertise of researchers with those skilled in facilitating participatory processes and in linking actors across the value chain for a system perspective on the technology and 2) collaboration with resource-poor farmers actively involved in the research process so that their implicit knowledge about their agro-ecological and socio-economic conditions can be utilized to develop technologies relevant to their needs and priorities. The returns to this investment in developing specific technologies can be maximized if areas with relatively large recommendation domains are targeted.

The results also indicate that because participatory efforts to develop CA technologies will require collaboration across disciplines and across actors in the value chain, they will have 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. For diverse actors to work together to develop CA technologies, there must be some agreement on a definition of CA. Disagreement is likely between those who focus on the hard system (sustainability of the soil) and those who focus on the soft system (farmers' priorities, markets and policies). It is also important to recognize the gulf between those who see commercial inputs (such as fertilizer, hybrid seed and herbicides) as fundamental to effective CA use and those who favor organic, low-input CA technologies.

The context-specificity of the performance of CA technologies and the diversity of farmers and their conditions in Mozambique make farmers' participation in the technology development process an absolute necessity. For researchers to effectively play the role of "innovation broker" they will need to have skills in facilitating group processes and resolving conflicts, in order to bring together stakeholders with diverse perspectives. 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. A promising beginning for effectively linking researchers, NGOs and extension for collaborative research is the national CA working group, which is currently hosted by the national agricultural research institute (IIAM). These collaborative efforts need to be participatory in order to effectively develop technologies that can be adopted by farmers. Researchers can more easily connect with farmers' realities if these collaborative efforts are decentralized, such as through regional CA working groups.

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LIST OF ACRONYMS

AGRA – Alliance for a Green Revolution in Africa
AKDN – Aga Khan Development Network
CA – Conservation Agriculture
CARE – Cooperative for Assistance and Relief Everywhere
CGIAR - Consultative Group on International Agricultural Research
CIAT - International Centre for Tropical Agriculture
CIMMYT - International Maize and Wheat Improvement Centre
DNEA – National Directorate of Agricultural Extension
ECA – Empresa de Comercialização Agrícola
FAO – United Nations Food and Agriculture Organization
FFS – Farmer Field School
FSR – Farming Systems Research
GDP – Gross Domestic Product
IAASTD – International Assessment of Agricultural Knowledge, Science and Technology for Development
IAR4D - Integrated Agricultural Research for Development
ICRISAT – International Center for Research in the Semi-Arid Tropics
IFDC – International Fertilizer Development Corporation
IIAM - Agricultural Research Institute of Mozambique
ILRI – International Livestock Research Institute
IP – Innovation Platform
IRD – International Relief and Development
NGO – non-governmental organization
PARTI - Platform for Agricultural Research and Technology Innovation
PROMEC - Projecto de Promoção Económica de Camponeses
SIMLESA – Sustainable Intensification of Maize and Legumes in Southern Africa
UN – United Nations
UNAC – National Peasants' Union

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1. Introduction

The development of improved agricultural technologies has tremendous potential for improving the livelihoods of smallholder farmers in least developed countries - some of the poorest people in the world (World Bank, 2007; Pretty et al., 2011). Sets of technologies such as conservation agriculture (minimum tillage, mulching and rotations) have the potential to sustainably increase yields and decrease farmers' vulnerability to climate change (Rockström et al., 2009; Hobbs, 2007). However, the benefits and challenges associated with reducing tillage are variable across soil types and rainfall regimes (Giller et al., 2009; Baudron et al., 2012). Furthermore, there are 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). As part of the innovation process, CA technologies need to be adapted to specific agro-ecological and socio-economic contexts for farmers to benefit from adoption (Giller et al., 2009; Wall, 2007) and this can be facilitated through participatory research approaches (Ekboir, 2003).

The research and extension arms of the Mozambican Ministry of Agriculture and their partners (donors, research centers, universities and NGOs) aim to support innovation in smallholder farming with appropriate technologies to improve livelihoods. Conservation agriculture research and promotion has grown dramatically in southern Africa but low adoption levels have led to a polarized debate on the suitability of CA to smallholder farmers in the region (Giller et al., 2009). This leads to the question of how funds for research and extension should be allocated so that smallholders can benefit as much as possible from CA with a realistic perspective on the limitations of CA technologies. This paper focuses on the process of effectively developing and adapting CA innovations (whether through formal research or non-traditional research activities) as the first phase in the innovation process, with less emphasis on dissemination. The case for highly participatory agricultural research is presented as the way to move forward with developing appropriate CA technologies in Mozambique.

The aim of this paper is to analyze the specific challenges and opportunities facing the Mozambican Ministry of Agriculture and its partners as they consider how to effectively invest in adapting CA technologies for Mozambican smallholders. The approach taken was to learn from the practical experiences with CA in Mozambique through the following activities: 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 program managers, and 4) in-depth interviews with key informants implementing participatory CA projects using Farmer Field Schools (FFS) and Innovation Platforms (IPs).

The following section outlines four lessons from the literature on agricultural research for resource-poor farmers that are especially relevant to the case of CA in Mozambique. After providing some background information about the Mozambican agricultural context, the methods that were used for the research activities are described. The results are organized around the same themes as the lessons from the literature, starting with the evidence of the need for local adaptation of CA and ending with the expected challenges to participatory research efforts. In the discussion specific considerations for the institutional support needed for a participatory CA innovation process in Mozambique are outlined.

