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Conservation Agriculture in Mozambique - Literature Review and Research Gaps

by

Philip Grabowski, Forbes Walker, Steve Haggblade, Ricardo Maria, and Neal Eash

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Working Paper Series

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Conservation Agriculture in Mozambique - Literature Review and Research Gaps

EXECUTIVE SUMMARY

Conservation agriculture (CA) has been promoted in Mozambique since 1996 in order to increase smallholder productivity, reduce erosion, increase soil fertility and improve the drought tolerance of rainfed agriculture. Though many studies and CA projects have been carried out during these years across the diverse agro-ecological conditions in the country, there are still wide gaps in knowledge about the ability of CA to improve smallholder agriculture in each context. This report reviews scientific literature and project reports in order to better assess what is known about CA in Mozambique. The key research gaps that need to be filled to better assess how CA can be used to benefit smallholder farmers are identified in the realms of both bio-physical and socio-economic research.

On the biophysical side the most important research gaps are as follows:

- There is a lack of basic agronomic studies for the different agro-ecological zones, especially regarding plant populations, fertilization rates, cover crops, rotations and weed control strategies. These would facilitate CA adoption and be useful more generally.
- Limited scientific studies directly compare CA and conventional tillage systems for the different agro-ecological zones and cropping systems.
- An assessment of different manual reduced tillage and planting systems (basins, jab-planters, dibble sticks, “Chinese” hoe etc.) is needed.
- Soil changes under CA with cassava are poorly understood, especially regarding the permanence of soil organic matter (SOM) after soil disturbance from harvesting.

On the socio-economic side the priority research topics are as follows.

- Studies to better understand farmer decision making, highlighting the profitability and riskiness of CA relative to the conventional system of production including thorough analysis of labor changes by season and gender impacts.
- Studies on how CA is being promoted with farmers and the relative successes of different extension/education approaches including cost-effectiveness and the long-term benefits of building farmers’ capacity to learn and adapt.
- Eventually a large scale adoption study would be useful for charting progress on CA across the country and for characterizing adopters and non-adopters.
- Over the long term it would be useful to develop panel data, by establishing a baseline in a new area before farmers use CA and continuing over the course of 5 or more years to assess the impact of the technology on their livelihoods.

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by

Philip Grabowski, Forbes Walker,
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1. INTRODUCTION

Conservation agriculture (CA) is generally defined as a set of management practices that minimize soil disturbance, incorporate legumes through rotations or intercropping, and maintain crop residues on the soil surface. These practices are promoted in order to reduce erosion, improve soil quality through the gradual build-up of soil carbon (C) and in the long term, improve soil fertility and water infiltration. Other benefits of conservation agriculture can be decreased labor requirements, increased yields, earlier planting and greater drought tolerance due to improvements in soil physical properties.

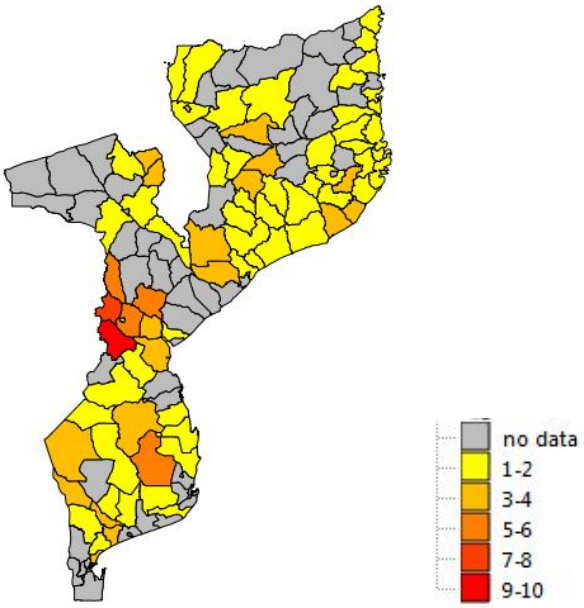
Conservation agriculture has increased in popularity with many development agencies across Southern Africa due to the potential to offer more sustainable production systems for smallholders (FAO 2001, Twomlow and Hove 2006). Interest centers on CA's potential for improving smallholder productivity and for enabling farmers to sustainably manage soil fertility under conditions of increasing pressure on African land and water resources. Despite its considerable potential, some authors remain cautious, pointing to scattered and generally low adoption rates as well as wide differences in situation-specific outcomes (Giller et al., 2009; Rockstrom et al., 2009).

Mozambican agriculture is generally characterized by lower yields and lower input use than other countries in the region as well as greater probability of climatic extremes such as droughts, floods and cyclones. Because of this, local policy makers and agricultural specialists have expressed interest in exploring the potential for CA to improve smallholder productivity and decrease vulnerability to climatic events and overall climate change in Mozambique.

