University of Reading

Economics and Adoption of Conservation Agriculture in Cabo Delgado, Mozambique

PhD Livelihoods (International Development and Applied Economics)

School of Agriculture, Policy and Development

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Declaration I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Abstract

Conservation Agriculture (CA) is an agro-ecological approach to sustainable production intensification. Low rates of adoption have plagued Sub-Saharan-Africa despite years of promotion. A polarised debate has emerged centred on the farm-level costs/benefits (particularly for the poorest farmers), including when benefits occur, labour requirements (including weeding) and in particular whether CA requires high inputs.

The thesis draws on a household survey of 197 farmers in Metuge district (Cabo Delgado, Mozambique) in tandem with participatory stakeholder interviews administered in 2014. Probabilistic cash flow analysis compares CA and conventional cropping for different crop mixes and planning horizons. Secondly, a socio-psychological model explores intention to use CA. A novel Monte-Carlo Markov chain algorithm using socio-psychological factors and conventional determinants of adoption is also incorporated in order to explore adoption dynamics.

The thesis finds evidence of benefits for the poorest farmers and in the short-term under CA (without high inputs) but which are dependent on crop mix and opportunity cost of labour assumed. Socio-psychological factors play a strong role in the adoption process; farmers' attitude is found to be the strongest predictor of intention to use CA mediated through key cognitive drivers such as increased yields, reduction in labour, improvement in soil quality and reduction in weeds (which are precisely the areas of current contention). Interestingly, Farmer Field School participants have a significantly stronger positive attitude towards CA.

The employment of the novel Monte-Carlo estimation (as do the stakeholder interviews) also identify Farmer Field School membership, the role of village facilitators in engaging with farmers on CA and willingness to be part of a group play an important role in adoption. Importance of labour reduction, soil quality improvement and perceptions of pests also significantly influence adoption suggesting social learning interactions (taking account of these issues) vis-à-vis an appropriate innovation system are critical to CA usage.

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Abbreviations

Information Communication Technologies (ICT)

Aga Khan Foundation (AKF)

Non-Governmental Organisations (NGOs)

Farmer Field Schools (FFS)

FAO (Food and Agriculture Organisation of the United Nations)

CGIAR (Consultive Group for International Agriculture Research)

World Wildlife Fund (WWF)

SDAE (Agriculture directorate i.e. Agriculture extension)

VDO (Village Development Organisation)

NARS (National Agricultural Research System)

Community Based Extension (CBE)

Innovation Platforms (IP’s)

Associação Meio Ambiente (AMA)

Sub-Saharan Africa (SSA)

Chapter 1: Introduction

This thesis is comprised of a series of papers (of which some have been published, are under review or being finalised for submission) presented as chapters in between an introductory chapter and a concluding chapter.

The following outlines the problem statement of the thesis followed by a definition of Conservation Agriculture (CA) and a section on the history of tillage. This is accompanied by a short narrative on the emergence of the two schools of thought, namely no-tillage as opposed to tillage agriculture and the genesis of CA. An overview of CA adoption worldwide, disaggregated by region is then provided followed by an overview of the literature which outlines key debates within the CA literature. The final section of this chapter presents background to the study area and the specific research objectives and questions of the thesis to be addressed. It will also briefly explain the methodological approaches taken. This will include an explanation of each papers' contribution to the specific research question/objectives stated.

Problem statement

In 2050, it is estimated that the world's population will be close to 9 billion (UN, 2006; Alexandratos, 2005). Many scholars have shown future food trends in light of population growth to be positive (Dyson, 2000; Alexandratos 2005). This being said 'winners' and 'losers' are envisaged and it is estimated that the Middle East and Sub-Saharan Africa, will face the most serious food shortages not least because of their high demographic growth, but also their stagnant /declining cereal growth rates and subsequent dependency on cereal imports (Dyson, 2000). With increases in incomes and higher rates of urbanization (increase in total proportion of the population living in urban areas) dietary changes are likely to occur as more individuals will demand different types of food such as meat and this will also change many farming systems (Pretty, 2008).

The complex interaction of population growth, technological advancement and climate change have impacted heavily on agricultural and environmental sustainability. Modern farming systems that are used throughout the industrialized world have been characterized by high use of inputs and mechanization of agriculture. Some proponents argue that technological progress and conversion to high-input agriculture has caused rapid loss to agricultural biodiversity (Jackson et al., 2005). For example, the destruction of wilderness and biodiversity as a result of population growth and economic growth; accumulation of pesticides, residues and damage to water quality to mention a few (Goklany, 1998). However, it is also true that technological advancements through new forms of agricultural research have resulted in many parts of the wilderness being saved and thereby forsaking the need to bring new areas into cultivation (Treverwas, 2001). Many, thus, propose that improving efficiencies of water, nutrients and mechanization with the aid of genetically modified cultivars will provide the improvements in food production necessary to meet future demands. Proponents also contend that improving the productivity of land on the most fertile soils provides a win-win situation as marginal lands where biodiversity is often highest can be conserved to preserve vital germplasm that may be needed for the future (Huston, 1995; Brussard et al. 2010). Notwithstanding the potential to increase food production through conventional intensive agriculture it has been well documented that such agricultural systems are a source of significant environmental harm (Tilman 1999; Pretty et al. 2000). Moreover, other authors have noted that land management systems applied in many areas of the world including the semi-arid areas are damaging soils and limiting their capacity to generate rising yields on a sustainable basis (FAO, 2008).

Consequently a ‘business as usual’ approach to agricultural development is seen as one which will be inadequate to deliver sustainable intensification production for future needs (Shakson, 2006). Thus, the discourse on agricultural sustainability now contends that systems high in sustainability are those that make best use of the environment whilst protecting its assets (Pretty, 2008). For example, harnessing genetic potential of plants, animals and other scientific developments without causing undue harm to the environment.

A number of other technologies and agriculture practices are now termed pro-agrobiodiversity and attempt to increase overall agricultural sustainability. For example, Integrated Pest Management (IPM), conservation tillage (low tillage) and agroforestry. Many of these technologies are multifunctional in that they lead to positive gains in a number of areas within the agroecosystem such as nitrogen fixing legumes prevent pests and diseases as well as contribute to improvements in productivity (ibid). Similarly, there have been notable positive spin-offs found from the adoption of agricultural sustainable farming options on a number of domains. Ostrum (1990) and Pretty (2003) have shown that in a number of developing country contexts that adoption of sustainable agricultural practices/technologies has led to improvements in natural capital (positive water table and higher water retention); better social capital (more social organization and better connectedness to political institutions) and advancement in human capital (reverse migration and positive child and health nutrition particularly in dry seasons).

CA now forms part of this alternative paradigm to agricultural production systems approaches. Some have referred to this alternative form of agriculture as the ‘biological and ecosystems’ paradigm (Kassam and Friedrich, 2010) or alternatively the eco-agriculture approach (Brussard et al., 2010). In this approach, land provides a wide array of ecosystem system services which have a bearing on social welfare from the wellbeing of local people to that of the world community (e.g. carbon sequestration) (ibid). It has also been argued that it provides the best method for sustainable agriculture development (Friedrich and Kassam, 2009; Kassam et al., 2009). Furthermore, in a comparative study assessing the impact of a number of other conservation technologies (CA being one) in terms of financial net returns at the farm level and agronomic benefits CA was found to be the most beneficial (FAO, 2001).

Research has shown that CA can make a significant contribution to sustainable production intensification (including agricultural land restoration) and can meet future food needs for future human populations (Uphoff et al., 2006; FAO, 2008; Pretty, 2008; Kassam et al., 2009, FAO, 2010). However, to date in much of the developing world including Sub-Saharan Africa (SSA) and the Mediterranean environments, despite a long history of research and positive results there have only been small rates of adoption (Kassam and Friedrich, 2010).

What is Conservation Agriculture?

CA has been defined as: (i) *Minimum Soil Disturbance*: Minimum soil disturbance refers to low disturbance no-tillage and direct seeding. The disturbed area must be less than 15 cm wide or less than 25% of the cropped area (whichever is lower). There should be no periodic tillage that disturbs a greater area than the aforementioned limits. (ii) *Organic soil cover*: Three categories are distinguished: 30-60%, >60-90% and >90% ground cover, measured immediately after the direct seeding operation. Area with less than 30% cover is not considered as CA. (iii). *Crop rotation/association*: Rotations/associations should involve at least 3 different crops (FAO, 2012).

Over the past decades different terms have emerged from No tillage to conservation tillage and minimum tillage. Many of these have been ascribed to CA. However, CA is more than just purely no tillage; it is, as mentioned above, as the simultaneous application of all three principles (FAO, 2012). A wide variety of the differing typologies have also been defined and discussed (See Kassam et al., 2009) though the definition provided by the FAO is one which is widely used and also used by the recently formed CA-COP (Community of Practice).

The simultaneous application of all three principles is also an important feature. For example, the use of rotations contributes to improvements in biodiversity (within and above soil) which leads to more available nitrogen for plants and reduces pest populations. The addition of permanent organic soil cover i.e. retention of crop residues as opposed to burning the residues, for instance, increases organic matter in the soil and improves provision of water and nutrients to plant roots ‘on demand’ (Kassam et al., 2009). This is a key factor in improving and maintaining yields. Finally, tillage tends to accelerate ‘oxidative breakdown’ (as explained in the next section) of organic matter which increases the release of Carbon dioxide to the atmosphere, which is beyond those normally associated with soil respiration purposes (Kassam et al., 2009)

The following outlines the history of tillage coupled with the emergence of the no-till school of thought and the emergence of CA.

So why till?-The history of tillage

Tillage dates back many millennia to the epoch of humanity’s settled agricultural existence in Tigris, Euphrates, Nile, Yangtze and the Indus River (Hillel, 1998). Numerous varieties of tillage tools were created which ranged from simple digging sticks to hoes that were drawn by animals. It is thought that the first initial plough named the ‘ard’ was created in Mesopotamia between 4000 to 5000 BC. The romans developed this further with an iron plough after which the soil-inverting plough was created during the 8th to 10th century AD. Further developments include the heavy plough and the mouldboard plough used in the US which was created in the late 18th century. It was developed into a cast iron plough and marketed by John Deere in the 1830’s (Lal, 2007).

Mass adoption of tillage, however, occurred at the start of the industrial revolution at the end of the nineteenth century. Through mechanization, tractors and so forth, tillage became widely available (Hobbs et al 2008). This was largely aided by the advent of the steam horse in the early part of the 20th century (Lal, 2007). By 1940, there were almost 2 million tractors in use within the United States which contributed to a dramatic increase in farm incomes (Danbom, 1995).

Hobbs et al (2008) summarises the historical justification for using tillage. Firstly, tillage was used as a method to soften soil so that a seedbed can be prepared after which seed can be easily placed in moist soil to allow for good germination. Secondly, as crops and weeds compete for water and nutrients, tilling would reduce the ability for weeds to do this early in the crop growth cycle. Thirdly, tillage helped to hasten the rate of soil organic matter oxidation and mineralization through releasing soil nutrients vital for crop growth. Fourthly, crop residues from the previous crop were buried into the soil along with organic or inorganic fertiliser thus allowing for more nutrients to be available to the soil. Fifthly, tillage enabled the temporary breakup of the compact layer found in the soil. Finally, that tillage was thought to play a critical role in controlling soil-borne pests and pathogens.

Although there have been clear benefits from tillage including increased yields from improved soil fertility and agronomic productivity, many commentators have argued that it has brought about mixed fortunes as it did not consider the impact on the environment and the natural resource base (Hobbs et al 2008; Lal, 2007).

Previous work has shown of the remarkable role that earthworms played in the formation of soil. It was in fact Charles Darwin that showed that long before the plough land was regularly ploughed by worms. Worms in fact help to make soil by "*slowly plowing, breaking up, reworking and mixing dirt derived from fresh rocks with recycled organic matter*" (Montgomery, 2007, Pg. 11).

What does tillage do then? One might ask. In fact, tillage both reduces the number of earthworms and soil dwelling organisms (Montgomery, 2007). Lal (2007) further postulates that ploughing causes a decline in soil structure and that it exacerbates wind and water erosion. This is largely because the soil is loosened and crop residue buried, which enables rainfall to wash away vital nutrients for plant growth from the soil for the soil. This is primarily because of the confounding effects of soil organic matter oxidation and mineralization. On the one hand it helps to release vital nutrients to the soil but also decreases the concentration of soil organic matter (ibid). Thus, contrary to the justification mentioned above, there is also evidence to indicate that tillage and conventional mono-cropping leads to an increase in soil borne pests, reducing vital soil fauna. It has thus been argued that soil degradation, as a consequence of long-term tillage, has been responsible for the destruction of civilisations through history (Montogomery, 2007).

The emergence of the no-till school of thought and CA

The "dust bowl" era which occurred during the 1930's in the American Great Plains largely brought the issue of soil erosion to the forefront. The role of intensive tillage combined with regional drought is considered the main cause (Lal, 2007: Field et al., 2009). It is estimated that this caused the degradation of 91million hectares of land (Utz et al., 1938) and loss of approximately 800 million metric tons of topsoil (Johnson, 1947; Hansen and Libecap, 2004)
It was not until the 1940's, however, where the role of tillage was questioned. Edward H. Faulkner in a manuscript entitled: 'The Ploughman's Folly' questioned the scientific basis for tillage arguing:

"*In all truth, the ultimate scientific reason for the use of the plough has yet to be advanced. If I were advising farmers on the subject of ploughing, my categorical statement would be Don't -- and for that position there is really scientific warrant*." (Faulkner, 1942).

It was from this point that two schools emerged namely the no-till movement and those advocating the use of the plough. The no till movement took off in the 1960's, although not widely used in the U.S it began to take up prominence in other parts of the world including Latin America. It was not until the 1970's in Brazil where the genesis of what today is called CA was formed. Together with scientists, farmers transformed merely no-tillage farming into CA. Experimentation also took hold in other parts of the world such as with no tillage and mulching in West-Africa (Greenland, 1975; Lal, 1975, 1976). CA began to spread significantly in the 1990's across South America and international research centres such as FAO and CGIAR centres also began to show interest. Study tours to Brazil and regional workshops in different parts of the world lead to increased adoption and awareness across the globe including in Asia, Central Asia and African countries such as Zambia, Tanzania and Kenya. In the 2000s industrialised countries (e.g. Canada, Australia, Spain and Finland) also saw increased adoption of CA and interest in an integrated farming concept rather than merely no-tillage or conservation-tillage. There continues to be locally adapted improvements to the system by farmers and researchers alike (Friedrich et al., 2012).

The following provides a detailed overview of the worldwide adoption of CA and regional distribution to date.

Overview of worldwide adoption of Conservation Agriculture

CA is now practiced on more than 125 million hectares worldwide across all continents and ecologies (Friedrich et al 2012). Table 1 shows the breakdown of the extent of adoption (i.e. in this case land area under CA) by country. The adoption of CA has grown exponentially in the past decades. It is estimated that CA adoption in 1973/74 was only 2.4 million hectares worldwide. By the end of the nineties this has grown to 45 million hectares. In the last 11 years alone CA has expanded at about 7 million hectares per year (Friedrich et al., 2012).

Table 1. Extent of Adoption of CA by 2011 Worldwide (countries with > 100,000 ha)

Country	CA area (ha)
USA	26,500,000
Argentina	25,553,000
Brazil	25,502,000
Australia	17,000,000
Canada	13,481,000
Russia	4,500,000
China	3,100,000
Paraguay	2,400,000
Kazakhstan	1,600,000
Bolivia	706,000
Uruguay	655,100
Spain	650,000
Ukraine	600,000
South Africa	368,000
Venezuela	300,000
France	200,000
Zambia	200,000
Chile	180,000
New Zealand	162,000
Finland	160,000
Mozambique	152,000
United Kingdom	150,000
Zimbabwe	139,300
Colombia	127,000
Others	409,440
Total	124,794,840

Source: Adapted from Friedrich et al (2012)

Regional distribution of Conservation Agriculture

CA is now practiced from high rainfall areas in South America (e.g. Brazil and Chile) to those with very low precipitation (e.g. Western Australia and Morocco) (Friedrich et al 2012). It is also practiced on various farm sizes from smallholders to much larger farmers and on a wide variety of soils from heavy clay to highly sandy (ibid). South America has the highest rate of adoption closely followed by North America (Table 2). Low rates of land coverage under CA are found in Europe and Africa. Overall, however, of the total arable land worldwide, land under tillage still predominates, as CA still only accounts for 9% of the total (ibid).

Table 2 Extent of adoption of CA by continent by 2011

Continent	Area (hectares)	Percent of world total land area under CA
South America	55,464,100	45
North America	39,981,000	32
Australia & New Zealand	17,162,000	14
Asia	4,723,000	4
Russia & Ukraine	5,100,000	3
Europe	1,351,900	1
Africa	1,012,840	1
World total	124,794,840	100

Source: Adapted from Kassam and Friedrich (2012)

A number of reasons for the ‘low adoption’ of CA have been cited including the knowledge intensive nature of the system, the historical prejudice (or mindset of farmers) towards tillage and pervasive government policies in certain countries which have discouraged adoption (ibid). For example, Friedrich et al (2012) cite EU’s direct payments and subsidies to farmers in the US as reasons hindering further adoption of CA in these regions. Furthermore, they note that despite high levels of adoption of CA in Latin America (i.e. here defined as land area under CA), farmers have been encouraged through government subsidies and policies to practice soyabean mono-cropping (which leads to soil erosion). This thereby negates one of the fundamental principles of CA i.e. practicing crop rotation. It is estimated that only half of the area under no tillage in South America is of ‘good quality’ (Friedrich et al., 2012). In the Indo Gangetic plains across India, Pakistan, Nepal and Bangladesh, large adoption of no-till on wheat has occurred but there has been minimal adoption of full CA i.e. simultaneous application of all three principles (ibid).

In SSA despite small rates of adoption and criticism that has argued that CA is not conducive for many small-scale farmers, it is now practiced by more than 400,000 small-scale farmers throughout the region (Friedrich et al., 2012).

Table 3 shows the adoption among countries within Sub-Saharan-Africa. Given the lack of mechanisation in much of Africa direct seeding through a mechanised direct seeder has not been possible and thus farmers rely on other instruments to seed including manual systems and animal led traction. Manual forms include dibble sticks, jab planters or basins.[1] Animal traction is also used whereby a ripper tine opens up a slit in the soil and fertiliser and seed is placed inside (Thierfelder and Wall, 2010). Farmer Field schools (FFS) have also been used to strengthen farmers understanding of the principles of CA and how it can be locally adapted (Friedrich et al., 2012). Within Southern Africa there have been mixed experiences with CA. Positive results have been reported, however, from Zimbabwe (Mashingaidze et al., 2006), Zambia (Haggblade and Tembo, 2003) and Lesotho (Pretty, 1998, 2000).

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[1] CA use with the use of basins is widely used across SSA. Planting basins are a manual seeding CA system originating from the Zai pit system in the Sahel (Lahmar et al., 2012). It was primarily developed to allow better water harvesting i.e. to improve capture of run-off water and thereby improve infiltration (Zougmoure et al., 2014) Brian Oldrieve a Zimbabwean farmer also pioneered the approach through local adaptation in the 1990s (Oldrieve, 1993). CA systems using basins differ to some forms of conservation farming systems used in Zambia and Zimbabwe that require regular soil-tillage inside the basins i.e. minimum tillage systems where tilling is done inside the basins using discs or tines in order to create a seedbed. (See Kassam and Brammer, (2016) and Wall et al., (2013) for an explanation).

Table 3 CA adoption in Sub-Saharan Africa by 2011

Country	CA area (ha)
Ghana	30,000
Kenya	33,000
Lesotho	2,000
Malawi	16,000
Madagascar	6,000
Mozambique	152,000
Namibia	340
South Africa	368,000
Sudan	10,000
Tanzania	25,000
Zambia	200,000
Zimbabwe	139,300
Total	981,640

Source: Adapted from Kassam and Friedrich (2012)

In Mozambique (where this study is based), however, to date despite success in terms of increased productivity and relative production savings, benefits of CA particularly among the poorest has been questioned. (Nkala, 2012).[2]

A more detailed overview of the key issues that have emerged within the CA literature (particularly concerning SSA and Southern Africa) and wider adoption literature is explored in the next section.

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[2] A description of the study area is provided following the literature review section and is given in more detail within each of the chapters.

Literature overview

The low rates of adoption in SSA and Southern Africa (described in the previous section), have contributed to a controversial debate surrounding the benefits of CA for smallholder farmers (both in terms of the private and social benefits accruing from adoption). These include a polarised debate on farm level costs/benefits, carbon sequestration and soil quality improvements. The following section outlines the main debates with respect to the literature on SSA and Southern Africa in particular.

Labour, weeding and organic mulch

It has been well established, even by critics that many of the principles of CA are in itself ‘good agriculture practice’ such as crop rotation and crop residue retention (Giller, 2012) and have ancient origins (Hobbs et al., 2008) Most recently, authors have questioned the mode in which CA is being used as an ‘across-the board’ recommendation to farmers (Giller, 2012), despite other authors stating that it has to be locally tailoured and adapted by farmers and is not a panacea (Thiefelder et al., 2013; Friedrich et al., 2012). Giller (2012), however, vehemently opposes some of the fundamental principles and benefits of CA by stating that:

“ *Many of the benefits of minimum or no-tillage farming — such as carbon sequestration and boosting crop yields — are far from proven…tillage can save labour, allows farmers to plant early and controls weeds. It helps to prevent runoff and erosion if the soil is not protected by mulch, for which smallholder farmers often lack the organic resources*” (Giller, 2012, P41).

Firstly as mentioned above, a distinction has to be made between that of CA and No-tillage. Principles of CA throughout the literature have often been wrongly attributed to No-tillage (Corsi et al., 2012). Secondly, Giller, (2012) advocates tillage, arguing that it saves labour in spite of contrasting research showing that CA in fact increases labour efficiency (FAO, 2011). CA has been shown to reduce labour requirements generally by 50 percent (Friedrich et al., 2012). Similarly, research from Tanzania has also shown that in the fourth year of implementing Zero-tillage, labour requirements fell by more than half (Friedrich and Kienzle, 2007). Lange (2005) has also highlighted the dramatic increase in returns to labour for smallholders in Paraguay under full CA compared to Tillage Agriculture.

Akin to Giller’s arguments (2012; 2009), Baudron et al. (2012) have found for farmers in the Zambezi Valley (Zimbabwe) that lack of availability of labour for weeding, as a consequence of increased weed infestation, is an important factor which reduces the uptake by farmers of

CA. Although it is important to note that they argue that the region is not a microcosm of Southern Africa and therefore it is difficult to extrapolate wider i.e. for Southern Africa as a whole. Rusinamhodzi et al. (2012) have recently shown another example for Southern Africa, namely from central Mozambique which highlighted that the practice of a maize-pigeon pea intercrop under no- tillage increased weeding labour requirement by 36%. Although this was not compared to the same intercrop within a full CA system; rather it was compared to tillage agriculture under monocropping. However, Chauhan et al. (2012) have argued that in general there is a poor understanding of weed dynamics within a CA system which can have a bearing on farmer adoption of CA. The authors argue for more effective and efficient application of herbicide and exploring the potential of inclusion of herbicide tolerant new crop varieties within CA systems. Corsi et al (2012) do make note that one of the impediments to adoption of CA is the knowledge intensive nature of CA which thereby means few farmers are able to adequately set up rotations aimed at improving overall biomass and reducing weed growth in time. Corsi et al. (2012) also provide a number of examples of cover crops which can control invasive weeds such as some species of sorghum help to control Cyperus rotundus. Others play multifunctional roles and can be both nitrogen fixing, help to control weeds and can also provide a source of mulch which can protect the land from grazing, particularly in the dry season, as it is non-edible to cattle.

Giller et al. (2009) also argues that for resource poor farmers particularly in SSA where there is a strong crop-livestock interaction, the lack of mulch due to the priority of left-over crop residues being needed to be fed to livestock as a drawback of CA. There has been some concern particularly in certain agro-ecologies such as the sub-humid and semi-arid climatic zones that a number of challenges to CA exist because of insufficiency in rainfall. For example, issues relating to the limited amount of biomass that can be produced which reduces both the potential of needed cover crop to protect the soil and residues that are vital source of fodder for livestock (Shaxson et al., 2008; Friedrich and Kassam 2009). Managed grazing as a solution to this though has been proposed (Corsi et al., 2012).

Yields, inputs and time-horizon controversies

Does CA use improve yields?

There has been strong debate about whether CA leads to improvements in yield. Giller (2012) has strongly questioned CA’s contribution to ‘boosting of crop yields’ and elsewhere Giller (2009) has further mentioned in more detail that with the adoption of CA there is concern over decreased yields and especially its relevance for resource poor smallholders in SSA.

Thierfelder et al. (2013) finds some substance in the ‘good agronomy’ argument that some detractors of CA have long argued is more important than CA itself (Giller, 2012) e.g. the need for good nutrient management, crop residue retention and adequate nitrogen fertiliser in particular, regardless of tillage provides similar results.

Kassam et al. (2009) has, however, noted that CA as opposed to tillage systems have shown improvements from between 20-120 percent in yields across all continents and agro-ecologies from Asia to Latin America and Africa. In contrast, Thierfelder and Wall (2012), however, found recently in Zimbabwe that although there were no improvements in yield for maize in CA treatments to ploughed treatments there were improvements in some soil quality indicators over time.

A meta-analysis of 610 studies suggested that no-till as opposed to conventional tillage results in a yield penalty of approximately 10% (Pittelkow et al., 2015). However, this does not qualify as CA i.e. simultaneous application of all three principles (Kassam and Brammer, 2016) and when the other principles are used together with no-till i.e. mulching and crop rotation the negative effects are reduced (Pittelkow et al., 2015). Moreover, it has been suggested that CA only has yield benefits relative to conventional agriculture in dry climates (Rusinamhodzi et al., 2011; Pittelkow et al., 2015). Thierfelder et al. (2016) has shown, however, that CA can have benefits across varying agro-ecological zones but are dependent on local adaptations to different environments. For example, direct seeding CA systems provided yield benefits in areas of higher rainfall compared to conventional tillage whereas basins performed least favourably. In contrast, in lower rainfall areas, basins did better than conventional tillage and direct seeding.

Is CA only successful with high inputs?

Other authors although supporting the concept of CA have found increases of yield under CA with the application of mineral fertiliser and have argued that in order to aid the uptake of CA concentrating on farmers with access to mineral fertiliser and herbicides is of paramount importance. For example, it has also been suggested that early adoption of CA requires an increase in herbicide cost which offsets the lower machinery costs, although, recent assessments show that herbicide cost declines over time under CA (Friedrich and Kassam, 2009).

Access to fertiliser and other inputs including herbicides are therefore a contentious issue, with a number of authors arguing that for CA to improve productivity; appropriate fertiliser applications and herbicide applications need to be used (Rusinamhodzi et al., 2011; Thiefelder et al., 2013). Similarly, Nkala et al. (2012) and Grabowski and Kerr (2013) have both argued that without subsidised fertiliser inputs CA adoption will be limited either to only small plots or abandoned altogether. Grabowski and Kerr (2013) having studied CA adopters and disadopters in Angonia, (Mozambique) found that CA was successful on small plots and can improve yields, however, due to capital and labour constraints it is unlikely to be adopted on a large scale.

Wall et al. (2013) found in their review that of the studies with improved yields most were fertilised (including animal manure) and had both retained residues as mulch and employed chemical weed control complemented by hand weeding.

A recent meta-analysis of CA in rainfed semi-arid areas also concluded that in order for yield increments to occur CA needed the aid of high inputs, especially nitrogen fertilisers (Rusinamhodzi et al., 2011). In fact of the 27 studies used in the meta-analysis most were comparing no-tillage to tillage and at the most no-tillage with mulch residue retention but none of the studies cited compared all of the principles of CA i.e. simultaneous application of three principles when comparing the results to tillage agriculture. In contrast, recent research, however, has shown several successful examples of CA throughout Sub-Saharan Africa. One of which in Tanzania, showed maize yields increasing from 1 tonne to 6 tonnes. This was also done without the use of agrochemicals and rather using livestock manure, as a fertiliser (Owenya et al., 2011).

Long term experiments of Franzluebbers (2008) show with minimum soil disturbance there are greater levels of phosphorus, potassium, iron and zinc which enhance soil fertility and stability in yields. Others have noted that CA systems over time require less nitrogen fertiliser for the same output (Corsi et al., 2012). Moreover, it has also been suggested that reducing the need for nitrogen fertiliser through nitrogen fixing legumes will reduce fertiliser application. Boddey et al (2009) found in Southern Brazil, bringing leguminous green manures such as lupins and hairy vetch into a rotation before maize can substitute for nitrogen fertiliser application. Similarly, there is also evidence to show that planting legumes before the main crop leads to much higher yields of the main crop (Franzluebbers, 2007). Notwithstanding increased weed infestation, in Mozambique it has been argued that practicing an intercrop under no tillage improves rainfall infiltration, increases soil carbon, improves soil structure, and yield leading to increased profitability (Rusinamhodzi et al., 2011).

Other long-term on-farm studies have in fact controlled for fertiliser application rates. Rusinamhodzi et al., (2011), found that CA does have added benefits but these are largely found in the long term. A systematic review conducted by Wall et al., (2013) for CA in Eastern and Southern Africa (maize-based systems) also found that of the 40 reports reviewed, yields were generally equal or higher than conventional agriculture. Of the 6 reports from 40 where CA yields were lower than from conventional agriculture, little to no fertiliser was used, and one study was carried out on very poor soils (Wall et al., 2013). Wall et al., (2013) further postulate that adequate soil fertility levels and adequate biomass production is important to achieve successful CA systems. Interestingly, of the 23 reports which reported maize yields of 10% or higher under CA these were found under diverse soil and rainfall types.

Short term vs long term benefits

Other ‘bones of discontent’ with CA are the particular time horizon especially that many of the benefits are likely realised in the long term and that farmers particularly in Sub-Saharan Africa (SSA) are concerned with immediate costs and benefits (such as food security) rather than the future (Giller et al., 2009).

A criticism of most of the published research on CA is that it is based on long-term on-farm trials (with little done on household level studies). This being said, most are positive albeit showing that yield benefits are usually in the long-term and within the short-run, especially within the first few seasons results are variable. Yields under CA may even decrease compared to conventional ploughing, especially in the short run (Thierfelder and Wall, 2012). In addition, Baudron et al. (2012) has, therefore, argued that when analysing the impact of CA farmer profit must be a criterion used rather than merely returns to land and labour.

One comment, however, does seem plausible, although authors have dismissed productivity enhancement particularly in the short-run they fail to look at the effect on the whole farm budget i.e. profit. Rusinamhodzi et al. (2011) has argued that there remain incentives to abandon ploughing because of savings in fuel and labour but these need to be ‘quantified’.

Furthermore, with respect to SSA, Pannell et al., (2014) found there has been scant research in the region on smallholder farmers that delves into farm- level economic analysis of CA with appropriate sophistication. They conclude that there are key deficiencies in much of the economic analysis, to date, including a lack of consideration of the time lags, realistic discount rates, and of appropriate opportunity costs for labour and crop residues.

CA social benefits

CA has also been criticised over its claim over promoting carbon sequestration (Giller, 2012). However, a comprehensive review by Corsi et al. (2012) show that CA allows for higher rates of carbon sequestration when compared to tillage agriculture. Moreover, they cite particular reasons that relate to no carbon sequestration or carbon loss namely: (i) soil disturbance, (ii) monocropping, (iii) specific crop rotations (some rotations yielding more SOC accumulation than others) and (iv) mismanagement of crop residues and v) soil sampling that has been done at a depth of more than 30cm. Thierfelder and Wall (2012) have also shown that in Zimbabwe under sandy soils, direct-seeded CA compared to ploughed treatments had 106% higher Soil carbon in the first 20cm. There are also ancillary benefits to carbon sequestration under CA including reduction in greenhouse gas (GHG) emissions. For example, tillage agriculture uses up to 80 percent more energy than CA (ibid). The authors also argue that CA was found not to have improved soil pH, organic carbon or levels of Soil Phosphorous (Nyamangara et al., 2013). The exact quantification of impact to climate mitigation has also recently been refuted by Powlson at al. (2016) who argue the benefits might be overstated due to improper sampling (focussing on soil depth not equivalent mass) and SOC (soil organic carbon) stock may not increase overall but rather only improve in the surface layer. The authors do contend, however, the practice of crop diversification (as the focus to improve carbon sequestration) rather than merely no-till and mulching deserves more attention and has more scope in contributing to climate change mitigation.

It is argued that benefits of CA need to include the numerous social benefits (positive externalities) that result from adoption. For example, improved soil moisture retention under CA has been found to result in a 30% water saving compared to conventional tillage based systems (Bot and Benites, 2005). Additionally, there are other potential social benefits as better infiltration rates of water into the soil, reduce run-off loses of excess water and provide replenishment of groundwater and a more steady flow of rivers and wells even in the dryer months of the year (Kassam et al., 2009).

Voluntary payments for ecosystem services have been initiated in Canada whereby industry purchase carbon offsets from farmers associations which are practicing government-approved no-till production protocol (Haugen-Kozyra & Goddard, 2009). However quantifying these benefits and providing the enabling environment (policies and so forth) to make these accessible to farmers particularly in SSA is in itself an area of research.

Impact on the poor

A key gap in the literature is determining the impact of CA on the poorest farmers. Nkala et al. (2012) used the Sustainable Livelihoods Framework to assess the impact on key outcomes i.e. food security crop productivity and household wealth suggesting the impact on the poorest farmers were marginal and that better-off farmers were likely to benefit more from CA. Moreover, the authors suggested that subsidised inputs were needed in order for the poorest to benefit. The research, however, did not delve into an economic comparison where farm-budget data was gathered and relied on a simple binary variable to determine if production had increased since using CA (i.e. yes/no). Little has been done therefore comparing the impact of CA of differing wealth strata and at various years of usage.

The next section provides an overview of technological change, adoption theory orthodoxies with reference to CA and innovation systems.

Drivers of technological innovation

In agriculture, technological innovation has traditionally followed either one of two paths; (i) mechanical technology, which leads to labour saving and (ii) biological (chemical and biological) which leads to land saving (Ruttan, 1982). Ruttan’s induced technical innovation model, describes how particular factor endowments (abundance of land or lack of it) spurs technical innovation and how even rises in prices also effect technological change. For example, a rise in fertiliser and labour, relative to the price of land and machinery respectively, would induce advances in biological and mechanical technology. Ruttan’s model also suggests that appropriate policies and price signals can induce developers to create products that are tailored to particular regions. However, Hayami and Ruttan (1985) also developed a theory of induced institutional change where institutions adjust to exogeneous changes (change in price or technology). More recently other researchers have highlighted the role public agricultural research institutions have played in bringing about technological change (Alston et al., 1995 among others). As with many social scientists the central premise of technological change is that it is exogenous to socioeconomic systems and that given the right signals the appropriate technology will appear (Hall and Clark, 1995).

Adoption of innovations theories and diffusion theory

There is extensive literature on the theory of adoption behavior. Griliches (1957) in his pioneering work on hybrid corn showed that profitability was the largest determinant of adoption, and diffusion of the technology follows a S-shaped curve whereby the adoption of a technology goes through a slow-gradual growth before experiencing a period of dramatic and rapid growth followed by a plateau. Later, Rogers (1983) put forward a notion of adoption that agreed that attributes of the technology were important, but that profitability was only one component. He stated that five attributes of innovations are (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability. Thus profitability was only one component of a wide variety of "costs" to the adopter. Moreover, Rogers (1983) also made a distinction between adoption i.e. the use or non-use of a given technology at a point in time and diffusion being the manner in which technology is communicated within a social system. Though, the diffusion of innovations model regards information as the key determining factor in determining adoption (Rogers, 2003). Rogers (2003) suggests a sequence of stages by which an adopter goes through: knowledge, persuasion, decision, implementation, and confirmation.

Friedrich and Kassam (2009) have noted that CA adoption follows a similar S-shaped curve. Others, however, argue that with conservation technologies such as soil conversion and integrated pest management to name a few, these are considered to follow a different form of adoption than conventional new technologies (FAO, 2001). Furthermore, evidence has shown that although conservation technologies lead to a higher social benefit it may also result in financial loss at the farm level which hinders adoption (FAO, 2001).

Recent economic theory contends that the adopter makes a choice based on maximization of expected utility subject to prices, policies, personal characteristics and natural resource assets (Caswel et al., 2001). Rogers (1995) further suggested that there are adopter categories, namely: innovators, early adopters, early majority, late majority and laggards. This presupposes, however, that the technology is a 'finished product' and farmers either accept or reject a given innovation (Meijer et al., 2015) whereas more recent research has suggested the adoption of innovations form part of a complex web of interactions which involve a wide range of actors (Roling and Jiggins 1998). For example, farmers' adaptations and experimentation of the technology are often essential in the adoption process and somewhat neglected by scientific research institutions (De Wolf, 2010). Farmers' goals, however, vary widely and they are likely to have different aspirations and conditions thus one cannot simply equate this with e.g. merely profit maximisation (Leewis, 2004)**.**

Innovation systems thinking

The traditional models of both technological change and adoption have centred on the linear model of innovation. Typically, this is associated with the transfer of technology from research to extension to farmers as opposed to that of modern innovation systems thinking. The concept of an innovation has also altered in recent years from being one centred around merely a technological advancement such as a new seed variety to one which hinges on new forms of social and organisational norms (Leeuwis, 2011). More specifically innovation systems thinking at its core presupposes that it is these other nodes (social, organisational etc) that bring about innovation. Thus, the concept of adoption and diffusion of a ready-made innovation which many proponents of the linear model of technological innovation subscribe to has shifted to that of innovation as a “collective process that involves the contextual re-ordering of relations in multiple social networks” (Leeuwis, 2011, p..).

In the case of Zero Tillage (ZT) adoption in Brazil, Ekboir (2003) argues that ZT has been a social construct. For example, Conservation Agriculture adoption in Latin America has been largely farmer driven (Friedrich et al., 2012; Ekboir 2003). Many institutions and organisations including universities played a limited role in recognising the potential of the ZT development until widespread adoption had occurred (ibid).

Adoption theory re-examined

Although Rogers (2003) did later incorporate the concept of knowledge and persuasion being important in the adoption process these are still regarded as stages. Rather than ‘stages’ it has been argued that people require different ‘aspects of learning’ and therefore different types of information at a given time. For example, farmers for instance may be ‘aware’ of a certain issue but to become ‘mobilised’ may require information on ‘problem-solving’ or ‘efficacy issues’ (Leeuwis, 2004).

The technology adoption/diffusion concept put forward by Rogers (1983), also looks at adoption of a ‘technology’ at a single snap shot in time and fails to realise that farmers may move within adoption and out of adoption.

Farmers (among other reasons) may very well be experimenting, lack a particular resource or require different forms of learning about a particular innovation but may very well choose to use an innovation at some point in the future. It is also possible that particular innovations may not fit in with their own personal motivations and or specific ‘domains of farming’ which may also overlap at any one time (Leeuwis, 2004). For example, farmers may have technical/economic goals such as reducing labour or inputs. Secondly, ‘relational’ aspirations which can also include political may be apparent such as maintaining good relations with neighbours, labourers and others. For instance, farmers may be influenced by certain organisations to ‘adopt’ because of an incentive, be this prestige in their area or payment or support (in the form of credit/gift) but would not otherwise do so (Kiptot et al., 2007). The authors brand such adopters as ‘Pseudo adopters’. This also akin to many criticisms of NGO and other organisations that help to increase the uptake of new technologies only to find ‘adoption’ can often be short lived when particular incentives (e.g. subsidies or free fertilizer) are phased out (Grabowski et al., 2013; Nkala et al., 2012). Another type of aspiration is more cultural involving social norms and values e.g. if something is good or bad or important or not. Others note that adoption of CA differs from the diffusion model of adoption as it requires like other conservation technologies a ‘voluntarism’ on behalf of the farmer (Van es, 1983).

Although by no means exhaustive, psychological models have thus been used more frequently to understand the use of farming practices. Leeuwis (2004) for example, presents a model focusing on cognition.

Socio-psychological models

A vast array of studies have focussed on farm characteristics and socio-economic factors that influence adoption. Little research, however, has been done which has focused on cognitive or social- psychological factors that influence farmers’ decision making such as social pressure and salient beliefs (Martínez-García et al., 2013). Socio-psychological theories which are helpful in this regard are The Theory of Planned Behaviour (TPB) and Theory of Reasoned Action (TRA). The TPB and TRA frameworks have been used in several studies to assess farmers’ decision making for a range of agricultural technologies (Beedell and Rehman, 2000; Martínez-García et al., 2013; Borges et al., 2014). This has included more specifically studies which have assessed conservation related technologies such as water conservation (Yazdanpanah et al., 2014) including organic agriculture (Läpple and Kelley, 2013), soil conservation practices (Wauters et al., 2010) and more recently payment for ecosystem services related initiatives (Greiner, 2015).

Combining frameworks

Most research on agricultural technology adoption has also arguably focused on 'extrinsic' factors e.g. socio-economic factors and social networks rather than intrinsic factors (e.g. knowledge, attitude, perceptions) (Meijer et al., 2015). In relation to CA research one can also find a reason to explore use of a psychological model and more conventional factors associated with farmers' adoption process given there are 'few studies incorporating both sets of variables' (Meijer et al., 2015). It also warrants and a deeper look at the innovation system as a whole and interactions among actors as for instance there is a 'limited understanding of how attitudes are shaped by extrinsic factors' (ibid).

This notion is supported to some extent by Knowler and Bradshaw (2007) who have shown for an aggregated analysis of the 31 distinct analyses of CA adoption that there are very few if any universally significant independent variables (education, farm size etc) that affect adoption. Just two, 'awareness of environmental threats' and 'high productivity soil' displayed a consistent impact on adoption i.e. the former having a positive and the latter a negative impact on adoption. Stevenson et al., (2014) has further argued that the understanding the process of CA adoption in Asia and Africa is a key area of research. Given this and the relatively low rates of adoption of CA in Southern Africa it is important to incorporate both modus operendi in understanding the process of adoption of CA.

Background of study area

Cabo Delgado is the northernmost province situated among the coastal plain in Mozambique. The majority of inhabitants, within the province rely on subsistence agriculture (mainly rainfed agriculture). Conventional agriculture practices are still pervasive and mainly done through ploughing by hand-hoe or animal traction. Farmers also invariably practice 'slash and burn' agriculture, whereby left over crop residues and natural vegetation are burnt and different plots of land are cultivated each year. Plots are often cultivated again after a fallow period.

Mozambique consists of ten different agro-ecological regions. These have been grouped into three different categories which are based in large part on mean annual rainfall and evapotranspiration (ETP). The highland areas represent high rainfall regions (>1000mm, mean annual rainfall) with low evapotranspiration and correspond to zones R3, R9 and R10.

The medium altitude zones in contrast (R7, R4) correspond to zones with mean annual rainfall ranging between 900-1500mm and medium level of ETP. Finally, low altitude zones (R1, R2, R3, R5, R6, R7, R8) which are hot with comparatively low rainfall (<1000mm mean annual rainfall) and high ETP (INIA, 1980; Silici et al., 2015).

The Cabo Delgado province falls within three agro-ecological zones R7, R8, and R9. The particular district under study (Pemba-Metuge) is situated within R8; distribution of rainfall is often variable with many dry spells and frequent heavy downpours. The predominant soil type in the R8 zone is Alfisols (Maria and Yost, 2006). These consist of red clay soils which are deficient in nitrogen and phosphorous (Soil Survey Staff, 2010).