2. Lessons from the literature

2.1 Effective innovation requires farmer participation

Over the last 70 years there has been an increasing emphasis on using formal agricultural research to improve the living conditions of resource-poor smallholder farmers in developing countries. The dominant strategy has been the transfer of technology approach, where technologies flow from experiment stations through extension services to farmers with little opportunity for information to flow back to researchers. While this approach has had some success in areas with high agricultural potential, its limitations have become evident in less favorable agro-ecological conditions. Due to the complexity of both the livelihood strategies of resource-poor farmers and of their agro-ecological conditions this approach has largely failed to support effective innovation by resource-poor farmers (Bingen and Gibbon, 2012; Buhler et al., 2002; Ekboir, 2002). Instead, a system that enables researchers to learn from farmers' experiences with technologies would make the process of developing and adapting technologies more effective, thereby also improving the efficiency of dissemination efforts.

Research to support agricultural innovation requires combining farmers' detailed knowledge about their problems with scientific problem-solving skills from many academic disciplines, such as agronomy and agricultural economics. For this reason effective agricultural research in many areas of low-income countries is trans-disciplinary: blurring the lines between scientific disciplines as well as breaking down the distinction between researchers and other stakeholders (Bruce et al., 2004).

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.

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 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). The "Farmer-First" movement developed innovative methodologies, such as Participatory Rural Appraisal, for researchers to collaborate with farmers to jointly analyze information, with a dual aim of improving research and empowering farmers (Chambers et al., 1989).

The successes of participatory methodologies, when implemented correctly, has led to general acceptance that the participation of resource-poor farmers is indispensable for agricultural research in developing countries. Nevertheless, widespread awareness of the importance of farmers' participation does not mean that participation is effectively implemented. The theoretical development about the importance of farmer participation has not been accompanied by fundamental changes in how agricultural research for resource-poor farmers is carried out (Buhler et al., 2002). The de facto mode of operation continues to be technology transfer from researcher to farmer, with limited use of farmer participation in the technology development process. 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 continue to dominate the flow of information and fail to address the context-specific constraints to adoption.

2.2 How participation is implemented affects the information flow

While participation won the philosophical debate and became accepted as necessary, how it is actually implemented is open to interpretation (Buhler et al., 2002). Attitudinal changes must accompany methodological changes for farmers' participation to actually influence how problem solving is carried out (Chambers, 1997). Yet, even with the appropriate attitude there is a wide array of approaches to participatory agricultural research. The level and quality of interactions with farmers are what determine the amount and types of information that will flow to researchers.

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, 1989). At the low end, researchers carry out on-farm trials simply by contracting farmers to run their experiments. Just beyond this, researchers consult with farmers about their needs, run experiments on their land and then consult with them about their observations at the end. At the collaborative level, farmers are involved with researchers through all phases of the research. Finally, at the collegial level the formal research system is actively supporting the informal research systems of farmers and recognizing that the complementarities in knowledge and skills can be utilized for strengthening each other (Biggs, 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

Adapted from Buhler et al., 2002 Table 5.1; Biggs, 1989

Across this continuum, the conditions where the approach is most appropriate depend on the information needs of the problem being solved through the research. The contractual and consultative levels of participation are primarily suited to problems where the importance of farmers' "sticky" information is relatively low. Researchers can improve their technical problem solving skills with minimal or irregular interactions with farmers. On the other end, the collegial level is best suited for problems that do not require much technical expertise from researchers but where farmers' in-depth knowledge of the context is essential.

Between these two extremes, the collaborative level of participation is likely to be the best approach. When agricultural innovations require intimate familiarity with the farmers' context and advanced technical knowledge from researchers, collaboration is essential for effective problem solving.

Examples of technologies requiring the increased effort for 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).

One way to implement the early stages of a collaborative innovation process is through Farmer Field Schools (FFS), a methodology that uses adult education principles and is particularly well-suited for new context-specific farming practices that require behavioral change (Braun et al. 2006). In the FFS approach a group of about 20 to 30 farmers participate in regular meetings in a field with an outside facilitator to try out and compare recommended agricultural practices (Waddington et al. 2012). Researchers aiming to develop appropriate technologies could use this forum to carefully document farmers' perceptions and the agronomic performance of the technologies as they are collaboratively adapted. The formal interactions during group meetings would ideally be followed up by informal visits by the researchers to see how farmers are adapting technologies on their own farms (as described in Misiko and Tittonel, 2009).

There is concern that the high level of researcher effort and the few farmers actually served through such a participatory approach make it impractical for achieving broad impacts with many farmers. However, if the practices that are developed can be used or easily adapted by a large number of farmers then the process need not be repeated in each community. The cost-effectiveness of a participatory approach at the collaborative level can be increased by identifying recommendation domains that reflect both agro-ecological conditions and farmers' economic characteristics and by collaborating with dissemination partners early on (Conroy and Sutherland, 2004).