Conservation agriculture has been promoted since 1996 in Mozambique by a variety of development agencies and research organizations starting with Sasakawa Global 2000 (SG2000). Currently there are at least 27 development organizations, 10 research organizations and 5 private sector organizations actively involved in conservation agriculture in Mozambique across 84 of 128 districts (Grabowski and Mouzinho 2012, Figure 1).

This report aims to support efforts to utilize CA for smallholder agricultural development in Mozambique by reviewing the evidence available from research and project reports. It also aims to provide guidance on future investments in CA by identifying the research gaps that need to be filled for a more accurate assessment of what CA has to offer in response to the many challenges faced by smallholder farmers in Mozambique.

Figure 1: Number of CA research and development organizations operating in each district



Data source: MSU/IIAM Survey of Experts.

A. Review of the available evidence on conservation agriculture in Mozambique

The scientific information on conservation agriculture includes biophysical research (such as yield differences, soil changes and water dynamics) as well as socio-economic research (such as the effectiveness of promotion methods, profitability, labor changes, gender impact analysis, adoption studies, and livelihood impacts). Many of the documents reviewed contribute some information to both biophysical and socio-economic aspects of conservation agriculture. Most studies at least mention something about yields and provide some perspective on what is preventing widespread adoption, though with various levels of sophistication in how the data is obtained and analyzed.

Because of the limited amount of research published in scientific journals on conservation agriculture in Mozambique this report includes a wide range of gray literature including student theses, project reports and presentations given by researchers. The authors would like to recognize the efforts of two students from the University of Eduardo Mondlane who gathered much of this gray literature and summarized their perspectives on the documents as a support to this report (see Ismael and Mosse, 2012).

2. BIO-PHYSICAL RESEARCH

Conservation agriculture is often promoted as a farming method that promotes yield stability and food security especially at the outset of changing the production system from tillage intensive to direct seeding and residue retention. The FAO defines three broad principles that make up CA: minimum or reduced soil disturbance, maintaining a permanent soil residue or vegetative cover, and crop rotations or intercropping with legumes (FAO, 2002).

In order to adopt CA farmers have to have practical ways of:

- Placing seed in the soil at an appropriate depth
- Controlling weeds effectively
- Maintaining or improving soil fertility
- Controlling pathogens and diseases

In addition farmers must have effective research and extension support by qualified professionals. Rather than giving farmers a single "prescription" for seeding, weeding, soil fertility and other management practices, it is expected that adoption rates of CA will increase if farmers are given a variety of options. For example, farmers may want to use different planting methods or planting equipment due to variations in soil textures between fields. Some farmers may wish to rotate their fields with legumes such as soybean (*Glycine max* L.) that could be a cash crop, whereas others may want to grow legumes such as pigeon peas (*Cajanus cajan* L.) that they have greater experience with. Furthermore, farmers will be better able to discern which option is best for them if they have increased knowledge about the fundamentals of soil fertility and agronomy underpinning the options.

A. Yield differences with CA and conventional systems

Promoters of CA in Africa have suggested that CA in some environments can increase crop yields, when compared to tillage systems. Several studies have controlled for differences in input use and found yield gains under CA , typically due to early planting made possible by dry season land preparation and water harvesting during low-rainfall years (Haggblade and Tembo 2003; Kabwe et al. 2007; Nyagumbo 2008).

In contrast, Thierfelder and Wall (2012) found that in Zimbabwe when CA systems are directly compared with tillage systems, there was no immediate increase in maize (Zea mays L.) yield. However, there was a gradual improvement in soil quality that in some years can lead to significantly higher crop yields under CA. One factor working against short term yield increases is that moving crop residues to the soil surface delays the mineralization of their nutrients for up to two seasons depending on the site location and climate (Verhulst et al., 2010). Typically it takes five or more years for improvements in soil quality (increased water infiltration, less runoff and improved soil structure) that can result in increased crop yields. For example, in Malawi, it took about five or six seasons for CA systems to significantly out yield tillage systems (Thierfelder et al., 2012). This is the same experience that farmers in North America had when adopting no-till. In the early years of adoption the reduction in erosion, fuel, labor and equipment costs was seen as an advantage of these systems even with a lack of an increase in yields.