A recent study using the human development poverty index ranks Cabo Delgado as the second poorest province in Mozambique (INE, 2012). The province also has one of the highest rates of stunting prevalence in the country (Fox et al., 2005). Other issues such as the high population growth rate in Mozambique further exacerbate the poverty nexus.

Conservation Agriculture in Cabo Delgado

CA adoption in recent years has been stimulated in the province largely with the support of the AKF-CRSP (Aga Khan Foundation Coastal Rural Support Programme), which has been promoting CA in the province since 2008. Farmer Field Schools, have been established within each of the districts, and helped to encourage adoption of CA among farming households. As of 2014, there were 266 Farmer Field Schools that focus on CA with a combined membership of 5000 members.

AKF's approach has differed to other NGOs in the region as provision of incentives such as vouchers/subsidies or inputs such as herbicides, chemical fertilisers and seeds in order to stimulate adoption have not been provided. Given the lack of draft and mechanical power in Cabo Delgado, manual systems of CA have been promoted. AKF's approach has aimed to improve soil fertility through the use of legumes as green manure, cover crops and perennials; developing mulch cover with retention of crop residues and dead plant biomass such as grass (e.g. *Panicum maximum, Eragrostis, Digitaria* and *Brachiaria).*

A number of manual systems have been promoted in the region given the lack of animal or mechanised power. Firstly, the use of a dibble stick which is a pointed stick used to open small holes in crop residues for planting seed. Secondly, micro-pits (the most commonly used manual system being used) are often used in the early years of CA to break soil compaction. AKF- CRSP has promoted the use of micro pits (35cm long x 15cm wide x 15cm deep). Finally, the use of jab planters have also recently been promoted in the region. These are used to make small holes in crop residue and simultaneously apply seed and fertiliser and/or manure into the planting holes made.

This region in Mozambique provides an interesting research case study to explore given the outstanding issues raised in the literature review surrounding CA's applicability to Southern Africa. In addition, given CA has been promoted for almost a decade in the particular province provides scope to explore adoption dynamics and issues relating to economics e.g short-term vs long term benefits. Furthermore, no previous research which has been peer-reviewed relating to Conservation Agriculture has been conducted in this region.

Further detail on specific research objectives and research questions are provided in the next section.

Research objectives/questions

A review of the literature has confirmed the lack of empirical research related to farm-level economic studies related to CA in SSA. Furthermore, little research has been done using household farm budget data which accounts for the opportunity costs facing farmers (e.g. labour and crop residues) and the year of usage under CA i.e. in order to compare short term and longer term benefits. Furthermore, adoption studies relating to CA and agricultural technologies more broadly have made limited use of incorporating socio-psychological factors/models to understand farmers' decision making. Limited understanding of successful innovation systems related to agriculture technologies/Conservation Agriculture particularly related to reaching the poorest farmers also provide scope for inquiry.

The thesis therefore, focusses on three main objectives. Firstly an exploration of the economics of CA relative to tillage based agriculture which will enable a better understanding of whether short term benefits are likely to occur with CA and to what extent external inputs are needed for CA to be beneficial. It will also explore whether CA is benefiting the poorest farmers and provide further insight into contentious issues such as labour and weeding related to CA use. Secondly, it seeks to examine the process of adoption of CA. This includes examining the drivers of adoption and the extent to which socio-psychological factors may help in understanding farmer decision making. Finally, it seeks to understand whether an innovation systems framework can be used to describe the process of adoption within the district under study and to what extent poorer farmers are able to benefit from the innovation system in its current form and thereby the innovation . The objectives and research questions are as follows:

1. Explore the farm level costs/benefits of CA relative to tillage based agriculture for different crop mixes.
    - At what point does CA break-even considering all opportunity costs? (1.1)
    - Is CA only profitable with the use of external inputs (including manure/compost) and new seed varieties? (1.2)
    - Does CA adoption reduce labour requirements and in particular weeding? (1.3)
    - Are the poorest farmers able to benefit from CA relative to tillage agriculture? (1.4)

2. Investigate what factors are important in the CA adoption process.
    - To what extent can a socio-psychological model be used to explain adoption dynamics related to CA? (2.1)
    - Do farm-level/household characteristics play a more important role in adoption or do other factors such as socio-psychological also factor in? (2.2)

3. Describe and investigate the innovation system of Conservation Agriculture in Cabo Delgado Mozambique.
    - How appropriate is the use of innovation systems thinking / an innovation systems approach to describe the innovation processes that take place regarding the CA innovation system? (3.1)
    - How well is the innovation system functioning? (3.12)
    - To what extent are the poorest farmers benefiting from the innovation system in its current form compared to better-off farmers? (3.2)

Thesis outline

The following collection of papers seeks to address the three main research objectives of this thesis and related research questions. Details of methodology, context of location of study and further literature are given in each publication.

Chapter 2 addresses farm-level economics of CA relative to tillage agriculture for a variety of crop mixes. Using detailed farm budget data, probabilistic cash flow analysis is used to compare the Net Present Value of CA compared to conventional cropping over the short and longer term for differing crop mixes and resource levels in order to address objectives 1. Principal component analysis (PCA) is also used in order to create a wealth index and compare farmers' returns within wealth strata.

Chapter 3 explores the role of a socio-psychological model in farmer decision making. A quantitative socio-psychological model is used to understand factors driving adoption of CA. Using the Theory of Planned Behaviour (TPB), it explores farmers' intention to use CA (within the next 12 months). Regression analysis and statistical significance tests are used.

The innovation systems approach is explored in Chapter 4 through social network analysis, mapping of partnerships and an actor innovation matrix. Results from the household survey are also used to understand users/non-users perceptions of the innovation and actors within the system.

Chapter 5 incorporates socio-psychological factors and conventional determinants of adoption (e.g. land size, education, age etc.) using a novel Monte-Carlo Markov chain algorithm to investigate adoption dynamics.

Chapter 6 provides a conclusion to the study and highlights possible areas for future research.

Chapter 2: Costs vs benefits-Is CA viable for smallholder farmers?[3]

Abstract: Conservation Agriculture (CA) has been widely promoted as an agro-ecological approach to sustainable production intensification. Across Sub-Saharan Africa, however, there have been low rates of adoption with fierce debate over its attractiveness for resource-poor farmers. Farm-level economics has been a key component of this debate with several authors questioning whether short-term benefits can occur with CA and advocating the need for more sophisticated economic analysis when comparing CA and conventional agriculture. This has included the importance placed upon more detailed farm-level data gathering as opposed to on-farm station research. This study uses farm-level budget data gathered from a cross-sectional survey of 197 farmers, for the 2013/2014 season, within a district situated in Cabo Delgado Mozambique, to compare the underlying economics of CA and conventional agriculture. The study is enriched by having observations reflecting each year of CA use i.e. first, second and third year. Probabilistic cash flow analysis is used to compare the Net Present Value of CA compared to conventional cropping over the short and longer term for differing crop mixes. Benefits are found in the short-term under CA but these are largely dependent on crop mix and the opportunity cost of labour assumed. We further employ Monte-Carlo simulations to compare the poorest farmers' net returns under different crop mixes and risk tolerance levels. Contrary to previous research, which has mostly suggested that better-off farmers are more likely to find CA useful, we find evidence that for the cohort of farmers under study the poorest are likely to find CA beneficial for a variety of crop mixes and risk-levels including under extreme risk aversion with the full opportunity cost of labour and mulch accounted for. These findings suggest that CA can be an attractive option for a wide variety of resource levels and crop mixes including those of the very poor in similar farming systems elsewhere in Sub-Saharan Africa.

Keywords: Conservation Agriculture, Farm-level economics

Introduction

Conservation Agriculture (CA) is now practiced worldwide across all continents and ecologies including on various farm sizes from smallholders to large scale farmers (Friedrich et al., 2012). It is defined as the simultaneous application of three principles, namely minimal soil disturbance, permanent organic soil cover (covering at least 30% of the cultivated area) and the use of rotations and/or associations involving at least three different crops (FAO, 2015). In Sub Saharan Africa, conventional tillage practice which is primarily practiced

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[3] A revised version of this chapter has been published as: Lalani, B., Dorward, P., Holloway, G., 2017. Farm-level Economic Analysis - Is Conservation Agriculture Helping the Poor? Ecological Economics 141, 144–153. doi:10.1016/j.ecolecon.2017.05.033

through the application of hand-hoe or plough has resulted in severe soil erosion and loss of soil organic matter (SOM) which has been further exacerbated through the practice of crop residue removal and burning (Rockström et al., 2009). Despite enthusiasm from proponents the adoption of CA has, however, remained fragmented throughout the region (Giller et al., 2009; Rockström et al., 2009).

There still exists a polarised debate, particularly in Sub-Saharan Africa, surrounding the merits of CA as an alternative to conventional tillage based farming. The debate has largely centred around the farm level costs/benefits, including the time horizon of benefits actually accruing, labour requirements and in particular whether CA requires the additional need of high inputs such as fertilisers and herbicides to be profitable (Giller et al., 2009; Rusinamhodzi et al., 2011). Others have argued that CA has not benefited the poorest farmers (Nkala, et al., 2011). In addition, there has been scant research in the Sub-Saharan African region on smallholder farms that delves into farm- level economic analysis of CA with appropriate sophistication (Pannell et al., 2014).

A wide ranging review of previous farm-level economic studies has been discussed in depth by other authors in this journal (Pannell et al., 2014). They conclude that there are key deficiencies in much of the economic analysis, to date, including a lack of consideration of the time lags, discount rates, appropriate opportunity costs for labour and crop residues. Moreover, omission of the role of risk and uncertainty in farm level economic analysis is widespread (Ngwira et al., 2013; Pannell et al., 2014; Thierfelder et al., 2016).

A further criticism of much of the literature on CA has also been directed to the multitude of ‘on-farm station’ trials and experiments which may not appropriately reflect farmers’ realities (Soane et al., 2012). A number of authors have suggested that farm-level data is needed to better analyse the impact of CA in different contexts (Ngwira et al., 2013 Pannell et al., 2014; Dalton et al., 2014; Carmona et al., 2015; Mafongoya et al., 2016). This applies to much of SSA and is reflected in Mozambque where considerable attention has been given to research on CA systems in recent years (Nkala et al., 2011; Nkala, 2012; Famba et al., 2011; Grabowski and Kerr, 2014; Thierfelder et al., 2015; Nyagumbo et al., 2015; Thierfelder et al., 2016). Most of these studies have focused on-farm level experiments whilst some have focused on farm-level economics (Grabowski and Kerr, 2014). Neither of these studies has addressed risk analysis or on-farm level economic analysis through large scale household surveys. Moreover, specific research relating to CA in Cabo Delgado (Northern Mozambique where this study is based) on farm-level economics is limited and/or has not been documented through peer-reviewed research to date.

In this study we use elements of the economic model framework presented by Pannell et al., (2014) to address some of the key concerns raised in the literature. The aim of this study is to better help understand whether CA provides an attractive option for the farmers within this case-study region when all known economic considerations are addressed. Given research, extension and development efforts in general are also focussed throughout the region on reaching the poorest, we also use this cohort to explore farmers' net returns under various risk levels and crop mixes used. The description of the model and approach is presented in the following section followed by the results. The final section provides discussion and conclusions to the paper.

Background of study area

Cabo Delgado is the northernmost province situated among the coastal plain in Mozambique. The majority of inhabitants, within the province rely on subsistence agriculture (mainly rainfed agriculture). Conventional agriculture practices are still pervasive and mainly done through ploughing by hand-hoe or animal traction. Farmers also invariably practice 'slash and burn' agriculture, whereby left over crop residues and natural vegetation are burnt and different plots of land are cultivated each year. Plots are often cultivated again after a fallow period. Provincial and district level yield data is sketchy though yield data for Mozambique (based on FAOSTAT data) highlight very low yields for staple crops compared to neighbouring countries in Eastern and Southern Africa. For example, average yields (calculated from FAOSTAT data based on the years 2008-2013), show relatively low yields for maize (*Zea Mays*), (1.12 tons/ha), cassava (*Manihot esculenta Crantz*), (10 tons/ha) and rice (*Oryza sativa* L.), (1.2 tons/ha). These are far lower than in neighbouring Malawi which has much higher cassava (15 tons/ha), maize (2.3 tons/ha) and rice (2.1 tons/ha) yields. Other countries in close vicinity such as Zambia have comparatively higher maize and rice yields but lower overall cassava yields than Mozambique (FAOSTAT, 2016).

Mozambique consists of ten different agro-ecological regions. These have been grouped into three different categories which are based in large part on mean annual rainfall and evapotranspiration (ETP). The highland areas represent high rainfall regions (>1000mm, mean annual rainfall) with low evapotranspiration and correspond to zones R3, R9 and R10. The medium altitude zones in contrast (R7, R4) correspond to zones with mean annual rainfall ranging between 900-1500mm and medium level of ETP. Finally, low altitude zones (R1, R2, R3, R5, R6, R7, R8) which are hot with comparatively low rainfall (<1000mm mean annual rainfall) and high ETP (INIA, 1980; Silici et al., 2015). The Cabo Delgado province falls within three agro-ecological zones R7, R8, and R9. The particular district under study (Pemba-Metuge) is situated within R8; distribution of rainfall is often variable with many dry spells and frequent heavy downpours. The predominant soil type in the R8 zone is Alfisols (Maria and Yost, 2006). These consist of red clay soils which are deficient in nitrogen and phosphorous (Soil Survey Staff, 2010).

A recent study using the human development poverty index ranks Cabo Delgado as the second poorest province in Mozambique (INE, 2012). The province also has one of the highest rates of stunting prevalence in the country (Fox et al., 2005). Other issues such as the high population growth rate in Mozambique further exacerbate the poverty nexus. Within the study district (Pemba-Metuge), current projections show that the population will more than double by 2040 (INE, 2013). Although population density is considered quite low in Mozambique as a whole (Silici et al., 2015) with increased population, climate variability and lack of labour to clear new land the need for intensification as opposed to extensification of land will be imperative for the future (Thierfelder et al., 2015). There are similar pressures in many other Sub-Saharan Africa countries where population pressure is even greater. In addition, similar rainfall amounts and constraints are experienced across large parts of SSA. Given wide ranging resource constraints e.g. water, soil and land envisioned in the decades ahead; other authors have referred to the notion of sustainable intensification (SI) which has been defined as a ‘process or system where agricultural yields are increased without adverse environmental impact and without the conversion of additional non-agricultural land’ (Pretty and Bhachura, 2014).

Conservation Agriculture in Cabo Delgado

CA adoption in recent years has been stimulated in the province largely with the support of the AKF-CRSP (Aga Khan Foundation Coastal Rural Support Programme), which has been promoting CA in the province since 2008. Farmer Field Schools, have been established within each of the districts, and helped to encourage adoption of CA among farming households. As of 2014, there were 266 Farmer Field Schools that focus on CA with a combined membership of 5000 members.

AKF's approach has differed to other NGOs in the region as provision of incentives such as vouchers/subsidies or inputs such as herbicides, chemical fertilisers and seeds in order to stimulate adoption have not been provided. Given the lack of draft and mechanical power in Cabo Delgado, manual systems of CA have been promoted. AKF's approach has aimed to improve soil fertility through the use of legumes as green manure, cover crops and perennials; developing mulch cover with retention of crop residues and dead plant biomass such as grass (e.g. *Panicum maximum, Eragrostis, Digitaria* and *Brachiaria).*

A number of manual systems have been promoted in the region given the lack of animal or mechanised power. Firstly, the use of a dibble stick which is a pointed stick used to open small holes in crop residues for planting seed. Secondly, micro-pits (the most commonly used manual system being used) are often used in the early years of CA to break soil compaction. AKF- CRSP has promoted the use of micro pits (35cm long x 15cm wide x 15cm deep). Finally, the use of jab planters have also recently been promoted in the region. These are used to make small holes in crop residue and simultaneously apply seed and fertiliser and/or manure into the planting holes made.

Materials and Methods

Survey procedure

This study is based on results from a survey of 197 farmers in the Metuge district, of Cabo Delgado Province Mozambique**.** A multi-stage sampling frame was employed to select the households from a list of local farmers provided by key informants in each of the villages. From the thirteen total clusters (i.e. in this case villages which were chosen based on whether the Aga Khan Foundation had initiated CA activities in the respective villages) six communities were then chosen at random from this list and households were subsequently selected randomly from the lists generated by key informants in these villages using population proportional to population size (PPS sampling). The initial sample consisted of 250 farming households being surveyed. As a result of non-response our final sample size was 197. The survey was translated into Portuguese and trained enumerators were used that were conversant in both Portuguese and the dialects used in the different villages.

Variables and measurement

The survey consisted of several sections and included questions about household and plot-level characteristics. Detailed farm budget data was gathered from respondents for the whole farm i.e. all crops grown (including seeding rate), size of cultivated area (and total land size), type of seed used, the amount, if any, of inputs used e.g. manure, fertiliser/herbicides or compost and total labour used (hired and family) during the cropping season measured in person hours i.e. number of persons used multiplied by numbers of hours worked in a typical day for the task multiplied by total number of days the task took (see page 200-206 of questionnaire in Appendix 1 for the farm budget questions). Yield was calculated by dividing reported production by reported area for each crop. The area reported was also expressed in hectares as this was the most familiar unit known to farmers. The aid of locally used metrics of measurement e.g. baskets and buckets of different sizes were used. A sample of buckets and baskets typically used by farmers were also weighed for specific crops in order to maintain consistency with appropriate conversion into kilograms. The Cabo Delgado region experienced some flooding in mid-2014. The wet conditions may, however, have differing effects for CA relative to conventional tillage. For instance, research on CA elsewhere in Southern Africa has shown high levels of water infiltration and soil moisture for crops which is particularly beneficial during seasonal dry spells, however, waterlogging and nutrient leaching may occur due to increased water infiltration which has a negative impact on plant growth in particularly wet years. (Thierfelder and Wall, 2009).

Adoption of Conservation Agriculture defined

We define the adoption of CA (i.e. the full package) as a farming household simultaneously applying on any given plot all three principles of CA which are:

(i) minimum soil disturbance with the use of micro-pits (which are usually used in the first few seasons) or no-tillage without the use of micro-pits i.e. direct seeding
(ii) Soil cover i.e. mulching (covering at least 30% of the soil surface)
(iii) Crop diversity using a rotation/association/sequence involving at least three different crops during the season.

Partial CA practices are defined using the following criteria:

(i) Growing less than three crops on a plot but using the three principles above or using a few principles (which must include at least minimal soil disturbance)

Conventional agriculture or No CA (used interchangeably in this study) users are farmers practicing conventional tillage agriculture with the use of hand-hoe. They may, however, be practicing intercropping and/or rotation, and growing up to three crops during the season.

Model description and key assumptions

Probabilistic cash flow analysis was used to create a stochastic model for net returns (Richardson and Mapp, 1976). In our analysis the two most common crop mixes used by the farmers surveyed were used i.e. one model comparing CA and conventional for farmers using the maize-cowpea (*vigna unguiculata*)-cassava mix and the other for farmers using the maize-cowpea-sesame (*sesamum indicum*) mix. We were unable to simulate those using partial CA practices i.e. two crops or CA users using four crops given the small numbers of observations for both. Thus our analysis is restricted to comparing CA users (using the full package) i.e. three crops relative to conventional agriculture users i.e. those using tillage with hand-hoe and not retaining crop residues as mulch.

The observed values from the survey were used to calculate probability distribution functions (PDFs) using the empirical distribution. For example, PDFs based on farmers in the first, second and third year of use of CA and for conventional users. Richardson (2006) outlines the approach through a series of steps. First, probability distributions for the risky variables must be defined and parameterised which includes simulation and validation. Second, the stochastic values which are sampled from the probability distribution are used in the calculation of, for example, cash flows. Thirdly, using random selection of values for the risky variables under study the completed stochastic model is simulated many times (i.e. 500 iterations). The results of the 500 samples thus provide information which can be used to estimate empirical distributions of e.g. net present values to evaluate the likelihood of success of a project.

As outlined above the stochastic model for net returns developed was validated by comparing the stochastic means for each year of CA and conventional with their historic means using Student t-tests set at alpha 0.05. Each failed to reject the null hypothesis which signalled that the stochastic net returns assumed their original means and variability. The Box-M test was also used to test if the simulated data have a covariance that is statistically significantly equal to the historical covariance matrix. This also failed to reject the null hypothesis which signalled both were the same. Secondly, we calculated the Net Present Value (NPV), a widely used financial criterion, used in previous studies on the same topic (Pannell et al., 2014; Knowler and Bradshaw, 2007; FAO (2001)). The NPV determines the present value of benefits by discounting given benefits/costs between a given year and a specific time period. The NPV for the particular duration considered is thus calculated (based on random selections from the PDFs for the various years) through Monte-Carlo simulation (500 iterations) using an excel Add-in Simetar©. We do not consider there to be any prior investment outlays for

CA. Net returns are calculated by yield per hectare multiplied by price for all crops in the specific mix less full labour costs (hired and family) and opportunity cost of mulch (i.e. for CA users). These are presented in the local currency i.e. Mozambique Meticais (MZN).[4] The model uses observations of farmers' in each year of CA use and therefore does not assume reductions in yield in the short-term or an increase in yield under CA after a 10 year period as do Pannell et al. (2014). We do however, take the third year users' of CA as the most likely going forward i.e. we use the PDF for the third year to calculate the fourth year onwards given much of the CA literature states that benefits are found after the third year and yields are variable in the first few seasons (Rusinamhodzi et al., 2012).

Base case scenarios are presented under a 20% discount rate and use output prices at harvest reported by farmers and checked by key informant interviews. Furthermore, to account for farmers' different planning horizons NPV's are presented covering 3, 5 and 10 years. Sensitivity analysis is often used in order to examine the role of alterations to key parameters involved in the farm enterprise (Pannell, 1997). Pannell (1997) asserts that to be done effectively scenarios should be presented for each altered parameter individually. Moreover, high and low or maximum and minimum should be set for the altering of parameters or 'with' or 'without' a constraint that may bias the decision maker. Thus, a sensitivity analysis is also performed and we solve the model assuming higher and lower discount rates of 10% and 30% respectively and for 'with' and 'without' labour scenarios given this is the primary cost to farmers. Different prices for maize and labour which typified high and low prices were also used in the sensitivity analysis. For the other crops i.e. cowpea, cassava and sesame we did not find much variation in the prices thus we solve the model for a scenario with higher prices i.e. assuming a 50% increase in price for these crops.

Crop grain to residue ratio using a 1:1 grain to residue ratio for maize and sesame and 1:1.35 for legumes i.e. cowpea and cassava is used to calculate the opportunity cost of mulch as feed. A detailed breakdown of the key assumptions and base case scenarios are presented in Appendix A. [5] A 'shadow' price for mulch was also constructed similar to the method used by Thierfelder et al., (2016). This provided similar estimations to the costs from the grain to residue ratio method thus we have retained the use of this method in our analysis.

The survey results showed that farmers invariably were using the local varieties of crops (not 'improved' purchased hybrids) and/or were also not using external inputs such as fertilisers,

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[4] 1 US dollar=30MZN (Mozambique Meticais) using exchange rate at time of survey

[5] We consider cassava under legume for the purpose of valuing the leaf residues. 'Green' in the case of cowpea (referred to in Appendix) refers to leaves harvested mid- season before seed is harvested.

herbicides, pesticides, composts and/or manure. Our model is thus based on farmers using the local crop varieties and no external inputs. We also do not consider the economics of switching to private access grazing (i.e. incorporating fencing as a cost) given farmers were invariably applying all of their crop residues as mulch (without the use of fences) and land to livestock ratios are very low in Mozambique.

Data analysis

Data was analysed in SPSS version 21. Principal component analysis (PCA) was conducted in order to establish a wealth index. A common method in a number of poverty studies is the first principal component (PC1) which explained the majority of variance in the data is then used as the index (Edirisinghe, 2015). Households were then ranked into terciles with respect to the level of wealth, taking three values referring to lower, middle and upper terciles. Disaggregating by wealth using this method allowed for a comparison to be made for households of similar level of resources including land and household size. Farmers' net returns for those in the poorest tercile using the same crop mix were simulated using 500 iterations using the multivariate kernel density estimate (MVKDE) Parzen distribution which provides the best solution for the use of sparse data (Lien et al, 2009; Richardson, 2006). The net returns accounted for opportunity cost of mulch and full labour costs i.e. hired and family labour.

A number of tools were then used to analyse risk. The first is Stochastic Efficiency with respect to a function (SERF) which identifies and ranks certainty equivalents with respect to a range of risk preferences (Hardaker et al., 2004). It has been argued as a more 'transparent' method (allowing graphing of a number of risky alternatives simultaneously) compared to pairwise rankings such as stochastic dominance (ibid). It assumes the decision maker prefers more utility to less, and thus the risky alternative which has the greatest certainty equivalents is preferred by decision makers for that particular level of risk aversion (Richardson and Outlaw 2008). Certainty equivalents reflect the amount of money where the decision maker is indifferent between the risky alternative and a certain amount. This tool assumes a negative exponential utility function similar to Pendell et al. (2007) and Fathelrahman et al. (2011) which are also the most common form used in expected utility (Richardson, 2006). Furthermore, the SERF tool also accounts for risk and uncertainty (i.e. absence of perfect knowledge or the decision maker having incomplete information) together in its calculation of certainty equivalents.

Secondly, Stoplight probability charts were used which do not require knowing the exact risk preference of the decision maker and instead provides target probabilities for different risky alternatives. It calculates the probability for instance of scenarios falling below a lower target, exceeding an upper target and/or those falling between the lower and upper target specified. Similar tools with the use of Simetar© have been used by other authors which have explored the net returns of CA and conventional under different risk levels for farmers in Malawi (Ngwira et al., 2013). The advantage of using the StopLight chart for ranking risky alternatives is that enables the decision maker to specify their lower and upper targets (e.g. net returns) and then let them decide which scenario is best using a simple graphic. There is therefore no need to specify a specific risk aversion coefficient/utility function which ultimately simplifies analysis and allows the decision makers to approach decisions according to the specific context and 'problem at hand' (Richardson and Outlaw, 2008).

Results

Summary statistics

Table 1 shows the summary statistics of the sample. Off-farm income is generally very low signifying the importance of agriculture in this region. Household sizes are quite high on average with low levels of educational attainment. Application of mulch refers to those farmers covering the soil with at least 30% of the cultivated soil surface covered (though most CA users surveyed reported applying mulch on all of their cultivated area).

Table 1 Summary statistics (n = 197)

Variable	Mean value, Frequency or Percentage (Standard deviation in parenthesis)
Sex of Household Head	(Male 65%; Female 35%)
Age of Household Head	62(27.9)
Marital status	(69 %= married, 2%= Divorced, 4%=Separated, 9%= Widowed and 16%=Single)
Education (Based on educational attainment i.e. grades completed 1-12)	2.4 (2.8)
Household size	5.2 (2.4)
Off-farm income (1 =yes, 2=no)	1.8 (0.3)
Number of plots owned	1.4 (0.5)
Mean Total Land size (hectares)	1.7 (7.0)
CA first year users	41
CA second year users	43
CA third year users	50
CA users > three years	11
No-CA	52
Current adoption	
Micro-pits with mulch and rotation/intercrop using at least 3 different crops	51%
No-tillage with mulch and rotation/intercrop using at least 3 different crops	12%
Partial adoption (mostly using two crops with mulch and either no till/micro-pits)	10%
No CA (no mulch)	24%
No CA (with mulch)	3%

Source: Adapted from Lalani et al., (2016) The majority of CA farmers used a three crop sequence during the growing season i.e. maize-cowpea and cassava and maize-cowpea and sesame being the most common. Likewise, for conventional farmers these were the most common three-way sequences. Conventional farmers also just cultivated two crops such as maize and cassava in the growing season. The most common four-way crop mixes used by CA users were maize-cowpea-pigeon pea (*Cajanus Cajan*) cassava or maize-cowpea-cassava-sesame.

Economic model

Tables 2 and 3 presents the Net present values calculated from the stochastic model for three planning horizons for the maize cowpea and cassava crop mix. The base case assumptions assume crop prices at harvest and the most common wage rate in the district (See Table A.1 in Appendix A).

Though neither of the options i.e. CA or conventional would be considered a profitable endeavour when labour is costed i.e. NPV greater than zero, the NPV which is least negative between the two would still be the preferred option. It shows that for the majority of scenarios CA is preferred (where shaded) relative to conventional over the short and longer term, but less preferred in the long run under the scenario of higher maize prices and high labour costs after 10 years. If one uses three years as the yardstick of the majority of resource-poor farmers' planning horizons CA would be the preferred option for this mix. Interestingly, under a zero labour cost scenario CA is still preferred over the short and longer term thus indicating that yield gains rather than yield dips in the first few seasons are possible with this crop mix.[6]

Moreover, to account for risk and uncertainty, certainty equivalents (not shown) were calculated using the Stochastic efficiency with respect to a function (SERF) tool in Simetar©. The SERF ranks certainty equivalents relative to a range of risk tolerance levels from risk neutral to extremely risk averse. Thus zero is defined as risk neutral or the LRAC (lower risk aversion coefficient) and the URAC (upper risk aversion coefficient) is calculated using the formula of 4/average wealth of the decision maker (Hardaker et al., 2004; Richardson, 2006). This formula was used in the first instance but did not provide appropriate looking certainty equivalent lines as the SERF lines became asymptotic to the X axis.[7] An expert in simulation

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[6] Similar findings to the base case were found under a 10% discount rate for each crop mix. These are not presented due to space constraints.

[7] The lines become asymptotic to the X-axis because when the 4/net worth formula is used the net worth is very small relative to the returns simulated. The default value suggested seems to work better. If the CE lines

was consulted and suggested using 0.00001 as the URAC equated with an extremely risk averse farmer based on the type of net returns under analysis and thus provided relatively flat CE lines and ensured the SERF lines did not became asymptotic to the X-axis (J. Richardson, personal communication). Thus, where shaded both risk neutral and extremely risk averse farmers' would find CA the preferred option. Likewise (where unshaded) and where conventional has the advantage it also had higher certainty equivalents under the same risk tolerance levels.

Table 2 Net present value per hectare for CA and Conventional maize-cowpea and cassava mix for three different planning horizons using base case assumptions and altered parameters from base

Parameter	Conservation Agriculture			Conventional Agriculture		
	3 years	5 years	10 years	3 years	5 years	10 years
Base case	-8984	-13885	-20586	-10282	-14597	-20463
Maize high	-7515	-11845	-17729	-8289	-11769	-16498
Maize low	-9434	-14565	-21539	-10945	-15540	-21785
Zero Labour	7254	9873	13433	6398	9083	12734
Labour high	-25358	-37929	-55016	-27162	-38563	-54060
Labour low	-5829	-9305	-14028	-7066	-10032	-14063
50% increase in cowpea price	-7363	-11985	-18270	-9663	-13719	-19232
50% increase in cassava price	-7905	-12187	-18006	-9655	-13707	-19216

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become asymptotic to the X-axis that implies a mis-specified upper risk aversion coefficient (URAC) which mainly makes identifying the rankings impossible.

Table 3 Net present value per hectare for CA and Conventional maize-cowpea-cassava mix for three different planning horizons using base case assumptions with a 30% discount rate and altered parameters from base

Parameter	Conservation Agriculture			Conventional Agriculture		
	3 years	5 years	10 years	3 years	5 years	10 years
Base case	-7588	-11043	-14700	-8864	-11888	-15089
Maize high	-6342	-9375	-12587	-7146	-9584	-12166
Maize low	-8003	-11599	-15405	-9437	-12656	-16064
Zero Labour	6289	8124	10067	5516	7397	9390
Labour high	-21634	-30444	-39786	-23418	-31406	-39864
Labour low	-4913	-7348	-9926	-6092	-8170	-10371
50% increase in cowpea price	-6185	-9423	-12853	-8331	-11172	-14182
50% increase in cassava price	-6710	-9709	-12886	-8324	-11163	-14170

Tables 4 and 5 show that for farmers using the maize-cowpea-sesame mix conventional agriculture would be preferred over the short and longer term planning horizons. However, for farmers' with a high opportunity cost of labour CA especially under higher discount rates i.e. CA would be preferred over the short to medium term (Table 5). In this context where there is little off-farm income the high opportunity cost refers to the value of time for alternative means. There is wide ranging literature on ‘time use poverty’ which is also referred to as ‘household overhead’ especially in relation to Sub-Saharan Africa (Blackden and Wodon, 2008). Thus, it must be noted that although there are few viable alternative economic opportunities (e.g. in this district under study) the cost of time in the local context can be higher for certain households. For example, women in particular are seen to have a higher opportunity cost of time than men and may have to devote time to farm labour and other important activities within the household such as having to tend to children or perform other activities like fetching water/firewood and caring for the sick etc. (ibid). Thus, farm practices which reduce the amount of time needed for farm- labour may be attractive.

This does also raise an important question as to the sustainability of agriculture in these areas particularly when many of the mixes lead to a negative NPV for instance. Although this is associated to some extent with how labour (family labour in particular) is costed as mentioned above there is also the issue of whether agriculture is a viable route out of poverty. Harris and Orr (2014) show in their study of natural resource management interventions that smallholders in SSA are inhibited by small farm size and that due to limited access to markets and low production levels net returns are not high enough to lift themselves out of poverty (unless farm size can be expanded), however, the direct benefit is likely to be in the form of improved household food security. Of course this begs the question of whether farm land can be expanded without encroaching on non-agricultural land etc. but it does highlight the benefits of such interventions to household food security and the need to experiment with crop sequences that are likely to be most beneficial to enable a move out of poverty. In terms of contributing to broad based economic development improving productivity among smallholders and in general investment in rural areas are likely to go hand in hand as there will be likely strong ‘forward and backward linkages’ arising from this. For example, it is argued that agricultural growth is often a catalyst to non-farm activity (e.g. through processing of crops) whilst non-activity can also generate investment (e.g. through inputs) which can generate investment on-farm (Wiggins et al., 2010). Thus, ‘small farm development is not only desirable for its impacts on poverty, but also feasible even in changed circumstances’ (ibid).

Table 4 Net present value per hectare for CA and Conventional maize-cowpea-sesame mix for three different planning horizons using base case assumptions and altered parameters from base

Parameter	Conservation Agriculture			Conventional Agriculture		
	3 years	5 years	10 years	3 years	5 years	10 years
Base case	9364	11394	14155	9755	13950	19416
Maize high	13175	16258	20451	13908	19745	27680
Maize low	8093	9772	12056	8371	11885	16661
Zero Labour	27465	36096	47826	28773	40848	57265
Labour high	-8957	-13606	-19924	-9491	-13474	-18890
Labour low	12853	16155	20646	13421	19055	26711
50% increase in cowpea price	11479	14156	17797	12242	17381	24365
50% increase in sesame price	18156	22996	29578	17428	24744	34688

Table 5 Net present value per hectare for CA and Conventional Maize-cowpea-sesame mix for three different planning horizons using base case assumptions with a 30% discount rate and altered parameters from base

Parameter	Conservation Agriculture			Conventional Agriculture		
	3 years	5 years	10 years	3 years	5 years	10 years
Base case	8382	9805	11312	8410	11279	14317
Maize high	11747	13907	16195	11990	16081	20412
Maize low	7261	8437	9683	7217	9678	12285
Zero Labour	24020	30066	36469	24806	33268	42227
Labour high	-7445	-10701	-14150	-8182	-10973	-13929
Labour low	11397	13711	16161	11571	15518	19697
50% increase in cowpea price	10221	12096	14083	10555	14155	17967
50% increase in sesame price	16069	19460	23051	15026	20152	25579

A case study of the poorest

Whilst the economic model presented is helpful in providing insight particularly with regards to the early years under CA for different mixes it is unable to compare households of similar resource-levels e.g. land size and household size. To account for this farmers' were grouped into different wealth terciles using PCA. The descriptive statistics for the poorest group are presented in Table 6. Within the poorest tercile CA households seem to be poorer (i.e. have slightly larger household size, older household head etc.) than Non-CA households which signals that adoption of CA is more likely among poorer households. This is triangulated by the household poverty score which used similar questions to those of the household poverty score card developed for Mozambique by Schreiner et al. (2013) to better categorise farmers based on poverty level. These, for example, include questions on type of housing, specific household assets etc. Thus, both conventional and CA farmers within this tercile are likely to be in 'extreme poverty' according to this metric. Furthermore, farmers within this tercile used family labour only (with no hired labour) and had virtually no off-farm income (Table 6).

Table 6 Characteristics of CA and conventional farmers for poorest wealth tercile (S.D)

	N	Mean household poverty score*	Mean Age of HH Head	Mean Household size	Mean Off-farm income (1=yes,2 =no)	Mean Total land size (hectare)
CA	36	26 (10.3)	67 (30.4)	4.8 (2.3)	1.9 (0.25)	0.83 (0.51)
Conventional	17	29 (9.3)	58 (30.7)	4.6 (1.7)	2.0 (0.00)	0.84 (0.37)

*scores below 30 indicate a very high likelihood of being in 'extreme' poverty according to National and International poverty lines. Standard deviation in parenthesis

Table 7 shows the breakdown of labour by task. It shows a clear reduction in labour for weeding for CA users compared to conventional and overall reduction of labour of approximately 17% which includes lower land preparation time.

Table 7 Total person hours used per hectare by task for CA and conventional for poorest wealth tercile

Type of task	Cultivation system	N	Mean	Standard Deviation
Land preparation	CA	36	344	189
	Conventional	17	449	291
Weeding	CA	36	167*	117
	Conventional	17	263	220
Harvesting	CA	36	208	222
	Conventional	17	205	164
Total Person hours	CA	36	839	425
	Conventional	17	1013	470

*significantly different between CA and conventional ($p < 0.10$)

Risk simulation analysis

To examine under what circumstances CA is likely to be an attractive option for these farmers it is important to be able to compare farmers' actual net returns under the same crop mixes used and in accordance with different attitudes to risk and uncertainty as outlined earlier. Figure 1 shows the certainty equivalents (CE's) for the most frequent crop mixes used by the poorest farmers. The Absolute Risk Aversion coefficient shows a range of risk tolerance levels from risk neutral to extremely risk averse i.e. as used earlier in the paper i.e. zero denotes risk neutral and 0.00001 extremely risk averse. It shows that over a range of risk aversion coefficients the CE's remain fairly constant as risk aversion increases. Thus farmers would have a higher CE under the maize-cowpea-sesame mix and would also prefer other crop mixes relative to the conventional maize-cassava mix being used. For example, both a risk neutral farmer and an extremely risk averse farmer using the CA four crop cassava mix would need to receive approximately a payment of 3000 MZN to be indifferent between the three crop cassava mix under CA and would further need to receive approximately 6000 MZN to be indifferent from the conventional maize-cassava mix. For the maize-cowpea-sesame mix a risk neutral farmer would need to receive a payment of roughly 3000 MZN to be indifferent between the higher ranked CA maize-cowpea sesame and conventional maize-cowpea sesame. The CE is slightly higher for a highly risk averse farmer for this mix as they would need to receive approximately 4000 MZN to be indifferent between the higher ranked CA maize-cowpea sesame and conventional.

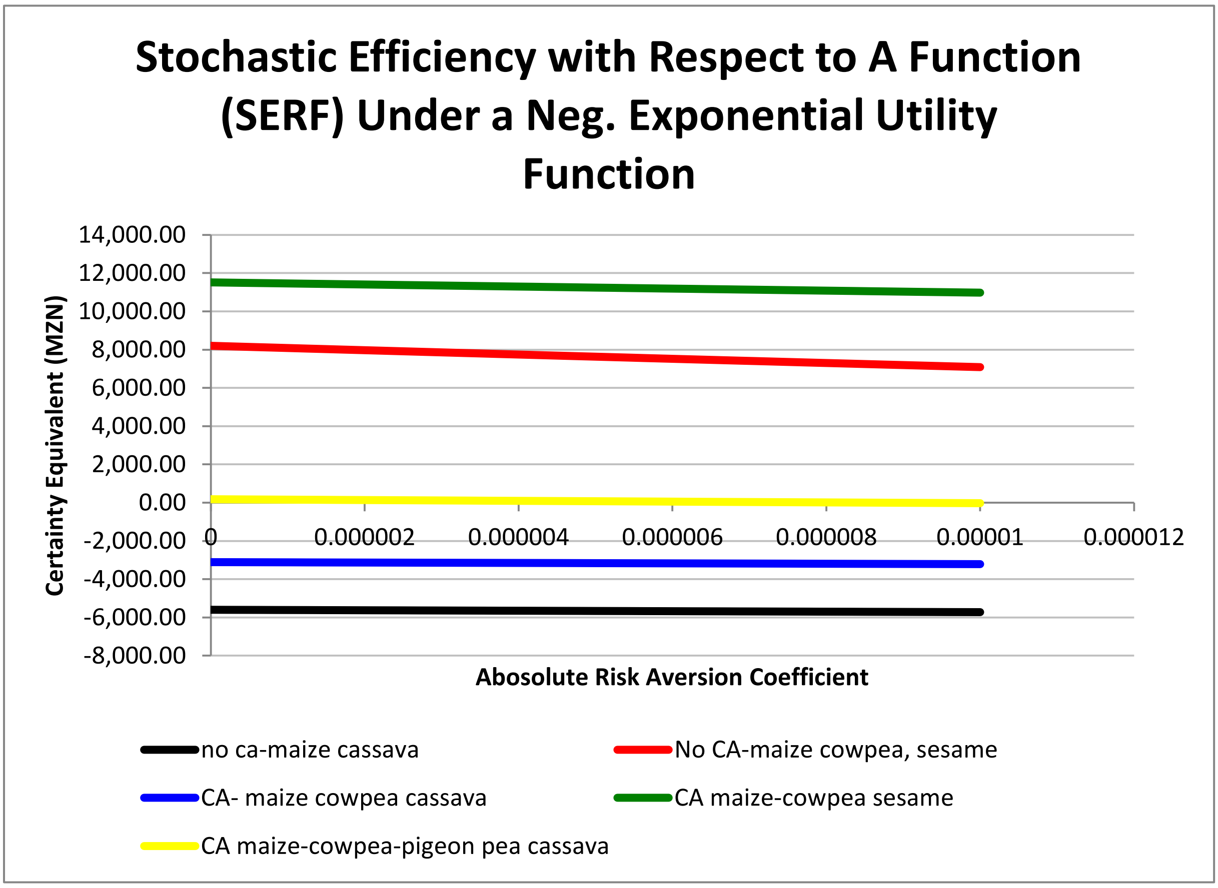

Figure 1 Certainty equivalents (CE's) for the most frequent crop mixes used by the poorest farmers under different risk tolerance levels

Similarly, Figure 2 shows probability of breakeven and target net return which in this case is the mean net return of all crop mixes plus one standard deviation. Green shows probability of net income above the threshold of 10,597 MZN (i.e. mean net income plus one standard deviation) and cautionary (light yellow) between 0 and the threshold of 10,597 MZN. Red signals probability of a negative net income i.e. lower than 0 i.e. breakeven. In general, risk-averse farmers would prefer the outcome with the least red and most green (Richardson and Outlaw, 2007). However, the risk neutral to slightly risk averse farmer would prefer the outcome with the most green (ibid). For example if Thus the CA maize-cowpea-sesame mix provides the highest probability of net returns above the threshold of 10, 597 MZN and the least probability of a red outcome i.e. below the minimum threshold of breakeven. For example, farmers using the maize, cowpea and sesame mix would have a probability of 41% of achieving a net income higher than 10, 597 MZN and 59% for a net income between 0 and 10,597 MZN. It would thus provide the best bet to breakeven for farmers. Interestingly, the least favoured mix would be the conventional maize-cassava mix which is unlikely to breakeven and almost certainly has net returns lower than breakeven.