While this participatory approach to agricultural innovation holds great promise, it is important to avoid repeating the mistakes of the Farming Systems Research (FSR) movement. FSR led to many important insights into the production constraints of smallholder farmers in Southern Africa, but 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. 1) Most FSR projects were operating at the consultative level and rarely reached a truly collaborative level of participation (Merrill-Sands et al., 1991). 2) FSR focused too narrowly on farm-level issues with little attention to the broader systems in which they were embedded (Bingen and Gibbon, 2012). For example, in India farmers faced a problem with growing pigeon pea due to cattle grazing in the dry season, but FSR researchers saw this as a "development issue" that was not an appropriate focus of their research (Biggs, 1995). 3) 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 need for participation at the collaborative levels has been addressed above and we now turn to systems issues followed by institutional support issues.

2.3 Many agricultural problems cannot be solved at the farm level

The actions farmers take in their fields can only be understood in the context of the ecological, economic and social systems in which they are embedded. Research to develop agricultural innovations must consider the organization of factor and product markets in addition to technology development (Klerkx et al., 2012). For example, agricultural researchers may focus

on developing improved crop management practices that match farmers' resources assuming input prices remain high and credit availability remains low. This would not be as beneficial as what could be accomplished through a systems approach that addresses limitations in the input supply chain and rural credit markets simultaneously with crop management research and improved marketing of harvests.

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 agricultural innovation.

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

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.

The systems approach to agricultural innovation has become operationalized through what are called Innovation Platforms (IPs). The platform aims to provide space for collaboration by creating a new forum where all of stakeholders can interact to collectively focus on solving a common problem (Klerkx et al., 2012). To catalyze the interactions of these stakeholders an "innovation broker" needs to take leadership, usually a researcher or extensionist. This person has three main on-going functions even once the IP is up and running: articulating the demand for innovation, strengthening and broadening the composition of the network, and managing the process of innovation where actors have different norms, values, and reward structures (Klerkx et al., 2012). Playing this role effectively requires skills in group facilitation and conflict resolution.

This strategy is the central feature of the Integrated Agricultural Research for Development (IAR4D) approach used by Consultative Group on International Agricultural Research (CGIAR) centers across sub-Saharan Africa (Lynam et al., 2010). In theory IPs are not simply coordinated development networks but "equitable, dynamic spaces designed to bring heterogeneous actors

together to exchange knowledge and take action to solve a common problem" (Cadilhon, 2013, p.2).

One concern with this approach is that the dominant flow of information will continue to be from researchers, development agencies and other stakeholders to farmers. Unless the innovation broker enables farmers to truly share information and set priorities, the innovation process will miss all the potential benefits from farmers' participation. Without farmers' effective participation IPs are merely a new name for coordinating development efforts with a unique emphasis on including the private sector. A case study of an IP focusing on CA in Zambia emphasizes benefits from coordination at the district level and harmonization of CA messages to farmers but no evidence that this resulted in increased adoption or significant adaptations drawn from farmers' feedback on CA technologies (van der Lee et al., 2011). Similarly, farmers in Burkina Faso were members of a joint planning committee for research but effectively had no power to influence the research agenda (Ashby and Sperling, 1995). Farmers that are better organized will be better able to articulate their needs to researchers and other partners (Rajalahti et al., 2008).

2.4 Participatory research requires institutional support

Technology companies learned that prioritizing client-responsiveness required organizational changes especially affecting how work was managed (Peters and Waterman 1984, cited in Merrill-Sands 1991). Effectively fostering organizational change to meet the needs of a more client-oriented participatory agricultural research has been identified as one of the key implementation challenges of the FSR approach (Merrill-Sand et al., 1991; Biggs 1995) and it continues to be a struggle in implementing the Agricultural Innovation Systems approach (Klerkx et al., 2012; Rajalahti et al., 2008).

Specifically, for researchers to effectively implement the participatory processes outlined in sections 2.2 and 2.3, research systems must support them to:

1) Cross boundaries: Interact with farmers, NGOs and extension workers; Cross institutional boundaries of disciplines and commodities
2) Focus on practical problem solving, not just publications
3) Implement an evolutionary research process

In order for agricultural researchers to collaboratively foster innovation they will need to spend significant time with farmers and the other actors in the supply chain as well as scientists in other disciplines or working on different crops. Case studies from FSR projects show that where these linkages were prioritized, research managers had firsthand experiences with the benefits from these interactions (Merrill-Sands et al., 1991). For example, senior researchers at experiment stations in Nepal would hike through the surrounding villages for a few weeks each year to better understand farmers' realities (Biggs, 1995). The commodity orientation of most agricultural research organization goes against the system perspective needed to address the problems of resource-poor farmers (Buhler et al., 2002), though it is not prohibitive of a client-oriented participatory approach as long as interdisciplinary research planning is prioritized (Merrill-Sands et al., 1991).

One implication of interdisciplinary and trans-disciplinary research is the need for scientists to gain a better understanding of each other's perspectives to have effective communication across boundaries (Moore, 2009). Developing effective solutions requires natural scientists and social scientists to be able to understand the constraints and opportunities in the system that is not their specialty. Furthermore, all scientists need to be able to understand the practical concerns of farmers and private sector actors to effectively collaborate with them.

To overcome the challenges of collaboration, researchers need incentives to engage in practical problem-solving, not just the production of peer-reviewed publications, which may not address farmers' needs (Biggs, 1995; Klerkx et al., 2012). 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 without necessarily hurting publication productivity and almost certainly making the results more meaningful. 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).