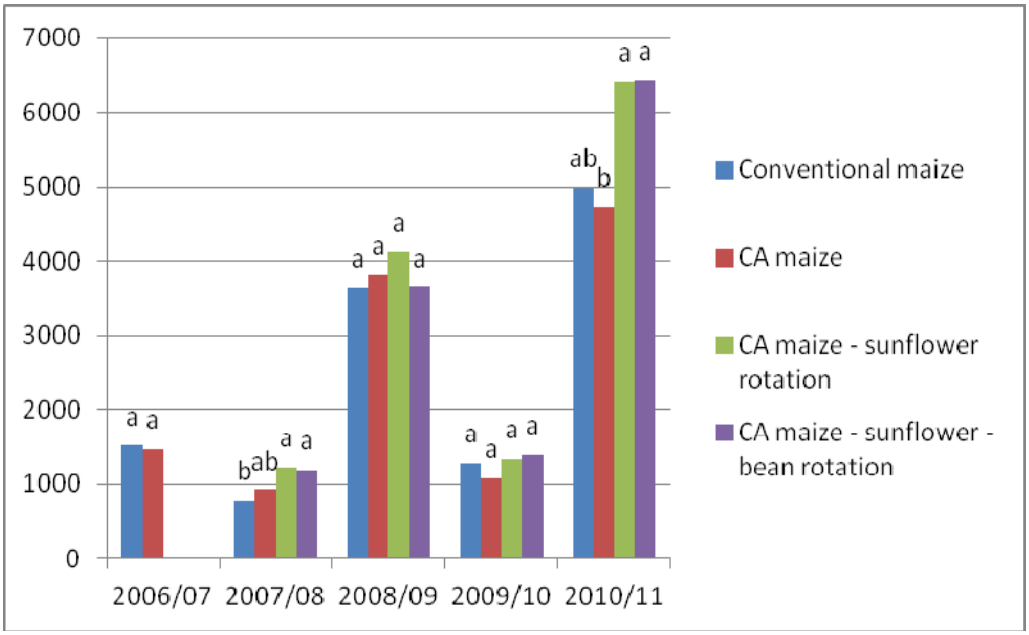
Data supporting CA yield increases in Mozambique remain limited. Many claims of increases in crop yields of CA compare fertilized CA systems with unfertilized "farmer practices" that are sometimes planted late with less than optimal weed control. Many documents provide some basic information about yield differences between conservation agriculture and conventional practices, though often it is only provided for one or two years and many do not control for planting date, weeding effort and inputs used (Table 1). Though there are many CA research and promotional projects being implemented in Mozambique, in reality few agronomic and fertility studies have documented the combined effects of using all three CA principles (minimum soil disturbance, permanent soil cover, and crop rotation) together. Many of the research trials are site-specific and do not provide a broad picture of the limitations and opportunities of conservation agriculture across Mozambique.

Table 1: Summary of yield differences reported between CA and conventional in Mozambique

Source (and location of study)	**Crop**	**CA (kg/ha)**	**Conventional tillage (kg/ha)**	**Comment**
Siambi 2010 - ICRISAT (Gaza)	Maize	1,200	700	Not statistically significant - few replications, many years no difference b/w CA and conv.
Ncube et al 2008 (Chokwe, Gaza)	Maize	111	14	Not statistically significant
	Cowpea	121	92	
Camba (2007) (Limpopo basin, Gaza)	Maize	245	200	Modeled estimate of mulch benefit
Thierfelder et al (2012) (Sussendenga, Manica)	Maize	See Table 2 below	See Table 2 below	Rainfall causes year to year variation, yield increases with multiple components over several years
Famba 2011 (Sussendenga, Manica)	Maize	No difference		Termites as problem
Nhancale (2000) (Manica)	Maize	3,300	2,000	No increase in costs
Zandamela et al (2006) PROMEC (Sofala)	Maize	800	1,000	No replications mentioned
Grabowski (2011) (Angonia, Tete)	Maize	1450-1,660	700	Not controlled for inputs which were higher for CA plots
Dambiro et al (2011) (Cabo Delgado)	Maize	3,200	800	Different years - no control
	Cowpea	1,700	600	
Zandamela et al (2006) CARE (Nampula)	Maize	2,500	1,600	For year 2003/04, unclear how many replications if any.
	Groundnuts	1,050	700	

Following the onset of CA, several dynamic soil processes alter the soil microbiological communities that gradually affect the soil physical properties. These processes are poorly understood until several seasons have passed and measurements such as total soil carbon (C) validate the effect of CA. These results are elusive due to few long-term trials (only at Sussendenga, Manica) and C measurements that only include C on a mass basis rather than a volume basis. This is problematic because converting from tillage to CA will often change the bulk density so the amount of soil being analyzed will vary. During conversion to no-tillage bulk density may increase in the short-term (McCarty et al., 1998), but then decrease after several years.

Figure 2: Long term results of CA maize yields (kg/ha) at Sussendenga Research Station, Manica



Source: Thierfelder et al., 2012

B. Soil changes with CA and legumes

Few studies in Mozambique directly document the biophysical changes observed from integrating legumes into the conservation agriculture system but the indirect effects on yields and labor have been documented in some studies. Rusinamhodzi et al. (2012) analyzed yield and labor requirements for intercropping maize with pigeon pea or cowpeas using either an in-row intercrop (legumes between maize plants in the same row) or an alternate row pattern (separate maize rows and legume rows) in Manica province. They found positive land equivalent ratios (LER) from intercropping and reduced risk of crop failure. Similarly LERs of 1-2 were found for maize groundnut intercrops in Maputo province (Eliseu, 1991). Siambi (2010) also analyzed maize pigeon pea intercropping in Gaza province and found no reduction in maize yields due to the presence of the pigeon pea but no LER is reported. In a CARE final project report (Sampath, 2010) for Inhambane there is some information about soil nutrients with cover crops. The report states that soil N increased and soil P decreased with the cover crop over three years but not

enough details about the soil test methodology or the characteristics of the soil are provided to understand if these findings were meaningful for crop production.