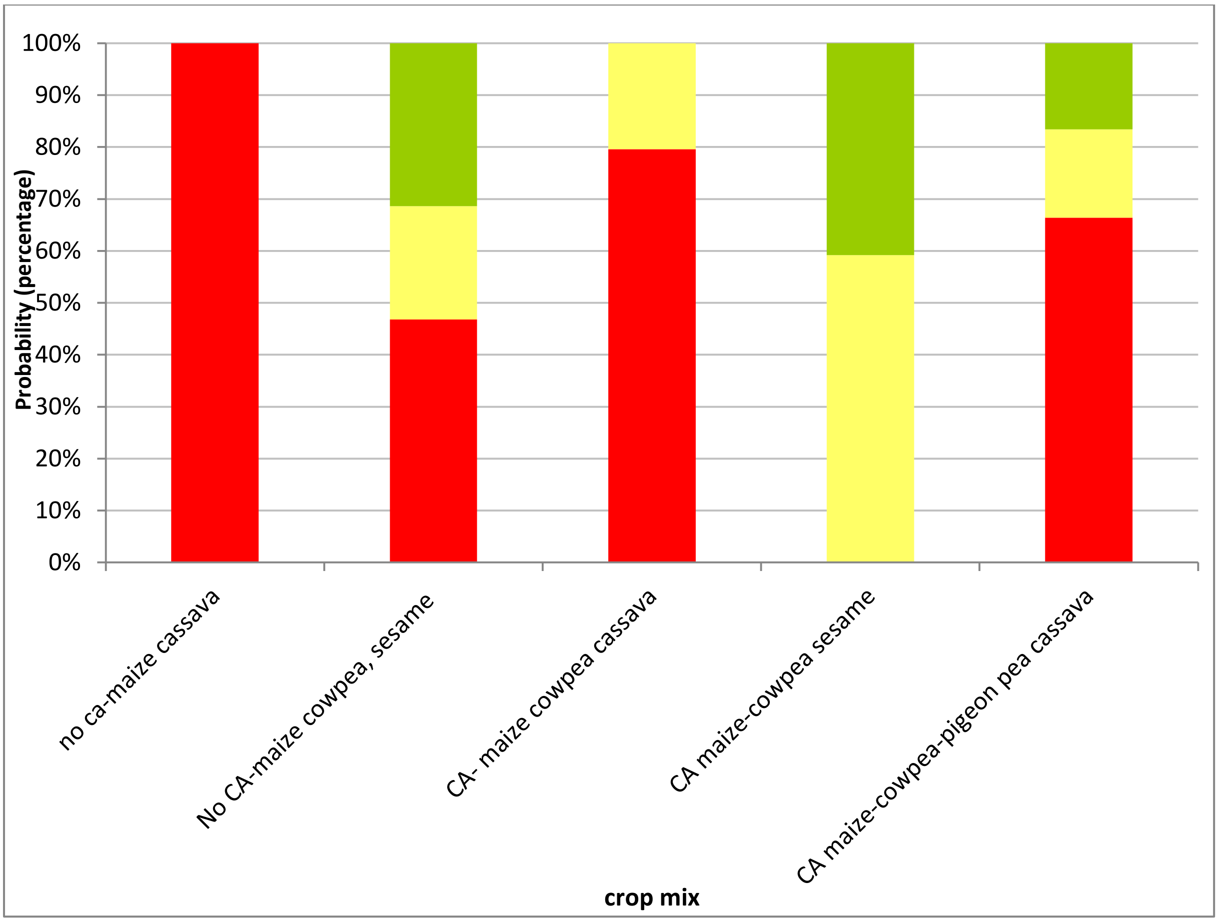

Figure 2 Stoplight probability chart showing probability of achieving less than breakeven (i.e. zero) and target net return of 10,597 (mean plus one standard deviation) for different crop mixes for the poorest wealth tercile.

Discussion and conclusion

This study has investigated, using an economic model and risk analysis to what extent CA relative to conventional agriculture (within this case study district) is economically viable. Whilst acknowledging there are limitations to our approach (e.g. small sample size for certain crop mix simulations and cross-sectional data gathered for one season as opposed to panel data over several seasons) the study is strengthened by having observations of farmers using CA in each year of use i.e. first year, second year and third year. Furthermore, the study addresses some of the key concerns raised in the literature on previous farm-level economic analysis, namely the use of appropriate planning horizons, discount rates and opportunity costs facing farmers which reflect their realities. The economic model finds evidence that under higher discount rates CA can be an attractive option relative to conventional under a number of scenarios and depending on crop mix can even provide yield benefits relative to conventional agriculture over the short and longer term. Equally, there can be yield dips or conventional agriculture is likely to be ‘economically’ superior for other crop mixes but CA may have the advantage for farmers with a higher opportunity cost of labour.

Thus, some conclusions seem plausible. Firstly, the particular mixes used by farmers in this study provide some indication that farmers may also have differing motivations when approaching the use of CA e.g. primarily yield but also labour maximisation if subsistence based (produce solely for consumption) which may be the case for cassava based crop mixes and labour maximisation if otherwise e.g. for those with a higher opportunity cost of labour where farmers are likely to rely to a greater degree on purchasing additional food to meet their household requirements.[8]

For example, those using the sesame mix invariably sold the sesame produced given its high level of return where as farmers using the various cassava mixes consumed all of their produce. Moreover, if one looks at the cumulative distribution function (See Figure B.5 in Appendix B) of the poorest farmers using the sesame mix, conventional farmers (i.e. no CA) actually have the highest probability of achieving the very highest net returns (i.e. above 30,000 MZN) relative to CA farmers using the same mix (See Figure B.3 in Appendix B). It is thus the reduction in labour for this mix for CA farmers, which likely provides more stable net returns relative to conventional rather than higher yields per se. This may also be the case for farmers using the four-way crop mixes (among the poorest tercile) as opposed to two or three crops under conventional, as the labour reduction, particularly during land preparation time under CA extends the cropping cycle, essentially increasing the intensity of cropping which allows more crops to be grown in the season and improves the overall economic returns (FAO, 2001). Thierfelder et al. (2016) has also noted that CA will be attractive for poor farmers if there is focus on ‘energy efficient cropping systems’ which provide benefits to both labour and economic returns for farmers. Giller et al., (2015) has also noted that smallholder farmers also focus on maximising other production factors to minimise risk such as labour and capital rather than merely focusing on maximising yield.

Secondly, this study also supports the notion that CA can be a viable option for farmers without the use of high inputs including labour, the need for new cultivars or use of herbicides

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[8] Though it should be noted that in reality the majority of farming households are considered net buyers.

and fertilisers. Survey results, for instance, point to a reduction in weeding time without the need for herbicides. This is in sharp contrast to previous research which suggests that weeding time is likely to increase under CA without the use of herbicides (Giller et al., 2009). The results are in line with those of Thierfelder et al. (2013) which suggest that hand weeding is also an effective way to combat weeds without the need of herbicides. Thirdly, CA is being used by and deemed to be an attractive option (based on farmers' actual net returns) for the poorest farmers for a variety of crop mixes and risk tolerance levels including under extreme risk and uncertainty. This is contrary to previous farm-level economic analysis which suggests that farming households with smaller plots of land are unlikely to find CA (i.e. the full package) attractive (Pannell., et al 2014). The results do, however, support findings elsewhere in Mozambique (though the economic analysis did not account for the opportunity cost of mulch and only one crop was used rather than at least 3 under CA by definition) which suggests on smaller plots of land higher yields with CA practices can be realised relative to conventional agriculture (Grabowski and Kerr, 2014). Similarly, other on-farm experimental studies such as by Thierfelder et al. (2013) have also illustrated that on small plots of land all three principles of CA can be employed without fertiliser or herbicides being used and can be beneficial for farmers.

Furthermore, the majority of households in this study are using micro-pits similar to basins used elsewhere in Mozambique and Sub-Saharan Africa. An economic comparison of CA under different CA systems (as would comparison with partial CA practices being practiced in this study i.e. 2 crops) would also have been helpful in this regard. The site specific attraction that some CA systems have may explain the higher rate of adoption of micro-pits in this district (e.g. micro-pits are more commonly used in this district which is drier than other regions in Mozambique and is thus likely to be more attractive than in wetter areas). Qualitative information gathered from focus group discussions with farmers in the study also suggested that in some areas of the study district, micro-pits were considered less favourable among farmers because of waterlogging.[9] Thus, it should be noted that basins have been shown to be more productive and risk reducing in other dry climates (Mafongoya et al., 2016) whilst direct seeding is considered more attractive both in terms of productivity and labour reduction in wetter regions (Thierfelder et al., 2016).

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[9] Farmers also often used micro-pits in the early seasons to break the hard pan after which direct seeding is more commonly used.

The study findings are also supported by other analysis of farmers' perceptions (i.e. for the same cohort of farmers in this study) which uses a socio-psychological model to assess farmers' intention to use CA (Lalani et al., 2016). Lalani et al. (2016) show through regression estimates which accounted for 80% of the variation in intention that farmers' attitude is the strongest driver of intention to use CA which is mediated through key cognitive drivers such as increased yields, reduction in labour, improvement in soil quality and reduction in weeds. Yield was found to be the strongest driver to use CA followed by reduction in labour, improvement in soil quality and reduction in weeds. Farmers with a high intention to use CA also perceived CA to perform better in a drought year than those with a low intention ($p<0.05$). Interestingly, the poorest farmers had the highest intention to use CA and found CA the easiest to use compared to better-off farmers ($p<0.05$). Carmona et al. (2015) has recently argued that there is a lack of research on CA which sheds lights on farmers' motivations and perceptions of CA. Pannell et al. (2006) has further suggested that farmers' goals play a key role in the decision to use rural innovations be these social, personal, economic or based on environmental concerns to name a few. Innovations are also more likely to be adopted if they are easy to test and learn about before adoption (Pannell et al., 2006). Of course farmers perceptions be they through measurements based on farmer recall or a study of their motivations may not align with experimental research findings. They do, however, provide an important indication into the adoption process and thus allow an understanding of what farmers perceive to be beneficial in their own contexts.

However, notwithstanding this the potential for CA to be of benefit to the poorest in particular i.e. those with very small plots of land in similar circumstances and farming systems should not be discounted. It is clear from this study that farmers can find CA attractive with the resources they have e.g. local variety of seed, family labour and no external inputs but nonetheless require support in terms of reducing the risk and uncertainty of taking up a 'new' management system. The wide ranging support from NGOs in this regard (e.g. FFS and other support mechanisms to enhance farmer to farmer exchange such as seed multiplication groups or associations) can reduce 'uncertainty' as farmers learn about and observe what others are doing. Moreover, it has also been suggested that certain factors which are most likely to have the strongest impact on reducing uncertainty such as the reduction in labour associated with no-till should be the focus of extension approaches related to CA (Pannell et al., 2014). Thus, these social learning mechanisms play an important role in this regard and will be increasingly important in other parts of Sub-Saharan Africa to better communicate benefits, constraints and solutions among farmers. For example, in this study region those with a low intention to use CA perceived CA to be labour intensive and requiring a high degree of knowledge and skills which is in sharp contrast to the perceptions of those with a high intention to use CA (Lalani et al., 2016). Interestingly, Farmer Field School members found CA the easiest to use and had stronger beliefs regarding the benefits of CA i.e. increased yields, reduction in labour etc. (Lalani et al., 2016). Ward et al. (2016) recently suggested that rather than subsidies and voucher programs being used as an incentive; 'tailouring training and knowledge programs' in relation to risk farmers face will be important in addressing adoption of CA.

In this regard, further research which combines farmers' motivations and their risk management strategies with more conventional economic/risk analysis would help to identify different crop mixes/sequences for different conditions. TerAvest et al. (2016) recently identified the need for additional research on diverse rotations under CA (including grain legumes and those with higher protein yields) in Eastern and Southern Africa. Though not specifically related to CA but which could be a methodological approach utilized in further research, Kamanga et al. (2010) studied effects on soil quality over time alongside household level farm budget data for differing farmer typologies and through risk analysis determined different cropping options may be attractive when soil quality is important rather than merely economic/financial considerations. Thus, there are likely to be cases where conventional–tillage systems have short-term benefits which are more attractive economically and factors such as soil erosion may have a bearing on long-term productivity and economic returns which may favor CA or CA practices being used in the long run. (Stonehouse, 1991; Fatherlrahman et al., 2011). Other authors have also noted the need for 'individual preferences' to be considered in risk analysis (Fatherlrahman et al; 2011; Ngwira et al 2013). Moreover, future research may also consider the wider implications to society at large of different systems being used. For example, the possibility that other benefits to society may not be quantified such as the potential of CA use to increase carbon sequestration or reduce soil erosion which may improve water quality and thus could warrant incentives (e.g. payments for ecosystem services) being provided to farmers if the cumulative benefits to society are higher than conventional tillage systems and where economic returns particularly in the short-term may be lower than conventional systems (Ngwira et al., 2013).

Acknowledgements

The authors wish to thank the Aga Khan Foundation (Mozambique) for funding the household survey component of this study.

Appendix A

Table A.1 Base case assumptions used in Economic model

Parameters	Price per kg
Maize	10 MZN green maize and 5 MZN grain
Cowpea	24 MZN for green and grain
Sesame	50 MZN
Mung bean	18 MZN
Cassava	7 MZN
Labour	8 MZN per hour based on 50 MZN cost of labour for one person in a typical day based on a 6 hour working day.
Mulch	Grain to crop residue ratio of 1:1 for maize green, grain and sesame. For legume (cowpea, cassava, pigeon pea) is calculated at 1:1.35

Table A.2 Sensitivity analysis assumptions i.e. altered parameters from base case

Parameters	Price per kg
Maize	10 MZN green maize and 8 MZN grain (high); 10MZN green and 4MZN (low)
Labour	17 MZN per hour (high) and 7 MZN per hour (low)

Appendix B

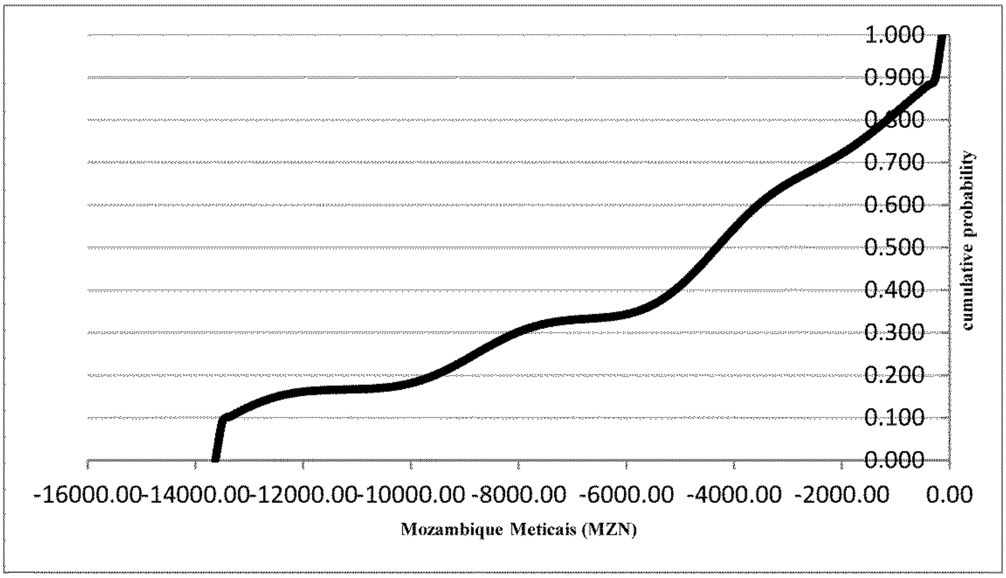

Figure B.1 Cumulative distribution function for net returns of conventional (No-CA) farmers using maize-cassava crop mix (poorest tercile)

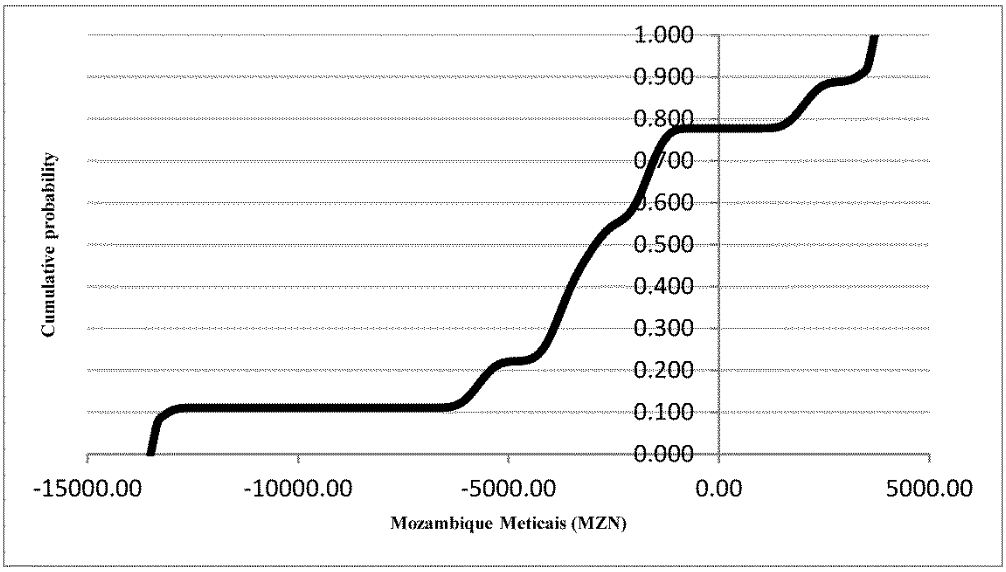

Figure B.2 Cumulative distribution function for net returns of CA farmers using maize, cowpea and cassava crop mix (poorest tercile)

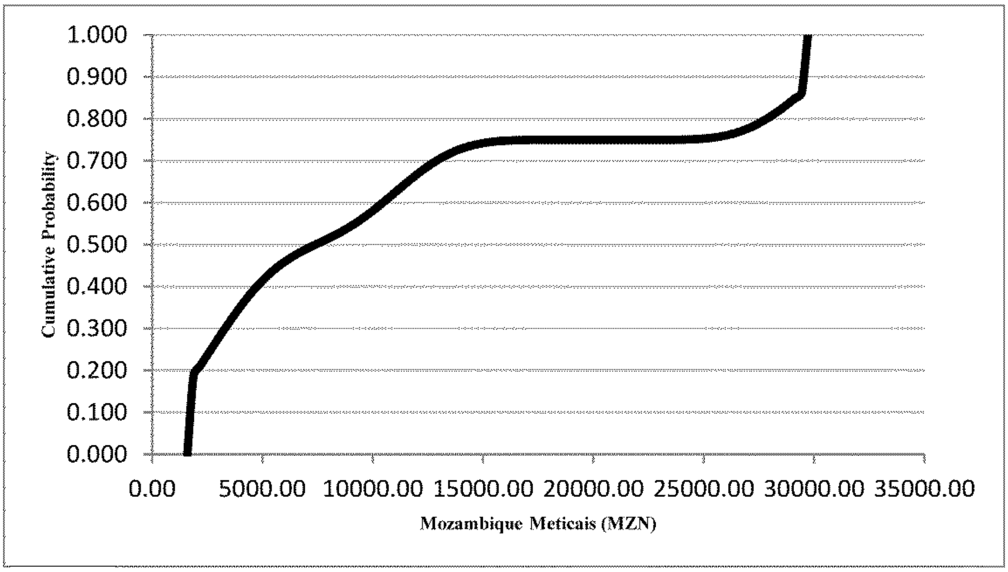

Figure B.3 Cumulative distribution function for net returns of CA farmers using maize, cowpea and sesame crop mix net (poorest tercile)

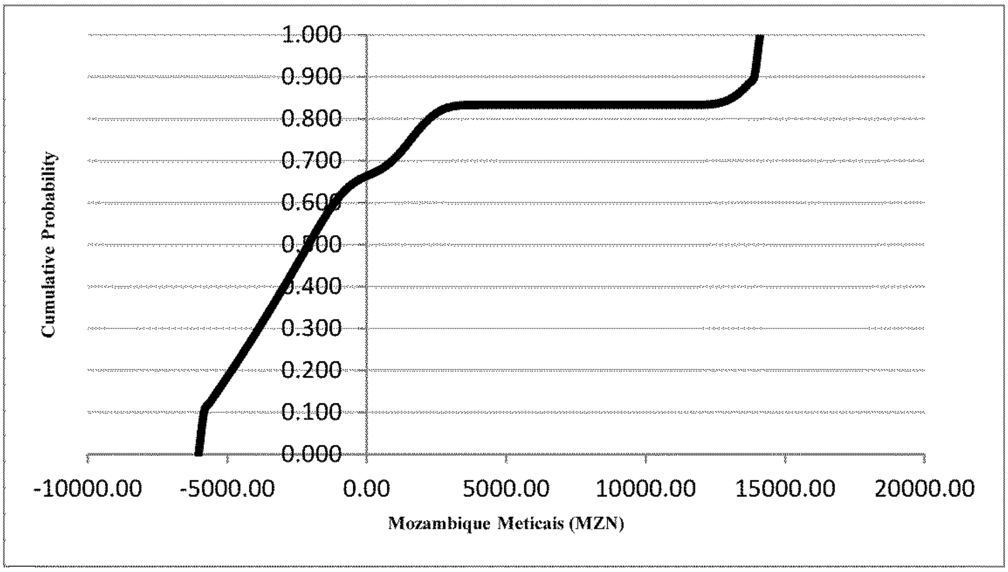

Figure B.4 Cumulative distribution function for net returns of CA farmers using maize, cowpea, pigeon-pea and cassava crop mix (poorest tercile).

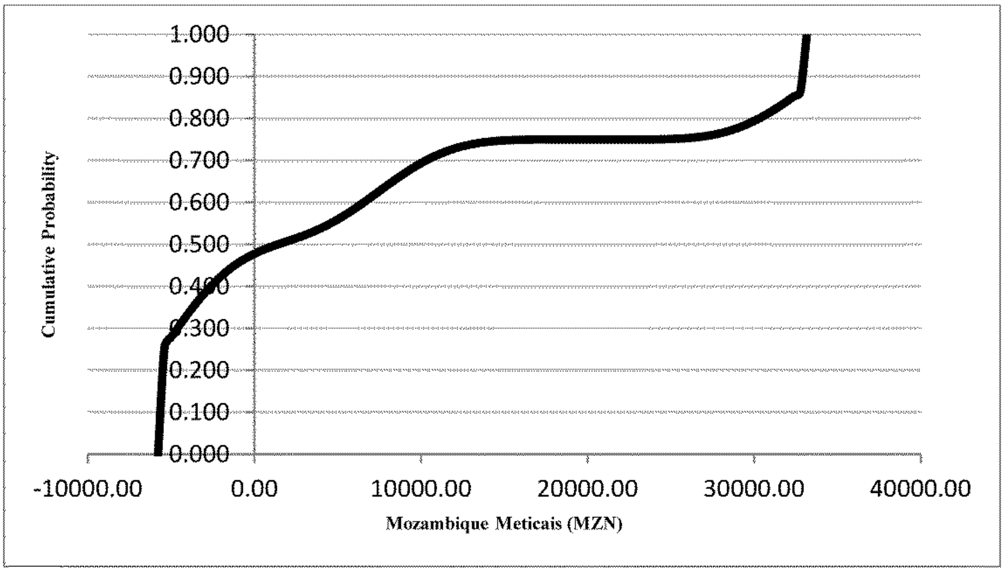

Figure B.5 Cumulative distribution function for net returns of conventional (No-CA) farmers using maize, cowpea and sesame crop mix (poorest tercile).

Appendix C

Table C.1 Yields (kg/ha) for maize, cowpea cassava mix (CA and Conventional) used for simulations in Simetar© i.e. Tables 2 and 3

year of CA use/conventional	maize green	maize grain	cowpea green	cowpea grain	cassava
1	50	360	0	0	0
1	100	600	50	120	150
1	50	420	0	0	0
1	50	300	50	336	0
1	50	120	25	56	90
1	150	240	0	0	0
1	0	0	0	0	0
1	0	0	0	0	0
1	50	240	50	112	
1	100	360	0	0	113
1	50	200	50	100	300
2	50	360	25	60	
2	100	360	0	0	0

2	50	0	0	0	0
2	25	120	0	0	400
2	100	480	56	56	390
2	50	120	50	224	180
2	50	120	0	56	540
2	50	120	50	56	0
2	50	60	0	0	0
2	25	180	0	0	350
3	50	120	0	0	0
3	30	360	0	0	0
3	50	300	25	28	200
3	100	240	20	28	480
3	0	0	0	0	300
3	50	180	10	28	225
3	100	600	0	0	330
3	50	60	0	28	150
3	0	0	0	0	0
3	30	300	30	112	330
3	100	240	0	0	300
3	33	320	20	19	200
conventional	0	900	0	0	0
conventional	25	300	0	28	75
conventional	60	180	30	56	30
conventional	0	0	0	0	0
conventional	50	360	0	0	320
conventional	40	267	20	37	120
conventional	20	200	0	0	50

Table C.1 Yields (kg/ha) for maize, cowpea sesame mix (CA and Conventional) used for simulations in Simetar© i.e. Tables 3 and 4

year of CA use/conventional	maize green	maize grain	cowpea green	cowpea grain	sesame
1	90	900	0	0	0
1	30	960	0	0	60
1	50	3333	30	224	200
1	100	240	25	56	120
1	100	360	30	56	390
1	33	240	10	75	180
1	50	360	60	56	540
2	67	320	33	75	160
2	100	180	50	112	180
2	13	390	0	0	0
2	50	720	60	56	240
3	50	480	0	0	180
3	50	360	0	28	60
3	100	840	0	224	240
3	150	240	25	112	10
3	17	200	0	0	40
3	25	360	10	28	0
3	50	300	0	0	360
conventional	50	300	0	0	60
conventional	67	320	33	112	240
conventional	75	1800	0	0	100
conventional	100	480	50	56	120
conventional	67	400	0	19	240
conventional	90	900	100	224	180
conventional	60	400	20	75	80

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Chapter 3: Can a socio-psychological model explain farmer decision making?[10]

Abstract: Conservation Agriculture (CA) has been widely promoted as an agro-ecological approach to sustainable production intensification. Despite numerous initiatives promoting CA across Sub-Saharan Africa there have been low rates of adoption. Furthermore, there has been strong debate concerning the ability of CA to provide benefits to smallholder farmers regarding yield, labour, soil quality and weeding, particularly where farmers are unable to access external inputs such as herbicides. This research finds evidence that CA, using no external inputs, is most attractive among the very poor and that farmers are driven primarily by strong motivational factors in the key areas of current contention, namely yield, labour, soil quality and weeding time benefits. This study is the first to incorporate a quantitative socio-psychological model to understand factors driving adoption of CA. Using the Theory of Planned Behaviour (TPB), it explores farmers' intention to use CA (within the next 12 months) in Cabo Delgado, Mozambique where CA has been promoted for almost a decade. The study site provides a rich population from which to examine farmers' decision making in using CA. Regression estimates show that the TPB provides a valid model of explaining farmers' intention to use CA accounting for 80% of the variation in intention. Farmers' attitude is found to be the strongest predictor of intention. This is mediated through key cognitive drivers present that influence farmers' attitude such as increased yields, reduction in labour, improvement in soil quality and reduction in weeds. Subjective norm (i.e. social pressure from referents) and perceived behavioural control also significantly influenced farmers' intention. Furthermore, path analysis identifies farmers that are members of a Farmer Field School or participants of other organisations (e.g. savings group, seed multiplication group or a specific crop/livestock association) have a significantly stronger positive attitude towards CA with the poorest the most likely users and the cohort that find it the easiest to use. This study provides improved understanding relevant to many developing countries, of smallholder farmers' adoption dynamics related to CA, and of how farmers may approach this and other 'new' management systems.

Keywords: Conservation Agriculture, Adoption, Theory of planned Behaviour

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[10] A version of this chapter has been published as: Lalani, B., Dorward, P., Holloway, G., Wauters., E. 2016 Smallholder farmers' motivations for using Conservation Agriculture and the roles of yield, labour and soil fertility in decision making. Agricultural Systems, 80-90,146. http://dx.doi.org/10.1016/j.agsy.2016.04.002

Introduction

The complex interaction of population growth, technological advancement and climate change have impacted heavily on agricultural and environmental sustainability. Modern farming systems that are used throughout the industrialized world have traditionally been characterized by high use of inputs and mechanization of agriculture involving tillage. Notwithstanding the potential to increase food production through conventional intensive agriculture it has been well documented that such agricultural systems are a source of significant environmental harm (Pretty, 2008; Tilman, 1999). In Sub-Saharan Africa, conventional tillage practice usually through hand-hoe or animal traction has resulted in soil erosion and loss of soil organic matter (SOM) which has been further exacerbated by the practice of crop residue removal and burning (Rockström et al., 2009). Consequently a ‘business as usual’ approach to agricultural development is seen as one which will be inadequate to deliver sustainable intensification for future needs (Shaxson et al., 2008). Thus, the discourse on agricultural sustainability now contends that systems high in sustainability are those that make best use of the environment whilst protecting its assets (Pretty, 2008).

Conservation Agriculture (CA) forms part of this alternative paradigm to agricultural production systems approaches. Most recently, authors have questioned the mode in which CA is being used as an ‘across-the board’ recommendation to farmers without proven benefits in terms of boosting yields, labour reduction and carbon sequestration (Giller, 2012). This is compounded by internal debate with those advocating for the use of CA practices with different terms emerging from ‘no-tillage’ to ‘conservation tillage’ and ‘minimum tillage’ over the past decades. Many of these have been ascribed to CA. A wide variety of the differing typologies have also been defined and discussed (Kassam et al., 2009). CA is, however, defined as: (i) *Minimum Soil Disturbance*: Minimum soil disturbance refers to low disturbance no-tillage and direct seeding. The disturbed area must be less than 15 cm wide or less than 25% of the cropped area (whichever is lower). There should be no periodic tillage that disturbs a greater area than the aforementioned limits. (ii) *Organic soil cover*: Three categories are distinguished: 30-60%, >60-90% and >90% ground cover, measured immediately after the direct seeding operation. Area with less than 30% cover is not considered as CA. (iii). *Crop rotation/association*: Rotations/associations should involve at least 3 different crops. (FAO, 2015).

CA, by definition, is now practiced on more than 125 million hectares worldwide across all continents and ecologies (Friedrich et al., 2012). It is also used on various farm sizes from smallholders to large scale farmers and on a wide variety of soils from heavy clay to highly sandy (ibid). There have, however, been mixed experiences with CA particularly in Sub-Saharan Africa (Giller, 2009) where human and animal powered CA systems predominate (given the lack of mechanisation) as opposed to machine powered systems (i.e. involving minimal soil disturbance) that are being used elsewhere in the world. Furthermore, across Sub-Saharan Africa there have been low rates of adoption which have fuelled controversy surrounding the benefits of CA both in terms of the private and social benefits accruing from adoption. Akin to Giller's arguments (Giller, 2009; Giller, 2012), Baudron et al. (2012) found for farmers in the Zambezi Valley (Zimbabwe) that CA required additional weeding and lack of labour availability for this task reduced uptake. Chauhan et al. (2012) have also argued that in general there is a poor understanding of weed dynamics within a CA system which can have a bearing on farmer adoption of CA. Sumberg et al. (2013) also explored the recent debates surrounding CA and questioned the 'universal approaches to policy and practice' which may limit the understanding of different contextual factors and alternative pathways.

Other issues surrounding the CA discourse involve the particular time horizon for benefits to materialise and that farmers are concerned with immediate costs and benefits (such as food security) rather than the future (Giller, 2009). Rusinamhodzi et al. (2011) found that CA does have added benefits but these are largely found in the longterm. Yields under CA may even incur losses compared to conventional agriculture, especially in the short run and in excessively wet years (Thierfelder and Wall, 2010). A recent systematic review conducted by Wall et al. (2013) for CA in Eastern and Southern Africa (maize [*Zea mays*]-based systems) also found that yields were generally equal or higher than conventional agriculture. Wall et al. (2013) further postulate that successful CA systems require adequate soil fertility levels and biomass production. The feasibility of crop residue retention, particularly in strong mixed crop-livestock systems has also been questioned (Giller, 2009).

Nkala (2012) also suggests that CA is not benefiting the poorest farmers and they require incentives in the form of subsidised inputs. Grabowski and Kerr (2013) further argue that without subsidised fertiliser inputs CA adoption will be limited either to only small plots or abandoned altogether. Access to fertiliser and other inputs including herbicides are therefore a contentious issue, with a number of authors arguing that for CA to improve productivity; appropriate fertiliser applications and herbicide applications need to be used (Rusinamhodzi et al., 2011; Thierfelder et al., 2013b). Wall et al. (2013) found in their review that of the studies with improved yields most were fertilised (including animal manure) and had both retained residues as mulch and employed chemical weed control complemented by hand weeding-requiring inputs that in reality are beyond the reach of most smallholders.

Recent economic theory contends that the adopter makes a choice based on maximization of expected utility subject to prices, policies, personal characteristics and natural resource assets (Caswell et al., 2001). Similarly, a vast array of studies within the agricultural technology adoption literature have focused on farm characteristics and socio-economic factors that influence adoption. Limited research, however, has been done which has concentrated on cognitive or social- psychological factors that influence farmers' decision making such as social pressure and salient beliefs (Martínez-García et al., 2013).

Thus, in analysing the factors that affect adoption, understanding of the socio-psychological factors that influence farmers' behaviour is an important consideration. With respect to CA research, this notion is supported to some extent by Knowler and Bradshaw (2007) who have shown for an aggregated analysis of the 31 distinct analyses of CA adoption that there are very few significant independent variables (education, farm size etc.) that affect adoption. Just two, 'awareness of environmental threats' and 'high productivity soil' displayed a consistent impact on adoption i.e. the former having a positive and the latter a negative impact on adoption. Wauters and Mathijs (2014) similarly meta-analysed adoption of soil conservation practices in developed countries and also found that many classic adoption variables such as farm characteristics and socio-demographics are mostly insignificant, and if significant, both positive and negative impacts are found. Other authors have also suggested that adoption should not be viewed as a single decision but rather a decision making process over time as farmers continually try, adapt and decide on when to use technologies (Martínez-García et al., 2013). Furthermore, in a recent meta review of CA studies, Stevenson et al. (2014) have suggested a key area for research in Asia and Africa will be understanding the process of adoption.

Research on CA in Cabo Delgado (Northern Mozambique where this study is based) is sparse and/or has not been documented by way of peer-reviewed research. Previous studies on CA systems have been conducted elsewhere in Mozambique (Nkala et al., 2011; Nkala, 2012; Famba et al., 2011; Grabowski and Kerr, 2013; Thierfelder et al., 2015; Nyagumbo et al., 2015; Thierfelder et al., 2016). Most of these studies have focused on on-farm level experiments whilst some have focused on farm-level economics (Grabowski and Kerr, 2013) and determinants of adoption (Nkala et al., 2011). In addition, other studies in Mozambique have explored adoption of chemical fertiliser and new maize varieties using socio-psychological constructs (Cavane and Donovan, 2011) and explored adoption of new crop varieties through social networks (Bandiera and Rasul, 2008) whilst others have used more conventional approaches (i.e. using farm level/household characteristics) to assess agriculture technology adoption (Uaiene et al., 2009; Benson et al., 2012) or further econometric approaches used to examine the impact of adoption of various improved agricultural technologies on household income in Mozambique (Cunguara and Darnhofer, 2011). Leonardo et al. (2015) also recently assessed the potential of maize-based smallholder productivity through different farming typologies. Thus household level studies exploring adoption dynamics with a socio-psychological lens have been lacking both on CA and within the agricultural technology adoption literature in general i.e. not restricted to Mozambique (as outlined earlier).

Socio-psychological theories which are helpful in this regard are The Theory of Planned Behaviour (TPB) and Theory of Reasoned Action (TRA). The TPB and TRA frameworks have been used in several studies to assess farmers' decision making for a range of agricultural technologies (Beedell and Rehman, 2000; Martínez-García et al., 2013; Borges et al., 2014). This has included more specifically studies which have assessed conservation related technologies such as water conservation (Yazdanpanah et al., 2014) including organic agriculture (Läpple and Kelley, 2013), soil conservation practices (Wauters et al., 2010) and more recently payment for ecosystem services related initiatives (Greiner, 2015). In relation to CA practices, previous studies have been conducted by Wauters et al. (2010) relating to for example, reduced tillage, which includes residue retention and the use of cover crops. These studies have focused on Europe and also have dealt with the behaviours as individual practices, e.g. the intention to use cover crops.

To our knowledge, having reviewed the various online search databases (e.g. Web of Science and Scopus etc.), for studies that use TPB in relation to Conservation Agriculture, this study is the first quantitative theory of planned behaviour study assessing farmers' intention to use Conservation Agriculture by definition i.e. the simultaneous application of minimum soil disturbance, organic mulch as soil cover and rotations/intercrops and/or use of associations.

This study makes a contribution to the existing literature by researching farmers’ perceptions of CA use and addresses issues surrounding beliefs farmers hold with regards to specific areas of contention i.e. yields, labour, soil quality and weeds. We test the validity of the theory of planned behaviour in explaining farmers’ intention to apply CA. Further, we test the added explanatory impact of farmer characteristics. After confirming the usefulness of the TPB to understand farmers’ intentions, we proceed by investigating farmers’ cognitive foundation, i.e., their beliefs that underpin their attitudes, norms and perceived control.

The following provides a background to the study area followed by the methodology and results section. The final section provides a discussion and conclusion.

Background -Study area

Cabo Delgado is the northernmost province situated on the coastal plain in Mozambique.
Its climate is sub-humid, (or moist Savanna) characterized by a long dry season (May to November) and rainy season (December to April).

There are ten different agro-ecological regions in Mozambique which have been grouped into three different categories based in large part on mean annual rainfall and evapotranspiration (ETP). Highland areas typified by high rainfall (>1000mm, mean annual rainfall) and low evapotranspiration correspond to zones R3, R9 and R10. Medium altitude zones (R7, R4) represent zones with mean annual rainfall ranging between 900-1500mm and medium level of ETP. Low altitude zones (R1, R2, R3, R5, R6, R7, R8) which are hot with comparatively low rainfall (<1000mm mean annual rainfall) and high ETP (INIA, 1980; Silici et al., 2015). The Cabo Delgado province falls within three agro-ecological zones R7, R8, and R9. The district under study (Pemba-Metuge) falls under R8; distribution of rainfall is often variable with many dry spells and frequent heavy downpours. The predominant soil type is Alfisols (Maria and Yost, 2006). These are red clay soils which are deficient in nitrogen and phosphorous (Soil Survey Staff, 2010).

Though provincial data is sketchy, yields for staple crops in Mozambique are very low compared to neighbouring countries in Southern Africa. Average yields (calculated from FAOSTAT data based on the years 2008-2013), for example, show relatively low yields for maize (1.12 tons/ha), cassava (*Manihot esculenta Crantz*), (10 tons/ha) and rice (*Oryza sativa* L.), (1.2 tons/ha). These are lower than neighbouring Malawi which has much higher cassava (15 tons/ha), maize (2.3 tons/ha) and rice (2.1 tons/ha) yields. Maize and rice yields in Malawi are virtually double those in Mozambique. Zambia has comparatively higher maize and rice yields but lower overall cassava yields than Mozambique. Maize yields (2.7 tons/ha) in Zambia, on average based on the past five years, are triple those in Mozambique and rice yields in Zambia are virtually double (1.7 tons/ha) (FAOSTAT, 2016).

The majority of inhabitants, within Cabo Delgado province rely on subsistence agriculture, where livestock numbers are very low and market access is often limited due to poor roads and infrastructure. Research has highlighted that the prevalence of stunting (55%) is the highest among all provinces in Mozambique (FAO, 2010). Furthermore, poverty studies also place Cabo Delgado among the poorest in Mozambique (Fox et al., 2005). A more recent study using the human development poverty index ranks Cabo Delgado as the second poorest province in Mozambique (INE, 2012). This is compounded by high population growth in Mozambique which exacerbates the poverty nexus. Current projections show that the population of Pemba-Metuge district will more than double by 2040 (INE, 2013). Though population density is considered very low across Mozambique (Silici et al., 2015) intensification as opposed to extensification of land will be imperative for the future with increased population, climate variability and lack of labour to clear new land (Thierfelder et al., 2015). Similar pressures exist in much of Sub-Saharan Africa and in many countries population pressure is far greater.

Conservation Agriculture in Cabo Delgado

CA adoption has gathered momentum in Cabo Delgado, in recent years, largely stimulated by the institutional presence of the AKF-CRSP (Aga Khan Foundation Coastal Rural Support Programme), which has been promoting CA in the province since 2008. The establishment of a number of Farmer Field Schools, within each of the districts, has also helped to encourage adoption of CA among farming households. As of 2014, there were 266 Farmer Field Schools that focus on CA running in Cabo Delgado with a combined membership of 5000 members.

Unlike other NGOs in parts of Mozambique and Sub-Saharan Africa, AKF have not provided inputs such as herbicides and chemical fertilisers in order to stimulate adoption. Given the lack of draft and mechanical power in Cabo Delgado, manual systems of CA have been promoted. AKF’s approach has aimed to improve soil fertility through the use of legumes as green manure, annual (cover also as crops) and perennials, developing mulch cover with residues and vegetation biomass (produced on-farm or brought in from the surroundings i.e. bush areas) and compost.

Materials and Methods

Theoretical framework

The TPB is a social-psychological model which seeks to understand the dynamics of human behaviour (Ajzen, 1991). The model predicts the intention to perform a particular behaviour based on three factors. These are: (i) attitudes towards the behaviour which can be either positive or negative, (ii) subjective norms (i.e. social pressures to adhere to the certain behaviour) and (iii) perceived behavioural control (i.e. to what extent the individual perceives to have control over engaging in the behaviour). These three factors together either form a positive or negative intention to perform the behaviour under study (See Figure 1). In addition, if there is adequate actual behavioural control e.g. presence of sufficient knowledge, skills and capital then the individual will act on their intention. Ajzen (2005) has suggested that it is possible to substitute actual behavioural control for perceived behavioural control. For this study perceived behavioural control is taken as a proxy for actual behavioural control. The TPB is the successor of the Theory of Reasoned Action (TRA). Theory of Reasoned Action was developed first, by Fishbein and Ajzen (1975) and posited that people's behaviour was explained by two considerations. The first was attitude, or the degree to which people evaluated the behaviour as positive or negative. The second was subjective norm, the perceived social pressure from others to perform the behaviour or not. Empirical evidence showed that this theory was successful in explaining people’s behaviour as long as they have full volitional control over performance of the behaviour, i.e. all necessary conditions in terms of presence of necessary requirements and absence of any inhibiting factors were met. As this is only the case in a limited number of contexts and behaviours, the TPB was developed. In this theory, the concept of perceived behavioural control was added, which reflect the perceived degree of control a person has regarding his/her own capacity to perform the behaviour. This perceived degree of control has to do with the degree to which all the necessary prerequisites in order to perform the behaviour are met. As a general rule of thumb, the stronger the attitude, subjective norm and perceived behavioural control the stronger the intention is likely to be to perform the behaviour (Davis et al., 2002).