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. This can be especially difficult in a bureaucratic management system where research proposals are required to have specific and rigid logical frameworks. Agricultural Innovation Systems require skills in adaptive management where decisions on implementation are based on the information gathered from regularly scanning the environment (Klerkx et al., 2012). Similarly FSR was conceived of as an adaptive process able to respond to farmers' changing needs (Merrill-Sands et al., 1991).

This flexibility can be made more possible when a research system supports decentralized planning and has an egalitarian organizational structure. Decentralized research planning allows research managers who are familiar with the projects on the ground to respond to feedback from farmers (Biggs, 1995). This tends to work better in research systems that have regional centers, which also reduces the transportation costs of getting researchers into the villages more frequently (Merrill-Sands et al., 1991). An egalitarian organizational system encourages creative thinking and the upward flow of communication, though this is often challenging to implement in societies with a more hierarchical culture (Buhler et al., 2002).

Because of the time required for the development of collaborative networks for innovation and the building of trust and understanding among partners, long-term projects supporting such an approach are highly desirable. However, calls for focusing on long-term projects have been around for many years, and donors are simply not willing to fund those (Buhler et al., 2002). Research managers will continue to face the challenge of developing a long-term strategy by harmonizing the efforts of a multitude of short-term projects.

With this overview of the literature on the benefits of participatory agricultural research and the challenges in its implementation we can now apply these concepts to the case of CA in Mozambique. But first an overview of Mozambican agriculture is provided.

3. Background

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 2003 where they stagnated through 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 its 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). While land is generally abundant, population densities are higher in the most productive regions where land availability can be a limiting factor (Mather 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 as can be seen by the research projects of the International Maize and Wheat Improvement Centre (CIMMYT) and the International Centre for Tropical Agriculture (CIAT) and by the increased promotional efforts of development agencies from both government and non-governmental organizations (Nkala et al., 2011). In 2012 a CA working group was established at IIAM with the mandate to develop a national program for increasing the impact of CA for smallholder farmers. The CA working group consists of research, extension and NGO staff and is hosted by the Platform for Agricultural Research and Technology Innovation (PARTI) that coordinates agricultural research and technology transfer activities

between the IIAM and its partners.

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).

4. Methods

This study analyzes how to effectively invest in adapting CA technologies for Mozambican smallholders. Four data collection exercises were used to systematically analyze the practical experiences with CA in Mozambique. First, an inventory of CA projects was carried out using data provided by CA researchers and project managers. The focus of the inventory was to identify how the principles of CA were being combined in each region. A review of the scientific literature and project documents was also carried out to analyze the performance of CA across the country. Next, research and development priorities for up-scaling CA were explored using a survey of CA program managers, with an emphasis on understanding the level of agreement about the potential of specific types of CA and how to reach that potential. Finally, in-depth interviews were carried out with key informants who were implementing participatory CA projects using Farmer Field Schools (FFS) and Innovation Platforms (IPs). The focus of the interviews was to identify the challenges that can be expected in pursuing a participatory approach to CA research and how those challenges can be addressed.

4.1 Inventory of CA experiences in Mozambique

An inventory CA researchers and project managers was carried out to identify the combinations of CA principles and technologies that were being researched and promoted in each region. Initially these researchers and project managers filled out a form to provide details of what CA principles and technologies they were using in their projects. The summarized results of these forms were presented to a broad audience of CA stakeholders at a workshop in Maputo (Donovan and Mouzinho, 2012). Based on feedback from this meeting follow-up questions were developed and additional project managers were contacted in order to obtain a clearer and broader understanding of experiences with CA in Mozambique.

4.2 Literature review of the performance of CA across Mozambique

In addition, 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. For further information see Grabowski and Mouzinho (2013a).

4.3 Survey of experts

A two round on-line survey of researchers and project managers experienced with work on 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 as described in Nhamusso et al. (2012).

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 time frame.

A list of 43 individuals 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 experts responded to at least one round of the survey (30 in round 1 and 25 in round 2 with 20 responding to both rounds). For further information see Grabowski and Mouzinho (2013b).

4.4 In-depth interviews

Seven months after the initial inventory results were presented, the results of the expanded inventory of CA projects, literature review of CA evidence and the survey results were presented 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, in-depth interviews were carried out with CA project managers involved in Farmer Field Schools and Innovation Platforms in Mozambique. The interviews were recorded and transcribed.

5. Results

The results of this study are presented in four sections. First, the need for farmers' participation in the CA innovation process is highlighted by evidence of the context-specificity of CA performance in Mozambique. Next, the level of famers' participation in current research and promotion is shown to be inadequate for effective adaptation of CA technologies. The evidence of the need for an innovation systems approach to CA is presented in the third section. Finally, the anticipated challenges of collaborative research are presented based on the survey responses from project managers.