The introduction of legumes into maize-based systems may further increase carbon sequestration in the soil and increase soil nitrogen (N) status, but these effects will vary depending on the legume, the soils, and climate. The impact of legumes with a low C/N ratio (and thus relatively fast rate of decomposition) may be short lived compared to non-legume species with a higher C/N ratio. If the legume selected is a grain legume, a significant amount of the fixed nitrogen can be removed with the harvest. For example, in a study of cowpeas (Vigna unguiculata L.) in West Africa the average amount of nitrogen fixed was estimated at about 22 kg N ha^{-1} but 70 percent was removed with the grain which depending on the variety resulted in a nitrogen balance of between -10.6 and +7.7 kg N ha^{-1} (Sanginga et al., 2000). Studies are needed to better understand the trade-off between including legumes and non-legumes in the cropping system. In some situations, the inclusion of non-legume species may be more beneficial because they provide more persistent soil cover and greater benefits associated with increased carbon sequestration.

Many of the CA studies were conducted in central Mozambique (Manica, Sofala and Tete) on relatively productive soils which are not representative of other parts of the country, especially the sandy soils of the coastal plain. There is a need to research the effect of CA on soil quality in more challenging environments such as the sandy coastal plains, where agriculture is also the main livelihood strategy for many households. The performance of CA technologies must be assessed in contrasting soils and agro-ecological conditions to have a better understanding of how it can best be employed across the diverse agro-ecological contexts of Mozambique.

C. Water dynamics with CA

Conservation agriculture has been demonstrated to improve soil quality through the gradual increase in soil organic matter content which results in improvements in soil physical, chemical and biological properties. Improvements in soil structure, aggregate stability and other physical properties increase the infiltration of water into the soil profile and thus benefits crop yields during periodic dry spells. Reductions in rainfall runoff have also been showed to reduce soil erosion losses. Improvements in soil physical properties and water dynamics have been observed in studies initiated in Zimbabwe in 2004 (Thierfelder and Wall, 2012) but have not been reported yet in Mozambique.

Thierfelder et al. (2012) summarize agronomic results from 2005 to 2011 of CA maize in rotation and association with different crops in Malawi, Mozambique, Zambia and Zimbabwe and find that rotation with or without legumes improved water infiltration (between 70 and 238%), soil moisture, soil carbon, macro-fauna and crop productivity. Similarly Thierfelder and Nyagumbo (2011) find that CA with rotations increase infiltration and reduce erosion in the same countries. In Mozambique, Famba (2011) showed that CA at Sussendenga research station decreased runoff and erosion. Empirical evidence from ABACO project (Maria et al., no date) indicated significant differences on soil moisture content between conservation agriculture and the conventional system. Measurement with water mark sensors clearly indicated higher soil water content in the

CA system when compared with conventional system in a clay-sandy soil. Niquice (2006) modeled water infiltration with mulch in the Limpopo basin, Gaza and found that in-field water harvesting was insufficient to reduce water stress during maize flowering if there is poor rainfall distribution even if total precipitation was average. It is also reported that the agricultural season can be extended to allow for relay cropping lablab after CA maize in Cabo Delgado, which is only feasible because of the surplus moisture held by the mulch (Dambiro et al., 2011).

Crop -livestock competition for crop residues has made it challenging for farmers to retain mulch in many neighboring countries. In Mozambique cattle population is low in many parts of the country and competition for residues is less of an issue in these areas. Bias and Donovan (2003) report that this is because "during independence and the civil war, livestock herds were decimated and disease currently limits the range of cattle/oxen ownership" (p.87). Exceptions include agro-ecological zones 3 and 6 where many cattle and goats are raised, which Amane and Mlay (2002) describe as unsuitable for agriculture except for livestock production. Rural livelihoods in Gaza province (Zone 3) are primarily based on livestock, though millet and sorghum are also grown there (Bias and Donovan, 2003). FAO's report on CA in this area mentions the expected challenge of livestock grazing for cover crop adoption. There are also areas where cattle are important in Manica province near Sussendenga.