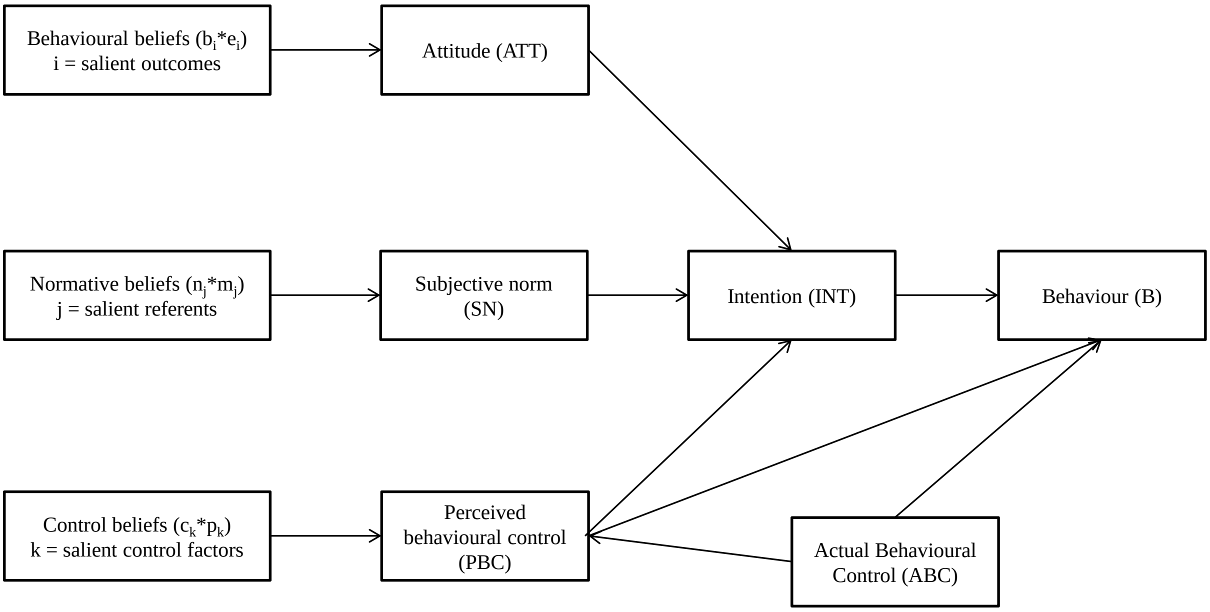

Figure 1 Theory of planned behaviour (Adapted from Azjen, 1991)

Attitudes, subjective norms and perceived behavioural control are the results of behavioural, normative and control beliefs respectively. These beliefs are the cognitive foundations that determine the socio-psychological constructs. The belief based measures are calculated using the expectancy-value model (Fishbein and Ajzen, 1975). Behavioural belief or the expectation that the belief will lead to an outcome (b) is multiplied by the outcome evaluations of those beliefs(e). Each of the beliefs are subsequently multiplied by their respective outcome evaluation. These are then aggregated to give an overall attitude weight. Similarly, for subjective norm, each normative belief i.e. the expectations of others also termed referents (n) is multiplied by the motivation to comply with their opinions(m). These are then summed to create an overall weight for subjective norm. Finally, control beliefs, (c) are multiplied by the perceived power of the control belief (p) that either inhibit or help to facilitate the behaviour. These are also aggregated to create a weight for perceived behavioural control (Wauters et al., 2010; Borges et al., 2014). The relationship between the cognitive foundations (beliefs) and their respective constructs is shown in the following equations:

$$A = \sum_{i=1}^{x} b_i \, e_i$$

$$SN = \sum_{j=1}^{y} n_j \, m_j$$

$$PBC = \sum_{k=1}^{z} c_k \, p_k$$

Similar notation is used to that of Wauters et al.(2010) and Borges et al., (2014) where i is the ith behavioural belief, x the total number of behavioural beliefs, j the jth referent, y the total number of referents, k the kth control factor and z the total number of possible control factors. While we will not quantitatively calculate attitude, subjective norm and perceived behavioural control using the expectancy-value theory, this theory offers us a framework we can use to investigate the cognitive foundations that determine attitude, subjective norm and perceived behavioural control.

Survey procedure

We adopted a sequential mixed-method research approach, in which qualitative data collection preceded the quantitative data collection stage. Sequential mixed-methods are widely used in agricultural research to shed light on often complex phenomena, such as farmers' behaviour (e.g. Arriagada et al., 2009). The results of the first stage were used to design the data collection instrument used in the second stage. According to the TPB conceptual framework, outlined above, key themes exploring the advantages and disadvantages of the behaviour in this case CA use were explored. Moreover, these interviews were used to elicit information on social norms and social referents and existing factors affecting adoption of CA. Knowledge of these factors is necessary to construct the survey instrument intended to quantitatively assess farmers beliefs related to the outcomes, referents and control factors. In this qualitative stage, 14 key informant interviews and 2 focus groups discussions (FGD) were carried out in three different villages over the period of a month from February to March, 2014.

As with most qualitative data analysis the transcriptions were coded and categorised into groups using deductive content analysis (Patton, 2002). These were done first by colour i.e. highlighting aspects which related to the theory of planned behaviour. Sub-themes were then explored which related to specific aspects of the theory of planned behaviour such as behavioural beliefs and social referents. Links within categories and across categories were also looked for. The final result of this stage was a complete list of all salient outcomes, all salient referents and all salient control factors. This list was subsequently used to design part of the survey, as explained in the next section. For the complete lists of all salient outcomes, referents and control factors, we refer to tables 5, 6 and 7 respectively. The term 'all accessible' is used in these table captions which refer to the complete lists of salient outcomes, referents and control factors gathered in the first stage.

A translator was used that was conversant in the different dialects used in the district. Access to the village and district was granted through discussion with the village elders through the Aga Khan Foundation district facilitator.

The study presents results from a survey of 197 farmers in the Metuge district, of Cabo Delgado Province Mozambique**.** A multi-stage sampling procedure was used to select the households from a list of local farmers provided by key informants in each of the villages. The total clusters (i.e. in this case villages were chosen based on whether the Aga Khan Foundation had a presence there and started on CA awareness work). This list came to 13 villages. Six communities were chosen randomly from this list and households were selected randomly from the lists in these villages using population proportional to population size. In the initial sample, 250 farmers were surveyed. Due to non-response of 53 farmers, our final effective sample size was 197. The survey was translated into Portuguese and trained enumerators were used that were conversant in both Portuguese and the dialects used in the different villages.

Variables and measurement

The survey consisted of several sections. The first 4 sections contained questions about household and farm characteristics, about agricultural production practices, about plot level characteristics and about the previous use of conservation agriculture. The next two sections dealt with household assets and food and nutrition security. The seventh section assessed farmers' current CA adoption. The remaining sections contained questions dealing with the TPB. Since the survey was performed in the course of a larger research project, in the remainder of this section, we only explain the measurement of those variables that were used in the analyses reported in this study (see sections H-J of questionnaire in Appendix 1 for questions related to theory of planed behaviour).

Age (AGE) was measured as a continuous variable, village (VILLAGE_ID), and education (EDUC) were measured using codes for the villages i.e. 1-6 and levels of educational attainment in the case of education. Membership of a CA Farmer Field School (MEMBER_FFS), membership of other organisations (MEMBER_OTHER), sex (SEX) were measured using dichotomous variables. Principal component analysis (PCA) was conducted in order to establish a wealth index (i.e. POVERTY_INDEX).[11] As is common in a number of

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[11] This is a wealth index with the poorest farmers ranked in group 1 and the better-off farmers in group 2 and 3 accordingly.

poverty studies the first principal component (PC1) which explained the majority of variance in the data was used as the index (Edirisinghe, 2015). Households were then ranked into terciles with respect to the level of wealth, taking three values referring to lower, middle and upper tercile (POVERTY_GROUP).

The TPB variables were measured using Likert-type items or items from the semantic differential, i.e., questions to which the respondent has to answer on a scale with opposite endpoints. Intention (INT) was assessed by asking the farmer how strong his intention was to apply CA on his/her farm over the next year, on a scale from 1 (very strong) to 5 (very weak). Attitude (ATT) was assessed using two items. The first asked the farmer to rate the importance of using CA on the farm in the course of the next year, on a scale from 1 (very important) to 5 (very unimportant). The second item asked the farmer to indicate how useful it would be to apply CA on the farm in the next year, on a scale from 1 (very useful) to 5 (very useless). The final score for attitude was calculated as the mean score of these two items.

Subjective norm (SN) was assessed by asking the farmer how likely it is that identified important others (salient referents) would think he/she should apply CA in the next year, on a scale from 1 (very likely) to 5 (very unlikely). Finally, perceived behavioural control (PBC) was assessed through a question about the difficulty of applying CA in the next year, on a scale from 1 (very easy) to 5 (very difficult). When inserting the data in a database, all these items were recoded from -2 to +2, with low values being unfavorable and high values being favorable towards CA.

Behavioural beliefs are farmers' beliefs about the salient outcomes of CA. During the qualitative stage, we identified a list of salient outcomes. For each of these outcomes, two questions were included in the survey, one for belief strength and one for outcome evaluation. Strength of the behavioural belief was measured by asking the respondent to indicate his/her agreement with the statement that application of CA resulted in the particular outcome, on a scale with endpoints 1 (strongly agree) and 5 (strongly disagree). Outcome evaluation was measured by asking the farmer the importance of that outcome, on a scale from 1 (very important) to 5 (very unimportant). Both items were recoded into a bipolar scale from -2 to +2, with -2 values meaning that the outcome was very unlikely and very unimportant to the farmer and +2 indicating the opposite.

Normative beliefs are beliefs about important referents. During the qualitative stage, we identified a list of salient referents, and for each of these, two questions were included in the survey. Strength of normative belief was measured with the question "how strongly would the following encourage you to use conservation agriculture on your farm?" on a scale with endpoints 1 (strongly encourage) to 5 (strongly discourage). Motivation to comply was also measured on a unipolar scale from 1 (very motivated) to 5 (not at all motivated) with the question: "How motivated would you be to follow the advice of the following regarding using conservation agriculture on your farm?" Both items were recoded into bipolar scales from -2 to +2, with -2 indicating that the referent would strongly discourage CA and that the farmer was not at all motivated to comply with advice from this referent, and +2 meaning the opposite.

Control beliefs are beliefs of the farmers about control factors (barriers or motivators). Control belief strength assessed the degree to which the control factor is relevant for the specific respondent. For example, "Do you have enough labour to use CA in the next 12 months?" scaled from 1 (strongly agree) to 5 (strongly disagree). Power of control factor measures the degree to which the control factor can make it easy or difficult to apply CA. This was measured by asking the farmer whether they agreed with the statement that the presence of this control factor was important to be able to apply CA, on a scale from 1 (strongly agree) to 5 (strongly disagree). The first item was recoded into a scale from -2 to +2; with -2 meaning that the control factor was not present.

Data analysis

Data was analysed in SPSS version 21. First, the data was cleaned by checking for cases with too many missing values, outliers and irregularities. As the survey was performed using personal enumeration, no cases had to be excluded because of too many missing values. Further, no outliers or other irregularities were found. All scale questions exhibited an acceptable degree of variation, meaning that not too many scores were in just one scale category. Second, we calculated descriptive statistics of the sample, including farm and farmer characteristics, adoption rate and TPB variables. Third, we performed a series of mean comparison analyses to compare the mean level of the TPB variables between different groups, using analysis of variance (ANOVA). When there were more than two groups, we performed post-hoc tests, which were evaluated using Tukey HSD in case of equal variances and Dunnett's T3 in case of unequal variances. The equality of variance assumption was evaluated using the Levene's test. We compared mean scores of the TPB between a number of variables that have been hypothesized to influence adoption of conservation practices, these being highest education level of the household head (EDUC), sex of the household head (SEX), membership in a CA Farmer Field School (MEMBER_FFS), membership in other organisations (MEMBER_OTHER), between the different villages (VILLAGE_ID), and between three groups on the poverty index (POVERTY_GROUP). We also computed correlations between TPB variables, and age of the household head (AGE) and the continuous poverty index (POVERTY_INDEX). Fourth, we tested the ability of the theory of planned behaviour to explain farmers' intention to apply CA, and investigated the role of the aforementioned farm and farmer characteristics. This was done using a hierarchical regression analysis with intention as dependent variable, in which attitude (ATT), subjective norm (SN) and perceived behavioural control (PBC) were added in the first step and the farmer characteristics in the second. Regression analysis was done using simple ordinary least squares (OLS) and assumptions were checked. As this analysis suggested that, in line with Ajzen (2011), the impact of these factors was fully mediated through the TPB predictors, we performed a path analysis in AMOS. First, we included all paths between these farmer characteristics and the three TPB variables, and gradually eliminated insignificant paths. As an additional check of the model, we dichotomized intention into a new variable, HIGH_INT, being 1 when intention was higher than 0, on a scale from -2 (very negative intention) to 2 (very positive intention) and 0 otherwise. The mean scores for attitude (ATT), subjective norm (SN) and perceived behavioural control (PBC) were compared between these two groups of those with low intention and high intention, using ANOVA analysis. Fifth, we examined the belief structure, by means of a Mann-Whitney U test, which assesses whether significant differences exist in the beliefs held by those with low intention and high intention.

Results

Summary statistics

Table 1 shows the summary statistics of the sample. Off-farm income is generally very low signifying the importance of agriculture in this region. Household sizes are quite high on average with low levels of educational attainment. Very low use of external inputs were found with only one farmer from the sample using a pesticide or compost and no farmers were using fertilisers, herbicides or animal manure (Lalani, 2016). Application of mulch refers to those farmers covering the soil with at least 30% of the cultivated soil surface covered.

Table 1 Summary statistics of the sample (n = 197)

Variable	Mean value or Percentage (Standard deviation in parenthesis)
SEX of Household Head	(Male 65%; Female 35%)
AGE of Household Head	62(27.9)
Marital status	(69 %= married, 2%= Divorced, 4%=Separated, 9%= Widowed and 16%=Single)
EDUC (Based on educational attainment i.e. grades completed 1-12)	2.4(2.8)
Household size	5.2(2.4)
Off-farm income (1 =yes, 2=no)	1.8(0.3)
Number of plots owned	1.4(0.5)
Mean Total Land size (hectares)	1.7(7.0)
Current adoption	
Micro-pits with mulch and rotation/intercrop using at least 3 different crops	51%
No-tillage with mulch and rotation/intercrop using at least 3 different crops	12%
Partial adoption/adaptation (mostly using two crops with mulch and either no till/micro-pits)	10%
No CA (no mulch)	24%
No CA (with mulch)	3%

Table 2 presents summary statistics of the TPB variables. It shows that the farmers in the sample have on average a positive intention to apply CA in the next 12 months. Likewise, they have a positive attitude towards CA, they are influenced by social norms to apply CA and they perceive CA as easy to use.

Table 2 Summary statistics and mean comparison of the theory of planned behaviour variables (n = 197)

	INT[h]	ATT[h]	SN[h]	PBC[h]
All	0.888 (0.713)	0.876 (0.496)	1.061 (0.667)	0.741 (0.699)
Villages				
Saul (n = 33)	1.061 (1.116)	1.046 [a] (0.642)	1.152 (0.755)	0.727 (0.911)
Nangua (n = 57)	0.947 (0.692)	0.886 (0.500)	1.070 (0.728)	0.772 (0.756)
Tatara (n = 38)	0.658 (0.582)	0.684[a] (0.512)	0.974 (0.716)	0.605 (0.679)
25 Juni (n = 24)	0.958 (0.550)	0.958 (0.327)	1.125 (0.537)	0.875 (0.448)
Nancarmaro (n = 11)	1.000 (0.000)	1.000 (0.000)	1.182 (0.405)	1.000 (0.000)
Ngalane (n = 34)	0.794 (0.538)	0.809 (0.427)	0.971 (0.577)	0.677 (0.638
Sex				
Male (n= 129)	0.861 (0.798)	0.857 (0.546)	1.054 (0.711)	0.690 (0.789)
Female (n = 68)	0.941 (0.515)	0.912 (0.386)	1.074 (0.581)	0.838 (0.477)
Education				
No education (n = 93)	0.893 (0.598)	0.844 (0.478)	1.054 (0.632)	0.817 (0.551)
Education (n = 104)	0.885 (0.804)	0.904 (0.512)	1.067 (0.700)	0.673 (0.806)
Membership in CA Farmer Field School				
Member (n = 122)	1.148[b] (0.400)	1.090 [b] (0.249)	1.262 [b] (0.442)	0.992 [b] (0.375)
No member (n = 75)	0.467 [b] (0.890)	0.527 [b] (0.592)	0.733 [b] (0.827)	0.333 [b] (0.890)
Membership in other organisations				
Member (n = 40)	1.100[c] (0.672)	1.063 [c] (0.282)	1.300 [c] (0.564)	0.950 [c] (0.639)
No member (n = 157)	0.834 [c] (0.715)	0.828 [c] (0.527)	1.000 [c] (0.679)	0.688 [c] (0.706)
Poverty group				
Low (n = 64)	1.078[d] (0.762)	0.992[e] (0.441)	1.359[f] (0.675)	0.938[g] (0.560)
Middle (n = 65)	0.800 [d] (0.712)	0.846 [e] (0.537)	0.969 [f] (0.612)	0.631 [g] (0.782)
High (n = 64)	0.813 [d] (0.639)	0.813 [e] (0.484)	0.875 [f] (0.630)	0.688 [g] (0.687)

a significant difference between Tatara and Saul ($p < 0.05$) b significantly different between members and non-members ($p < 0.001$) c significantly different between members and non-members ($p < 0.05$)

d significantly different between low and middle and between low and high ($p < 0.10$) e significantly different between low and high ($p < 0.10$)f significantly different between low and middle and between low and high ($p < 0.05$) g significantly different between low and middle and between low and high ($p < 0.10$)

h Means scores and standard deviation on a scale from -2(unfavourable towards CA) and +2 (favourable towards CA)

Relationship between TPB variables and farmer characteristics

Table 2 presents the results of a series of ANOVA analyses comparing TPB variables between groups with different characteristics. There is no significant difference in any of the variables between villages, with the exception of attitude, being significantly higher in Saul compared to Tatara. Furthermore, the TPB variables do not differ between male and female farmers, or between educated and non-educated farmers. There is a significant difference between farmers who belong to other organisations (e.g. savings group, seed multiplication group or specific crop/livestock association) and those who do not. Farmers who are members of the CA Farmer Field Schools have more favourable values of all TPB variables, as do farmers who belong to any other group. The difference is much more pronounced for membership of the CA Farmer Field Schools. Lastly, there is a statistically significant difference according to the poverty group, a wealth classification based on the poverty index, described above. Farmers from the low wealth group have significantly more favourable values towards CA than farmers from the middle or high group. This is confirmed by computing the Spearman's correlation between the TPB variables and the POVERTY_INDEX, which is always negative and significant (INT: -0.211; ATT: -0.199; SN: -0.311; PBC: -0.201; $p < 0.01$). AGE, finally, had no significant correlations with any of the TPB variables.

The theory of planned behaviour model

The TPB suggests that intention is explained by attitude, subjective norm and perceived behavioural control. In addition, the analysis reported in table 2 suggests that there are some farmer characteristics that influence farmers' TPB variables. According to Ajzen (2011), the impact of such variables on intention is usually mediated through attitude, subjective norm and perceived behavioural control.

To investigate the validity of the theory of planed behaviour, we first ran a hierarchical regression analysis with intention as dependent, entering attitude, subjective norm and perceived behavioural control in the first step, and adding the farmer characteristics in the second step. The results are presented in table 5. It shows that attitude has the highest influence on intention, followed by perceived behavioural control. Subjective norm has the lowest influence. All three TPB-variables have a significant influence on intention. The model R^2 was 0.795, indicating that attitude, subjective norm and perceived behavioural control combined, explain 80% of the variation in intention to apply CA in the next 12 months.

Adding the farmer characteristics increase R² only marginally and none of the additional variables are significantly different from 0. This is in line with the mediation hypothesis.

The Durbin-Watson test statistic of this hierarchical regression was 1.857, indicating no violation of the homoscedasticity assumption. Upon analysis of the residuals, however, we did find minor violations of the normality assumption. Therefore, as an additional test of the validity of the model, we dichotomized intention, as described above, and compared mean attitude, subjective norm and perceived behavioural control between those with low and high intention. The results are shown in table 3. Furthermore, we notice that attitude, subjective norm and perceived behavioural control have significant and positive correlations with intention, thereby further confirming the empirical validity of the model.

Table 3 Results of the ANOVA mean comparison of TPB variables between farmers with low and high intention to use CA (n = 197)

	ATT[b]	SN[b]	PBC[b]
Low intention (n = 41)	0.037[a]	0.098[a]	-0.390[a]
High intention (n = 156)	1.096[a]	1.314[a]	1.039[a]

[a] significantly different between those with low and high intention, p < 0.001

[b] mean value on a score from -2 (very unfavourable) to +2 (very favourable)

Table 4 Results of the hierarchical regression analysis on intention to adopt CA, with basic TPB variables only in the first step, and farmer characteristics added in the second step (n=197)

	Standardized coefficient	R^2
ATT	0.529***	
SN	0.137 **	
PBC	0.303 ***	
		0.795
ATT	0.563 ***	
SN	0.139***	
PBC	0.298***	
POVERTY_INDEX	0.022	
SEX	-0.013	
AGE	-0.037	
EDUC	-0.049	
MEMBER_FFS	0.038	
MEMBER_OTHER	0.007	
		0.796

** $p < 0.01$

*** $p < 0.001$

In the final analysis, we further investigate the mediation hypothesis, suggesting that the association of farmers' characteristics with intention (reported in table 2) is mediated through the TPB-variables. We estimated a path model, using AMOS, first including all possible paths from each of the farmer characteristics to attitude, subjective norm and perceived behavioural control. After elimination of all insignificant paths, the final model is as presented in figure 2.

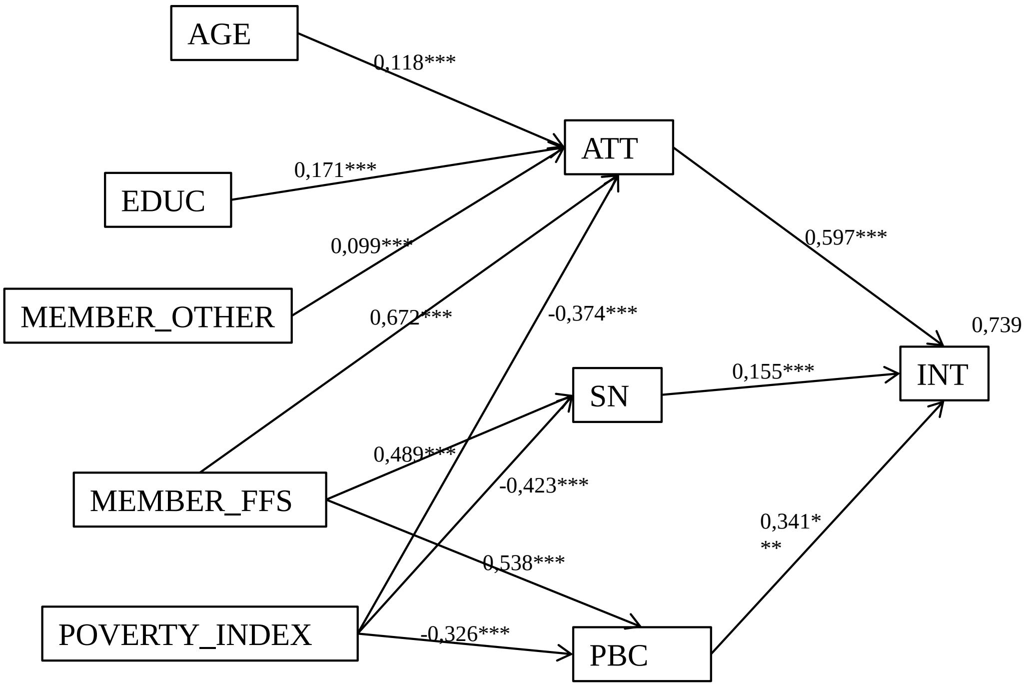

Figure 2 Path analysis of the impact of TPB variables and farmer characteristics on intention to apply CA (n = 197; standardized regression coefficient above arrows; *** p < 0.001; squared multiple correlations above rectangles)

This path model confirms the impact of attitude, subjective norm and perceived behavioural control on intention. Furthermore, it shows that age, education and membership of other organisations have a small but significant positive influence on the attitude towards CA. Older farmers have a more positive attitude towards CA. The more educated a farmer, the more positive his/her attitude towards CA. Farmers who are members of other organisations have a more positive attitude towards CA. More importantly, there are two other farmers' characteristics with a far greater impact. Farmers who are members of a CA Farmer Field School have a substantially more positive attitude towards CA, they perceive higher social norms, and they find it substantially easier to use. Finally, the poorer a farmer is on the poverty index, the more positive his/her attitude, the more favourable his/her perceived social norms and the easier he/she finds it to apply CA.[12]

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[12] For example, the negative correlation here indicates that the lower the farmer is on the wealth index (i.e. the poorer the farmer is) the more positive their attitude etc.

Analysis of the belief structure.

Table 5 highlights that farmers with a high intention to use CA have favourable perceptions of the benefits associated with using CA. Positive behavioural beliefs are seen as a cognitive driver to use of a technology (Garforth et al., 2006). Thus, there are clearly eight overall cognitive drivers. Furthermore it has been argued that if persuasive messages attack specific beliefs about an object these can result in changes to attitude regarding that object (See McGuire, 1985; Petty and Cacioppo, 1986 cited in Ajzen, 1991). The three strongest in this case are: (i) increased yield, (ii) reduction in labour, and (iii) CA improves soil quality. Other cognitive drivers which scored particularly highly are CA performs better in a drought year, CA reduces weeds and CA provides benefits in the first year of use. Those with high intention also feel CA is able to be used on all soil types and does not increase the amount of pests signified by the negative value for those beliefs.

Table 5 Mean comparison of belief strength and outcome evaluation of all accessible outcomes, between farmers with high intention and low intention to use CA (n=197)

Salient Outcome	Behavioural belief strength			Outcome evaluation		
	High intention (n = 156)	Low intention (n = 41)	U test	High intention (n = 156)	Low intention (n = 41)	U test
CA increases yield	1.50 (0.54)	0.02 (0.27)	**	0.99 (0.33)	0.02 (0.42)	**
CA reduces labour	1.48 (0.54)	0.05 (0.38)	**	0.99 (0.33)	-0.02 (0.61)	**
CA improves soil quality	1.47 (0.57)	0.20 (0.46)	**	0.98 (0.37)	0.10 (0.54)	**
CA reduces weeds	1.41 (0.63)	0.07 (0.41)	**	0.94 (0.42)	-0.10 (0.58)	**
CA increases pests	-0.30 (1.24)	0.22 (0.53)	**	-0.69 (1.10)	-0.05 (0.55)	**
CA can't be used on soil types	-0.78 (0.71)	0.29 (0.68)	**	-1.07 (0.73)	0.05 (0.63)	**
CA leads to benefits i.e. yield in the first year of use	1.39 (0.74)	0.07 (0.41)	**	0.82 (0.61)	-0.07 (0.52)	**
CA performs better than conventional in a drought year	1.42 (0.60)	0.02(0.42)	**	1.01 (0.36)	0.00 (0.50)	**

**denotes significance 0.001 level, standard deviation in parenthesis

Table 6 shows that farmers with a high intention to use CA are more likely to feel encouraged to use CA through social referents such as the AKF village facilitator, Farmer Field School and the government. Nevertheless, those with weak intention highlighted the potential of certain social referents to play a more important role in influencing adoption. Overall, those with a weak intention have a lower motivation to comply with the opinion of others, but a motivation to comply that is still positive, especially with regards to the AKF village facilitator, government and other experienced farmers. Those with a high intention to use CA also scored a significantly higher score than those with low intention for the role of a spouse in influencing likely adoption and radio and television. Interestingly, overall those with high intention to use CA also place more importance on self-observation and self-initiative and more of an importance of group work i.e. associations/groups.

Table 6 Mean comparison of strength of normative belief and motivation to comply regarding all accessible referents between farmers with high intention and weak intention to use CA (n=197)

Referents	Normative belief strength			Motivation to comply		
	High intention (n = 156)	Low intention (n = 41)	U test	High intention (n = 156)	Low intention (n = 41)	U test
Government	1.07 (0.26)	0.78 (0.42)	**	1.06 (0.23)	0.83 (0.44)	**
NGO	1.02 (0.14)	0.81 (0.40)	**	1.02 (0.14)	0.76 (0.43)	**
Radio	0.82 (0.45)	0.37 (0.54)	**	0.82 (0.40)	0.46 (0.55)	**
TV	0.81 (0.43)	0.29 (0.41)	**	0.79 (0.43)	0.32 (0.53)	**
Village Facilitator AKF	1.28 (0.45)	0.83 (0.38)	**	1.14 (0.35)	0.85 (0.36)	**
Association/group	1.02 (0.14)	0.73 (0.50)	**	1.00 (0.00)	0.78 (0.42)	**
Farmer Field School	1.10 (0.34)	0.59 (0.50)	**	1.08 (0.29)	0.66 (0.53)	**
Sibling	0.76 (0.49)	0.27 (0.59)	**	0.78 (0.44)	0.24 (0.68)	**
Spouse	0.96 (0.22)	0.63 (0.49)	**	0.97 (0.20)	0.61 (0.54)	**
Self-observation	0.59 (0.89)	-0.05 (0.86)	**	0.62 (0.89)	-0.10 (0.89)	**
Self-initiative	0.56 (0.85)	-0.15 (0.88)	**	0.58 (0.82)	-0.10 (0.86)	**
Grandfather	0.56 (0.85)	-0.10 (0.86)	**	0.55 (0.84)	-0.10 (0.83)	**
Other experienced farmers	1.01 (0.08)	0.83 (0.44)	**	1.00 (0.00)	0.78 (0.42)	**

**denotes significance 0.001 level, standard deviation in parenthesis

Table 7 shows that farmers with a high intention to use CA perceive that they have enough labour and knowledge and skills to use CA. As with the normative/behavioural beliefs these control beliefs mediate to what extent one has control over the particular behaviour i.e. in this case perceived behavioural control which is defined as how easy or difficult it is to apply the practice. It is interesting to note that those with high intention to use CA do feel that CA does require adequate knowledge and skills which signals a potential barrier to using CA. However, farmers with high and low intention do not feel that group work is a pre-requisite to using CA. Pests and soil type which have been cited as potential barriers to adoption for CA in other farming contexts do not seem to affect usage in this farming system. For example, farmers with high intention to use CA feel they are able to adequately control pests and that pests do not limit the success of using CA. Furthermore, farmers with high intention also believe that mechanisation is not needed to perform CA thus supporting the notion that this manual form of CA as opposed to tractor or animal powered is perceived to be a favourable option for farmers in this region. For farmers with larger land holdings that would like to increase the scale of CA, other forms of CA, animal or tractor powered direct seeding systems may be attractive.

Table 7 Mean comparison of strength of control belief and power of control regarding all accessible control factors, between farmers with high intention and weak intention to use CA (n = 197)

Control factors	Strength of control belief			Power of control		
	High intention (n = 156)	Low intention (n = 41)	U test	High intention (n = 156)	Low intention (n = 41)	U test
Enough labour to do CA	1.09 (0.29)	0.17 (0.50)	**	-0.99 (0.16)	0.39 (0.63)	**
Enough knowledge/skills to do CA	1.39 (0.60)	0.05 (0.22)	**	1.49 (0.56)	0.51 (0.60)	**
Expect to be part of a group	0.19 (1.03)	0.02 (0.27)	Ns	0.21 (1.46)	0.42 (0.63)	Ns
I can practice CA with the soil I have	1.35 (0.69)	0.10 (0.37)	**	-0.96 (0.28)	0.34 (0.62)	**
Can deal with the pests I have	1.35 (0.63)	0.07 (0.41)	**	-0.97 (0.20)	0.34 (0.62)	**
I will have enough mechanisation to do CA	-0.99 (0.08)	0.29 (0.60)	**	-0.99 (-0.08)	0.34 (0.62)	**

**denotes significance at 0.001 level, Ns denotes non-significance, standard deviation in parenthesis

Discussion and conclusions

This study investigated, using a socio-psychological model, farmers' intention to apply CA in the next 12 months. The results show that the model explains a high proportion of variation in intention. In addition, farmers' attitude is found to be the strongest predictor of intention followed by perceived behavioural control and subjective norm. These findings thus take on broader significance within the literature as they identify key drivers behind the use of CA (all three pillars) that may be relevant for similar farming systems - against a backdrop of debate around yield, labour, soil quality, and weeds. Farmers with a high intention invariably found these as strong cognitive drivers. Most striking is that yield is the strongest driver followed by labour and soil quality. In addition, farmers' with a high intention to use CA also perceived benefits (i.e. increase in yield) in the first year of use which has also been a focus of debate within the research community, namely the degree to which CA leads to short-term yield gains (Rusinamhodzi et al., 2011). Thierfelder et al. (2013a), however, have found for some crop mixes that CA can provide gains in the first year of use relative to conventional agriculture. Furthermore, the study found the poorest are those with the highest intention to use CA which is also contrary to other authors that have suggested the poor are unlikely to find CA beneficial without subsidised inputs such as fertilisers and herbicides (Nkala, 2012). This is a noteworthy result, and is in contrast to commonly held opinions that it is the more affluent farmer who is the most likely to be interested in or able to apply conservation practices (e.g. Saltiel et al., 1994; Somda et al., 2002). Okoye (1998), however, found similar findings to this study with poorer farmers more likely to adopt soil erosion control practices. The results from this study also showed for those with a weak intention to use CA, perceptions of CA requiring a high-level of knowledge/skills and labour predominate.

Recent research on sustainable intensification opportunities, in another province of Mozambique, identified significant 'knowledge gaps' among the poorest farmers. Results from a participatory modelling exercise suggested that a 'first stepping stone' for poorer farmers would be the introduction of basic agronomic practices such as suitable plant populations, adequate row-spacing and adjustment in sowing dates that would substantially improve productivity (e.g. 120% increase in maize yields) before costly inputs such as fertilisers and herbicides are used. (Roxburgh and Rodriguez, 2016). Furthermore, the returns from investment in fertiliser application were greatest for the medium and high-performing farmers (Roxburgh and Rodriguez, 2016). This may explain the attraction of manual systems of CA in this study (highest intention to use CA among the poorest and yield increase the strongest overall cognitive driver among farmers in this study) that do not require costly external inputs and could be the focus for similar groups of farmers and related research elsewhere in Sub-Saharan Africa. Manual systems of CA have been productive in other parts of Mozambique benefiting from a number of attributes relative to conventional-tillage based agriculture including timely planting and precise seed placement (Thierfelder et al., 2016). Moreover, direct seeded CA systems (similar to those used in this region) have provided yield benefits over time due in large part because of better planting arrangements, increased soil quality over time, improved soil moisture conditions for crop growth/development and less soil disturbance (Thierfelder and Wall, 2010). Use of manual systems of CA e.g. direct seeding have also led to labour savings and higher returns to labour (Thierfelder et al., 2016) which is important for the poor (the second strongest cognitive driver in this study i.e. reduction in labour).

Thus one of the major constraints to adoption is the perception of CA requiring a high level of knowledge and skills which is most likely the case for smallholders in other parts of Sub-Saharan Africa (Wall et al., 2013). Reducing risk (i.e. production risk and price risk) and ‘uncertainty’ (i.e. absence of perfect knowledge or the decision maker having incomplete information) is paramount in the adoption process. The study highlights that observation and self-initiative were considered significant motivating factors for farmers with a high intention to use CA thus signalling that farmers have likely observed other farmers using CA (or as a result of their own observations from their own farms) and have formed the perception of CA being performed manually with success. Garforth et al. (2004) also found that local and personal contacts played an important role in adoption of a technology and Martínez-García et al. (2013) showed self-observation and self-initiative to be strong social referents as farmers invariably would decide to use an innovation based upon observations made or upon taking the initiative through testing. This has an effect of reducing the uncertainty in taking up a ‘new’ management system such as CA.

Central to this (reduction in uncertainty) are the social learning mechanisms that are formed through locally constructed innovation systems. Wall et al. (2013) also note the need for local innovation systems that involve farmer to farmer exchange and participatory methods which help to adapt CA to local conditions. One such component is the use of the Farmer Field School approach found in this study region. The study found, for example, that FFS participants have a significantly higher intention to apply CA in the near future (Table 2 and 4). Secondly, path analysis (Figure 2) shows that this effect is not just due to the fact that farmers perceive benefits from CA use (effect through attitude), but also through influencing subjective norms (i.e. participants have higher motivation to comply with social referents regarding CA), and by the perceived ease of use of this technique (i.e. they perceive CA as the easiest to use). Waddington and White (2014) have also suggested that for the FFS methodology to be effective it should follow a ‘discovery- based approach’ where farmers are able to learn through observation and experimentation with new practices. They also assert that ‘observability’ is important in influencing non-FFS farmers to adopt FFS practices.

Risk in much of Sub-Saharan Africa, such as this region of Mozambique, is associated with primarily rainfall. Seasonal distribution of rainfall is likely to increase in variability coupled with a reduction in rainfall throughout the region as a result of climate change (Lobell et al., 2008). This will undoubtedly exacerbate the risks to production facing farmers. Interestingly, farmers' perception of those with a high intention to use CA indicated that CA performs better in a drought year. Thus, the perception of farmers, in this context, signal that CA reduces the risk associated with drought such as crop failure which may also help to stimulate adoption (particularly for risk-averse farmers). These perceptions may be a result of observation and/or experience on the part of the farmer but also a personal/collective bias built up by shared perceptions in the communities that CA has certain benefits. Thus, it should be noted that it is possible that farmers' perceptions may be different from research results in on-station/on-farm experiments or when actual measurement takes place. Research has suggested in the case of rainfall, for instance, that farmers' perceptions of rainfall reduction over time did not always match historical measurements (Osbahr et al., 2011; Sutcliffe et al., 2015). Nguyen et al., (2016) postulate that farmers are better at observing features that are 'touchable' and are 'felt personally' i.e. based on sensory experiences rather than other those such as rainfall amount which are not easily observed or perceived by human senses without the use of appropriate instruments. Yield, labour (e.g. time used for weeding) and weed reduction it can be argued are 'touchable' and 'personally felt' attributes that farmers incorporate into their formulations of perception and decision making. Furthermore, although soil quality is hard to measure, in the absence of laboratory testing, the visual soil assessment methodology used in FFS training in this context may explain some of the sensory observations that farmers use when formulating perceptions and thereby decision making. Notwithstanding the potential for bias or misrepresentation by farmers the social learning mechanisms described by Nguyen et al. (2016) that are suggested to enable farmers to effectively adapt to climate change are similar to ones found in this study in that they focus on both dimensions of learning (i.e. 'perceiving to learn' and 'learning to perceive'). For example, as one farmer in this study region remarked: *"Before I started CA I had noticed that when I would clear straw from my land and put it at the side of my field (i.e. to clear the main part of the plot for burning and re-planting the year after) the area with straw would still produce a crop and the soil was good. Therefore, I thought that putting straw down was a good idea so when I heard this was part of CA I thought it was a good idea"*. This provides an example of how observation/perception (perceiving to learn) played a role in garnering interest in CA. Two other farmers remarked: *"I learnt about CA from the goat association then I decided to attend a field trip to a demonstration plot as part of a group" ..... "I decided to try and divided my plot with CA and without CA and after seeing the difference I now use*

CA on all of my land". Thus participating in the demonstration plot/field trip and experimenting may constitute as 'learning to perceive'.

In sum, farmers' perceptions provide a valuable insight into the adoption process and it is ultimately the 'balance of benefits' that farmers perceive which will determine adoption (Wall et al., 2013). This study has identified that contrary to much of the literature surrounding CA in recent years (in Sub-Saharan Africa) farmers are motivated to use CA (within this farming system) primarily because of their attitude which is strongly influenced by their perceptions towards the benefits of CA vis-à-vis a locally constructed innovation system that has created opportunities for social learning and thereby reduced the risk and uncertainty associated with a 'new' management system such as CA. The results of this study may help to formulate similar research elsewhere in the region which includes socio-psychological factors/models in exploring adoption dynamics. More broadly, it may also encourage further investigation on CA use which relates to what farmers consider important in their contexts (e.g. agro-ecological/socio-economic) and of particular relevance to the poorest. Farmers' expectations and experiences with CA and those of researchers, agricultural scientists and others could also be more closely aligned with further emphasis on the co-construction of knowledge. A need for enhanced 'farmer participatory adaptive research' which accounts for 'farmer preferences' has been one proposal (Wall et al., 2013). Sewell et al. (2014) also provides an example of an approach to innovation and learning whereby a community of farmers, social scientists and agricultural scientists were co-inquirers and through strong ties and trust being forged the co-construction of new knowledge formed. This collaborative approach to learning will likely improve understanding of how to adapt CA and other innovations to different conditions.

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Chapter 4: Unpacking the Innovation System- Are the poorest farmers benefiting?[13]

Introduction

Despite numerous initiatives promoting Conservation Agriculture (CA) across Sub-Saharan Africa there have been low rates of adoption in recent years. Furthermore, there has been strong debate regarding the ability of CA to provide benefits to smallholder farmers. Key areas of contention have surrounded yield, labour, soil quality and weeding with particular focus on the suitability of CA to benefit the poorest especially where external inputs are out of reach. Moreover, CA research and promotion in Southern Africa has also been criticized for being top-down and inflexible (Andersson and Giller, 2012; Grabowski and Kerr, 2014).

Recent research within Eastern and Southern Africa, as a case in point, has suggested, however, that constraints to adoption of CA can be overcome, but stress the need for local innovation systems that involve farmers exchanging among themselves and use of participatory methods which help to adapt CA to local conditions (Wall et al., 2013).

This chapter explores one such innovation system using a district in Cabo Delgado, Mozambique as a case study. The aims of the chapter are twofold. Firstly, to describe the process of construction of the innovation system, and by way of actors' perceptions of the system, to better understand key components central to its formation and functioning. Secondly, to explore farmers' perceptions of CA (including motivation to comply with certain actors in the innovation system) and the effectiveness of the current innovation system in reaching its target beneficiary- the very poor. The following provides an overview of the evolution in approaches to agricultural development, putting into context the emergence of innovation systems thinking. The methodological approach taken is then explained and includes background on the district under study. This is followed by a timeline of the key events that have formed the innovation system and explores perceptions/interactions and types of partnerships that exist among stakeholders within the innovation system. Farmers' perceptions of CA in the study district are then explored. The final section concludes the chapter and considers implications for other regions in Sub-Saharan Africa.

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Evolution of approaches to agricultural development

Agricultural development for part of the twentieth century mainly involved the so called ‘top-down’ or ‘reductionist' approach. This has largely been seen as a supply-led modus operandi, whereby research institutions developed high yielding varieties (HYV’s), namely wheat and rice, alongside improved application rates of synthetic fertiliser, pesticide and irrigation in order to maximise yield. Typically, transfer to farmers has been via the transfer of technology model (TOT) which assesses the new technology under controlled conditions to be then passed on to extension agents for dissemination to farmers upon completion (Pimbert, 1994) .

Notwithstanding the well documented impact such technologies and models have had on increasing agricultural productivity and household well-being per se (Mendola, 2007) , it has been argued that these have generally been successful in more favourable environments (Wiggins and Cromwell, 1995). Thus critics have shown wide distain for the neglected role of the context specific needs of beneficiaries and likely sustainability of much of the new technology being produced (Pimbert, 1994; Sumberg, 2005). This includes the impact on the natural resource base (Pingali, 2012). In recent years, this has prompted a gradual shift to more demand-led participatory research, which has involved farmers as key decision makers in the process of technology development.