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

The lessons from the literature suggest that developing effective crop management technologies for smallholder farmers requires high levels of their participation in the innovation process (Section 2.1). Widespread adoption of CA in Mozambique will require farmers' participation to

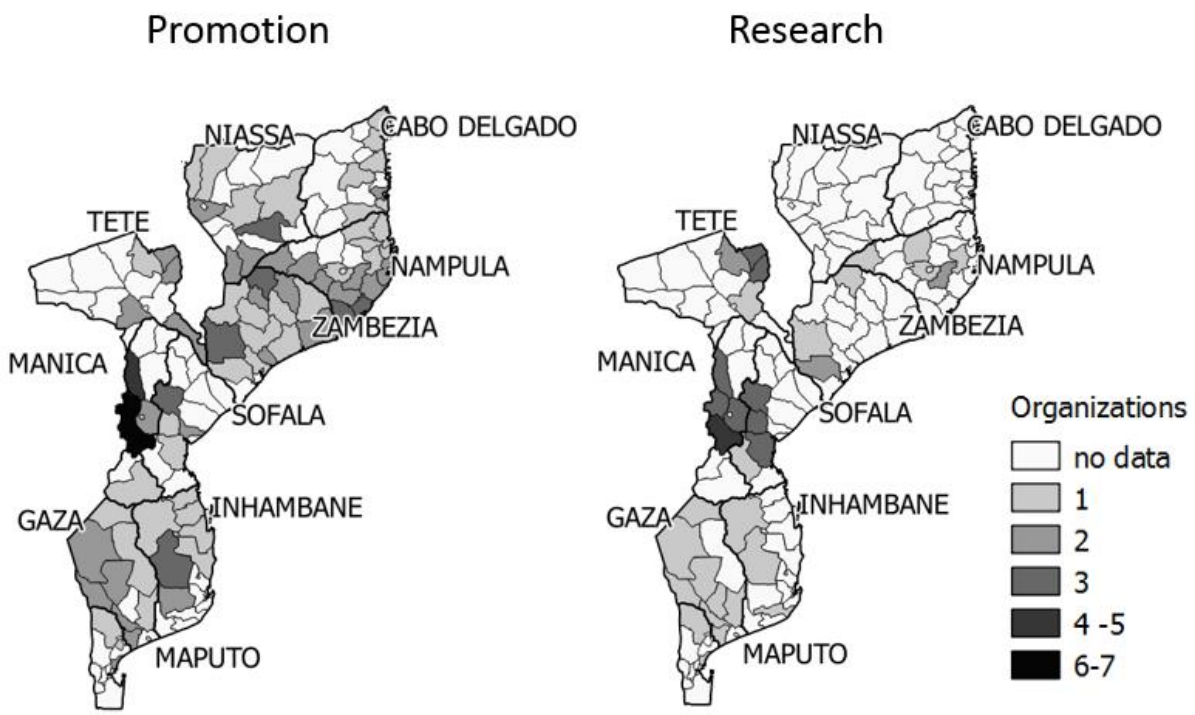
effectively adapt CA technologies to the diversity of agro-ecological contexts. The evidence of the need for this approach comes from the opinions of CA researchers and professionals as well as from the review of CA performance across Mozambique. Before detailing this evidence a brief summary of the extent of CA research and promotion and a summary of the perspectives of CA project managers is provided.

5.1.1 Promotion and research of conservation agriculture

CA promotional and research efforts are widespread across Mozambique. There are programs active in at least 84 of the 128 districts of Mozambique (81 and 33 respectively, Figure 1). The inventory documented the efforts of 29 development organizations, 10 research organizations and 5 private sector organizations actively promoting CA. The largest concentration of organizations for both research and extension is in Manica province in the districts surrounding Sussendenga research station.

In terms of how CA is promoted, minimizing soil disturbance is often emphasized as the first and most essential component, though there are exceptions. Manual CA systems of reduced tillage predominate, including basins 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[1]



Source: Inventory of CA organization in Mozambique
[1]Does not include FAO and DNEA who report working in all provinces

5.1.2 Perspectives on CA's potential

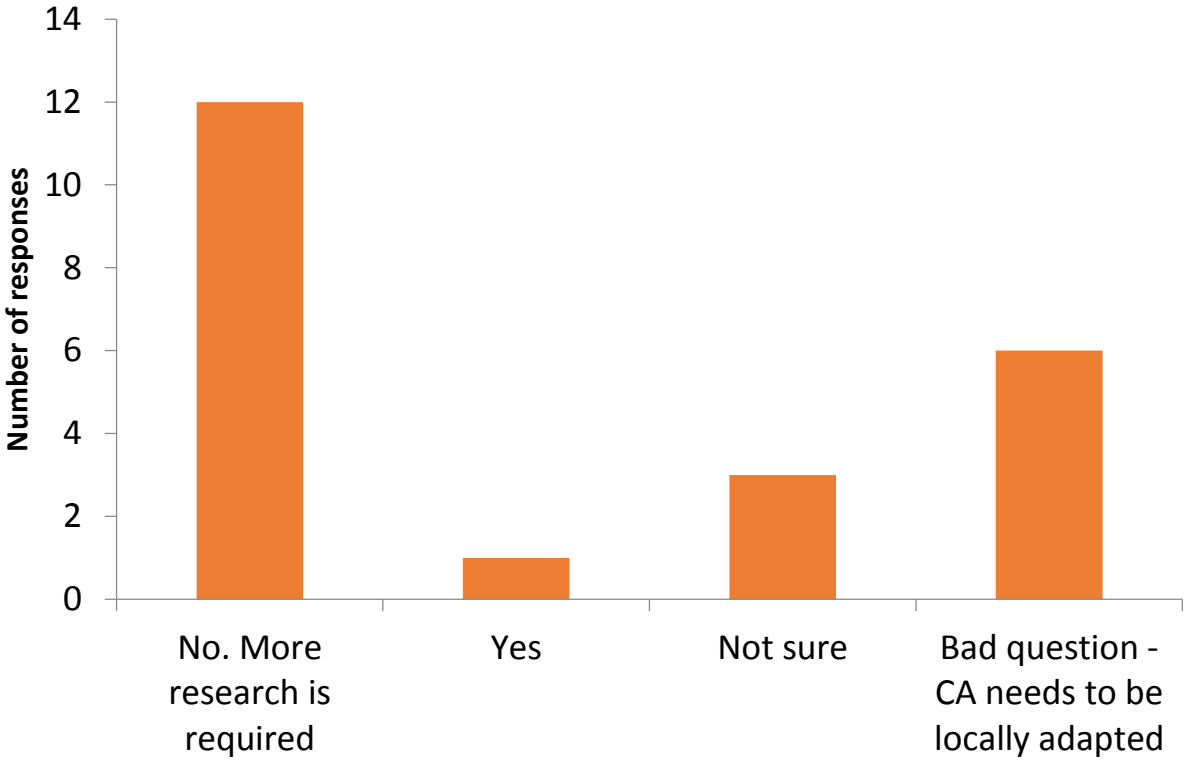
Most CA researchers and project managers said that CA is very important for agricultural development in Mozambique, but there was less agreement about the conditions where CA would be beneficial to smallholder farmers. Only 33% of respondents in the first round survey said that CA can benefit smallholders under all conditions and 45% said that CA is useful for all agro-ecological zones. Another 28% said that it is useful in "most" agro-ecological zones of the country, while 21% said that it is useful in "some" agro-ecological zones, specifying that its performance depends on soil and climatic conditions.