D. Biophysical research gaps

The key research gaps on the biophysical side are as follows:

1. There is a lack of basic agronomic studies (optimal plant populations, planting dates and fertilizer rates) for the different agro-ecological zones in much of Mozambique. In part this lack of basic extension recommendations can be attributed to lack of availability of fertilizer and other inputs in many parts of the country. For CA to be successfully adopted basic agronomic recommendations need to be developed for the different agro-ecological and cropping systems in the country.
2. There are limited scientific studies directly comparing CA and conventional tillage systems in different production systems for the different agro-ecological zones and cropping systems in Mozambique
3. Basic agronomic studies on the performance and integration of different cover or rotation crops in each agro-ecological zone are lacking. Information on optimal plant populations and planting strategies would be valuable to determine which cover crops can best improve soil fertility and reduce weed pressure and how they can be integrated within each farming system.
4. An assessment of different manual reduced tillage and planting systems (basins, jab-planters, dibble sticks, "Chinese" hoe etc.) for different cropping systems in the different agro-ecological zones in the country is lacking. For example, evidence suggests that basins do not perform on sandy soils and farmers need more than one option when it comes to planting.
5. An evaluation of different chemical and non-chemical weed control strategies is needed. While chemical weed control may be effective, the lack of herbicides in many

parts of the country makes investigation of non-chemical weed control systems important.

6. Soil changes under CA with cassava are poorly understood, especially regarding the permanence of SOM after soil disturbance from harvesting.
7. Measurement of crop yield needs to be complemented with changes in soil nutrient status and residue accumulation. For some species crop residues completely disappear in the tropical ecosystem. SOM fractioning may yield valuable data about carbon stocks.
8. Environmental services needs to be quantified. Much of research tends toward CA promotion oriented work rather than understanding the system in broader context.

3. SOCIO-ECONOMIC RESEARCH

In order for an agricultural technology to spread to farmers they must first learn about the technology. Then they can determine if it is economically and socially acceptable given their specific context. While many organizations have promoted CA in Mozambique through demonstrations and trainings there are few socio-economic studies that analyze the effectiveness of the promotional methods or the economic and social acceptability of conservation agriculture.

Many bio-physical studies and project documents mention socio-economic variables hypothesized to be constraining more widespread use of the technology but few thorough analyses have been carried out. It is expected that obtaining a better understanding of the profitability of CA and how it affects household labor and gender roles would help illuminate the constraints to CA adoption thereby enabling adaptations to the technologies that would make adoption more feasible. Though project documents provide some evidence about adoption levels there have been no wide-scale adoption studies. Similarly, little information is available about the long-term livelihood impact of CA adoption.

Table 2: Number of CA documents providing information about key categories of socio-economic information for Mozambique

	Effectiveness of promotional approaches	Profitability	Labor	Gender	Adoption levels	Livelihoods impact
Number of published socio-economic studies	0	2 (Grabowski 2011, Howard et al 2003)	0	0	0	1 (Nkala 2011)
Number of documents providing limited analyses	0	4	9	3 (basic)	15	7

A. Effectiveness of promotional approaches

A variety of promotional models are being used to spread information about conservation agriculture to smallholder farmers in Mozambique but no documents compare the effectiveness of these methods. The most common methods being used include Farmer Field Schools and demonstration plots where CA methods and conventional methods are directly compared.

B. Profitability of conservation agriculture practices including labor requirements

It is reasonable to expect farmers to adopt CA only if it is in their own best interest. Many types of CA require smallholders to invest in commercial inputs or new equipment but little formal analysis of the profitability of these investments has been carried out. In addition, types of CA that do not require commercial inputs may require higher amounts of labor (to make compost, weed and dig basins) as in Grabowski (2011). If the inputs (whether commercial or labor inputs) are greater with CA then yields must increase in order for CA to be more profitable than the conventional system. Alternatively, if CA saves on labor or purchased inputs the profitability of the system may be greater than the conventional practices even without yield increases.

<u>Overall profitability assessments</u>

Howard et al. (2003) provide an assessment of the profitability of high input maize production in Manica and Nampula as promoted by Sasakawa Global 2000 for the years 1997 and 1998. Farmers in the program received 15kg of improved OPVs and 50kg each of 12-24-12 NPK and Urea and planted at 50,000 plants per hectare. Though CA is not mentioned in the study much of SG2000's maize production in Mozambique used reduced tillage and used the same levels of fertilizer as in the study. The results indicate that high input maize production did not have significantly higher profitability than low income maize production and it was riskier - with the lowest yielding farmers losing $21-$45 per hectare.

Grabowski (2011) developed detailed labor, input and yield data for 18 CA maize farmers in one community in Angonia in order to understand why farmers were only using CA on plots where NGOs provided inputs. The results show that the prices for herbicides were too high to be profitable when compared with paying laborers to weed. Farmers preferred using their limited cash to buy fertilizer for their potatoes, presumably because they earn greater returns than applying it to maize. Compost production was too labor intensive to make it a profitable alternative to fertilizer at a large scale. Labor increases for digging basins, weeding and making compost meant that farmers would only use CA at a small scale where the opportunity cost of their labor was negligible.