The gradual shift from the 1960s to date has included the Adoption and Diffusion model (transfer of technology model) as outlined above, Farming Systems Research (FSR) model which emerged in the 1970’s, Agricultural Knowledge and Information System (AKIS) in the 1990’s and more recently the Agricultural Innovation Systems (AIS).

FSR involved diagnosing constraints and needs of farmers relevant to their farming system. It focused on a multidisciplinary approach with partnerships between farmers, social scientists technical specialists and more recently extension personnel and policy makers, together with attempts to increase efficiency through the provision of packages of interventions (Klerkx et al. 2012; Norman, 2002). The modus operandi involved on-farm testing and modification of technologies. This approach, however, has been criticised for its lack of focus on resource poor farmers and often poor communication between researchers and farmers which also inhibited the communication of the knowledge gathered (Chambers and Jiggins, 1987). FSR has further been criticised for focusing largely on farm-level issues and neglecting the broader system in which farmers are rooted in (Bingen and Gibbon, 2012).

This led to the emergence of the Agriculture and Knowledge Information System (AKIS) which was less linear in its approach. AKIS, in contrast to FSR, has focussed on strengthening systems that assist in the generation and dissemination of knowledge (Röling, 1994). The system was heavily criticised for the emphasis put on the role of the agricultural research system as the centre of innovation rather than the concept of multiple knowledge-bases and the role of different kinds of actors involved in agricultural innovation (Hall et al., 2001).

In response to these drawbacks, the Agricultural Innovation System has emerged in the 2000s with a primary focus on improving the capacity of farmers to innovate This perspective largely recognises the role of numerous actors (beyond the agricultural research system) that are able to contribute to agricultural innovation through diverse ways including promoting better knowledge flows and development, transfer and further adaptation of technologies (Temel et al., 2002). It therefore seeks to increase the capacities of actors which include smallholder farmers allowing them to learn, innovate and change (Hall et al, 2006).

It is clear that the concept of an innovation has thus altered over time from being one centred around merely a technological advancement, such as a new seed variety, to one which includes and hinges on new forms of social and organisational norms (Leeuwis, 2011). More specifically innovation systems thinking at its core presupposes that it is these other nodes (social, organisational etc.) that bring about innovation (ibid). Moreover, actors that have usually been excluded from the top-down approach to innovations development such as input dealers and Non-governmental organisations (NGOs) have become more prominent in the innovation process (Spielman, 2005).

The following explains some of the components involved in the AIS approach to innovation systems thinking from a Sub-Saharan Africa (SSA) perspective and includes some of the current criticisms. It is thus through this lens that this study aims to explore the construction of the agricultural innovation and its effectiveness in reaching the poorest farmers.[1]

What role of the market and the state? The emergence of civil society actors

With respect to SSA in particular there have been a number of constraints cited that have hindered the development of innovations. For example, weak demand for innovations from farmers and the highly bureaucratic and hierarchical nature of relationships that exist between research, extension and farmers (Sumberg, 2005). This is compounded by a number of market and government failures that have often given rise to civil society organisations attempting to fill this vacuum. This has been the case, for instance, where NGOs have been involved in the dissemination of improved seed varieties or agricultural service delivery (such as agricultural extension services) to smallholders given little private interest and waning governmental structures (Wiggins and Cromwell, 1995).

In relation to CA it has been suggested that in specific circumstances CA use requires the aid of subsidised inputs such as fertiliser from NGOs (Grabowski and Kerr, 2014; Nkala et al., 2011; Nkala, 2012). Furthermore, Nkala, (2012) argues that such subsidised inputs are imperative in helping the poorest farmers benefit from CA. However, Ngwira et al., (2014) has questioned the long term sustainability of financial incentives provided for CA use as it can omit the cognitive aspect and instead farmers may be using CA because incentives exist.

Community based approaches

To fill the void often left by the market and the state, community based approaches to common property management, service delivery or as conduits for market access in the form of associations/cooperatives have also been widespread. NGOs and development practitioners have also been instrumental in engendering the need for collective action often through group formation.

Feder et al. (2010), however, have shown that as with markets and states, community based approaches can fail too. Giving examples of a number of community based extension (CBE) initiatives, which include Farmer Field Schools (FFS), they highlight how they often have fallen prey to mismanagement of funds and 'elite' capture involving often wealthier participants accessing resources and social exclusion of the vulnerable and marginalised (women and poorer households, for instance). Thus it has been argued that CBE's are not always suitable and different systems may be needed in certain circumstances (Hayami, 2009).

There has therefore been a move to develop partnerships between diverse actors in order to provide a stimulus for innovation. As Leeuwis (2011) quite aptly note critical to innovation development and design is the role of communication, and thereby many facilitating actors can play roles as diverse as knowledge brokerage, mediation, and matching supply with demand.

Multi sector partnerships and Innovation Platforms

More recently Innovation platforms (IP's) have been promoted which involve complementary action taken by diverse actors. For example, Rubyogo (2010) has placed great importance on developing partnerships between stakeholders. For instance, actors including NARS, private companies and farmers' organisations have enabled 3.8 million households across SSA access new bean varieties. Often the seed sector has been plagued by difficulties including very low multiplication of certain varieties that would be useful for marginal areas (ibid). This initiative was thought largely successful as it decentralised seed multiplication of favourable varieties that were identified by farmers to particular agro-ecological zones, often through locally based producers supported by extension services. Farmers were also aided with better information by private companies providing improved labelling and packaging of seed (ibid).

Although there exists a number of examples of successful partnerships there has been concern raised about the modalities of partnerships and the number of partnerships (Hoffman et al., 2007). For example, the difficulty in managing and maintaining such partnerships given differing goals, organisational cultures and personalities involved (Sanginga et al., 2007). There is also the problem of high staff turnover of field staff in local NGOs and NARS (ibid). A further limitation is that the use of platforms and partnerships could be seen as another 'blueprint' for success (Sumberg, 2005). Klerkx et al., (2009) thus put forwards another notion of 'innovation brokers' that can help to mediate between partners. For example, in the case of no-tillage uptake in South America innovative brokers were instrumental in the development of the innovation. Many different networks tried various forms and approaches to organize innovation until it was suitability adapted to local conditions (World Bank, 2011). Moreover, Hounkonnou et al., (2012) has highlighted the importance of such platforms showing that communities with IP's have achieved higher poverty reduction than those without.

Is this innovation system reaching the poorest?

Given the diversity of stakeholders often involved in innovation systems the challenge is to develop innovations that are likely to generate a wide impact on poverty alleviation (Ortiz et al., 2103). How does one analyse the impact of an innovation? Or to what extent the system is helping the poor? EIARD (2006) has suggested that assessments should look at the perceptions of stakeholders which also include opinions of the community i.e. individuals and groups.

Biggs and Matsaert (2004) also assert that gathering views from different stakeholders involved in the innovation system is important to understanding particular needs and solutions. Furthermore, Ekboir, (2009) has suggested incorporating Social Network Analysis (SNA) to understand information flows and the size, efficiency and connectedness within a particular network. This has been used widely by other authors examining agricultural innovation systems (e.g. See Ortiz et al., 2013). Hall et al., (2006b) also advocate the use of sector timelines and partnership linkages in evaluating an innovation system.

Household-level formal surveys are also useful in looking at adoption and impact though they have been criticised for looking at adoption in a static state and failing to see adoption as a ‘process’ or the fact that adoption could be ambiguous i.e. differences within household ownership and use (RIU, 2010). The following describes the methodological approach taken in this study.

Methodological approach

A mixed methods approach which includes both qualitative and quantitative data was used. Thirteen key informant interviews and three Focus groups were conducted during August 2014 with various actors involved in the innovation system of CA in Metuge district of Cabo Delgado (See section 6.2.2). To explore the first aim of understanding the construction and functioning of the present innovation system an actor matrix using the Biggs and Matsaert (2004) framework was constructed and each actor was asked to provide a score for the other actors in the system reflecting their perceived role in the overall system. Using principles of social network analysis (Borgatti et al., 2009) each actor was also asked whether they had any informal/formal ties to the actors with respect to either information on CA or specific goods/ services related to CA. The typology of partnerships and learning presented by Hall et al., (2006b) a schematic of the partnerships/interactions within the innovation system is also presented.

This chapter also draws on results from a household survey administered in September 2014 in a total of 6 communities in Metuge District in order to gather perceptions of farmers using CA and not using CA. It also includes exploration of farmers' perceptions on motivation to comply with social referents regarding information on CA which sheds light on whom they consider important actors within the innovation system. Farmers were also disaggregated by wealth to compare farmers' perceptions among poorer and better-off farmers in order to examine whether the innovation system is effective in reaching the poorest farmers (See Section 6.2.1). 250 households were randomly selected from a list of users and non-users of CA (using probability proportional to population size). A total of 197 were interviewed (145 users of CA and 52 non-users).

Data analysis

In order to compare poorer and better-off farmers, Principal Component Analysis (PCA) was conducted to establish a wealth index. As is common in a number of poverty studies the first principal component (PC1) which explained the majority of variance in the data was used as the index (Edirisinghe, 2015). Households were then ranked into terciles with respect to the level of wealth. Given the ordinal (likert type data) used, tests of statistical significance were done using the Mann-Whitney U test.

Background to case-study

Cabo Delgado is the northernmost province located within the coastal plain in Mozambique. The majority of inhabitants in the province rely on subsistence (mainly rain-fed) agriculture, where given its geographic location is compounded by poor market access and limited infrastructure including roads. Recent research has ranked Cabo Delgado as one of the poorest provinces in Mozambique (Fox et al., 2005) with the highest prevalence of stunting in the country (FAO, 2010).

Its climate is sub-humid (or also termed moist savannah) characterized by a long dry season (May to November) and rainy season (December to April). Annual rainfall in the province is between 800-1000m though the intensity of rainfall sometimes results in heavy flooding throughout the province. The main crops incorporated into the cropping system used in Metuge district (the case study district) are maize, cowpea, sesame and pigeon pea. Lablab and mucuna are also grown The use of external inputs has seldom been used in the district and wider province and this includes compost or animal manure.

Conservation Agriculture (CA) has been defined by three main principles namely; (i) no or minimum soil disturbance; (ii) use of organic soil mulch cover and (iii) crop diversity using rotations/associations/sequences involving three different crops (FAO, 2015).[2]

Thus usage of CA in this chapter is defined by a farming household simultaneously applying on any given plot all three principles of CA which are:

(iv) No-tillage or minimum soil disturbance with or without the use of micro pits in the first few seasons.[3]

(v) Soil cover i.e. mulching (covering at least 30% of the cultivated soil surface)

(vi) Crop diversity using a rotation/association/sequence involving at least 3 different crops during the season.[4]

No CA or conventional users are defined here as farmers practicing conventional tillage agriculture with the use of hand-hoe. They may, however, be practicing intercropping and/or rotation, and growing three or more crops during the season or mulching.[5]

CA adoption has steadily increased in Cabo Delgado, in recent years. This has been supported by the institutional presence of the Aga Khan Foundation Coastal Rural Support Programme (AKF-CRSP), which began promoting CA in the province in 2008. AKF have taken a different approach to other NGOs elsewhere in Mozambique and SSA as they have not provided or subsidised the use of external inputs such as fertilisers and herbicides. Instead the focus has very much been on improvements in soil fertility through use of legumes (as green manure), and perennials. Moreover, this has also included the focus on using different sources of mulch including the retention of crop residues but also vegetation biomass such as grass or other dead plant material either produced on-farm or brought in from surrounding areas i.e. bush areas. Compost projects have also been initiated though compost is not widely used among CA users in this case study district/wider province. [6]

Figure 1 Micro-pit without mulch

Figure 2 Micro-pit with organic mulch cover i.e. crop residues, grass and other biomass

Figure 3 Jab planter **Figure 4** Dibble stick being used by a Farmer

The household survey revealed the majority of CA farmers were using a three crop sequence during the growing season i.e. maize-cowpea and cassava or maize-cowpea and sesame being the most common. Likewise, for Non-CA farmers these were the most common three-way sequences. Many Non-CA farmers also just cultivated two crops such as maize and cassava in the growing season. Among the CA farmers, 19% were using four-way crop mixes e.g. maize/cowpea/pigeon pea/cassava or maize/cowpea/cassava/sesame.[7]

Box 1 Manual Conservation Agriculture Systems

A Dibble stick is a pointed stick which is used to open small holes (in crop residue) for planting seed.

The second system is the use of micro pits in the initial few seasons to break soil compaction. In Cabo Delgado (Mozambique), AKF- CRSP has promoted the use of micro pits (35cm long x 15cm wide x 15cm deep).

The third system used is the jab planter. First imported to Zimbabwe and Mozambique in the early 2000’s attempts have been made to make them locally. Two compartments, one for fertilizer (animal manure and ash can be used as a substitute to chemical fertilizer) and one for seed are mounted on. Below the compartments are two tips which once pushed into the soil (making small holes) and released, the fertilizer and seed drops into the planting holes. The jab planter can pierce through mulch-covered soil with relative ease but has the disadvantage of on occasion ‘clogging and becoming sticky’.

Source: Adapted from Johansen et al., (2012) and notes from Author

The former crop mix seemed the most popular among poorer households with smaller plots and the latter more common among wealthier households with larger land holdings. (Lalani, unpublished results).

Conservation Agriculture Innovation System- Metuge district

The timeline of key activities that occurred in the set-up of the innovation system is presented in Table 1.

Table 1 Timeline of CA innovation system set-up

Activities	Responsible	Year	Role
MOU signed between Aga Khan Foundation and Ministry of Agriculture	AKF higher level staff/ Agricultural directorate	2007	Work on CA part of strategic plan on agrarian reform with government.
AKF staff Spent 3 weeks in 2008 training facilitators on CA principles in order to create demonstration plots in district.		2008	Facilitators help to set-up demonstration fields in each village with select number of farmers
Establishment of Farmer Field Schools (FFS) and seed multiplication groups	AKF District level and AKF Village facilitators	2010	
Setting up Benchmark farmers	FFS and AKF facilitators	2012	Benchmark farmers are those that have used CA for at least three years and chosen to exhibit the full CA system in use to other FFS members.
Linkage with associations and setting up of sales commission for a variety of crops including legumes- 'connecting' role with Rural shops	AKF and FFS	2013	
Assisting village development organisations (VDO's) in CA training and to identify community promoters. Establishment of CA clubs and CA forum (regional meeting of all CA club members and invitation to agricultural directorate and other NGO's working in region to participate). Use of theatre to improve awareness of CA and land degradation e.g. burning of crop residues	AKF	2013/2014	CA clubs consist of a select few from the farmer field schools in each village/community that are experienced CA farmers and are chosen to go to other villages without farmer field schools to engage with communities on CA.

Actors innovation matrix and social network analysis

Table 2 shows the actor matrix using the Biggs and Matsaert (2004) framework. Each actor provides a score for the other actors in the system reflecting the strength of their perceived role in the overall system. Specific ties that may exist between actors, be these informal/formal, related to exchange of information or specific goods/services with respect to CA, are explored in Table 3.

Table 2 Actor innovation matrix

Type of actor	CA club	CA community promoter	Benchmark farm	AKF village facilitator	AKF district coordinator	AKF Agriculture director	Member of Agriculture directorate (SDAE)	Seed multiplication group	Sales commission	Rural shops	FFS	VDO	Other farmers Non-FFS	WWF	Media
CA club		2	2	3	3	2	1		3	2	2	2	2	1	1
CA community promoter					3	1	2	2	3	2	3	2	2	1	1
Benchmark farmers	1	2		3	2	3	2	2	1	1	2	2	2	1	1
AKF village facilitator	1	3	1				1	3	3	2	3	1	1	1	1
AKF district coordinator	1	2	1d	3			1e	3	1	1	3	1		1a	1c
AKF agriculture director	3	3b	3	3	3		3	3		3	3	1	2	2a	1c
Member of Agricultural directorate director (SDAE)		2	3	3	3	3		2	2	1	3	2	2	1	1
Seed multiplication	2	3	3	3	2	3	2		2	3	2	3	3	1	1
Sales commission/association		2	3	3	3	3	1	2		2	2	2		1	1
Rural shops		2		3	3	3	3		1			1	1	1	1
FFS female (four members)	1	2	2	3	3	1	1	1	1	1		3	2	1	1
FFS male(four members)	1	1	3	3	2	2	2	2	2	1		2	2	1	3
VDO	2	3	2	3	3	3	3	3	2	2	2	1	1		
Other farmers	2	3	3	2	2	1	1	3	2	2		2		1	1
WWF		2	1	3	3	3	1	1	1	2	1	2	1		1
Media**															
Average score per actor	1.6	2.3	2.1	2.9	2.7	2.3	1.7	2.3	1.9	1.8	1.9	1.8	1.8	1.1	1.1

Key

* The numbers in the matrix indicate strong (3) and weaker linkages (2, and 1). Blank means does not know or not applicable . Reads from left column to row cell i.e. type of actor in the column provides their view on the actor on the adjacent row. This is the same format used in Table 4 which describes the linkages.

a= Respondents suggested this partnership needs strengthening. As presence of other NGOs are limited in project area but other NGOs are present in other districts within the province.

b= Respondent suggested this needs strengthening. For example, plans for promoters to play more of a key role but respondent mentions this has just started so the promoters' role is minimal at this stage.

c= More use of ICT being used which could transmit information on prices and weather could be done through the use of mobile phone technology.

d= mentioned benchmark farmers are too often very good at CA but are not so good in explaining technical aspects to farmers that are having difficulty with CA etc.

e= AKF could also be invited to exchange ideas on CA with the agriculture directorate. Agriculture extension staff could invite AKF facilitators to the demonstration plots/trainings they are involved in and agriculture extension staff could also attend AKF facilitator trainings on CA.

** Unable to meet media representatives due to political sensitivities at the time (i.e. Radio and Television)

Table 3 Actor tie matrix and social network analysis indicators (1= tie, 0=no tie)[8]

Type of Actor	CA club	CA community promoter	Benchmark farm	AKF village facilitator	AKF district coordinator	AKF Agriculture director	Member of Agriculture directorate (SDAE)	Seed multiplication group	Sales commission	rural shops	FFS	VDO	Other farmers non FFS	WWF	Media	Total ties i.e. interactions mentioned by actor	Out-degree centrality	In-degree centrality
CA club		1	1	1	1	1	1		1	1	1	1	1	0	0	11	0.8	0.5
CA community promoter		0	0	0	1	1	1	1	1	1	1	1	1	0	0	9	0.6	1.0
Benchmark farmer		1	0	1	1	1	1	1	0	0	1	1	1	0	1	10	0.7	0.9
AKF village facilitator	1	1	1	0	1	1	1	1	1	1	1	1	1			12	0.9	0.9
AKF district coordinator	1	1	1	1	0	1	1	1	1	1	1	1	1			12	0.9	1.0
AKF agriculture director	1	1	1	1	1	0	1	1		1	1		1	1	0	11	0.8	0.9
Member of Agriculture directorate (SDAE)		1	1	1	1	1	0	1	1	0	1	1	1	0	0	10	0.7	0.9
Seed multiplication	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	12	0.9	0.8
Sales commission/association		1	1	1	1	1	1	0	0	1	1	1		0	0	9	0.6	0.8
Rural shops		1		1	1	1	1	1	1	0		0	0	0	0	7	0.5	0.8
FFS female	0	1	1	1	1	0	0	1	0	1	0	1	1	0	0	8	0.6	0.8
FFS male	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	12	0.9	0.9
VDO	1	1	1	1	1	1	1	1	1	1	1	0	0			11	0.8	0.8
Other farmers	1	1	1	1	1	0	1	1	1	1		1	0	0	0	10	0.7	0.1
WWF		1	1	1	1	1	1		1		1	1	1	0	0	10	0.7	0.1
Media																		
Total received ties	*7*	*14*	*12*	*13*	*14*	*12*	*13*	*11*	*11*	*11*	*11*	*12*	*11*	*1*	*1*	154		
Average score per actor (from actor matrix)	1.6	2.3	2.1	2.9	2.7	2.3	1.7	2.3	1.9	1.8	1.9	1.8	1.8	1.1	1.1			

The key findings from the actor matrix and social network analysis are summarised as follows:

- The actor innovation matrix signals a strong role for a number of actors including the AKF facilitator, district coordinator and seed multiplication group. In contrast, the government role is seen as weaker (SDAE). (See Table 2).
- Table 3 shows the results of the social network analysis. It follows a directed graph format where existence of a tie/interaction between actors, related to information (informal/formal) or goods/services with respect to CA, is signalled by one and absence of a tie by zero. In a directed graph format, A may have a tie with B but this may not be reciprocal i.e. B may not seek information or goods/ services from A (Scott, 2000). Overall, there is a dense network in this innovation system signalled by the high network density approximately 0.69 overall. Network density measures the extent to which the nodes in the network are tied to other nodes and expressed as a proportion of all the possible ties within the network. The closer the figure is to one the greater the density of the network. In this case the value indicates that 69% of the possible ties in the network exist. A high network density figure is an indication that information is able to flow faster (Valente, 1995).
- Centrality analysis identifies those actors playing the most relevant roles within networks (Table 3). It is based on the extent to which the actors' network revolves around a single node. In-degree relates to number of ties received by a node which indicates its importance (prestige of an actor) and out-degree relates to the number of ties initiated by the node which is a signal of how influential an actor may be. For example, the government agriculture directorate (SDAE) has a lower out-degree centrality but a higher number of ties in-degree. This may be an indication of strong ranging formal ties/linkages with other actors but limited influence as the weak score in the matrix suggests.
- AKF village facilitators, staff and community promoters scored very highly in the out-degree centrality which signals their 'prestige' in the innovation system. FFS farmers also scored particularly high in this regard.
- The media has a very low number of linkages but has a higher score among CA users signalling potential role of Radio/TV (See section 4).

Innovation system explored

Figure 5 shows the key interactions within the CA innovation system as identified by the different actors in the matrix. The arrows highlight different partnerships but also types of learning mechanisms. The thick bold arrows symbol ‘partnerships’ which are formal usually requiring a formal Memorandum of Understanding (MOU). These are likely to involve joint learning and innovation and can help to stimulate learning through ‘interacting’, ‘imitating’ and ‘mastering’ (Hall et al., 2006b). The dash arrows signal partnerships which are termed contract based i.e. usually requiring a formal contract. For example, AKF employees are village facilitators and agricultural extension staff are employees of the agricultural directorate. They, however, receive training through ‘imitating’, interacting or ‘searching’ (Hall et al., 2006b). Dot arrows highlight often ‘self-constructed’ networks that help to build social capital and which may be informal or formal in nature but are designed to improve information flows. Light black arrows signal linkages to supply of input or output markets. Some learning occurs here through interaction (Hall et al., 2006b). Finally, the dash-dot arrows signal ‘paternalistic’ partnerships that are designed to spread knowledge goods or services irrespective of preferences or agendas (Hall et al., 2006b).

Role of NGO’s – Aga Khan Foundation and others

The Aga Khan Foundation (AKF) plays a key role in technical assistance and training of the village facilitators and community promoters that are then responsible for setting up Farmer Field Schools (FFS). Prior to the role of community promoters being responsible for setting up farmer field schools this role was done by AKF facilitators (See Table 6.1). AKF have also helped to play a ‘connecting’ role by supporting the creation of farmer organisations and strengthening existing civil society based organisations e.g. Village Development organisations (VDO). The VDO is now responsible for choosing the community promoter for CA from the village who is trained by the village level facilitator.

Other NGOs e.g. Umokazi and World Wildlife Fund (WWF) are not currently working in the district but Umokazi have done some previous work on ‘good agricultural practices’ in the district which involved, for example, training extension agents and farmer groups on eliminating burning of crop residue, application of mulch and planting in lines. WWF have a project on CA in the surrounding national park. There is currently no coordination with WWF on CA with AKF though WWF have partnerships with Associação Meio Ambiente (AMA) and Kulima on CA which are both national NGOs working in the surrounding national park. However, AKF and the WWF have exchanged information and agreed on a common approach in terms of promoting the same key messages in the district/national park on the use of CA.

Local Government organisations

The government organisation SDAE (agricultural directorate) has set up a number of farmer led demonstration plots on CA. The matrix also reveals that SDAE's role is perceived to have less significance with respect to CA information flows in the district than other actors. There also seems to be very low interaction between AKF and SDAE which could also be improved.

Private Sector

There is little by way of input suppliers of equipment and/or other agricultural inputs which may be of additional support to the CA innovation system. For example, locally made jab planters or implements that could be attached to animals to improve the scale of direct seeding. Rural shops, however, have been identified as providing seeds to farmers which offer options for the use of diversified crop rotations. Although some of the actors in the matrix have noted that rural shops could play an increasingly important role by improving publicity and marketing efforts related to CA and the use of different seed types e.g. legumes. Input (seed) supply companies also enter into contracts with rural shops. Thus different seed types can be found in a variety of rural shops. To improve information flows within the innovation system the government led agricultural extension and NGO's such as AKF partner with the Radio to provide information on seed availability in rural shops (location and type of seed available). This information is used by all producers (CA users and non-users). Rural shops also provide other equipment to farmers such as hoes, machetes etc. which are particularly useful for the manual system of CA being used.

Media

District/national television programmes related to CA have also been shown. Radio has also been used (as described earlier) though coverage in some districts is minimal. More use of ICT being used which could transmit information on prices, climate information (e.g. forecasts/warnings) or meetings/ could be done through the use of mobile phone technology.

Benchmark farmers and other experienced farmers

A benchmark farmer acts as a conduit for other farmers ('lead' farmer) on best practices of CA in the district. These benchmark farmers, a few of whom then form the CA club, are involved in sharing their experiences with other farmers in villages where FFS groups have not been set-up and represent the district at the regional level meetings on CA. For example, the CA regional forum (See Table 1). The exchange of innovative and pioneer farmers and their experiences through networks usually provides the fastest development of suitable technologies (Pretty, 2003). These groups can play a powerful role in encouraging others to join (Kassam et al., 2014).

Though the benchmark farmers were seen in a positive light within the innovation system as a whole they were described as being ‘very good at CA but are not so good in explaining technical aspects to farmers that are having difficulty with CA’ (See matrix).

Farmer Field School

Although farmers in FFS cover the main methods involved in CA farmers may well choose some of these methods and not others.. For example, using the micro-pit as an entry point or trying without. Thus, the network partnerships between the CA clubs, benchmark farms and FFS encourage social learning between ‘experienced’ CA farmers and others. The FFS also acts as a platform for social learning by encouraging, for example, some farmers testing different components i.e. different crops into the rotation, and or finding different sources for mulch, solutions for pests/diseases and then sharing these findings with other farmers. Responses from FFS female farmers indicated, however, that farmers felt they were not invited to the government agriculture extension demonstration plots whereas male FFS farmers were. This may be a reason why FFS female farmers scored the role of government as weak compared to males which scored the government’s role as higher.

The AKF staff highlighted (see matrix) that the members of the FFS are encouraged to spread information on CA to at least 5 other people and that farmers would often share information about CA in the local masjids (mosques), among neighbours and family members. Local level village and district level staff (directly involved in formations of FFS and training facilitators) from AKF noticed that farmers played a key role in encouraging other farmers to use/try CA.

Associations and groups

Through FFS’s AKF also share market information which enable individual farmers to connect with producer associations that sell in bulk to traders. Among these groups sales commissions have been formed which aim to improve market linkages with traders. For example, the sales commission then interacts with traders to negotiate the sale of certain crops such as maize and sesame. Sales commission and associations also play a reinforcing role as they have a vested interest in increasing quality and quantity of members - i.e. they also provide information to farmers on the use of treated seed, composting techniques etc. The traders likewise also interact with the sales commission on crops in demand such as specific legumes. Kassam et al., (2014) have noted that small groups can form into larger bodies such as associations and cooperatives which if suitably organized can have enormous clout in both bargaining with traders but also pressuring national and regional bodies for services like extension and research in relation to CA. Other groups also play an important ‘network’ role. For example, seed multiplication groups play a strong role in providing information related to CA (See Matrix).

Having explored the innovation system (the first aim of this chapter) the next section goes on to consider farmers’ perceptions of the innovation itself and of aspects of the innovation system.

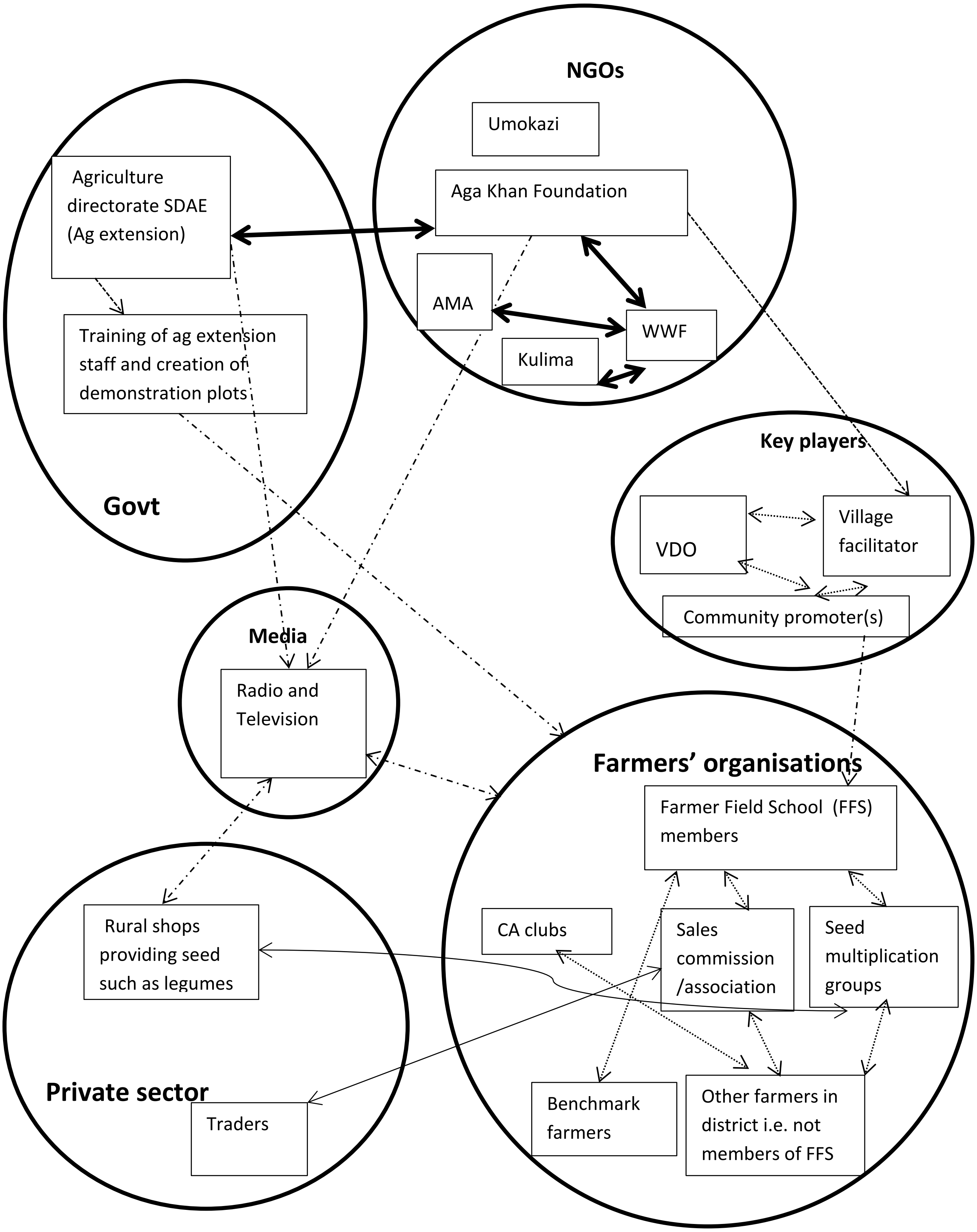

Figure 5 Interaction of innovation actors in the Conservation Agriculture innovation system for Metuge District, Cabo Delgado (arrow signal flow of information or goods and services related to CA) Thick bold arrow= partnerships may be formal which may require MOU. Dotted arrow=networks. Dash arrow=contract based. Light black arrow= goods and services that help to link to input and output markets and dash dot arrow= 'paternalistic' partnership i.e. knowledge provided irrespective of agendas.

Farmers' perceptions of CA and different social referents

The first part explores farmers' perceptions of CA and includes reasons for not using CA among non-users and an exploration of the specific beliefs surrounding CA (among users and non-users) drawing out differences between poorer and better off farmers. The next section reports findings on social referents and motivation to comply with these referents regarding information on CA. This sheds further light on the innovation system and how poorer and better-off farmers view different actors.

Non-users of CA

Figure 6 shows the reasons farmers provided for not using CA. The majority of farmers (Over 80% of those not using CA) cited lack of information as the primary reason. Only a s handful of farmers considered lack of labour or concern over weeds as the reason for not using CA. Moreover, lack of equipment or inputs are unlikely to be an impediment in this setting. Given that farmers using CA, in this district, are not using external inputs such as fertilisers and herbicides may provide more of an incentive to use CA (or at least experiment/test CA on their land) given the low capital requirements needed to use CA.

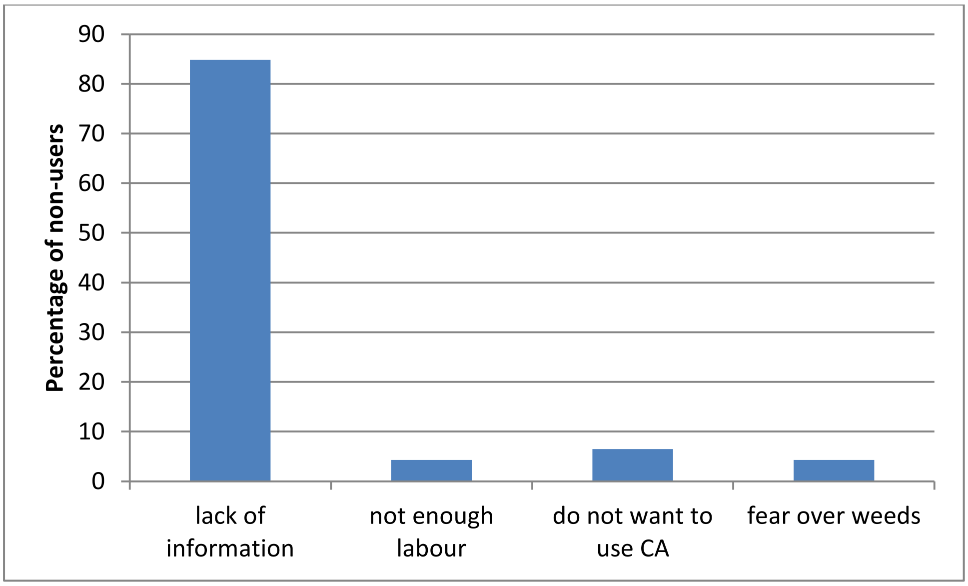

Figure 6 Reasons for not using CA among non-users (N=52)

On a likert type scale (strongly agree 1 to 5 strongly disagree) users and non-users were asked about their perceptions of CA. Farmers were also asked about whom they would likely consider feeling motivated to listen to regarding information on CA. (1 very likely to 5 very unlikely) over the next 12 months and their perception towards using CA. Not sure/cannot say are used interchangebably to denote a neutral response.

Among non-users poorer farmers had more favourable perceptions of CA than better-off farmers. This is particulary associated with the benefits associated with CA i.e. benefits in the first year and a drought year, reduction in weeds, reduction in labour and increase in yields (Figure 7a and 7b). Farmers' perceptions were statistically different between the poorer and better-off farmers for all categories ($p<0.05$) except for the categories: 'increase in pests' and 'cannot be used on all soil types'. Both groups of non-users of CA (poorer and better-off farmers) percieved CA to increase pests.

Interestingly, there were also differences among the wealth terciles with respect to the social referents that farmers felt were motivated to comply with regarding information on CA (Figures 8a and 8b). The poorer farmers signalled a higher motivation to comply with social referents including spouse, sibling, self-observation and self-initiative than better off farmers ($p<0.05$). Poorer farmers were also more likely to comply with Radio and TV. Satistically significant differences were also found between the poorer and better- off farmers with respect to Farmer Field School, the AKF facilitator and the Government ($p<0.05$), Strengths of motivation to comply with NGO's and other experienced farmers were not found to be statistically different. This suggests that farmers (irrespecctive of wealth category) equally value these two actors.

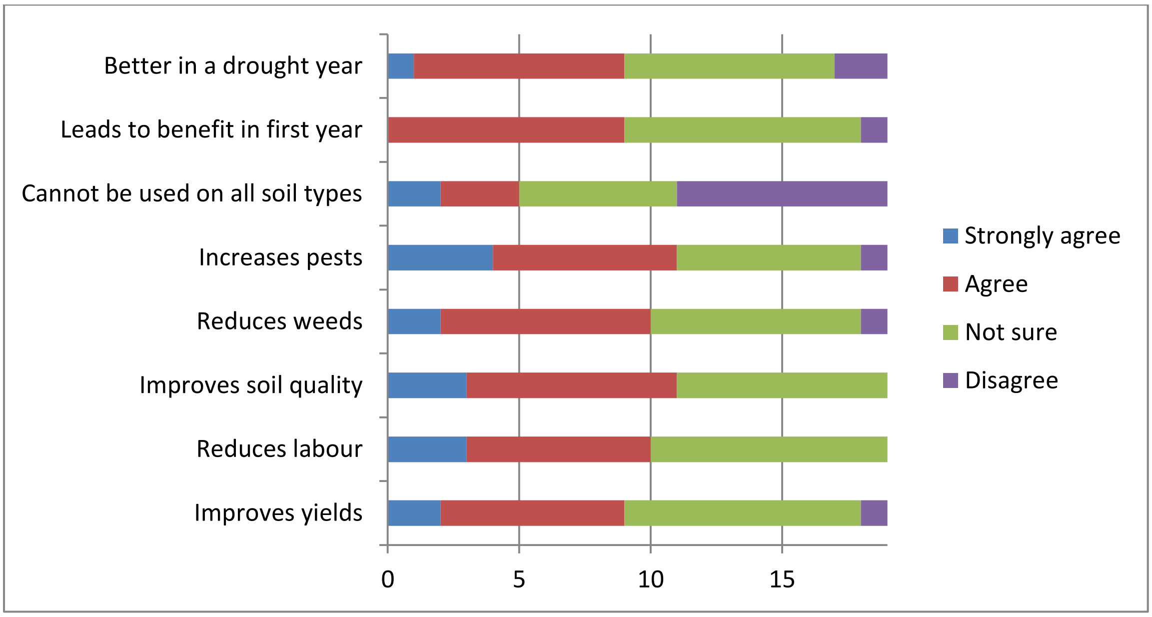

Figure 7a Frequency of responses related to perceptions of CA among the poorest wealth tercile of non CA users (N=19)

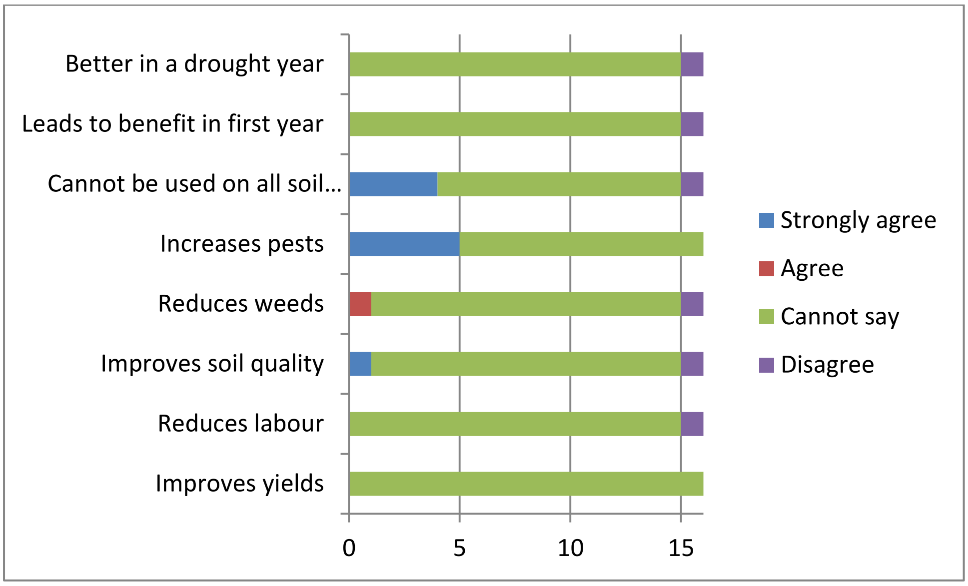

Figure 7b Frequency of responses related to perceptions of CA among the better-off wealth tercile of non CA users (N=16)

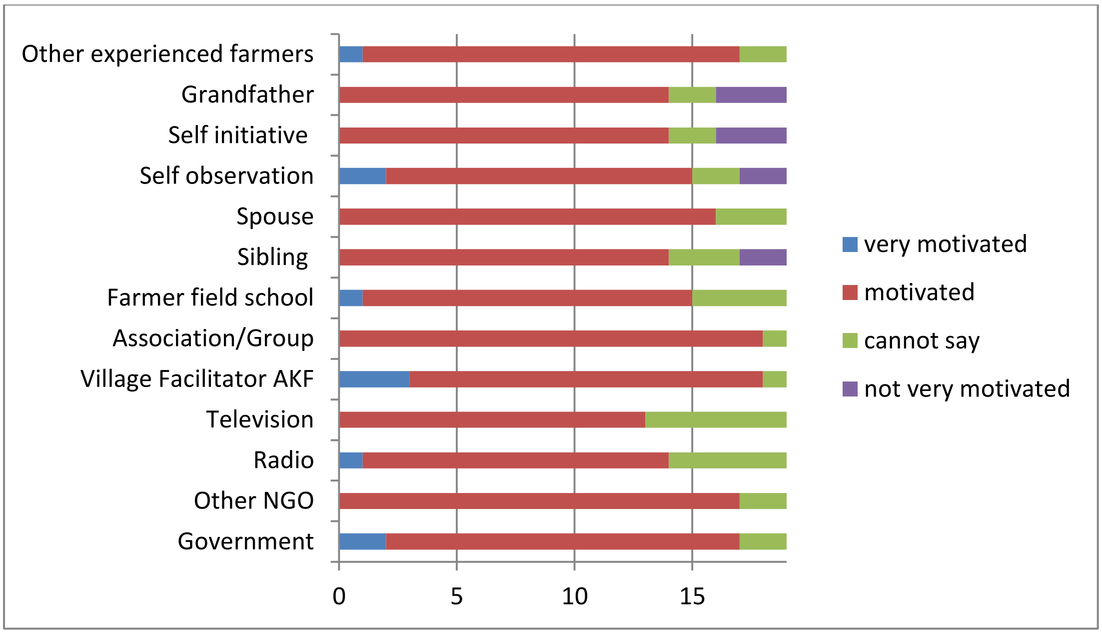

Figure 8.a Frequency of responses related to motivation to comply with different social referents regarding using CA among the poorest wealth tercile of non CA users (N=19)

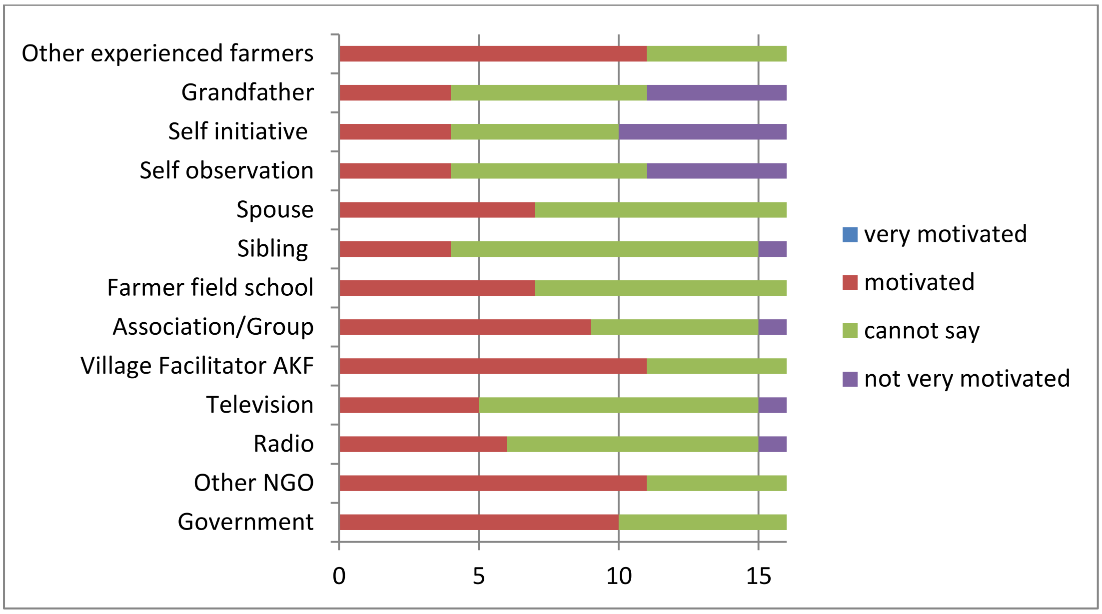

Figure 8b Frequency of responses related to motivation to comply with different social referents regarding using CA among the better-off wealth tercile of non CA users (N=16)

Users of CA

Overall both groups of farmers (poorer and better-off farmers) had favourable perceptions of using CA. These include the perception of increased yields, reduction in labour and reduction in weeds. Moreover, farmers also percieved benefits in the first year and during a drought year. The poor, however, felt that CA did increase pests and this was significantly higher than the better- off farmers ($p<0.01$). Though perceptions were invaraibly positive for both groups the comparisons also indicated that the poorer farmers had stronger overall perceptions of the benefits of CA ($p<0.01$). Both groups of users (poorer and better-off), however, percieved CA to be able to be used on all soil types (Figures 9a and 9b).