This was explored in the second round by asking respondents if they agree or disagree with a series of statements about the conditions where CA could be beneficial to smallholders. Most agreed that CA would benefit smallholder farmers if there is good technical support, and that it can be useful under all or most conditions. There was some contention on whether CA is primarily useful for poor soils and low rainfall, or for areas with high agricultural potential with high input use. Some respondents see CA as particularly useful in marginal areas, where the soil and water conservation benefits are in high demand. Others emphasize using CA in the best areas, where yield benefits can be realized rapidly because the basic soil and moisture conditions enable high yield potential. Most disagreed that CA only benefits farmers if it saves on labor or inputs, because the real concern is the profitability of those inputs.

5.1.3 The need to adapt CA to local conditions

Respondents generally agreed that the existing CA technologies are not ready for widespread dissemination, implying the need for farmers' participation in a process of localized adaptation. In round 1, when asked if a profitable form of CA that will lead to wide-scale farmer adoption has been identified, 67% said "No" and that more research is needed, and 22% said they were not sure. One of those who were unsure argued that it is not possible to develop a single form of CA for the diverse agro-ecological zones, and that local adaptations should be developed. In round 2, the same question was asked again but with an additional category that emphasizes the need for local adaptation. This time 55% said "No" and 27% said it was a bad question because of the need for local adaptation (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: CA 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?"



The importance of adapting CA technologies to the local context is also highlighted in the responses comparing the importance of various technologies available for achieving minimum tillage with CA. In both rounds, manual forms of minimum tillage were ranked as the most important, with respondents explaining that manual agriculture predominates 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.

Most respondents agreed that nearly all the research and development activities suggested in previous workshops were important for making CA benefit large numbers of smallholder farmers. In the second round respondents voted on which activities they felt needed to be addressed first.

Respondents' priorities 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.

5.1.4. The context-specificity of CA performance

A wide range of forms of CA have been used across Mozambique's diverse agro-ecological zones. The performance of each specific minimum tillage technology (and thus its relative utility for smallholder farmers) depends on the agro-ecological context and how it is combined with the other CA principles in each context (Table 3).

5.1.4.1. Southern Mozambique

Southern Mozambique has lower rainfall than the rest of the country and CA has been promoted primarily as a strategy for water conservation. CARE and IRD have promoted permanent planting basins in large-scale projects along the coast. The CARE project trained over 15,000 farmers on CA in Inhambane from 2007 to 2011, and documented high adoption levels of mulching (68%) and legume intercropping (90%), but only 30% of farmers used the basins because they were considered too labor-intensive and collapsed too easily in the sandy soils (Sampath, 2011). Both CARE and IRD emphasize drought-tolerant crop varieties to complement their CA efforts.

Research on CA in the more arid interior of the south has focused on how mulch and basins could improve rainfed crop yields by increasing water availability, but the evidence is 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. ICRISAT trials in Gaza Province on yield differences by tillage type over four years showed no significant differences due to extremely low rainfall, which led to total crop losses across treatments (Siambi, 2010). Some of the CA work in this region emphasizes mulching irrigated vegetables along flood plains, with little emphasis on reduced tillage, in order to reduce the labor needed for watering (Nhaca, no date). ActionAid has been supporting the National Peasants' Union (UNAC) in Maputo province and is working with the Eduardo Mondlane University to develop a new CA manual for this region.