Nhancale (2000) provides some profitability calculations of maize production in Manica. In this study total production costs were the same between CA and conventional but yields were 50% higher with CA making it more profitable.

Profitability of legume use

Rotations or intercrops with legumes are an important part of CA but without adequate markets to sell legumes farmers are unlikely to dedicate a third of their land to legume production. Rusinamhodzi et al. (2011) mention the importance of a market linkage for selling legumes in order to allow for intercropping. Similarly, in Thierfelder et al. (2012) rotations with legumes were less profitable than maize because of poor market prices.

Labor changes with CA

No large scale studies have been done to compare how labor requirements change from the conventional practices when CA is adopted in Mozambique. Grabowski (2011) provides detailed labor information from a few farmers in Angonia to allow a rough comparison between basins with compost, direct seeding with fertilizer and herbicides, and the conventional ridged intercrop (Table 5).

Weeding labor with CA is generally higher than conventional unless herbicides are used (Thierfelder and Wall, 2009; Grabowski, 2011). Rusinamhodzi et al. (2011) found the labor required for weeding increased when maize was intercropped with pigeon pea and cowpea. Weeds have been successfully controlled without herbicides in Mozambican CA projects through the use of cover crops (Taimo et al., 2005) and through the use of a thick layer of grass mulch (Dambiro et al., 2011). The labor required to collect and apply this mulch may be onerous to farmers (Nhaca, no date) and under certain conditions biomass may be limiting (Grabowski, 2011).

Nhancale (2000) found that 23% of farmers claimed CA was labor saving and that overall it saves 60% on total hours required per hectare. However, Nhancale (2000) does mention that CA land preparation requires more work and is tedious because of the many basins per hectare. In Angonia CA practices required higher labor requirements overall but less time on the physically demanding tasks where soil movement is required (Grabowski, 2011).

For horticulture there appears to be reduced labor in watering because of mulch (Nhaca, 2010). Taimo et al (2005) provide some illustrative data about onion production under irrigation comparing CA and conventional. Under CA land preparation labor went down from 45 days to 7, the number of weedings before harvest decreased from 14 to none with mulching, and irrigation frequency was able to be reduced from 3 times per week to 1 time per week.

Table 3. Maize yield and labor requirements by task for conservation agriculture (CA) and conventional systems from Grabowski and Kerr (forthcoming)

	CA Direct seeding (Angonia)	**CA Basins (Angonia)**	**CA Basins (Zimbabwe)**	**Ridged Intercrop (Angonia)**	**Conventional (Malawi)**
Number of plots	9	6	232	2	186
Yield (ton/ha)	1.66	1.2	1.78	0.7	0.90
Plot size (ha)	0.18	0.08	0.2	0.72	-
Land preparation and planting (hours/ha)	317	498	169	341	704[a]
Weeding (hours/ha)	262	663	336	440	520
Fertilizing (hours/ha)	230	175	95	0	56
Mulching (hours/ha)	274	270	77	122	0[a]
Harvesting (hours/ha)	195	164	56	77	136
Total (hours/ha)	**1278**	**1770**	**733**	**980**	**1416**
Power tasks (hours/ha)[b]	0	205	126	404	712
Labor per ton (hours/ton)	770	1475	412	1395	1564

Sources: Conservation agriculture data and ridged intercrop data are from Grabowski (2011). Conservation agriculture data from Zimbabwe are from Mazvimavi and Twomlow (2009). Conventional agriculture data for Malawi ridged maize are from Takane (2008).

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

[b] Ridge-making, banking and digging basins were regarded as tasks requiring greater physical exertion.

C. Gender

There are hardly any studies that even mention considering the impact of conservation agriculture from a gendered perspective. This is expected to be an important aspect of CA's social acceptability because of the key role of women in smallholder agriculture in Mozambique. No difference in labor by gender was found in Nhaca (no date) and Grabowski (2011) because there all tasks on CA plots were shared equally by men and women. However this may be because extra care was given to CA plots. In that case gendered labor differences could still be constraining CA use at a large scale. The national peasants' union (UNAC) has carried out major projects to promote greater gender equality among smallholders. In a recent evaluation of its work in Inhambane (which included CA) Mattick (no date) documents high female participation but unequal control of project resources. Even projects directly addressing gender concerns are facing limited success in achieving equitable gender outcomes. Therefore, it seems likely that projects

ignoring the gendered elements of agricultural change (especially labor) will fail to address the needs of female farmers and may even unintentionally have a negative impact on female farmers.

D. Adoption levels

Despite the fact that CA has been promoted in Mozambique since the 1990's there are no thorough adoption studies that can provide an aggregate picture of CA use at the national level. Assessment of the factors that correlate with CA adoption could facilitate the development of policies to enable more widespread adoption of CA by smallholder farmers.