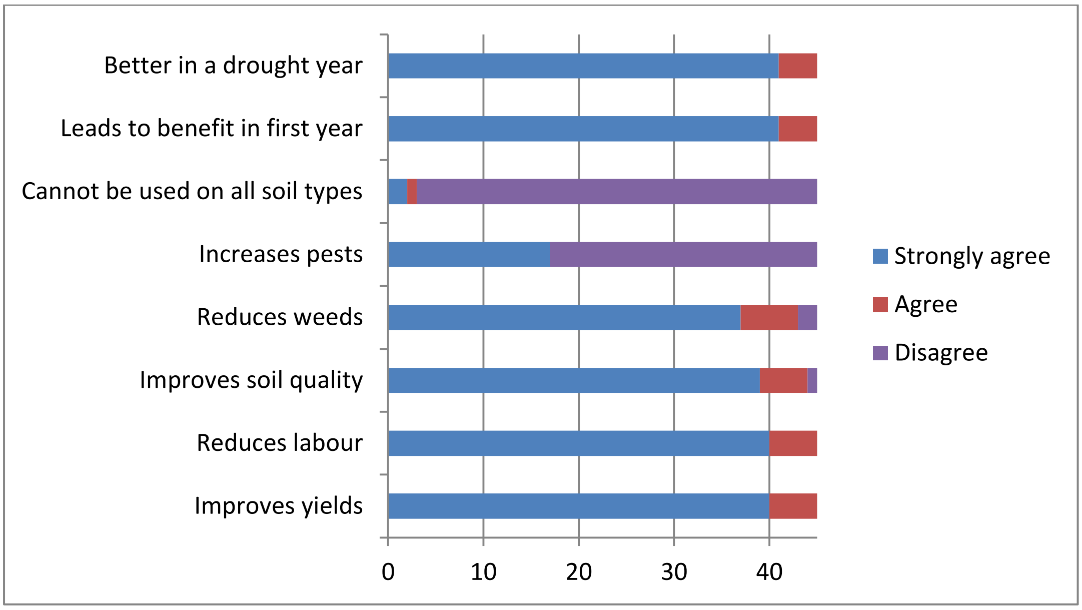

Figure 9a Frequency of responses related to perceptions of CA among the poorest wealth tercile of CA users (N=45)

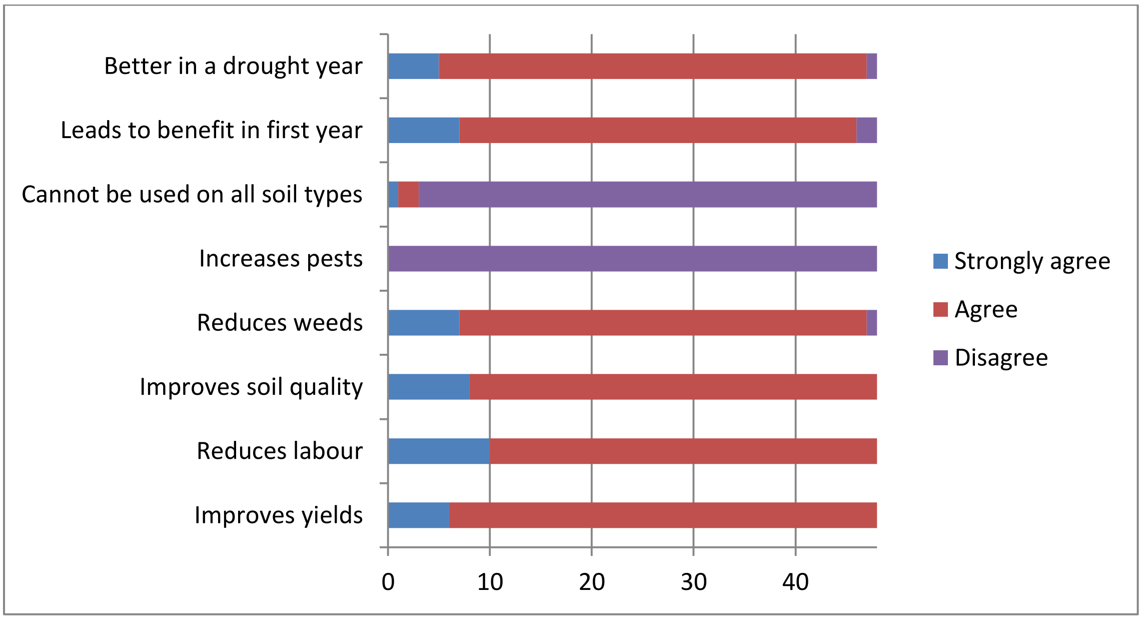

Figure 9b Frequency of responses related to perceptions of CA among the better off wealth tercile of CA users (N=48)

Poorer farmers had a higher score for TV, Radio and family referents such as elders e.g. grandfather and siblings ($p<0.05$). Both groups were equally motivated by experienced farmers, associaitons/groups and other NGO’s i.e. no statistically significant difference found. Poorer farmers, were also highly motivated by the AKF village facilitator, Farmer Field

School and Government compared to wealthier farmers (p<0.01). This is similar to the findings for non-users of CA (Figures 10a and 10b). Furthermore, as with non-users, poorer farmers using CA also had a greater appreaciation for self-observation and self-initiative (p<0.05). Self- observation and self- initiative were also found by Martinez- Garcia et al., (2013) to be strong social referents as farmers took up a technology after observations made or through taking the initiative through testing. Garforth et al., (2004) also found contacts (local and personal) played an important role in engendering adoption of a technology.

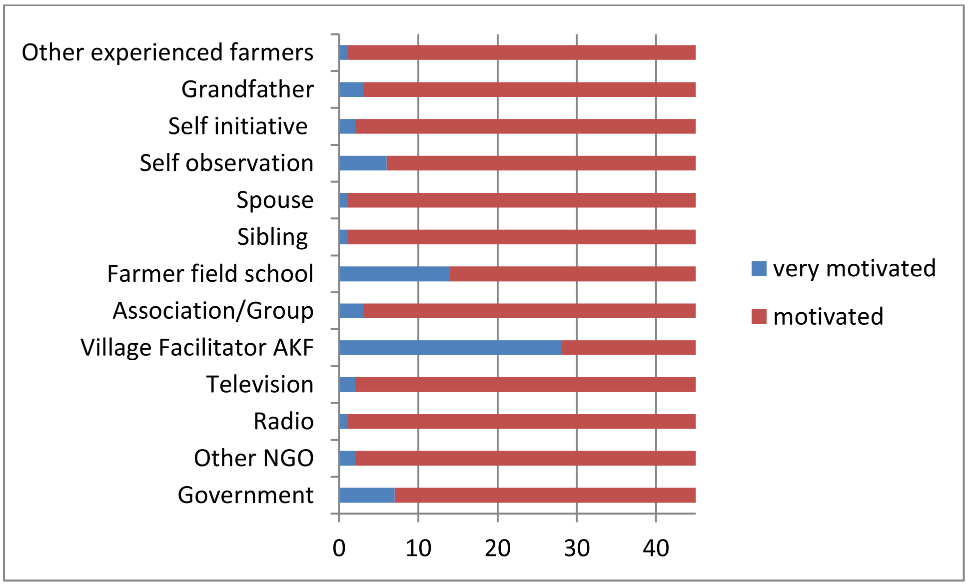

Figure 10a Frequency of responses related to motivation to comply with different social referents regarding using CA among the poor wealth tercile of CA users (N=45)

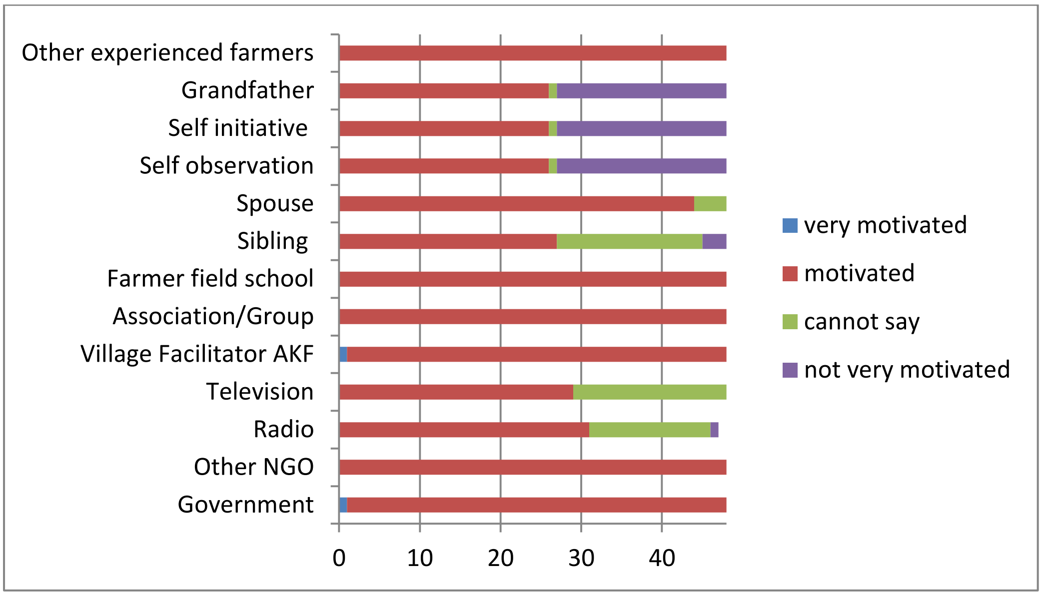

Figure 10b Frequency of responses related to motivation to comply with different social referents regardign using CA among the better-off wealth tercile of CA users (N=48)

Key findings among both users and non-users of CA, were that poorer farmers have more favourable perceptions of CA. The poorer farmers not using CA also expressed a stronger intention to use CA than wealthier farmers ($p<0.05$) (Lalani, unpublished results). It is also interesting to note that the perceptions of farmers using CA were also matched, in part, by the farm budget data gathered in the household survey. For example, lower weeding time was found under CA. Evidence of short-term benefits under CA were also apparent but these were largely dependent on crop mix and opportunity cost of labour assumed (Lalani, unpublished results).

Conclusion

Two specific aims have been explored in this chapter relating to: (i) the construction and functioning of the innovation system, viewed through an AIS ‘lens’ by using timelines, stakeholder perceptions, typologies of partnerships and social network analysis and (ii) perceptions of the users of the innovation itself and on whom they consider to be important actors in the innovation system (e.g. motivation to comply with information on CA). Furthermore, to ascertain whether the poor are beneficiaries of this innovation system farmers’ perceptions were disaggregated by wealth categories.

It is clear that the construction of the innovation system has been supported by a conducive policy environment including the MOU between AKF and the Ministry of Agriculture under the auspices of the strategic plan on Agrarian reform. However, the modus operandi used to achieve a functioning innovation system has been the ‘network’ partnerships that have been developed through the support from AKF (e.g. FFSs, community promoters, seed multiplication groups and village level facilitators) and farmers themselves (e.g. benchmark farmers) These social learning mechanisms vis-a-vis other actors in the innovation system (e.g. traders, rural shops and radio) have further enabled farmers to ‘innovate and change’ (Hall et al., 2006). Of course the ability of NGOs to help promote civil society based organisations in the first instance is also in part due to a conducive policy/legal environment that allow formation of organisations such as Village Development Organisations/ associations and other market/civil society actors to operate. These have often been lacking in some countries in Sub-Saharan Africa which has stifled agricultural innovation. For example, the strong influence of public extension exerting influence on smallholders in Ethiopia has limited the space for other potential actors, such as market or civil society actors, which has impeded innovation (Spielman et al., 2011). Interestingly, where NGOs were operating (whilst the government had a central role) they had stronger and far-reaching ties within the public sector sphere (e.g. with public sector service providers) and wider afield such as with Universities and research institutes providing greater scope for new information to stimulate innovation (ibid). This supports the findings of the social network analysis presented in this chapter i.e. the government agriculture directorate (SDAE) had strong formal ties/linkages (higher in-degree centrality) and lower out-degree centrality suggesting limited influence in terms of knowledge flows within the innovation system as the actor matrix also suggested. It has been well documented elsewhere that rapid uptake of CA will not take place without the appropriate enabling policy environment and institutional support to engage farmers at the community level (Kassam et al., 2015).

Of course there is the issue of sustainability when civil society actors may cease to operate in an area or if the overall effectiveness of community based approaches in reaching the poor is reduced through, for example, ‘elite capture’ (as outlined earlier in the chapter). Notwithstanding this, the social learning mechanisms in this case study region (e.g. FFS, AKF village facilitator and community promoters) which have been seen to be playing a strong role in the innovation system among the actors themselves, have been central to both developing the capacity and confidence of local groups and individuals and to reducing the risk and uncertainty commonly associated with undertaking a ‘new’ farm management system among smallholder farmers.

This is supported by farmers’ perceptions of the innovation (particularly favourable among the poorest) and motivation to comply with certain actors in the innovation regarding information on CA. Farmers expressed positive perceptions of key factors such as: (i) improved yields, (ii) reduction in labour and (iii) suppression of weeds. Farmers also feel that CA is able to contribute to benefits in the first year of implementation and in a drought year.

There is also evidence to support the notion that this innovation system is reaching its target beneficiary i.e. the poorest farmers. Interestingly, poorer farmers (among non-users and users of CA) had significantly stronger favourable perceptions of CA than wealthier farmers. There are also key differences in some of the social referents and key actors within the innovation system that farmers hold in high regard and are more likely to respond to in terms of receiving information on CA. For example, poorer farmers place a greater emphasis on social referents within the family e.g. spouse, sibling, or grandfather, and others such as the village facilitator and FFS ($p<0.05$). They are also more likely to respond to media campaigns from either Radio or TV ($p<0.05$). The village level facilitator and FFS were also given particularly high scores in the actor matrix and in the social network analysis which signals their pivotal role within this particular innovation system. Interestingly and importantly the results showed that poorer farmers value self-observation and self-initiative more than wealthier farmers ($P<0.05$). This indicates that although the opinions of key referents are important to poorer farmers, their own experience also plays an important role in the adoption process. Ngwira et al., (2014) also found that CA adoption occurs within a strong social context whereby farmers learn by observing what other significant persons are doing. Thus, the formation of constructed networks such as seed multiplication groups, associations with sales commissions may also further engender social capital coupled with CA adoption (as outlined earlier). However, a number of farmers did express an interest in using CA but a lack of desire to engage in group activities/networks, preferring one-to one interactions instead. Similarly, other authors have found that group activities may be unattractive to some farmers and bilateral contacts may be more appealing (Ngwira et al., 2014). Overall, the farmers' perceptions also highlight that they value interactions with the government, other NGOs, and the media with respect to using CA which may signal potential entry points to strengthen the innovation system further given these stakeholders have weaker roles at present in the innovation system. Alongside this, engagement of AKF (given its prominent role in the current innovation system) with research institutes/Universities and in perhaps enabling local equipment to be manufactured (e.g. supporting local entrepreneurship) may also improve the potential reach of the innovation system. This will further improve the 'space' for farmers to innovate which is crucial in developing locally relevant based adaptations based on CA principles (Kassam et al., 2015). For example, farmers have often found local solutions to issues surrounding e.g. mulch cover, weed management and equipment etc.

Other issues which might have wider applicability to the discourse on CA in Sub-Saharan Africa are:

- Farmers' perceptions here indicate that CA alone without external inputs such as fertilisers, herbicides pesticides or compost can improve yields relative to conventional agriculture without the use of these inputs. Furthermore, the majority of CA users (72%) were using the local variety of maize which illustrates that farmers are able to use CA with the resources they have.
- This innovation system also shows subsidising of inputs is not a necessary pre-condition to CA use.
- CA can be implemented in a variety of systems, be these manual systems as described here, or animal or mechanised systems. This case study of Northern Mozambique highlights that manual forms of CA can be attractive for farmers, particularly those with very small plots of land (half a hectare or less). Furthermore, where land to livestock ratios are low such as in Northern Mozambique, competition for mulch needed for livestock feed is not as pronounced as is the case elsewhere.
- There is evidence to suggest that potential fears over weeds and labour in such a farming system are not key constraints to adoption i.e. farmers have found CA to reduce labour requirements and weeding time. Nevertheless, weed control is a challenge for family farmers wherever there is good rainfall or irrigation, irrespective of soil management. Weed management has enormous implications for farmers in similar agro-climates in Southern Africa in particular. Managing some cover crops for no-till systems can be especially challenging without the use of herbicides.
- Disaggregation by wealth shows CA is being used by and benefiting the poorest farmers, rather than only benefiting wealthier farmers.
- Farmers' organisations are an important source of networking and learning which encourage innovation. Social referents can also play a key role in this regard.
- Overall, agricultural innovation systems like the one described here that include dense networks of mutually supporting stakeholders and special extension processes, such as Farmer Field Schools, appear to be powerful enabling approaches for knowledge-intensive innovations such as Conservation Agriculture.

Notes

1. An Innovation here is defined as ‘any knew knowledge introduced into and utilized in an economic or social process’ (OECD, 1999; cited in Spielman et al., 2005)
2. CA has been defined in a reference manner as: (i) No or m*inimum mechanical soil disturbance*: Minimum soil disturbance refers to low disturbance no-tillage and direct seeding. The disturbed area must be less than 15 cm wide or less than 25% of the cropped area (whichever is lower). There should be no periodic tillage that disturbs a greater area than the aforementioned limits. (ii) *Organic soil mulch cover*: Three categories are distinguished: 30-60%, >60-90% and >90% ground cover, measured immediately after the direct seeding operation. Area with less than 30% cover is not considered as CA. (iii). *Crop diversity involving rotations/associations/sequences ideally comprising* at least 3 different crops (FAO, 2015).
3. There are three manual seeding systems commonly used in the district: These are: (i) dibble stick; (ii) planting micro-pits as an entry point into CA; and (iii) jab planters. The use of dibble sticks and jab planters is still limited and micro-pits have been more commonly used in the district. (See Box 1)
4. Only a small number (10%) of CA users from those surveyed used 2 crops. As these farmers were following all the other principles we have incorporated their responses into the farmers’ perceptions of CA.
5. Only a handful of non-CA users were found to be practicing mulching.
6. Only one farming household was found to be using a pesticide or compost in the household survey undertaken. No fertilisers or herbicides were found to be used. (Lalani, unpublished results).
7. Only 2 households among the No-CA cohort were using four crops.
8. Uses same formulas and definitions as Scott, J (2000) for network density and out-degree and in-degree centrality. Network density is calculated using the formula for a directed graph i.e. L/n (n-1) where L is the number of ties and n the number of node or actors. Out-degree/in-degree centrality calculated by number of ties initiated divided by (n-1) i.e. n being number of nodes/actors. Network density overall is 69%. Network density for the FFS males (70%) is slightly higher than for the female FFS group (68%). Though FFS groups were organised into FFS female groups and FFS mixed groups interviews were conducted with males and females (irrespective of the particular grouping to explore any differences in gender dimensions).

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Chapter 5: Unifying the data[14]

Abstract

Prescriptive poverty reduction pathways often include reference to adoption of new technologies and formalizing, precisely, the adoption-effecting strategies still remains a considerable task confronting development practitioners. We provide insight in the context of two important features of the experimental setting confronting Conservation Agriculture that appear hitherto neglected by development contributors. One is a substantial sample of demographic and production features referencing Mozambique subsistence crop production collected in the summer of 2014 in the province of Cabo Delgado; and the other is a robust covariate selection algorithm constructed for the purpose of better understanding adoption-precipitating strategies available for conservation agriculture. We identify from a total of seventy seven covariates that only seven covariates are important as appropriate adoption precipitating strategies. These relate strongly to social capital (i.e. membership of a Farmer Field School), the practice of planting in lines, the perceived level of importance of reduction in labour and soil quality improvement as well as farmers' perceptions of reduced pests with Conservation Agriculture usage. Interestingly, the perceived social pressure from a village facilitator plays a significant role as does self-efficacy in terms of the willingness to be part of a group related to Conservation Agriculture. We further discuss extensions of the Markov Chain Monte Carlo estimation algorithm which may be relevant to future adoption studies, stimulated by previous studies, some appearing in this outlet, which provide the mainstay for our methodological modification and our ultimate contribution. The specific insights concerning adoption of Conservation Agriculture in the Mozambique sample setting are three, namely: First, we demonstrate the importance of objectively as opposed to subjectively detecting covariates. Second, we demonstrate the associated importance of correctly discerning the appropriate fixed effects precipitating adoption. Third we demonstrate one hitherto neglected aspect in adoption studies of like kind in correctly discriminating the aforementioned contributions across specific and appropriately designated sub-components of the sample space. The general insight relevant to development practice is that formal covariate selection seems possible in a broader and more extensive set of circumstances, perhaps, than previously considered possible; to the extent that this insight is useful, practitioners can profit from the application of like-styled statistical interventions constructed for the purpose of better discerning poverty-reduction pathways.

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[14] A revised version of this chapter is being finalised for submission to World Development as: Lalani, B., Dorward, P., Holloway, G., Poverty Reduction Pathways in subsistence Agriculture: Evidence from A Markov Chain Monte Carlo Experiment in Cabo Delgado, Mozambique .

Keywords: Poverty, technology adoption, covariate selection, models space, robust Markov-chain Monte Carlo methodology.

Introduction

Conservation Agriculture (CA) is now practiced worldwide across all continents and ecologies including on various farm sizes from smallholders to large scale farmers (Friedrich et al., 2012). It is defined as the simultaneous application of three principles, namely minimal soil disturbance, permanent organic soil cover (covering at least 30% of the cultivated area) and the use of rotations and/or associations involving at least 3 different crops (FAO, 2015).

In Sub-Saharan Africa, conventional tillage practice usually through hand-hoe or animal traction has resulted in soil erosion and loss of soil organic matter (SOM) which has been further exacerbated by the practice of crop residue removal and burning (Rockström et al., 2009). Thus, the discourse on sustainable intensification now contends that systems high in sustainability are those that make best use of the environment whilst protecting its assets (Pretty, 2008).

Development practitioners, agencies and governments have thus been heavily involved in promoting CA within the region in recent years. Recent studies have shown, however, that adoption of CA practices in Africa remains low (Rockström et al. 2009; Giller et al. 2009). Moreover, mixed experiences with CA particularly in Sub-Saharan Africa have been well documented (Giller, 2009). Furthermore, the low rates of adoption in Sub-Saharan Africa have fuelled controversy surrounding the benefits of CA both in terms of the private and social benefits accruing from adoption. Akin to Giller's arguments (Giller, 2009; Giller, 2012), Baudron et al. (2012) found for farmers in the Zambezi Valley (Zimbabwe) that CA required additional weeding and lack of labour availability for this task reduced uptake. Chauhan et al. (2012) have also argued that in general there is a poor understanding of weed dynamics within a CA system which can have a bearing on farmer adoption of CA. Access to fertiliser and other inputs including herbicides are therefore a contentious issue, with a number of authors arguing that for CA to improve productivity; appropriate fertiliser applications and herbicide applications need to be used (Rusinamhodzi et al., 2011; Thierfelder et al., 2013).

The political economy of agriculture has also been questioned by Sumberg et al. (2013) who suggested the 'universal approaches to policy and practice' taken by development agencies, and practitioners with regards to CA may limit the understanding of different contextual factors and alternative pathways.

In light of these longstanding debates, and low rates of adoption, Stevenson et al. (2014) recently suggested a key area for research in Asia and Africa with regards to CA will be understanding the process of adoption. Thus, understanding the drivers of adoption of CA has received increasing attention.

Previous studies on Conservation Agriculture adoption

Little consensus from CA adoption studies on factors influencing adoption have been found. This notion is supported to some extent by Knowler and Bradshaw (2007) show for an aggregated analysis of the 31 distinct analyses of CA adoption that there are very few if any universally significant independent variables (education, farm size etc) that affect adoption. Just two, ‘awareness of environmental threats’ and ‘high productivity soil’ displayed a consistent impact on adoption i.e. the former having a positive and the latter a negative impact on adoption.

Ngwira et al (2014) used a heckman two-stage model to first model the decision to adopt CA and then conditional on adoption modelled the extent of adoption of CA i.e. degree of adoption based on land under CA. The authors highlight the importance of farmers' organisations and hired labour as key factors influencing the decision to adopt and years of experience as well as small overall total land size as factors influencing the degree of adoption. In conjunction, proponents have argued that there are a number of exogenous factors which can also have a bearing on the enabling environment to allow CA adoption to flourish including appropriate governmental support and social capital. (Sobels et al., 2001; Ekboir, 2003).

Previous studies on CA systems have been conducted elsewhere in Mozambique (Nkala et al., 2011; Famba et al., 2011; Grabowski and Kerr, 2013; Thierfelder et al., 2015; Nyagumbo et al., 2015; Thierfelder et al., 2016). Few studies have explored adoption dynamics though Nkala et al., (2011) employed a probit model on determinants of adoption of CA revealing the importance of labour, wealth and subsidised inputs in adoption. Furthermore, attention towards the importance of female messengers in extension (using multivariate linear regression) was shown to increase the likelihood of adoption of sustainable land management technologies in Mozambique has received exposure recently in this Journal (Kondylis et al., 2016). Similarly, in relation to Northern Mozambique, Lalani et al., (2016), using socio-psychological constructs in a linear regression, showed farmers are interested in using CA without external inputs or the need for additional labour. Moreover, the poorest farmers and members of farmer field schools had the highest intention to use CA; found CA the easiest to use and also had the strongest positive attitude surrounding the benefits of CA use such as increased yield, reduction in labour, improvement in soil quality and reduction in weeds.

The adoption problem

As with much of the agriculture technology adoption literature, studies on determinants of adoption on CA have been based on binary-choice frameworks (i.e. use or non-use of a technology or practices), the modus operandi are the familiar probit and logit specifications. Though the probit specification is considered “the most celebrated binary choice specification (Koop et al., 2007).” more complex econometric specifications have also been used (e.g. ordinal and categorical response specifications such as the ordered probit and the multinomuial probit and logit specifications (Edirisinghe and Holloway, 2015). For example Teklewold et al., (2013) used a multivariative probit model to separate out different sustainable land management practices being adopted by households.

In addition, these interventions have largely been based on ‘frequentist’ approaches where covariates are chosen arbitrarily by the investigator and have invariably neglected the role of ‘search’ (Edirisinghe and Holloway, 2015). This absence and the dominance of such approaches is largely pervasive in the agricultural technology adoption as a whole (e.g. See reviews by Feder et al.(1985), Besley and Case (1993), Sunding and Zilberman (2001) and, more recently, Doss (2006)).

In most of the cases, the model choice is dictated by the data availability and the research questions are addressed using ad hoc procedures; the plethora of model choices leading to sometimes conflicting predictions about the adoption decision; the specific covariates deemed to affect the adoption decision; and, conditional on these covariates being chosen, their relative and absolute potency in policy prescription. Few attentions are devoted to the problem of ‘search.’ And the absence of such devotion generates additional scope for nuanced econometric enquiry.

The adoption problem confronting investigators

The adoption problem confronting investigators has often involved the issue of appropriately grouping data together. Conventional models have focused on clustering whilst alternatives such as finite mixture analysis exist. Bayesian models such as these are motivated by the possibility of unifying the data.

The use of conventional models can lead to erroneous hypothesis and false inference. Available methodology for grouping the data exist. These include classification clustering analysis or Bayesian finite mixture modelling (Binder, 1978; Titterington, Smith and Makov, 1985; Lavine and West, 1992; Diebolt and Robert, 1996; Dellaportas, 1998; and others)

In this investigation we enact empirical work using a novel approach to covariate- and fixed-effects selection. The approach has its roots immersed in a set of classic papers in finite-mixtures and, for this reason, shares one fairly problematic feature plaguing execution in finite-mixtures formulations. This problem surrounds the fact that the 'labelling' of the mixture subcomponents is 'ambiguous.'

A fairly substantial literature surrounding this 'problem' exists and is detailed in Robert, (1996), Marin and Robert, (2007); and Stephens (2000a; 2000b).This issue is fully embraced in recent work by one of the co-authors (Nicoll et al, 2016, in review) and in an extension of that work by Holloway (2016).

The mathematical solution to the problem of rectifying label-recalcitrance has deeper ramifications for the foundations of Bayesian inference; the derivation of robust empirical statements concerning the definition of a Bayesian model; and for improving the precision of making robust statements about empirical quantities of interest. The reader has accessible the background and foundational discussion in Holloway (2016) which focuses attentions on the first two aspects of the methodology. Present interests surround the third component and, specifically, the precision with which we are able to determine precisely the appropriate 'associations' across the entire sample comply of 197 observations from the region-name survey; the appropriate assignment of particular covariates across the two sample subcomponents; assignment of fixed effects across the subcomponents; and determination of the specific similarities and differences accruing among the two groups stemming from their sample collection, namely, the factors precipitating and impeding adoption of conservation-agriculture practices in the Cabo Delgado sample. The advantage of a finite mixtures model with covariate selection is to improve fit allowing otherwise subjectively invoked assumptions to be tested and guided by the data.

Put another way, the anticipated value of identifying exchangeable sub-components are three:

(i) Identify difference in cause (covariate dependence) and effect (conservation agriculture adoption principles)
(ii) Correctly infer magnitude of responsiveness to adoption stimuli
(iii) Ability to accurately predict adoption (based on features i and ii above)

The Mozambique sample setting

Cabo Delgado is the northernmost province situated on the coastal plain in Mozambique.

Its climate is sub-humid, (or moist Savanna) characterized by a long dry season (May to November) and rainy season (December to April).

There are ten different agro-ecological regions in Mozambique which have been grouped into three different categories based in large part on mean annual rainfall and evapotranspiration (ETP). Highland areas typified by high rainfall (>1000mm, mean annual rainfall) and low evapotranspiration correspond to zones R3, R9 and R10. Medium altitude zones (R7, R4) represent zones with mean annual rainfall ranging between 900-1500mm and medium level of ETP. Low altitude zones (R1, R2, R3, R5, R6, R7, R8) which are hot with comparatively low rainfall (<1000mm mean annual rainfall) and high ETP (INIA, 1980; Silici et al., 2015). The Cabo Delgado province falls within three agro-ecological zones R7, R8, and R9. The district under study (Pemba-Metuge) falls under R8; distribution of rainfall is often variable with many dry spells and frequent heavy downpours. The predominant soil type is Alfisols (Maria and Yost, 2006). These are red clay soils which are deficient in nitrogen and phosphorous (Soil Survey Staff, 2010).

Though provincial data is sketchy, yields for staple crops in Mozambique are very low compared to neighbouring countries in Southern Africa. Average yields (calculated from FAOSTAT data based on the years 2008-2013), for example, show relatively low yields for maize (1.12 tons/ha), cassava (*Manihot esculenta Crantz*), (10 tons/ha) and rice (*Oryza sativa L.*), (1.2 tons/ha). These are lower than neighbouring Malawi which has much higher cassava (15 tons/ha), maize (2.3 tons/ha) and rice (2.1 tons/ha) yields. Maize and rice yields in Malawi are virtually double those in Mozambique. Zambia has comparatively higher maize and rice yields but lower overall cassava yields than Mozambique. Maize yields (2.7 tons/ha) in Zambia, on average based on the past five years, are triple those in Mozambique and rice yields in Zambia are virtually double (1.7 tons/ha) (FAOSTAT, 2016).

The majority of inhabitants, within Cabo Delgado province rely on subsistence agriculture, where livestock numbers are very low and market access is often limited due to poor roads and infrastructure. Research has highlighted that the prevalence of stunting (55%) is the highest among all provinces in Mozambique (FAO, 2010). Furthermore, poverty studies also place Cabo Delgado among the poorest in Mozambique (Fox et al., 2005). A more recent study using the human development poverty index ranks Cabo Delgado as the second poorest province in Mozambique (INE, 2012). This is compounded by high population growth in Mozambique which exacerbates the poverty nexus. Current projections show that the population of Pemba-Metuge district will more than double by 2040 (INE, 2013). Though population density is considered very low across Mozambique (Silici et al., 2015) intensification as opposed to extensification of land will be imperative for the future with increased population, climate variability and lack of labour to clear new land (Thierfelder et al., 2015). Similar pressures exist in much of Sub-Saharan Africa and in many countries population pressure is far greater.

Conservation Agriculture in Cabo Delgado

CA adoption has gathered momentum in Cabo Delgado, in recent years, largely stimulated by the institutional presence of the AKF-CRSP (Aga Khan Foundation Coastal Rural Support Programme), which has been promoting CA in the province since 2008. The establishment of a number of Farmer Field Schools, within each of the districts, has also helped to encourage adoption of CA among farming households. As of 2014, there were 266 Farmer Field Schools that focus on CA running in Cabo Delgado with a combined membership of 5000 members.

Unlike other NGO’s in parts of Mozambique and Sub-Saharan Africa, AKF have not provided inputs such as herbicides and chemical fertilizers in order to stimulate adoption. Given the lack of draft and mechanical power in Cabo Delgado, manual systems of CA have been promoted. AKF’s approach has aimed to improve soil fertility through the use of legumes as green manure, annual (cover also as crops) and perennials, developing mulch cover with residues and vegetation biomass (produced on-farm or brought in from the surroundings i.e. bush areas) and compost.

A number of manual systems have been promoted in the region given the lack of animal or farm power. Firstly, the use of a dibble stick which is a pointed stick used to open small holes in crop residues for planting seed. Secondly, micro-pits (the most commonly used manual system being used) which are often used in the early years of CA to break the soil compaction. AKF- CRSP has promoted the use of micro pits (15cm long x 15cm wide x 15cm deep). These differ from basins being promoted elsewhere in Sub-Saharan Africa that require tillage each year. Finally, the use of the jab planters have also recently been promoted in the region. These are used to make small holes in crop residue and simultaneously apply seed and fertiliser and/or manure into the planting holes made.

Materials and Methods

Survey procedure

The study uses results from a survey of 197 farmers in the Metuge district, of Cabo Delgado Province Mozambique**.** A multi-stage sampling procedure was used to select the households from a list of local farmers provided by key informants in each of the villages. The total clusters (i.e. in this case villages were chosen based on whether the Aga Khan Foundation had a presence there and started on CA awareness work). This list came to 13 villages. Six communities were chosen randomly from this list and households were selected randomly from the lists in these villages using probability proportional to population size. In the initial sample, 250 farmers were surveyed. Due to non-response of 53 farmers, our final effective sample size was 197. The survey was translated into Portuguese and trained enumerators were used that were conversant in both Portuguese and the dialects used in the different villages.

Model description (Methodology)

Whilst a collection of mathematical details concerning the foundations of the specific innovation lie beyond the scope of the present paper, whose interests are primarily empirical, we emphasize distinction between preferred models under conventional probit methodology (single-sample conventional probit methodology) and our approach (multiple-sample probit methodology) which assigns the sample collection of 197 observations into appropriate subcomponents and, consequent upon appropriate assignment, determines the ‘correct’ (meaning, highest probability) assignment of covariates and fixed effects across the subsample division of the entire 197-unit sample.

The methodology was initially stimulated by a like-minded investigation aimed at assigning a collection of 49,914 petrel (*Pterodroma arminjoniana*) tracks across the Indian Ocean (Nicoll et al, 2016). The major innovation there is overcoming the finite-mixtures labelling problem that has plagued previous work (Lavine and West, 1992; Diebolt and Robert, 1994; Dellaportas and Smith, 1998; and Stephens, 2000b). The significance of overcoming the labelling assignment problem in that work is clear when it is compared to a conventional methodology (see, for example, the finite-mixtures application in Chib, 1995). When a conventional approach is applied employing a so-called artificial ‘labelling assignment’ we deduce that the total number of mixtures assignments is considerably expanded, highlighting a fairly heterogeneous set of geographic areas appropriate for endangered-species preservation. The exercise, however, has more than purely empirical gains.

The theoretical construct stemming impediments in mixtures estimation surrounds the important concept of 'exchangeability' and specifically that the mixtures label assignments are, themselves, 'exchangeable.'

Exchangeability was introduced, first, by the English logician Johnson (circa 1924) in the desire to treat 'objects' 'impartially.' de Finetti (1937, 1938) adopted this notion as the fundamental, over-arching concept surrounding a 'sample' of observations and the presentation of a 'model' by which the sample could be 'processed.' The profound consequences of this aspiration have been pursued (Bernardo and Smith, 2002) and are developed, neatly, (Bernardo, 1992) in user-friendly settings.

The further and deeper implications of exchangeability for empirical analysis are one. If exchangeability exists there exists a Bayesian model for processing and interpreting the sample information. If there exists subcomponents of a single sample complex, there exists multiple components over which the empirical investigator and the empirical investigation should apply a corresponding Bayesian model. Presently we are interested in the extent to which the latter aspect of exchangeability promotes incisive and accurate processing of the sample information; the nature of the adoption process for our sample of subsistence agrarian producers contemplating conservation agriculture practices; and the a correct assignment of covariates and fixed effects to the respective subcomponent groupings.

We relegate mathematical details of the search procedure to Holloway (2016) and to the compute algorithms available along with this submission. We focus here on the broader aspects of the methodology and its execution.

All aspects of the intervention surround repeated computations of the quantity $f(y)$ for which we assign the nomenclature 'marginal likelihood' or 'the evidence' for the sample quantities y $\equiv (y_1, y_2, .., y_N)'$. Here $y_1, y_2, .., y_N$ denote a collection of binary values $y_i = 1$ signifying that observation 'i' adopts conservation agriculture and $y_i = 0$, denotes otherwise. We note that the description of the sample evidence is, of course, conditional on covariates, which we denote, '**X**', comparing an N×K collection of observable components appropriate to each. We note, while suppressing, reference, for notational simplicity, that the covariates '**X**' also include appropriate fixed effects. And we extend this idea to various subcomponents of the sample space. Let j = 1, 2, .., M denote 'M' such divisions of the sample space, and consider groupings $\{y_{(1)}, \mathbf{X}_{(1)}\}$ $\{y_{(2)}, \mathbf{X}_{(2)}\}$, .., $\{y_{(M)}, \mathbf{X}_{(M)}\}$ and the associated depiction of the sample evidence, namely, $f(y) \equiv f(y_{(1)}|\mathbf{X}_{(1)}) \times f(y_{(2)}|\mathbf{X}_{(2)}) \times .. \times f(y_{(M)}|\mathbf{X}_{(M)})$. The algorithmic 'problem' confronting the investigation then reduces to assessments of $f(y)$ in three dimensions. One dimension is the number of subcomponents, here, referenced, simply, 'M.' Another dimension is the appropriate assignment of covariates, $\mathbf{X}_{(1),}$ $\mathbf{X}_{(2),}$ $\mathbf{X}_{(3)}$,....$\mathbf{X}_{(M)}$, to the appropriate sample subcomponents. And third is the assignment of the individual observations y_1, y_2, .., y_N into the various subcomponents.

Holloway (2016) presents a robust algorithm for such assignment. The algorithm, while sometimes slow to converge, eventually locates the appropriate assignment in a number of diverse empirical settings and in simulated data confirmations.

Experience with the algorithm on the Cabo Delgado sample is enacted first for a total of one million iterations. We commence search permitting the total number of subcomponents to range between a minimum of one and a maximum of one-hundred and ninety-seven. The results of the search suggest that there are, occasions when two subcomponents is preferred to three and that both are preferred to a single sample subcomponents across the full 197-observation sample. The reader should be made aware that such computation consumes approximately twenty-four hours on a modest hardware-software platform.

Given these preliminary findings we enact additional search permitting the iterations to extend to two-million calls. Two independent search executions are enacted. One search selects randomly around one-hundred subcomponents as the start setting; and the other selects randomly around ten. Both executions converge fairly rapidly to three sample subcomponents. And at approximately 1.2 million iterations both algorithms collapse to two subcomponents. The total executions consumed approximately forty-eight hours on the conservative computing platform. The graphics summarising the search procedure are listed (figures 1-2). The posterior search after search are dependency assignment of the bi variate sample.