5.1.4.2. Central Mozambique

CA work in central Mozambique has focused on how to increase maize yields and has been implemented by institutions such as the CGIAR centers and CLUSA. Much of the research combines CA with fertilizer and herbicides, while many of the NGOs promote CA without these

commercial inputs. The majority of CA research has been in the higher rainfall portions of this region, centered especially on Sussendenga research station. One notable challenge is high termite activity on the research station, especially for CA plots (Famba, 2011; Putz, 2008). CIMMYT has a number of on-station and on-farm research projects to study the yield effects of maize varieties, fertilizer application rates, rotations and tillage type. Despite high variability in rainfall between years, these trials show long-term yield benefits from CA, except during poor rainfall years (Thierfelder and Nyagumbo, 2011; Thierfelder, 2010). Research on maize-pigeon pea intercropping under no-till found increased land productivity and reduced risk of crop failure (Rusinamhodzi et al., 2011).

A number of constraints to CA use have been identified in this region. Farmers face credit constraints to the high-input system and the profitability of maize production may be low, even on years with average yields (Grabowski and Kerr, 2014). Some NGOs promote a low-input system using compost, that is more accessible to low-income households, but its widespread use is constrained by the labor needed to make basins and control weeds (Grabowski and Kerr, 2014). To effectively intercrop with pigeon peas, farmers would need better output markets and community-level control of free-range livestock (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.

Along the sandier and more arid coastal zone of central Mozambique CA has been promoted for over a decade. The PROMEC project trained over 1200 farmers between 2003 and 2006 and documented benefits from reducing irrigation needs for horticulture crops and effective weed control with a *Mucuna* spp. cover crop (Taimo et al., 2005).

5.1.4.3. Northern Mozambique

Many development agencies are promoting CA across northern Mozambique to increase yields of a diversity of crops. There is a conspicuous absence of research organizations in this region, though NGOs have hosted several national and international student research projects. CARE is promoting CA with cassava in Nampula with an emphasis on mulching and intercropping with legumes as well as minimum tillage land preparation. In-depth interviews with farmers there indicate that most are not practicing reduced tillage but the benefits of mulching and correct spacing have led to yield benefits and spontaneous adoption of those practices (Ljunkvist, 2013). 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. No reliable data are available for adoption levels in this area but there are reports of yield increases with CA despite a lack of commercial inputs. Cotton company representatives explained that though they have not yet started promoting CA, they are interested in promoting it in this zone as a means of increasing farmers' cotton yields.

Table 3: CA experiences by province (no data for Niassa and Quelimane)

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

5.2 Lessons from using Farmer Field Schools for CA

Effective research to adapt CA technologies for smallholder farmers in Mozambique will require participation at the collaborative level (see Table 1 and Section 2.2). The on-farm research that was reviewed in the literature on CA in Mozambique is typically carried out at the consultative level with researcher-designed experiments on farmers' fields with some level of 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 the research and interpreting the results.

Nevertheless collaborative levels of participation in the adaptation process were observed in CA promotional efforts, though they were not focused on formally researching agricultural innovations. These efforts used the Farmer Field School (FFS) approach to evaluate and improve the CA technologies promoted by their development projects. Program managers from four institutions (CARE, the Aga Khan Development Network (AKDN), the National Peasants' Union (UNAC) and the National Agricultural Extension Directorate (DNEA)) in Mozambique were interviewed to learn from their experiences with this process and how it could be adapted for participatory research on CA technology development.

UNAC uses FFS and farmer-to-farmer visits to provide training in a broad range of sustainable agriculture practices. 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 tehcnologies. 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.

DNEA has been a key proponent of the development of CA technologies from the beginning and has promoted CA nationally, though often with a technology transfer approach. The interviewee reported that DNEA is moving forward with a plan to make FFS the primary extension methodology for the nation after piloting it in 12 districts since 2008. This marks a significant

change in the role that the extension officer will be expected to play, transitioning from the provider of knowledge to a facilitator of a group learning process that utilizes the facilitator's technical expertise as one of many sources of new ideas. 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. A collaborative level of participation would also include farmers' regular involvement in deciding how to implement the adaptations of agricultural technologies.

Both CARE and the AKDN have a highly respected track record of effectively promoting and adapting CA with resource-poor smallholder farmers. 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 after the groups receive basic training on CA, the farmers establish a group field where they can compare practices across experimental plots. 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 challenges identified by the interviewee for implementing the approach in this way is the long time frame required for providing basic information about science and for developing the ownership of the group by its members.

In contrast, CARE uses its 40 FFS groups in Nampula as one part of its larger agricultural development strategy. CARE is more actively using the groups to carefully evaluate and adapt specific CA packages that can fit into the farming system, with a unique focus on cassava. Compared to AKDN there is less focus on farmers' ownership of how the trials are designed. The interviewees from CARE explained that the experimental comparisons are the same for all communities, except for one plot of the field managed by the group. On that portion they design the experiment themselves often planting maize and groundnuts, which are not emphasized in CARE's projects because of relatively poor performance in Nampula. The rest of the plots in the group field are 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 may be justified in areas where CA has no potential, but simply abandoning CA whenever it is resisted will not provide space for learning how to make CA as useful as possible despite challenges. On the other hand, CARE's guided approach to compare many specific CA practices can provide useful information without farmers having to bear the risk of implementation. But this approach must carefully consider farmers' abilities to carry out the prescribed methods on their own farms and their motivations to do so.

This requires close monitoring of farmers' feedback on the technologies and intimate familiarity with their social and economic realities.

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. In fact it could be argued that there are diseconomies of scale for highly collaborative groups - the more one has to manage, the worse they all perform. 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 greater chance of being adopted.