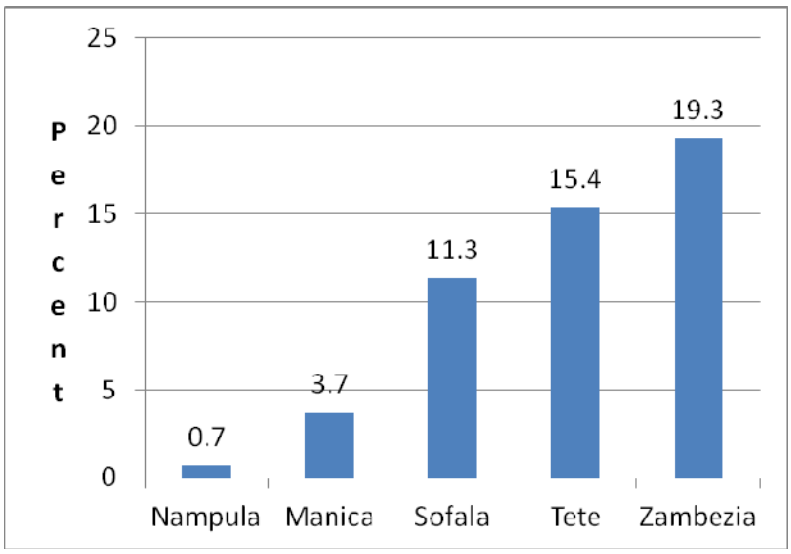
Some projects have data on adoption for their specific areas but it is often difficult to interpret that information in a meaningful way. For example the PROMEC project in Sofala reports having trained 1200 farmers but there is little data on farmers' actual practices (Taimo et al, 2005). In a survey of 29 farmers in Chókwè about water harvesting techniques 21% were using CA basins for water harvesting but there is no description of the sampling for these farmers and it seems unlikely that it was a representative sample (Mamade, 2006).

The SIMLESA project carried out a baseline survey in 2011 indicating 23% of farmers use conservation agriculture (SIMLESA, 2012; Cachombe and Menale, 2012) but this is likely due to sampling communities where CIMMYT had already been working. In fact a University of Tennessee survey of the same area found only 6.8% of farmers in communities exposed to CA training were using minimum or zero tillage (McNair et al., 2012) which suggests that the aggregate adoption level for those districts is much lower. This highlights the need to have well designed studies and properly executed surveys when collecting data for social and economic studies.

CARE's final project report (2011) for Inhambane has detailed adoption information by technology for the 15,000 farmers involved in that project (mulching (66%), cover crop use (77%) and legume intercropping (88%)). However, only 30% of farmers tried the basins because they said that they were too labor intensive and collapsed too easily in the sandy soils (Sampath, 2011). This finding highlights the need to conduct site-specific research with farmers that offer farmers a variety of options for the main components of the CA system (planting with minimum soil disturbance, weeding, rotations etc.).

Plans are underway to include questions about conservation agriculture in the next national agricultural survey which could allow for a better understanding of overall CA use in the country. In fact farm household data were collected on CA practices in selected high potential districts in the center and north (parts of five provinces) in 2011 (MSU/MINAG 2011 Panel Study) through a survey on price dynamics but the high levels of adoption reported (Figure 3) are not consistent with expectations. It is likely that the questions were not well understood and for this reason, interviewers will use photographs when asking the questions in future surveys to clarify what is meant by CA.

Figure 3: Use of Minimum Tillage in central and northern Mozambique in 2010/11 agricultural season



Source: MINAG/MSU Partial Panel Surveys 2008 and 2011 presented in Mouzinho (forthcoming)

E. Livelihood impacts

The only author whose research focuses on the livelihood impacts of CA is Nkala whose dissertation and 2 publications provide at least a theoretical framework and some initial data on this topic. Nkala (2012) explored the link between CA and livelihoods in three villages in Manica province documenting the vulnerability of many households and some productivity gains from CA. The data are not very informative because the survey directly asked farmers simple yes/no questions about improvements in their food security and livelihoods. Stronger evidence could be derived from panel data on consumption or food stocks over time during the course of adopting CA. Nevertheless Nkala makes many useful insights about CA and livelihoods. For example Nkala emphasizes how farmers are actively redesigning CA packages to fit their needs and asserts that a participatory approach to adapting the technology is more appropriate than a technology transfer approach.

A recent survey in Angonia found that CA farmers on the whole bought less maize and sold more maize than non-CA farmers, suggesting that CA may increase food security (McNair et al., 2012). This initial analysis however, did not control for a variety of other factors that are likely to correlate with CA adoption, which may explain the increased level of maize sales. For example the report notes that CA farmers on average have a larger household size and are more likely to be headed by a male (McNair et al., 2012)

F. Hypothesized Constraints to adoption

In addition to the above categories there are a number of other issues that may be constraining adoption. Most documents on CA in Mozambique put forth some ideas about what may be constraining widespread use of the technology. Some of the most common suggestions are briefly outlined here.