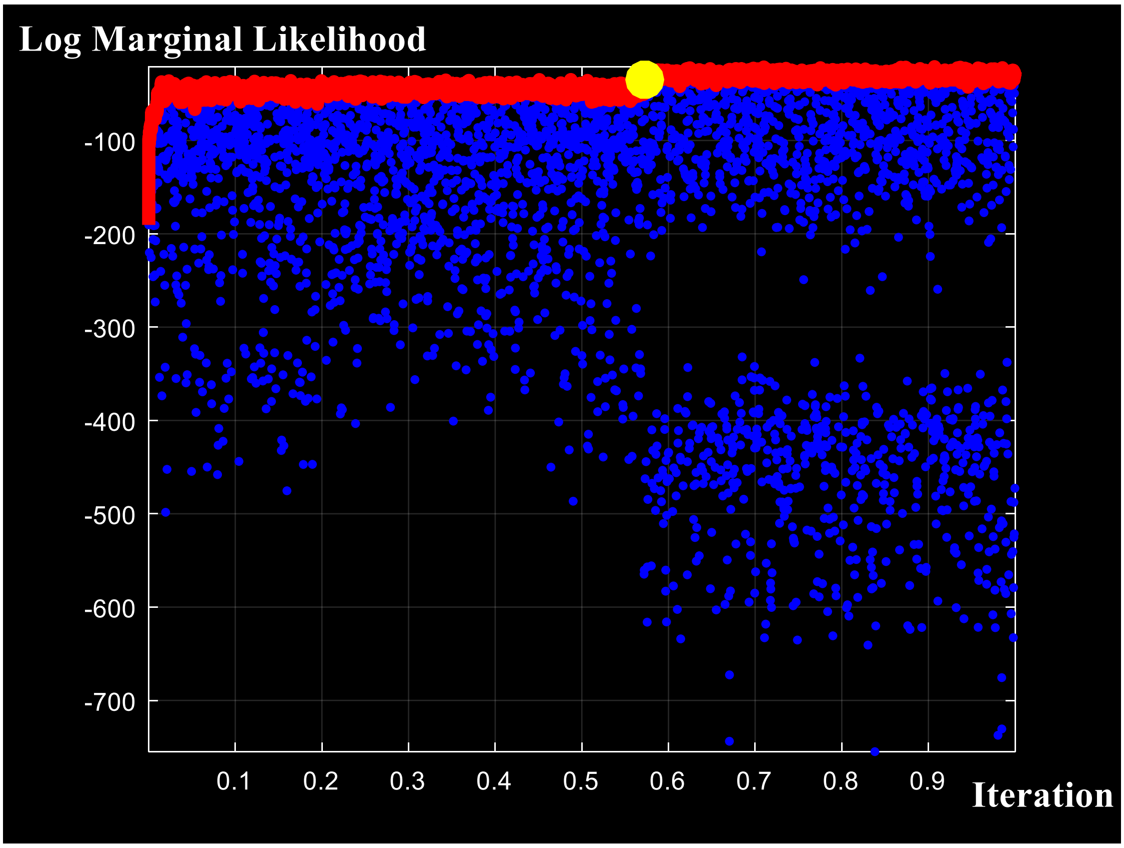

Figure 1 Model Evidence (The horizontal axis presents the number of iterations in the Markov-chain execution. The vertical axis reports the value of the marginal likelihood on the computationally convenient natural logarithmic scale. Highlighted by the yellow dot is the iteration at which the simulations step down from a three-component sample separation to a two-component sample separation. This iteration is approximately iteration# 1.2 million. The iterations are executed for a total of 2 million).

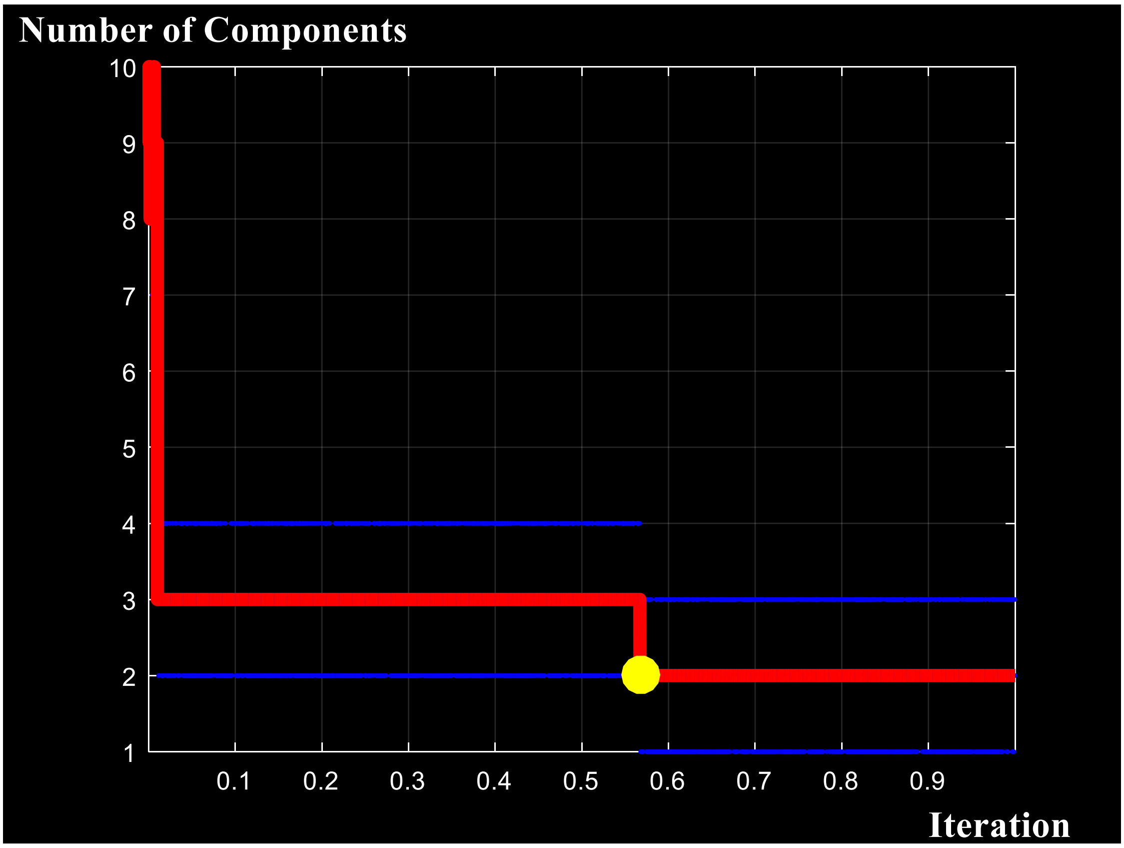

Figure 2 Number of sub sample components (The horizontal axis presents the number of iterations in the Markov-chain execution. The vertical axis reports the number of sample components. The red line shows the number of sample components depending on the number iterations. This converges from 10 models in the beginning to four models and three models. The yellow dot highlights the point at which the simulations steps down from a three-component sample separation to a two-component sample separation. It then stays at a two-components sample separation for the remainder of the iterations. This iteration is approximately iteration# 1.2 million. The iterations are executed for a total of 2 million).

Remaining analysis is conducted under the assumption that there are two sample subcomponents and that the convergent sample unit assignment (identical across the two executions) is the most likely description of the sample.

Two groups which roughly equate to non-adopters and adopters of CA means that they are essentially different and respond to different covariates. If three or more had been discovered the implication is that they should be modelled as three or four separate models and that the separate three or four groups may have behave quite differently. Thus the common assumption of one unifying whole is vacuous and inappropriate.

Choice of Covariates

A selection of 77 covariates are initially chosen to provide basis for the covariate search. These are detailed below in reference to particular blocks for convenience. These were chosen based on previous literature in relation to CA adoption studies (see Appendix A). The

ℓ (a) (Appendix A) refers to household/farm characteristics such as age of farmer, gender, educational attainment, marital status, farm size, area cultivated, location of plot, and extension services i.e. membership of farmer field school and other organisations i.e. proxy for social capital. These are similar to other studies using similar econometric models on CA or related practices (e.g. Nkala et al., 2011; Teklewold et al., 2013) Household size was also used as a covariate given a larger household size is hypothesized to positively influence labour.

Specific plot level characteristics were also considered i.e. planting in lines. Given wealth level has also been associated positively with adoption of CA use of the PPI approach was taken to get a better understanding of poverty among households surveyed. Larsen et al., (2014) also in this journal used the same approach.

The PPI constructed by Schreiner (2012) provides a score based on ten simple questions and determines the likelihood of a household being in ‘extreme’ poverty (e.g. a score less than 30 provides a high likelihood the household is in extreme poverty). Alongside this to explore another dimension of poverty we gathered information on food consumption based on the household dietary diversity score (HDDS) i.e. if households had eaten meat, eggs, or dairy products during the previous week. These were then multiplied by a weight and summed to create a final food consumption score. A poverty ranking (i.e. poor, middle and better-off) was also constructed using principal component analysis based on a number of the covariates listed above e.g. poverty score, food consumption score, and household characteristics/plot level characteristics to better categorise farmers in each wealth grouping.

The ℓ (b) (Appendix A) highlights specific advantages/disadvantages elicited through discussion with farmers in the region which relate to farmers’ beliefs about Conservation Agriculture. A number of these have also been cited within the broader literature on CA i.e. whether CA increases yields, reduces labour, increases pests etc. Other factors such as the degree of social pressure to perform the activity (i.e. from key social referents) and perceived behavioural control (i.e. degree to which farmers’ believe the certain behaviour is within their control) were also included as covariates. These have been shown to impact on the intention to use Conservation Agriculture and more broadly the adoption of other agricultural technologies such as improved grasslands (e.g. Lalani et al., 2016; Wauters et al., 2010). Given wide debate surrounding the economics of CA, particularly surrounding labour, we have included detailed farm budget data based on the primary plot used by the household. These include details on specific tasks which are contentious i.e. weeding and land preparation. (See ℓ(c); Apppendix A). Crop dummies related to the type of crop and whether the crop used is hybrid/local maize were included as dummies. Agricultural practices such as application of rotation/intercrop, mulch were also included as to are soil type and slope level.

Key explanatory variables chosen based on the literature were age of farmer, gender, educational attainment, marital status, farm size, area cultivated, location of plot soil type, slope, and extension services i.e. membership of farmer field school and other organisations i.e. proxy for social capital. These are similar to other studies using similar econometric models (e.g. Nkala et al., 2011; Teklewold et al., 2013) Household size was also used as a covariate given a larger household size is hypothesized to positively influence labour. Given wealth alongside socio-psychological characteristics such as ease of use have also influenced farmers decision making regarding CA (Lalani et al., 2016) we have also included these as potential explanatory variables in the initial choice of covariates.

Results and Discussion

Figure 3 contains the n x m-2 complete classification probability across the sample range ranked in ascending order. The Rank order probability is approximately normally distributed as confirmed by similarity of median and mean values signalled by the green dot. Range of reports 0.1 to 0.9

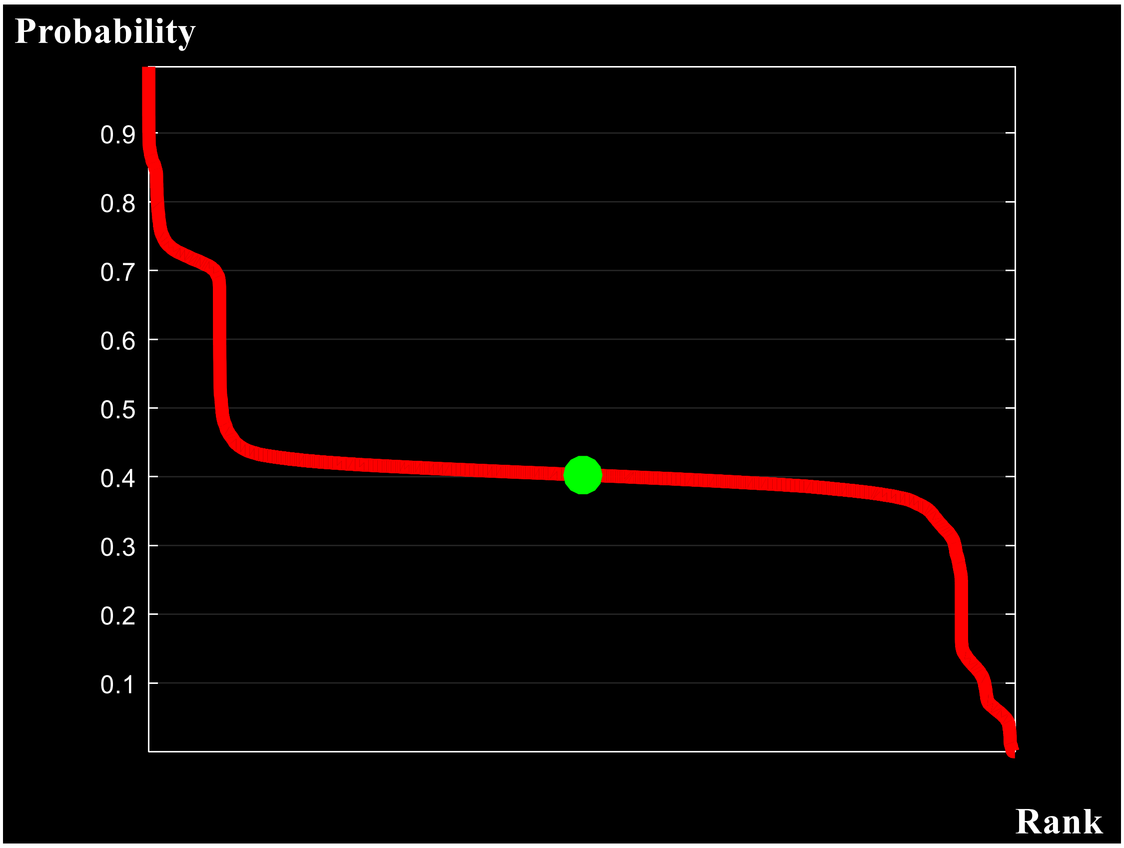

Figure 3 Association probabilities ordered by rank. (The horizontal axis presents the probability rank from highest probability to lowest probability of n x (n-1)/2 associations. There are 197*196/2 associations. The vertical axis reports the number of sample components. The green mark signals the median probability of the households being very closely related. The Median probability of households of association almost identical to the mean. In other words because visually identically median and mean this means distribution of probability is approximately normal).

Figure 4 contains information presented in figure 3 i.e. n x n contour plot. First 146 list adopting households and later 52 households are non-adopting households.

Figure 4 determines proximity of intra sub set as depicted by high probability. It portrays same as figure 3 via contour plot representing association probabilities across households. The higher the association the darker entry in the graphic. The Green/yellow highlight a high probability of not adopting and the darker lines a high probability of adoption. Thus, the darker lines which signal households among the non-adopting classification that have a higher likelihood of adopting may provide a target group for interactions regarding CA.

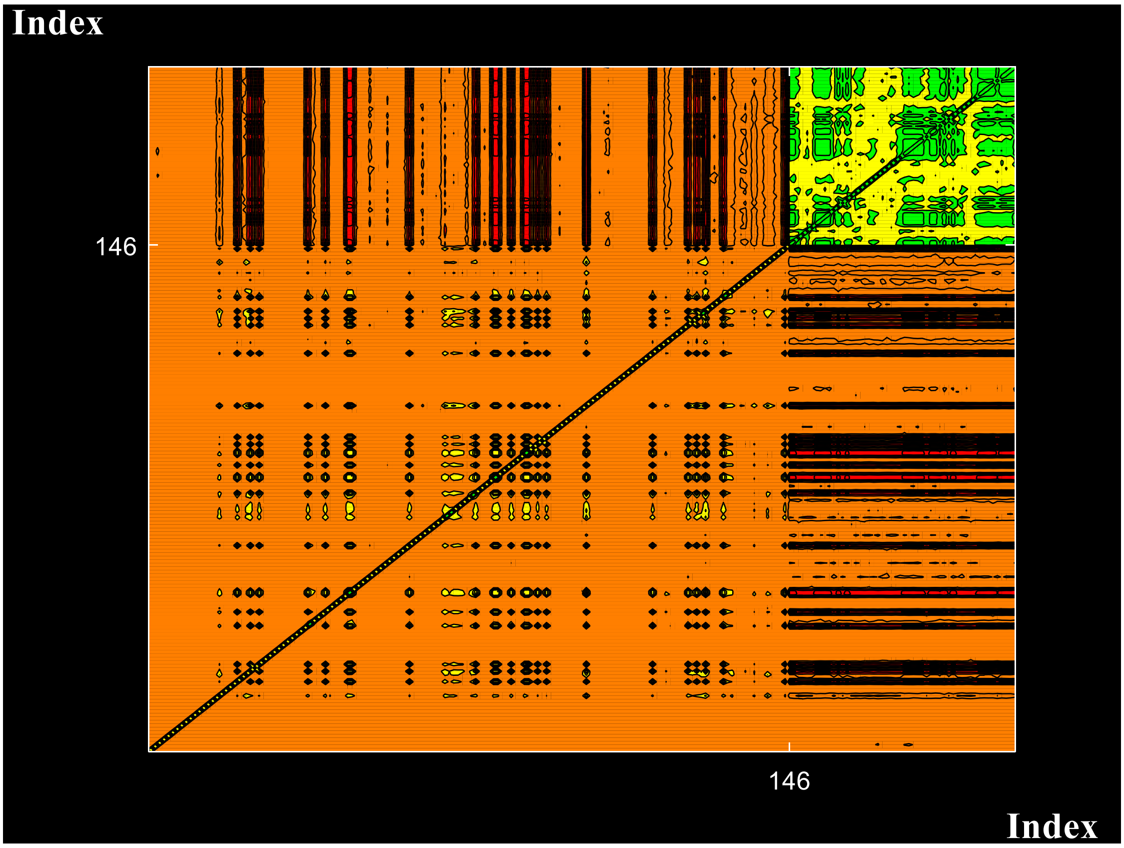

Figure 4 Contour plot for complete sample (Horizontal axis indexes the 197 households and the vertical axis indexes the 197 households. From 146 households onwards denote the non-adopting households i.e. classification 2. The different colours denote different association of probability. The non-adopting group i.e. classification 2 signalled by the square quadrant of green and yellow).

Two sub strata within sample are classified such that all non-adopting households reside in one classification (along with 6 households which would be classified as adopters) using conventional metrics. In contrast, classification group 1 consists of primarily adopters of conservation agriculture. Thus, using adoption and non-adoption as the benchmark used to classify groups according to many adoption studies we notice 6 violations.

Figure 5 allows us to look at the intra group classification for group classification 1 whilst Figure 6 shows the same for classification group 2.

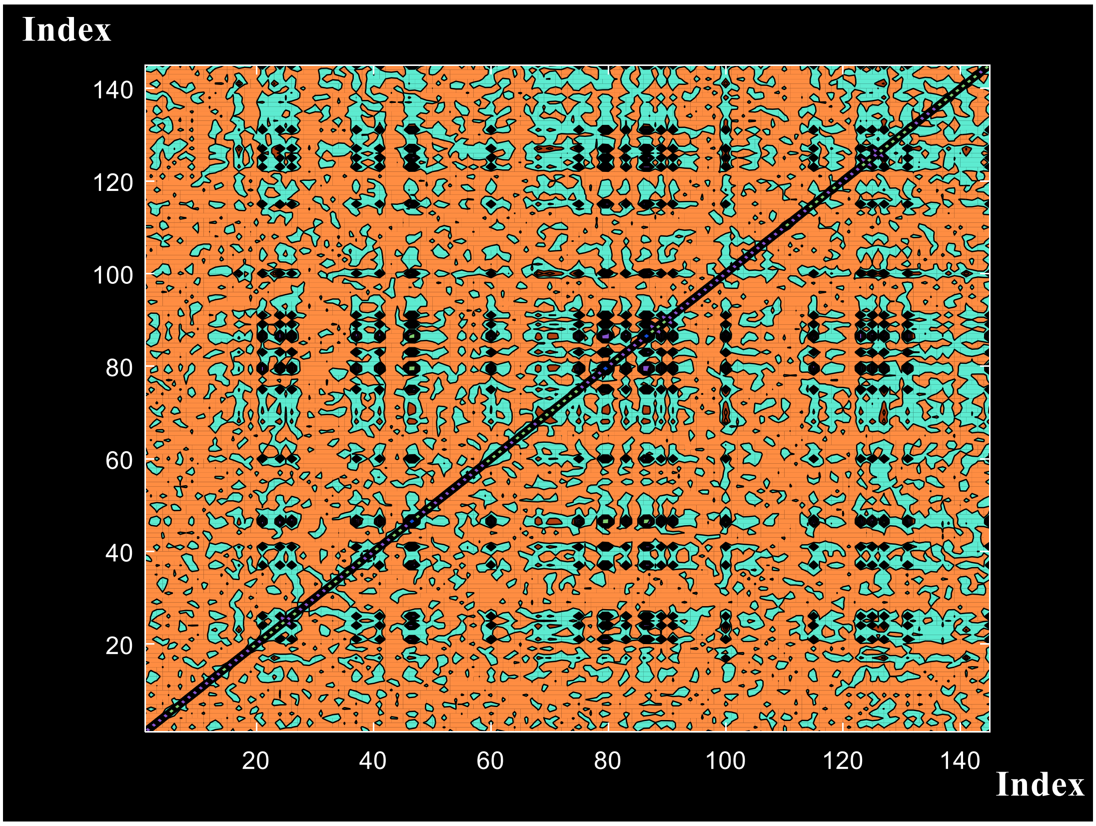

Figure 5 Group 1 association (This is an Index of 1-146 households (i.e. adopting group). Horizontal axis indexes the 146 households and the vertical axis indexes the 146 households. The different colours denote different probability of association. The darker shows the household with the highest probability of being similar followed by green and orange.)

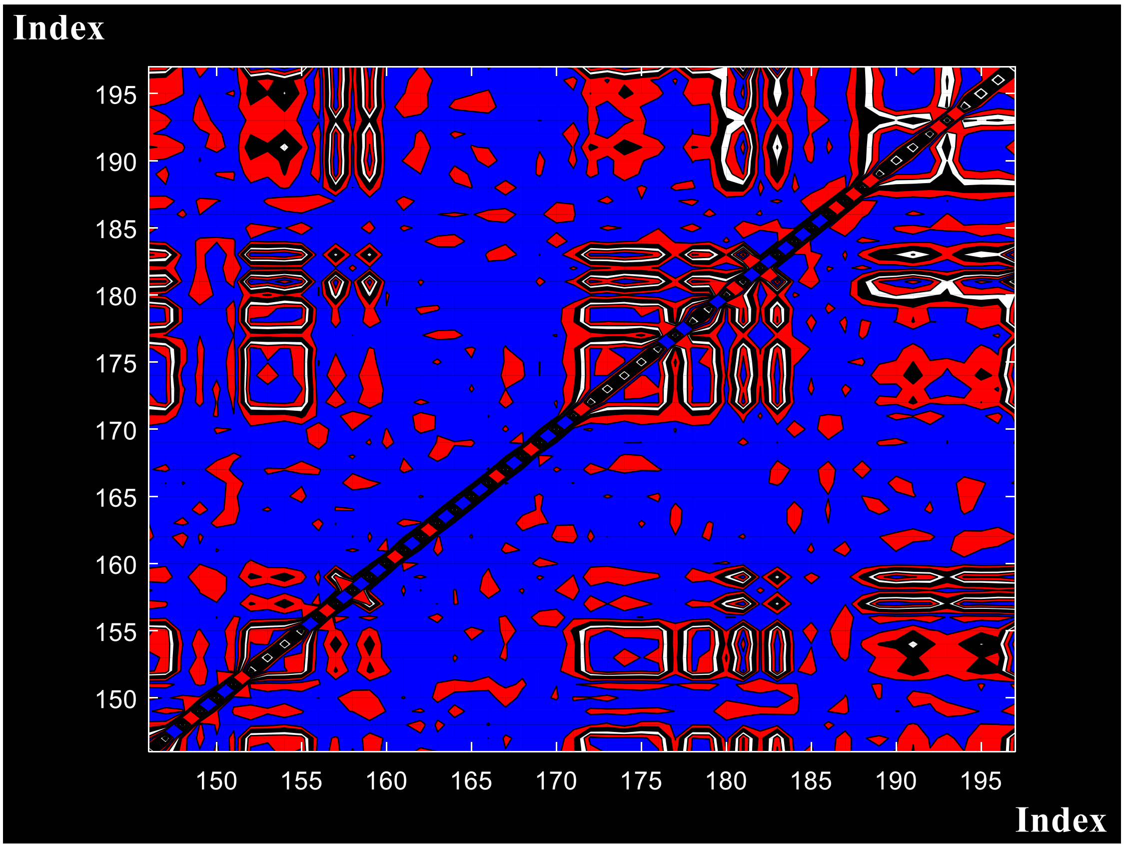

Figure 6 Group 2 association (This is an index of households 147-197 (i.e. non-adopting group). The horizontal indexes the 147-197 households and the vertical axis indexes the 147-197 households. The different colours denote different association of probabilities. The darker (black) shows the household with the highest probability of being similar followed by red and blue).

Figure 7 show the association probability for constants. For example the constant assignment has a benchmark probability that all constants have an equal impact on adoption as explanatory variables (i.e. a probability of 1/12=0.0833). Any constant with a higher probability of 0.083 highlights a constant that has a more important role in explaining the classification of either groups and thereby either non-adoption or adoption. For example, with respect to the constant, figure 7 shows constant 11 i.e. use of four crops and the overall constant as most important in classifying group 2 and the overall constant important in classifying group 1. This suggests that the enactment to include a constant across the whole sample is refuted.

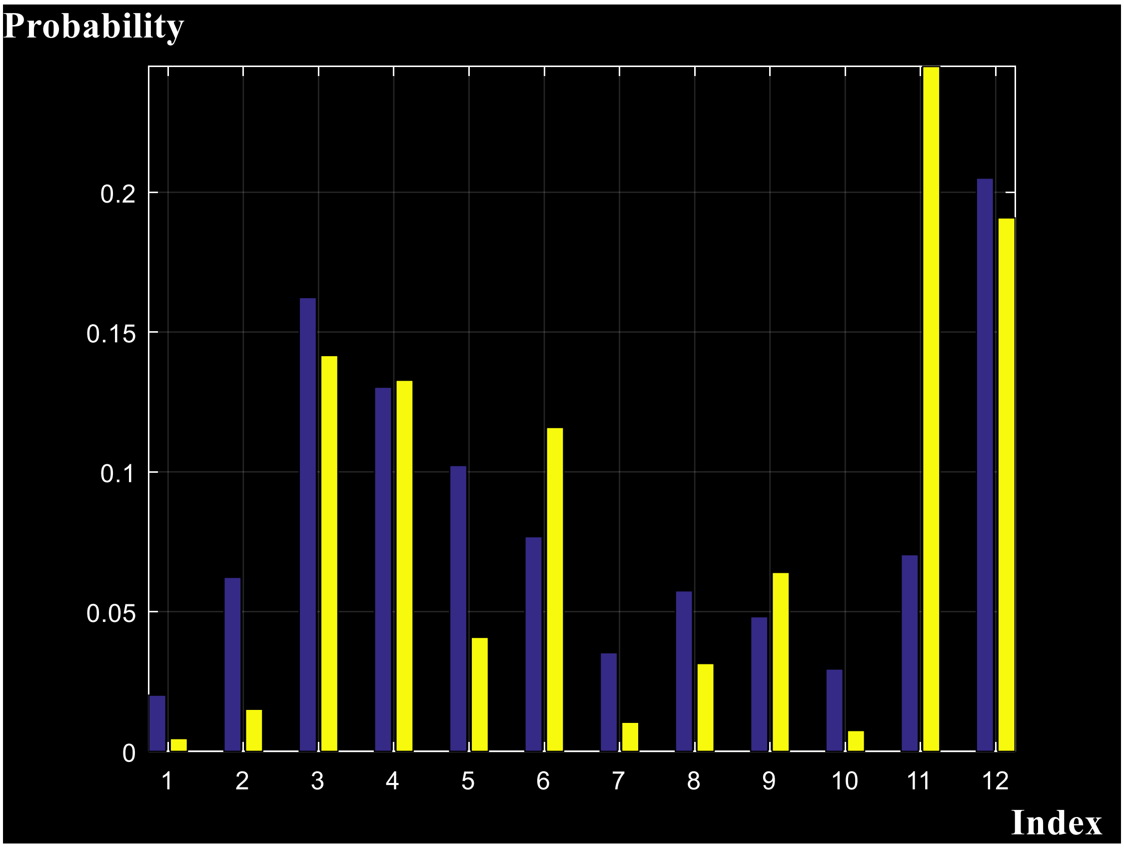

Figure 7 Constant assignment showing probability of importance across the bi component sample (The horizontal axis portrays the constant index 1:12 referring to the same constants listed in Appendix A. The vertical axis portrays the probability of assignment showing the importance of the constants across the bi component sample. Yellow indicates classification 2 consisting of mainly non-adopters of CA. It highlights that there is a high probability that constant 11 and 12 would be important in terms of association classification

group 2. In contrast, classification one (dark blue) constant 3 and 12 have a high probability of being relevant).

Figure 8 ranks probability of constants assigned as explanatory variables and then ranks the probability of importance across sub components.

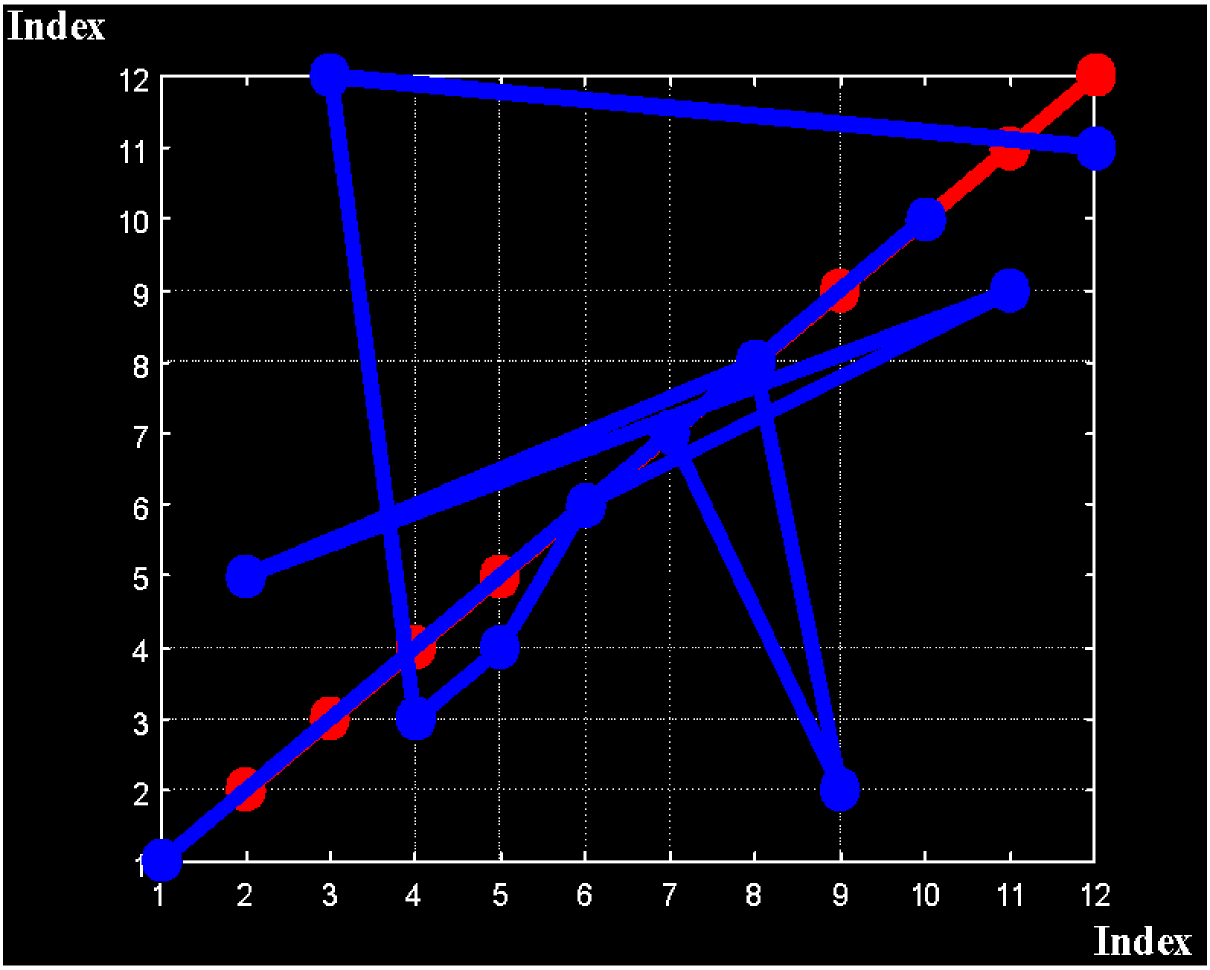

Figure 8 Rank Order Indications of Preferred Constants (The horizontal axis depicts the rank with '1' denoting highest probability and '12' the lowest probability (reference to previous figure). The red line and red dots indicate the rank order of the Group-One component; the blue line and blue dots indicate the rank order of the Group-Two component, using the rank-order index of Group-One as its basis. The departures from the 45-degree line indicate rank-order differences. There are seven such differences. We conclude therefore, that the two subgroups, Group-One and Group-Two have distinctly different fixed-effects dependencies.

Figure 9 shows covariate selection graphic showing probabilities of importance of covariates assigned as explanatory variables. For example the covariate assignment has a benchmark probability that all covariates have an equal impact on adoption as explanatory variables (i.e. a probability of 1/77=0.013). Any covariate with a higher probability of 0.013 highlights a covariate that has a more important role in explaining the classification of either groups and thereby either non-adoption or adoption. Figure 10 ranks the probability of the covariates assigned as explanatory variables and then ranks the probability of importance across the sub components.

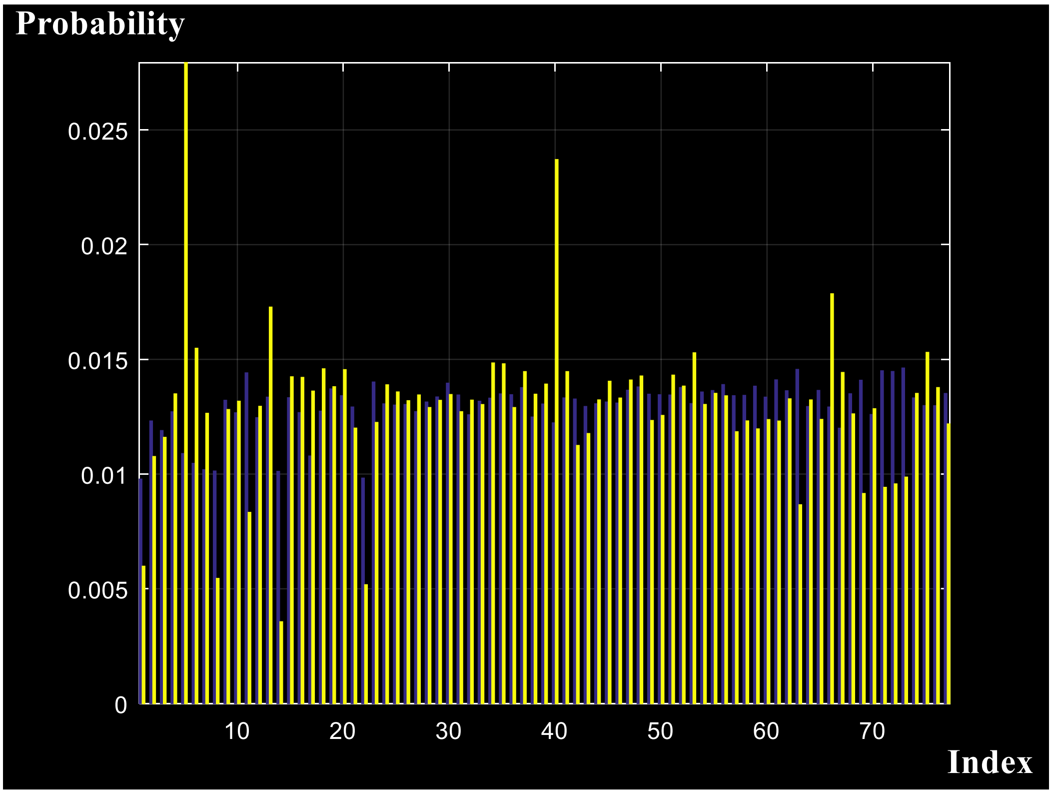

Figure 9 Covariate assignment showing probability of importance across the bi component sample (The horizontal axis portrays the covariate index 1:77 referring to the same covariates listed in Appendix A. The vertical axis portrays the probability of assignment showing the importance of the covariates across the bi component sample. The yellow bars indicates the probability of importance of the covariate as a predictor for classification 2 consisting of mainly non-adopters of CA. Whilst the dark blue illustrates the probability of importance of the covariate for prediction for classification one).

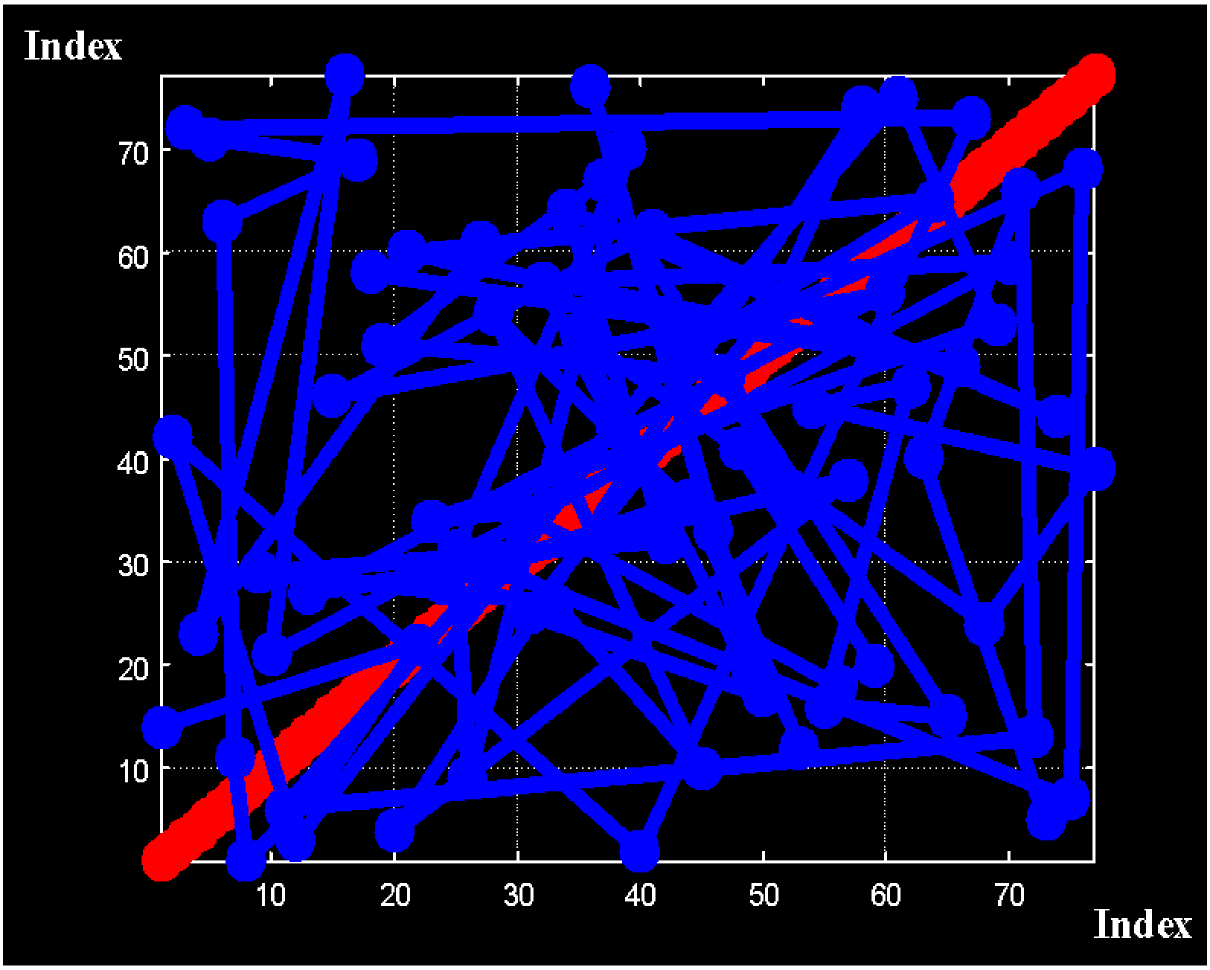

Figure 10 Covariate probabilities rank comparison (The horizontal axis depicts the rank with ‘1’ denoting highest probability and ‘77’ the lowest probability (reference to previous figure). The red line and red dots indicate the rank order of the Group-One component; the blue line and blue dots indicate the rank order of the Group-Two component, using the rank-order index of Group-One as its basis. The departures from the 45-degree line indicate rank-order differences. There are 68 such differences. We conclude therefore, that the two subgroups, Group-One and Group-Two have distinctly different covariate-effects dependencies).

The following explores through a number of probits using constants and covariates identified as important through the covariate search and a conventional probit model with covariates and constants used based on the literature related to CA.

Empirical results

In total fifteen probit models were run on the full sample with the dependent variable being the decision to use CA (i.e. the full package of minimum soil disturbance; mulch and intercrop and/or associations) or not adopt CA. Probit models 1-3 are based on the ten most important covariates chosen from the covariate search for those classified in group 1 using most important constants (see Table 1b; Appendix B).

Probit models 4-7 use the ten most important covariates chosen from the covariate search for those classified in group 2 using most important constants (see Table 2b; Appendix B). Likewise, probit models 7-9 (Table 3b; Appendix B) use the ten most important covariates chosen from the covariate search for those classified in group 1 and the ten most important covariates chosen from the covariate search for those classified in group 2 (covariates shown in Table8b; Appendix B).

Literature-based probit regressions

Table 1 shows probit models (for three different constants) based on a selection of twenty covariates that would most commonly be used in the literature on adoption of Conservation Agriculture. Probit models 10-14 (See Appendix B) have other variations based on the use of a different constant or smaller sub-set of covariates i.e. 10 covariates.

Table 1 shows the results of a probit model for a larger set of covariates which include farm and household characteristics, farm-level economics and farmers' perceptions relating to the theory of planned behaviour. In these models overall social pressure from referents 'spopinion', and the difficulty of CA are inversely associated with adoption suggesting the easier CA is to use and the stronger the perceived pressure to use CA the stronger the likelihood to adopt.[15] In contrast to the probit models presented with only ten covariates, family size (a proxy for household labour) in these models are inversely associated with CA adoption but are not statistically significant.

Membership of Farmer Field Schools (FFS) and other groups (e.g. association) as does planting in lines and social pressure i.e. 'spopnion' have a consistent and significant impact on adoption. Similarly, the poverty ranking and plot size are inversely related to CA adoption suggesting poorer farmers with smaller plots of land (i.e. main household plot 1) are more likely to adopt CA. Family size (a proxy for household labour) in these models are also inversely associated with CA adoption but are not statistically significant (see Table 1). This suggests that Conservation Agriculture adoption is not reliant on a high level of household

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[15] Variables such as 'spopinion' and 'difficultyusingca' are scaled 1 to 5 i.e. the easier they find CA and the more they perceive social pressure the lower the value.

labour availability. Moreover, the lower weeding and land preparation time is an indication of lower labour usage with CA.

Table 1 Probit model results using twenty covariates based on respective literature on Conservation Agriculture using overall constant.

	Model 15^c	
	Posterior mean	t-stat
Gender	-3.423	-2.302
Age	-1.799	-0.938
Highestlevelofeducation	1.191	0.564
Householdsize	-1.205	-0.373
Memberofffs	9.816	3.944
Othergroup	2.861	1.949
Livestock	1.300	1.203
Numberofplots	3.637	1.369
plot1size	-0.373	-0.097
Plantinlines	7.758	6.299
Householdpovertyscore	0.913	0.326
Foodshortage	-1.691	-1.468
Foodconsumptionscore	-0.369	-0.113
Intentionsallca	-2.447	-0.679
Usefulnessall	1.345	0.416
Difficultyusingcaonallland	-6.094	-1.898

Spopinion	-9.896	-3.078
Totalmanhrsperhalandprep	-0.294	-0.073
Totalmanhrsperhaweeding	-1.850	-0.504
Totalmanhrsperhaharvesting	1.383	0.385
Npovertyranking	-1.603	-0.711
Marginal likelihood[e]		-60.227
Mean R^2		0.953
Standard deviation pseudo R^2		0.020

A=soil type used as constant; b=plot1crop4dummies used as constant (i.e. numbers of crops used on main plot) and c = overall constant used. . D= implied t-statistic computed from the Gibbs sample. E=marginal likelihood computed g the GHK estimator. Coefficients with values outside the range plus or minus two are significant at 0.005 level.