5.3 The need for an innovation systems perspective for CA

Research to develop agricultural technologies is more likely to be effective if an innovation systems perspective is used to network actors across the value chain to reduce bottlenecks in the system (Section 2.3). This is especially relevant for CA in Mozambique where 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).

Some of the activities that were prioritized in the survey of CA researchers and project managers indicate widespread recognition of the importance of an innovation systems perspective. One of the prioritized policy actions was ensuring that both input and output markets work better for smallholder farmers. A system-wide perspective was also shown by respondents' selection of the following priority activities: introducing CA into agricultural training curricula, and increased collaboration and learning across CA-related agencies to avoid conflicting messages.

Despite this recognition of the importance of an innovation systems approach, it is not commonly implemented for CA in Mozambique. Many organizations either focus only on the farmer or try to improve one link in the value chain. For example, some NGOs try to help farmers who use CA market their crops and IFDC is helping develop fertilizer blends appropriate for smallholders and uses CA in its demonstration plots. There are only 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 in Manica and Tete provinces that uses innovation platforms, and ECA (Empresa de Comercialização Agrícola) is a contract farming operation in Manica province that links farmers with inputs, credit and markets. In-depth interviews were carried out with program managers from these two organizations to better understand their experiences fostering innovation of CA by networking agents across the value chain.

Innovation Platforms have been implemented for CA in Mozambique by only one project, SIMLESA, which operates in the central part of the country. ICRISAT and ILRI have also used IPs in Mozambique, but in the context of livestock commercialization in semi-arid zones (Manuel, 2012). Other CA projects have plans for using IPs but results were not available for this study.

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. Farmers in the project are carrying out agronomic trials for CA technologies. But these are designed by researchers and have high levels of input use (herbicides, seeds and fertilizer), which they could not afford on their own. The 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 four 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 so far 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 works with 2000 farmers in Catandica. ECA provides farmers with input loans at cost and coordinates linkages between seed and fertilizer suppliers and groups of farmers. The interviewees explained that similarly to SIMLESA's IPs, 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 some of 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.

5.4 Challenges anticipated for collaboration

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 will have 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. Collaboration requires effective communication and, for diverse actors to work together to develop CA technologies, there must be some agreement on what CA is and how

much commercial inputs need to be emphasized.

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, which suggests divergent definitions of CA and has serious implications for effective collaboration. For this reason, in the first round survey the possibility of incorporating residues through tillage was included 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 it was not important and argued that it is incompatible with minimal soil disturbance and should not be practiced.

Because of this ambiguity about the importance of minimizing soil disturbance, in the second round respondents were asked 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 and retains moisture, though it may also require additional labor. Another benefit is that there may be less erosion with mulch. Tilling has the advantage of controlling weeds and accelerating the decomposition of residues.

However, many respondents did not consider it to be "real" conservation agriculture 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 or intercropping with legumes) would be less than if minimum tillage were achieved as well. One additional criticism of emphasizing mulching, but not minimal soil disturbance, is that 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.

Within the middle ground of broadly defining CA by its three principles, there is still ample

opportunity for tension on how to develop CA technologies. Disagreement is likely between those who focus on the hard system (sustainability of the soil) and those 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). Experience promoting reduced tillage in Queensland, Australia shows that, even when the best technology was developed using positivist science, adoption was low until adult learning tools were used with farmers to help them understand why the technology was necessary for improving their production (Hamilton, 1998). Simply recognizing these differences in scientific paradigms may help agronomists and social scientists collaborate more effectively (Eigenbrode et al., 2007).

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. Some scientists and development practitioners see fertilizer, herbicides and improved seeds (such as hybrid maize) as the key tools for modernizing the smallholder sector. But others 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 round 2) stated that CA without these inputs was not even feasible. A few explained that the high C:N ratio of cereal mulch requires increased N 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' 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

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.

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 collaboration may not always be possible.

From a pragmatic perspective it seems that low-input CA technologies have the short-term advantage. 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 may help reducing the barriers to their use.

6. Discussion and Conclusion

The agro-ecological diversity of Mozambique, and the context specificity of CA technologies, make it especially challenging to develop suitable CA technologies using conventional agricultural research. For this reason farmers' participation in the CA technology development process is an absolute necessity. However, farmer involvement in research may be little more than symbolic when they are simply contracted to manage experiments. The benefits of farmers' participation will only be realized if their involvement in the research process utilizes their implicit knowledge about their agro-ecological and socio-economic conditions 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, which provides an opportunity for researchers to collaborate with extension and NGOs to carry out applied adaptive research with high levels of farmer 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 a value-chain approach to collaborative technology development is necessary for effective agricultural innovation, especially where CA technologies require commercial inputs, which are largely unavailable or unaffordable for smallholders in Mozambique. CA technology development will be more likely to result in widespread adoption if actors across the value chain can collaborate so that farmers have access to input and output markets. The concept of innovation platforms has potential for creating space for collaboration between researchers, extension and the private sector across the value chain. 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.

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. These support organizations can also develop basic research skills to aid them in the process of facilitating effective adaptation of CA technologies.

For the Mozambican Ministry of Agriculture to support this process of participatory client-oriented 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.

Participatory client-oriented agricultural innovation 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 is considering how to be jointly managed by both the extension and research branches of the Ministry of Agriculture.

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