Competition for Residue by Livestock

Though livestock populations are relatively low in Mozambique there are parts of the country where livestock production is important and where the competition for residues between livestock and CA may be constraining adoption. Thierfelder et al. (2012) observe that in areas of limited crop–livestock competition farmers have fewer difficulties adopting CA because they can retain crop residues in situ. In Chicualacuala Midgely et al. (2012) note that farmers have invested in ox-plowing and the benefits they experience from renting their animals out creates resistance to CA. In addition they note that free range cattle hinder the use of cover crops. Likewise, Rusinamhodzi et al (2011) saw livestock as a problem for late maturing pigeon pea.

Lack of easy and affordable access to inputs

In many of the CIMMYT and IIAM initiated CA demonstrations in Manica and Sofala provinces few if any farmers appear to be adopting CA on their own fields. Researchers posit that the lack of adoption relates to the unavailability of inputs (fertilizers, herbicides, insecticides and improved seed) and seeding equipment (jab planters, or animal traction direct seeders) and the lack of markets for their surpluses (for example, cowpeas are grown as part of the rotations but are not preferred food). Where inputs are available (in Chimoio town) they are very expensive and without access to small-loans or other credit facilities farmers are unable to purchase them.

Currently fertilizer is largely unavailable to smallholder farmers in Mozambique. Where it is available it is very expensive. For example in February 2012, Agro Focus in Beira was selling a 50kg of urea and 12-24-12 for about US$80 (or about $1,600 per ton). The Mozambique Fertilizer Company is importing and blending fertilizers near Chimoio (primarily for tobacco and sugar companies) where prices were about half that quoted in Beira. The following nitrogen fertilizers were available in February 2012: urea, ammonium sulphate and lime ammonium nitrate for 1000, 900 and 750 MT per 50 kg bag. Sulfate and muriate of potash was also available (at 1350 and 1100 MT per bag) and single super phosphate (800 MT per bag).

In addition to fertilizers, there is a need to find suppliers of legume seed to be used in the CA rotations. Phoenix Seeds in Vanduzi imports seed from Zimbabwe, Zambia and South Africa including soybean, sunhemp, pigeon pea and cow pea. There is a need to test the imported varieties alongside some of the local varieties at different agro-ecological zones.

While many of these inputs are not specific to CA, the difficulty smallholders' face in obtaining them does impact their ability to change to CA systems. Increased availability of fertilizer, insecticides and legume seeds would likely benefit many non-CA farmers as well as making CA more profitable.

Land tenure

Where there is insecure land tenure farmers may be unwilling to invest in improving soil quality over the long term through CA practices. Informal tenure systems may be adequate in many situations but this may not be the case where farmers are losing control of the land due to corrupt

private titling. This issue would be more of a concern where land availability is limited. This issues has not been assessed in the CA research in Mozambique.

G. Socio-economic Research Gaps

The gaps in the socio-economic research on CA in Mozambique are as follows:

1. One of the first priorities is to better understand farmer decision making about CA in each farming system of a given agro-ecological zone. This type of study would compare the profitability and riskiness of CA relative to the conventional system of production including thorough analysis of labor changes by season and gender impacts
2. Another useful set of studies would document in greater detail how CA is being promoted with farmers and the relative successes of different extension/education approaches including cost-effectiveness and the long-term benefits of building farmers' capacity to learn and adapt.
3. Studies on disadoption and reasons for limited adoption could help organizations that are promoting CA understand the barriers and constraints to more widespread adoption. Special attention should be given to considering how gender relations and labor allocation are affected by CA and how gender differences may be affecting CA adoption rates.
4. Eventually a large scale adoption study would be useful for charting progress on CA across the country. Ideally this type of study would not only document adoption levels but characterize adopters and non-adopters.
5. Over the long term it would be useful to develop panel data on farmers' assets and food security as well as field level soil and cropping characteristics, starting in a new area before farmers use CA and continuing over the course of 5 or more years.

4. CONCLUSIONS AND IMPLICATIONS

Despite many years of CA research and promotion there are still major knowledge gaps about how CA principles can be successfully applied to improve smallholder agriculture across Mozambique. The evidence from the available studies and reports about CA in Mozambique, when supplemented with studies from neighboring countries, suggests that conservation agriculture does have potential to sustainably improve smallholder agriculture but many obstacles need to be overcome for its use to be widespread. The diverse agro-ecological and socio-economic conditions across the country imply that CA technologies need to be locally adapted in order for wide-scale adoption to be at all possible. Local level collaboration between researchers, extension, NGOs, the private sector and smallholder farmers has the potential to close some of these gaps through the sharing of experiences. Both localized and national level CA efforts could greatly benefit from scientific research on the biophysical changes associated with CA and the socio-economic conditions required for it to be successful. This report highlights some of the most important research gaps that need to be addressed in order for the potential of CA for smallholder agriculture to be realized.

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