Comparison to the Bayesian models

The model presented in Table 1 has a higher R^2 and is closer to the Bayesian models which are based on the covariates chosen from the covariate search (see Tables 3b in Appendix B). This is also similar for other models using different constants related to the literature on conservation agriculture models (see Table 5b presented in Appendix B) Though the Bayesian models highlight the advantage of treating the sample as two sub-samples (i.e. group classification one and two) with different covariates affecting use and non-use of CA given using these also provides a better fit.

One model clearly dominates i.e. model 9c which uses the covariates selected using the search algorithm (see Table 3b in Appendix B). This has the highest R^2 and thereby model fit. It is clear that non-adopters are less likely to be members of a farmer field school or their spouse (if the household head has a spouse) and are unlikely to plant in lines as do adopters of CA. Moreover, non-adopters are also less likely to be willing to form part of a group and do not perceive CA to reduce labour or pests. Interestingly, these come up as important covariates that have a high probability of being important as associated with group 2 which mainly consists of non adopters (see Table 8b in Appendix B).

In comparison to the literature-based probit model, the probit models associated with the algorithm (i.e. Bayesian models) highlight that having enough rainfall, membership of FFS and planting in lines play a significant role in influencing adoption. Whilst for non-adopters the covariates that also showed up as important in the covariate search related to group 2 also included membership of FFS and planting in lines which suggests there are clear differences between the two groups especially with respect to these two covariates (Table8b; Appendix B). It is interesting to note that among the group 1 (mainly adopters category) FFS membership or planting lines were not considered as important covariates rather other covariates were found to be important in the covariate search such as those relating to perceived difficulty; social pressure from other experienced farmers but do not significantly impact on adoption in these models (Table 8b; Appendix B). Thus it suggests that these covariates play a stronger role in the likelihood of using Conservation Agriculture (i.e. associated with group 1 classification) but given membership of FFS is an important covariate that distinguishes non adopters from adopters and is important in the classification of group 2 suggests this also plays a mediating role in the adoption process and should not be discarded.

Some similarities are present with the literature based model and Bayesian model such as lower labour requirements relating to the farm-budget data gathered. For example, as with the conventional literature based probit regression (Table 1) weeding time is inversely associated with adoption as is farmer difficulty suggesting that lower labour is required and the easier farmers find CA the more likely they are to adopt. Weeding time is also seen as a good predictor of group 2 (i.e. non-adoption) which reinforces this (Table8b; Apeendix B).

In comparison to the conventional models the level of poverty is not a found to be an important predictor nor education, livestock or household size (see Table 2b; Appendix B). There is indication though (although not shown to be significant) that specific social referents play a more important role in influencing farmers to adopt CA i.e. village facilitators (See Table 2b; Appendix B). More importantly, conventional factors such as gender, education, and livestock which are more commonly associated with influencing adoption dynamics of agricultural technologies and which were found to be important in the literature based models were not found to be important covariates when subjected to the covariate search algorithm.

However, as mentioned earlier, to account for the various other models that might be used which use different constants/covariates other probits have been estimated which use covariates/constants which are related to the literature on CA. The final section below uses an average of all of the 15 models estimated which is likely to provide a better interpretation than merely relying on one model (even with its statistically superiority).

Is there a consensus across models?

In order to provide a consensus across all the different models, average covariates highlight which covariates are likely to play a significant role in the adoption process. The average across all models suggest there are only seven covariates which are important. These relate strongly to social capital i.e. membership of FFS, the practice of planting in lines, the level of importance of reduction in labour and the importance of soil quality improvement as well as farmers opinions regarding pests with the use of CA.

Interestingly, the perceived social pressure from a village factor plays a significant role as does self-efficacy in terms of the willingness to be part of a group in the next 12 months. Likewise the same was done for the constants (see Table 5b; Appendix B), which interestingly shows that none of the constants play a significant role in adoption and thus indicates that a probit model in this setting could be done without the use of a constant. More importantly, this goes against much of the literature on CA which has suggested that CA is only likely to be adopted on better soils (Knowler and Bradshaw, 2007) or more successful with new varieties (Chauhan et al., 2012).

Thus, based on the averages of all the models, there are clear differences among adopters and non-adopters. For example, non-adopters are less likely to perceive soil quality improvement with the use of CA is important and be involved in a Farmer field school. They also invariably do no plant in lines, as adopters of CA do, are less likely to perceive CA to reduce labour/pests and less willing to participate in a group related to CA.

Conclusion

Agricultural technology adoption studies have been dictated by the use of frequentist procedures in recent years. This can often lead to conflict about the adoption decision and which are based on the investigator’s decision about what covariates to include (Edirisinghe, and Holloway, 2015). This paper has identified that the problem of ‘search’ can be successfully solved with the employment of Bayesian approaches which can provide an additional and often more robust predictive tool in identifying covariates that impact on adoption.

This paper has shown the importance of key social learning mechanisms, farmers’ attitude and self-efficacy play a more important role than farm and household level characteristics in the adoption process. Though in this case the only farm-level characteristics which has a bearing on adoption is the practice of planting in lines which may also be associated with social interactions as explained below:

One farmer in the survey district added: *"Before CA was explained to me I burnt my crop residue and did not plant in lines or do any intercrop etc. Now I put mulch and intercrop and use a rotation. When I put mulch the soil is good and has good moisture. I also like it because I can sell the sesame and eat the maize"*. Similarly another farmer remarked:. *"Umokazi (National NGO) that used to work in the village/district explained about good agricultural practices i.e. planting in lines and I had a good experience with it. Then I heard from the Aga Khan Foundation village facilitator about CA and because certain principles like planting in lines were also used in CA I thought it was a good practice."* These views from farmers provide an example of some of the cognitive processes and social learning interactions which trigger transition from a relatively low knowledge base of sound agricultural practices to the use of CA or to 'good agricultural practices' and eventual sustainable intensification pathways such as CA.

We identify that involvement in a Farmer Field School, the role of village facilitators in engaging with farmers on CA and willingness to be part of a group play an important role in the adoption process. Given the importance that farmers place on labour reduction, soil quality enhancement and pest reduction with respect to the use of CA and the significant roles these also have on adoption (as does planting in lines) suggest that these issues should certainly form part of the social learning interactions which take place in these or similar settings.

We are able to make these different assessments across the separate subcomponents due to the new methodology and that a single-sample setting would be erroneous and lead to weak inference and possible erroneous predictions.

More broadly, which is relevant to development practice in general, is that formal covariate selection seems possible in a broader and more extensive set of circumstances, perhaps, than previously considered possible; to the extent that this insight is useful, practitioners can profit from the application of like-styled statistical interventions constructed for the purpose of better discerning poverty-reduction pathways.

Appendix A

ℓ(A)

1. gender
2. age
3. highestlevelofeducation
4. householdsize
5. memberofffs
6. spousememberofffs
7. othergroup
8. livestock
9. numberofplots
10. plot1size
11. plot1enoughrainfall
12. plot1distancetohome
13. plantinlines
14. plot1flooding
15. plot2size
16. plot2distancefromhome
17. plot2flooding
18. plot3size
19. plot3distancefromhome
20. plot3flooding
21. householdpovertyscore
22. foodshortage
23. foodconsumptionscore
77. npovertyranking

ℓ(b)

24. intentionsallca
25. importanceallca
26. intentionminimumtill
27. importanceminimumtill
28. usefulnessall

29. usefulnessminimumtill
30. difficultyusingcaonallland
31. difficultyusingminimumtill
32. opinioncayields
33. importancecayields
34. opinioncareduceslabour
35. importancecareduceslabour
36. opinioncaimprovessoilquality
37. importancecaimprovessoilquality
38. opinioncareducesweeds
39. importancecareducesweeds
40. opinioncaincreasespests
41. importancecaincreasespests
42. opinioncacantbeusedonallsoil
43. importancecacantbeusedonallsoil
44. opinioncaleadstobenefitinyearone
45. importancecaleadstobenefitinyearone
46. opinioncabetterindrought
47. importancecabetterindrought
48. spopinion
49. spgovernment
50. spngo
51. spradio
52. sptelevision
53. spvillagefacakf
54. spassociatedgroup
55. spffs
56. spsibling
57. spspouse
58. spselfobserve
59. spselfinitiative
60. spgrandfather
61. spotherexperiencedfarmers
62. doyouhaveenoughlabour
63. needlabourforca

64. enoughknowledge
65. youneedknowledge
66. willbecomepartofgroup
67. needgroupforca
68. caokwithmysoil
69. needrightsoilforca
70. candealwithpests
71. pestslimitca
72. haveenoughmechanforca
73. needmechanforca

ℓ(c)

74. totalmanhrsperhalandprep
75. totalmanhrsperhaweeding
76. totalmanhrsperhaharvesting

Constant

1. villagedummies
2. maritalstatusdummies
3. mainoccupationdummies
4. landownershipdummies
5. soildummies
6. slopedummies
7. caredummies
8. plot1crop1dummies
9. plot1crop2dummies
10. plot1crop3dummies
11. plot1crop4dummies
12. constant

Appendix B

Table 1b Probit model results using ten most important covariates chosen from the covariate search for those classified in group 1 using most important constants.

	Model 1[a]		Model 2[b]		Model 3[c]	
	Posterior mean	t-stat[d]	Posterior mean	t-stat	Posterior mean	t-stat
plot1enoughrainfall	-4.672	-3.619	-5.213	-3.897	-4.587	-3.488
foodconsumptionscore	5.284	2.895	6.751	4.795	6.409	4.337
difficultyusingcaonallland	-8.132	-4.055	-8.368	-4.262	-7.077	-3.220
spsibling	2.034	0.839	2.788	1.128	2.895	1.119
spotherexperiencedfarmers	-8.496	-2.989	-7.399	-2.682	-5.716	-2.102
needlabourforca	3.196	1.374	1.923	0.829	3.626	1.597
needrightsoilforca	1.731	0.680	1.716	0.720	1.844	0.758
pestslimitca	4.989	1.720	5.217	1.812	5.503	1.880
haveenoughmechanforca	6.832	2.109	7.841	2.382	8.022	2.436
needmechanforca	2.293	0.735	3.254	1.034	2.850	0.905
Marginal likelihood[e]		-65.336		-64.377		-64.483
Mean R^2		0.709		0.702		0.716
Standard deviation pseudo R^2		0.015		0.019		0.015

A=soil type used as constant; b=plot1crop4dummies used as constant (i.e. numbers of crops used on main plot) and c = overall constant used. D= implied t-statistic computed from the Gibbs sample. E=marginal likelihood computed usingthe GHK estimator. Coefficients with values outside the range plus or minus two are significant.

Table 2b Probit model results using ten most important covariates chosen from the covariate search for those classified in group 2 using most important constants.

	Model 4[a]		Model 5[b]		Model 6[c]	
	Posterior mean	t-stat[d]	Posterior mean	t-stat	Posterior mean	t-stat
memberofffs	7.532	3.671	8.465	3.771	8.485	3.326
spousememberofffs	2.553	0.800	2.264	0.760	3.487	0.932
plantinlines	4.621	4.777	4.598	4.592	4.218	4.361
plot3size	1.580	0.474	1.362	0.427	0.896	0.276
importancecareduceslabour	-4.445	-1.558	-5.771	-2.379	-6.460	-2.660
importancecaimprovessoilquality	-5.760	-1.745	-6.192	-2.120	-6.100	-2.030
opinioncaincreasespests	4.925	2.554	2.967	2.020	2.332	1.654
spvillagefacakf	-4.357	-1.704	-5.046	-1.921	-5.873	-2.335
willbecomepartofgroup	-0.259	-0.106	6.364	3.070	2.740	1.306
totalmanhrsperhaweeding	-0.967	-0.336	-2.419	-0.930	-2.489	-0.961
Marginal likelihood[e]		-64.483		-64.483		-64.399
Mean R^2		0.928		0.927		0.914
Standard deviation pseudo R^2		0.017		0.018		0.018

A=soil type used as constant; b=plot1crop4dummies used as constant (i.e. numbers of crops used on main plot) and c = overall constant used. D= implied t-statistic computed from the Gibbs sample E=marginal likelihood computed using the GHK estimator. Coefficients with values outside the range plus or minus two are significant.

Table 3b Probit model results using ten most important covariates chosen from the covariate search for those classified in group 1 and group 2 using most important constants

	Model 7[a]		Model 8[b]		Model 9[c]	
	Posterior mean	t-stat[d]	Posterior mean	t-stat	Posterior mean	t-stat
memberofffs	7.460	3.086	7.159	2.969	7.141	3.172
spousememberofffs	3.033	0.792	2.411	0.698	2.308	0.625
plot1enoughrainfall	-4.711	-2.172	-4.640	-2.176	-4.771	-2.276
plantinlines	5.142	4.763	5.279	4.695	5.201	4.797
plot3size	0.881	0.252	0.751	0.218	0.887	0.261
foodconsumptionscore	-0.451	-0.122	-0.347	-0.105	-0.527	-0.156
difficultyusingcaonallland	-2.418	-0.691	-2.644	-0.767	-2.370	-0.680
importancecareduceslabour	-2.503	-0.697	-2.860	-0.782	-2.645	-0.741
importancecaimprovessoilquality	-5.817	-1.608	-5.779	-1.602	-5.635	-1.573
opinioncaincreasespests	2.657	1.279	2.491	1.322	2.398	1.276
spvillagefacakf	-3.860	-1.361	-4.119	-1.469	-4.041	-1.415
spsibling	0.266	0.067	0.141	0.036	-0.277	-0.069
spotherexperiencedfarmers	-0.344	-0.080	-0.119	-0.028	-0.255	-0.060
needlabourforca	3.002	0.734	3.404	0.858	3.226	0.833
willbecomepartofgroup	-3.996	-1.099	-2.614	-0.683	-2.798	-0.771
needrightsoilforca	-0.955	-0.316	-1.049	-0.333	-0.886	-0.296
pestslimitca	3.374	0.823	3.427	0.824	3.433	0.829
haveenoughmechanforca	4.639	1.288	4.696	1.264	4.871	1.328
needmechanforca	3.227	0.882	3.160	0.872	3.227	0.894
totalmanhrsperhaweeding	-1.195	-0.357	-1.618	-0.460	-1.349	-0.398
Marginal likelihood[e]		-64.399		-62.918		-62.918
Mean R^2		0.961		0.961		0.962
Standard deviation pseudo R^2		0.015		0.015		0.014

A=soil type used as constant; b=plot1crop4dummies used as constant (i.e. numbers of crops used on main plot) and c = overall constant used. . D= implied t-statistic computed from the Gibbs sample. E=marginal likelihood computed using the GHK estimator. Coefficients with values outside the range plus or minus two are significant.

Table 4b Probit model results using ten covariates based on respective literature on Conservation Agriculture adoption and using most important constants

	Model 10[a]		Model 11[b]		Model 12[c]	
	Posterior mean	t-stat[d]	Posterior mean	t-stat	Posterior mean	t-stat
Gender	-0.625	-0.839	-0.674	-0.838	-0.316	-0.441
age	-1.876	-1.649	-1.545	-1.328	-2.219	-2.058
Highestlevelofeducation	3.126	2.232	3.310	2.436	2.781	2.182
Householdsize	0.815	0.432	1.214	0.633	1.367	0.775
Memberofffs	11.850	5.510	12.856	5.827	11.554	6.370
Othergroup	1.712	1.537	2.105	2.008	1.873	1.747
Livestock	1.089	1.755	1.745	2.624	1.292	2.132
Numberofplots	1.722	0.925	1.081	0.606	-0.332	-0.190
plot1size	-5.431	-2.048	-8.048	-3.063	-7.156	-2.862
Npovertyranking	-1.847	-1.195	-2.362	-1.569	-3.035	-2.023
Marginal likelihood[e]		-62.918		-62.918		-62.918
Mean R^2		0.791		0.852		0.817
Standard deviation pseudo R^2		0.037		0.028		0.036

A=soil type used as constant; b=plot1crop4dummies used as constant (i.e. numbers of crops used on main plot) and c = overall constant used. . D= implied t-statistic computed from the Gibbs sample. E=marginal likelihood computed using the GHK estimator. Coefficients with values outside the range plus or minus two are significant

Table 5b Probit model results using twenty covariates based on respective literature on Conservation Agriculture using most important constants.

	Model 13[a]		Model 14[b]		Model 15[c]	
	Posterior mean	t-stat[d]	Posterior mean	t-stat	Posterior mean	t-stat
gender	-3.302	-2.317	-3.359	-2.178	-3.423	-2.302
age	-1.950	-1.016	-2.234	-1.233	-1.799	-0.938
highestlevelofeducation	1.095	0.474	1.292	0.571	1.191	0.564
householdsize	-0.928	-0.287	0.173	0.053	-1.205	-0.373
memberofffs	9.930	4.294	9.687	4.404	9.816	3.944
othergroup	2.711	1.722	2.856	1.889	2.861	1.949
livestock	1.417	1.340	1.443	1.351	1.300	1.203
numberofplots	4.087	1.537	4.008	1.468	3.637	1.369
plot1size	-0.069	-0.018	-0.002	-0.001	-0.373	-0.097
plantinlines	7.752	6.378	7.744	6.054	7.758	6.299
householdpovertyscore	1.427	0.533	2.222	0.800	0.913	0.326
foodshortage	-1.675	-1.483	-1.192	-1.111	-1.691	-1.468
foodconsumptionscore	0.604	0.173	-0.706	-0.221	-0.369	-0.113
intentionsallca	-2.370	-0.649	-3.038	-0.828	-2.447	-0.679
usefulnessall	1.864	0.592	2.915	0.969	1.345	0.416
difficultyusingcaonallland	-5.896	-1.803	-6.089	-1.937	-6.094	-1.898
spopinion	-9.745	-3.078	-9.996	-3.173	-9.896	-3.078
totalmanhrsperhalandprep	0.171	0.044	0.539	0.135	-0.294	-0.073

totalmanhrsperhaweeding	-1.511	-0.419	-1.802	-0.510	-1.850	-0.504
totalmanhrsperhaharvesting	1.468	0.419	1.914	0.553	1.383	0.385
npovertyranking	-1.221	-0.547	-0.745	-0.329	-1.603	-0.711
Marginal likelihood[e]		-60.227		-60.227		-60.227
Mean R^2		0.952		0.953		0.953
Standard deviation pseudo R^2		0.021		0.020		0.020

A=soil type used as constant; b=plot1crop4dummies used as constant (i.e. numbers of crops used on main plot) and c = overall constant used. . D= implied t-statistic computed from the Gibbs sample. E=marginal likelihood computed using the GHK estimator. Coefficients with values outside the range plus or minus two are significant

Table 6b Model averaged covariates (significant covariates shown)

Covariate number	95% highest posterior density interval lower limit	Posterior mean centre	95% highest posterior density interval upper limit
5	4.95	8.46	13.48
13	2.68	4.60	6.58
35	-10.57	-5.77	-1.05
37	-12.29	-6.19	-0.94
40	0.05	2.97	5.82
53	-10.30	-5.05	-0.04
66	2.29	6.36	10.36

Table 7b Model averaged covariates (all constants are non-significant)

constant	95% highest posterior density interval lower limit	Posterior mean centre	95% highest posterior density interval upper limit
1	-0.00	-0.00	0.00
2	-0.00	-0.00	0.00
3	-0.00	-0.00	0.00
4	-5.37	-0.99	3.48
5	-4.14	2.59	10.68
6	-6.55	0.91	9.61
7	-7.3	0.50	9.72
8	-7.71	0.50	9.72
9	-0.59	4.64	11.14
10	-7.86	-1.02	5.68
11	0.00	0.00	0.00

Table 8b Top 10 covariates (used in probit models 7-9 reported in Table 3b) found from the covariate search that are considered important as associated with either being in group 1 (mainly adopters of CA) or group 2 (mainly non-adopters of CA).

group 1	group 2
72. haveenoughmechanforca	5. memberofffs
73. needmechanforca	40. opinioncaincreasespests
63. needlabourforca	13. plantinlines
71. pestslimitca	66. willbecomepartofgroup
11. plot1enoughrainfall	35. importancecareduceslabour
30. difficultyusingcaonallland	75. totalmanhrsperhaweeding
56. spsibling	6. spousememberofffs
23. foodconsumptionscore	37. importancecaimprovessoilquality
69. needrightsoilforca	53. spvillagefacakf
61. spotherexperiencedfarmers	18. plot3size

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Chapter 6: Conclusion

Summary of key findings and significance

Given the wide ranging debate surrounding CA in recent years, this thesis has made a contribution to the current literature by elucidating through more detailed economic enquiry (presented in Chapter 2) that farmers can benefit in the short-term (first few seasons) under CA and are not necessarily hampered by a dip in yields. Moreover, the benefits are not only restricted to the wealthier farmers (or those with more labour) and the poorest (under extreme risk and uncertainty) find benefits to labour and yield for a number of crop mixes relative to conventional agriculture. Furthermore, high inputs such as the use of fertilisers/herbicides or new seed varieties is not a necessary pre-condition for successful use of CA relative to convention agriculture as Chapter 2 also highlights farmers using the local variety of maize and no external inputs can find CA profitable. The findings presented in Chapter 2 also point to a reduction in weeding time (without the need for additional labour or herbicides) which is in sharp contrast to much of the literature to date i.e. CA has been found in other contexts to increase weeding time and only reduce weeding with the application of herbicides.

The economic analysis in Chapter 2 is also supported by the socio-psychological model employed in Chapter 3 which provides a contribution to the overall literature on CA and agriculture technology adoption studies more broadly given few studies have been employed that attempt to understand the cognitive drivers/barriers behind use of a ‘new’ management system. The findings support the contention that perceived behavioural control (including perceived difficulty of use and perceptions of CA needing knowledge/skills) impede the use CA. It also points to the role of social learning mechanisms such as Farmer Field Schools as playing an important role in this regard as Farmer Field School participants, for instance, have a significantly stronger positive attitude towards CA and find CA the easiest to use. Interestingly, the cognitive drivers which form farmers’ attitude are found to be the strongest predictor behind intention to use CA these being precisely the areas of current contention such as increased yields, reduction in labour, improvement in soil quality and reduction in weeds. The poorest are also found to have the highest intention to use CA which is contrary to much of the literature that argues that the poor are unlikely to find CA beneficial without subsidised inputs (e.g. Nkala et al., 2011). The findings presented in Chapter 3 also support the results from the economic analysis presented in Chapter 2 and provides further evidence that farmers’ are motivated by primarily economic benefits (yield and labour) and perceived biophysical improvements i.e. improvement in soil quality.

Chapter 4 presents an assessment of the innovation systems approach to CA use. Through stakeholder interviews, mapping of partnerships and social network analysis it highlights the key roles of ‘network partnerships’ in allowing for innovation and change to occur. It also shows that the poorest farmers using CA have stronger positive perceptions over the use of CA than wealthier farmers and that poorer farmers also value certain social referents more strongly in terms of receiving information on CA such as village facilitators and Farmer Field Schools etc. This suggests that this particular innovation system described is effective in reaching the poorest smallholder farmers**.**

The adoption/diffusion of innovations model alone does not take into account differences in farmers’ motivations but does help to understand information flows and thus whether the innovation system is functioning or not i.e. one function of an innovation system is knowledge exchange or what is termed ‘knowledge diffusion’ by some authors (Suurs et al., 2010). For example, Chapter 4 shows that the primary reason for not using CA among non-users was lack of information. However, this presupposes that it is merely information that would create ‘awareness’ and interests and cause a farmer to use an innovation or not. The socio-psychological model, however, helps to unwrap this and actually argues that farmers not using CA (or low intention to use CA) have perceptions of CA requiring a high level of knowledge/skills and/or requiring more labour. Moreover, we find that social learning mechanisms such as Farmer Field Schools are important in this regard (i.e. participants have a stronger perceived behavioural control and positive attitude regarding CA). Thus the way information is communicated and the type of learning (e.g. experiential learning) play an important role in the adoption process as do the role of mutually supporting stakeholders. Similarly, the order by which ‘awareness’ or ‘interest’ and ‘active experiential learning’ occurs is unlikely to be linear in terms of mere ‘stages’ and thus different types of information and learning are likely required (Leeuwis, 2004).

Thus, in this context the adoption of innovations framework does not adequately address the overall innovation processes that allow the ‘social system’ to emerge within this particular innovation system. Leeuwis (2004) further suggests that a combination of approaches such as social learning and adoption of innovations in conjunction with others can ‘complement inquiry’ to better understand the processes by which change occurs. Use of the innovation systems foci is thus particularly useful in this regard and may also be useful for other settings given the very poor in this study sample find CA useful and much of the literature argues that the poorest smallholder farmers are unlikely to find CA attractive (Giller et al., 2015; Nkala et al., 2011). As Leeuwis (2004) quite aptly notes however that “not only innovations that require ‘design’ and ‘redesign’, but also the processes aimed at creating them” (pg, 145).

Chapter 5 employs a novel Monte-Carlo Markov chain algorithm using socio-psychological factors and conventional determinants of adoption to explore CA adoption dynamics. It further supports findings presented in Chapters 2-4 that Farmer Field School membership, the role of village facilitators in engaging with farmers on CA and willingness to be part of a group play an important role in adoption. This reinforces findings elsewhere in the thesis that participation in group activities related to CA and social learning interactions through specific individuals/groups is important to adoption. Importance of labour reduction, soil quality improvement and perceptions of pests with CA also significantly influence adoption suggesting social learning interactions (taking account of these issues) vis-à-vis an appropriate innovation system are critical to adoption. Much of the literature to date argues that adoption of CA requires high levels of household labour availability, and high inputs whilst this novel approach shows that adoption, in this context, relates to farmers perceptions relating to the importance of labour reduction and reduction in pests. The inverse relationship between land preparation time, weeding time and adoption also highlights this point as does CA being used without the use of external inputs.

Limitations of research/future research

The main limitations of the study relate to the farm-budget data gathered. A more detailed account of farm labour (which would account for differences in gender and family support on-farm including the role of children) would have provided a more nuanced understanding of intra-household labour dynamics related to CA and conventional agriculture. Furthermore, yield measurement and inference is hampered by only having a snapshot i.e. one growing season as opposed to several/panel data set. More accurate yield measurement would also have been aided by calculating land area using GPS. The theory of planned behavior portion of the study could also have been strengthened by initially focusing on intention to use Conservation Agriculture in the next 12 months and then a follow-up a year later to ascertain whether it relates to adoption/actual use of CA (See Van Hulst and Posthumus, 2016).

Future research may focus on some of these gaps identified and longitudinal studies could also incorporate detailed panel data alongside soil samples for a subset of farmers to ascertain impact on biophysical parameters. The Theory of Planned Behavior approach with relation to

CA could also include spatial analysis e.g. using GPS coordinates of a whole village, for example, to investigate whether there is a spatial dimension to cognitive drivers/barriers because of where farmers are situated in relation to key personnel such as in this case a village facilitator or farmer field school member etc.

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Appendix 1: Household Survey Questionnaire

School of Agriculture, Policy and Development

I can confirm that Alison Bailey granted Ethical Clearance, with no changes to questionnaire below.

Amy Parkinson

Programme Administrator

School of Agriculture, Policy and Development

CA survey 2014, Pemba, Mozambique

Identification Sheet

Questionnaire No |___|___|___| District identification |___|___| Village identification |___|___|

Household number|___|___|___|Sex of respondent (1.Male 2.Female) |___|

GPS coordinates |___|___||___|___||___|___||___|___|

|___|___||___|___||___|___||___|___|

Language of Interview :

1. Macua
2. Portuguese
3. Makonde
4. Kimwani
5. Other: ___________

|___|

INTERVIEWER VISIT

Date	|__|__||__|__||__|__|__|__| *Day Month Year*	Time start interview	|__|__||__|__| *Hrs Min*

		Time end interview	|__|__||__|__| *Hrs Min*

Name of enumerator: __________________________ Name of team leader: ______________________

Enumerator code: |___|___| Team leader code: |___|___|

Signature ______________________________________ Signature ____________________________________

Hello, my name is ________ and I am working doing a study on behalf the University of Reading. Your village has been selected for a study on smallholder farming. We are collecting information on the household and specifically on agriculture and related practices.

You were selected as you are a smallholder in the area where the Aga khan Foundation works. The survey is voluntary and we will not share this information with anyone else.

This study involves a short interview There is no financial compensation for your participation; however we do hope that you will participate as your opinions are very important.

You are free to choose whether or not to participate in this study. You can stop the interview at any time. All information from the study will be kept confidential.

1	Do you agree to participate in this study?	1. Yes 2. No	|___|
1.1	If No (2), please explain the reasons why the household refused to participate in this study: ____ ____ ____ ________________		
If No (2), end the interview.			

SECTION A: Household composition and basic data. Include all members of the household who live in the dwelling and usually eat meals together in household size. Include those who are temporarily absent (less than 6 months in the last year). Do not include guests or paid workers.

<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>I</th></tr>
<tr><th>Sex of head of household</th><th>Age of head of household</th><th>Marital Status (See code)</th><th>Highest level of education completed? See code)</th><th>Main Occupation (See code)</th><th>Household size</th></tr>
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</table>

Codes for column A	Codes for column B	Codes for column C	Codes for column D	Codes for column I
1.Male **2**.Female	**9999**. Do not know	**1**. Married **2**. Divorced **3**. Separated **4**. Widowed **5**. Single	**00**. No education **01-12**. For class 1-12 record the actual class completed **13**. Technical/ Vocational Graduate **14**. University Graduate **15**. Madrasa only **16**. Adult literacy centre **17**. Pre-school **98**. Other ___________ **99**. Do not know	**00**. No occupation **01**. Private sector employee **02**. NGO employee **03**. Government employee **04**. Daily wage earner (casual worker) **05**. Self-employed (trade / business) **06**. Farming (agriculture/livestock) **07**. Unemployed- job seeking **08**. Housework **09**. Student **10**. Retired/Pensioner **11**. Ill/disabled **12**. Fishing **98**. Other _______________

SECTION B: AGRICULTURAL PRODUCTION AND PRACTICES

(head of household)

No.	Question	Coding		Skip	Response
B1	Are you a member of the CA farmer field school?	1.yes	2.No	**(if no go to B2)**	|___|
B1.1	If you have a spouse is she/he also a member of the CA FFS?	1.yes	2.No		|___|
B2	Are you a member of any other group/association other than farmer field school?	1.yes	2.No		|___|
B3	Do you have any livestock?	1.Yes	2.No		|___|
B4	Has the household earned any off-farm income this season?	1.yes	2.no		|___|
B5	Have you ever used CA?	1.yes	2.No	**If NO Skip to section C**	|___|
B6	How many years have you been using Conservation agriculture on your land?	1 First year of trying 2 2nd year 1. 3rd year 2. More than 3 years 3. Tried CA but have now stopped		**If 5 go to B5**	|___|
B7	If you stopped using CA what was the reason?	1. Lack of understanding of technique 2. Lack of equipment 3. Lack of labour/time 4. Lack of money 5. Pests/diseases 6. Soil type not good 7. Drought/flood 8. Do not want to use 9. Other 10. Does not know		**After skip to next section (if other please write down reason)**	|___| _________________

SECTION C

Nº	Question	Code	Response
C1. How many machambas did your household cultivate during this current growing season (2014) for all crops?		Indicate number of machambas	|___||___|
C1.1 Did you use Conservation Agriculture on all of your land i.e. all your machambas? (for those using CA or partial)		1=yes 2=no (if never used CA aske C1.2	|___|
	If no why haven't you used CA on all of your land?	1= not enough mulch 2=distance of plot 3= termites or rodents =not enough labour 4=weeds 5=spouse disagrees with using CA 6=other please state	|___|
C1.2 For those that have never tried CA why not? (all those who responded no to B6)		1=lack of information/assistance 2=not enough labour 3= do not want to use= 4=never heard of it 5= other please state____________________	|___|

	Machamba 1	Machamba 2	Machamba 3	Machamba 4
C2. What is the estimated area for each of your household's machambas that you cultivated this current growing season (2013/14) for all crops?	Plot 1 |___| . |___| ha OR |___|___|___|x|___|___|___| metres	Plot 2 |___| . |___| ha OR |___|___|___|x|___|___|___| metres	Plot 3 |___| . |___| ha OR |___|___|___|x|___|___|___| metres	Plot 4 |___| . |___| ha OR |___|___|___|x|___|___|___| metres
For Enumerator below Draw each machamba in the space provided, and list everything grown on that machamba for the growing season 2013/2014 Use this information as a check when filling out table on page 8. The drawing does not need to be to scale.				
For each machamba, list everything you have grown in 2013/14) growing season (make a sketch in the box provided of plot to help)				
If you grew maize did you grow a green manure cover crop i.e. legume before? (1=Yes 2=No)	|___|	|___|	|___|	|___|
Did you find there was enough rain at the beginning of and during the growing season? (1= Yes 2=No)	|___|	|___|	|___|	|___|
Distance of plot from home (in km)	|___|	|___|	|___|	|___|

	Machamba 1	Machamba 2	Machamba 3	Machamba 4
Type of land (own land (1) rented land(2) borrow-no cost (3)	|___|	|___|	|___|	|___|
Did you apply any Manure? (1= Yes 2=No)	|___|	|___|	|___|	|___|
If yes manure quantity (kg)	|___|	|___|	|___|	|___|
Did you apply any compost? (1=yes 2=no)	|___|	|___|	|___|	|___|
If yes compost quantity				
Fertilizer (1= Yes 2=No)	|___|	|___|	|___|	|___|
If yes Fertilizer quantity	|___|	|___|	|___|	|___|
Pesticides (1= Yes 2=No)	|___|	|___|	|___|	|___|
If yes Pesticides (quantity)	|___|	|___|	|___|	|___|
Herbicides (1= Yes 2=No)	|___|	|___|	|___|	|___|
If yes herbicides quantity	|___|	|___|	|___|	|___|
Minimum tillage 1= Yes 2=No)	|___|	|___|	|___|	|___|
Mulching 1= Yes 2=No)	|___|	|___|	|___|	|___|
If applied mulch did you purchase any extra for your land or just retain crop residue? =1 retain crop residue 2=bought extra	|___|	|___|	|___|	|___|
Rotation 1= Yes 2=No)	|___|	|___|	|___|	|___|
Intercrop 1= Yes 2=No)	|___|	|___|	|___|	|___|
Micro-pits 1= Yes 2=No)	|___|	|___|	|___|	|___|
Soil type 1= red/clay 2=sandy loam 3= dark soils	|___|	|___|	|___|	|___|
Slope of plot (1=Flat: 2=medium 3= steep)	|___|	|___|	|___|	|___|

	Machamba 1	Machamba 2	Machamba 3	Machamba 4
If respondent has spouse please indicate who takes care of each plot? (i.e. husband/wife) (1 for husband 2 for wife)	|___|	|___|	|___|	|___|
If using CA for how many years have you practiced CA on this plot? Use same codes as B6	|___|	|___|	|___|	|___|

For EACH MACHAMBA (list all the crops grown and how much was harvested below) Use the sketch made and the previous answers to help make sure all the information of the plot is t														
Plot ID	Type of crop	Intercrop type of crop	Harvested area by crop (metres or hectares)	Seed rate(type of unit)	# of units	Saved seed (Y/N)	Seed cost	Harvested green (type of unit)	# of units	Can you estimate how much 'green' unshelled would be in grain?	Harvested grain (type of unit)	# of units	Sold (type of unit)	# of units

Code for type of crop/intercrop
1Black sesame
2. White sesame
3. Rice
4. Maize (OPV improved variety)
4.1 Maize (local variety)
5. Cassava
6. Sorghum
7. Cow peas
8. Pigeon peas
10. Peanuts
11. Sweet potatoes
12Mung beans
13. Millet
14. Onions
15. Tomatoes
16. Cabbage
17. Eggplant
18. Carrots
19. Green pepper
20. Lettuce
21. Kale
22.pumpkin
23. Nhewe
24. Cashew nut
25.lablab

Codes for type of unit i.e. seed rate, harvest (green and grain) and amount sold
1=Bag (90 kg)
2=Bag (50 kg)
3= Bag (25 kg)
4=Can/bucket (10 litre)
5= Can/bucket (2 litre)
6=Can/bucket (1 litre)

	MACHAMBA (Labour) if respondent answers in weeks ask them is it 7 days a week i.e. how many days. For Hours ask them how many hours do you associate with one day of land prep, weeding and harvesting etc . For family labour and hired labour put numbers of persons used for this task												
Plot ID	Land prep (days)	Land prep (hours in a day)	Land prep Family labour number	Land prep Hired labour number	Weeding (hours in a day)	Weeding (hours in day)	Weeding family labour number	Weeding hired labour number	Harvesting (days)	Harvesting hours in a day	Harvesting family labour number	Harvesting hired labour number	Cost of a labour for a typical day

For Enumerator: Draw each machamba in the space provided, shade in the appropriate proportion and then fill in the response with the appropriate code.					
		Machamba 1	Machamba 2	Machamba 3	Machamba 4
D3	On what proportion of each cultivated machamba did you				

<table>
<tr><th colspan="6"><i>For Enumerator: Draw each machamba in the space provided, shade in the appropriate proportion and then fill in the response with the appropriate code.</i></th></tr>
<tr><th></th><th></th><th>Machamba 1</th><th>Machamba 2</th><th>Machamba 3</th><th>Machamba 4</th></tr>
<tr><td></td><td>practice minimum tillage/no tillage?
1. None
2. One quarter
3. One third
4. Half
5. Three quarters
6. All</td><td>|___|</td><td>|___|</td><td>|___|</td><td>|___|</td></tr>
<tr><td>D3.1</td><td>If you used minimum tillage/no tillage only on some of your machamba why did you till on the other parts?</td><td>|___|</td><td>|___|</td><td>|___|</td><td>|___|</td></tr>
<tr><td>D4</td><td>On what proportion of each cultivated machamba did you cover the ground with mulch?
1. None
2. One quarter
3. One third
4. Half
5. Three quarters
6. All
7. Used to apply mulch but now do not</td><td>|___|</td><td>|___|</td><td>|___|</td><td>|___|</td></tr>
<tr><td>D4.1</td><td>If you used to apply mulch why did you stop using it?</td><td>|___|</td><td>|___|</td><td>|___|</td><td>|___|</td></tr>
<tr><td>D5</td><td>Have you stopped using any other principles or associated practices of CA (if so what)?</td><td>|___|</td><td>|___|</td><td>|___|</td><td>|___|</td></tr>
</table>

For Enumerator: Draw each machamba in the space provided, shade in the appropriate proportion and then fill in the response with the appropriate code.

		Machamba 1	Machamba 2	Machamba 3	Machamba 4
D6	For Partial users of CA -The reason I use a few principles of conservation agriculture instead of all is because? (choose one of the reason or state reason)	|___|	|___|	|___|	|___|

Code for question D3.1.4.1 and D6
1. less labour
2. pests disease
3. weeds
4. soil type not good
5. didn’t know I could use minimum tillage with this crop
6. lack of knowledge/information on how to use CA
7. difficulty getting mulch/not enough
8. Other please state______________________________

Code for D5

1. Rotations or intercrop
2. Micro-pits

SECTION E: HOUSEHOLD ASSETS

We would now like to ask you some questions about your home, land and other assets that any member of the household may have or use

No.		Code	Response	score	points
E1	How many people do you have in your household? (can check with Section A column I)	**A. eight or more B. seven C. Six D. five E Four F three G two H one**	|___|	**A. 0 B. 2 C. 7 D. 9 E 15 F 23 G 30 H 34**	|___|
E2	What is the main material of the floor of the residence? (excluding kitchen and bathroom)	**A. uncovered (other) B. packed earth, wood/marble/granite/cement or tile**	|___|	**A. 0 B. 6**	|___|
E3	What is the main material of the walls of the residence?	**A.Reeds/sticks/bamboo/palm, wood or metal sheets, tin/cardboard/paper/ sacks, or other B. Adobe blocks, wattle and daub, cement blocks, or bricks**	|___|	**A. 0 B. 7**	|___|
E4	What toilet arrangement does the household use in its residence?	**A None, or other B Latrine of any kind C Toilet connected to a septic tank**	|___|	**A. 0 B. 6 C 14**	|___|
E5	What is the main source of energy for lighting in the residence?	**A.Firewood, or batteries B. LPG, oil/paraffin/kerosene, or candles C.Other 5.Electricity, generator, or solar panel**	|___|	**A. 0 B. 1 C 3 D 5**	|___|
E6	Does the household have a non-electric or electric clothes iron?	**A. No B. Yes**	|___|	**A. 0 B. 3**	|___|
E7	Does the household have a clock (wall, wrist, or pocket)?	**A. No B. Yes**	|___|	**A. 0 B. 4**	|___|

E8	Does the household have a radio, stereo system, or cassette player?	**A. No** **B. Yes radio only** **C stereo system (cassette player) (regardless of radio)**	|___|	**A. 0** **B. 5** **C 7**	|___|
E9	Does the household have a bicycle, motorcycle, or car?	**A. No** **B. Yes bicycle only** **C Motorcycle or Car (regardless of bicycle**	|___|	**A. 0** **B. 5** **C 15**	|___|
E10	How many beds does the household have (single, double, bunk beds, or for children)?	**A. None** **B. One** **C Two or more**	|___|	**A. 0** **B. 2** **C 5**	|___|

SECTION F: FOOD AND NUTRITION

No.	**Question**	**Code**	**Skip**	**Response**
F1	Have you experienced a food shortage during the last 12 months?	1. Yes 2. No		|___|
F2	If Yes roughly how long was this period of food shortage	Record the number of months		|___|

This section asks about food categories that the entire household has <u>eaten</u> (over the last seven days)

No	**Category**	**Examples**	**Frequency number of days you have consumed in last 7 days**
F4.1	Cereals and tubers	Maize xhima, bread, pasta, crackers, cookies, millet, sorghum, rice, wheat, maize, and other foods made from maize or wheat Cassava, potatoes and sweet potatoe	|___|
F4.2	Pulses	Beans, peas, groundnuts and cashew nuts	|___|
F4.3	Vegetables and leaves	Vegetables with dark leaves from cowpeas, leafy cabbage, moringa leaves, etc. Tomato, onion, eggplant, green peppers, lettuce, cucumber, okra, cabbage, beetroot, etc.	|___|

F4.5	Fruits		|___|
F4.6	Meats	Meat of cow, goat, rabbit, venison, gazelle, palapala, duck, turkey, chicken, wild poultry, pork, sheep, rat, etc.	|___|
F47	Milk and other dairy	Milk from cow, goats, cheese, yogurt, lactogen, condensed milk, powdered milk (Nido) Eggs (duck chicken)	|___|
F4.8	Oils and Fats	Oil, coconut oil, lard, margarine (rama), butter or other fats to cook	|___|
F4.9	condiments	Pepper, salt, spices, piri piri, lemon, garlic, ginger, etc.	|___|

SECTION G: INNOVATION BEHAVIOURS (for CA users or farmers adaptation/partial adoption) If Not using CA move to Section H

No.	Question	Coding		Skip	Response
G1	Did you experiment with all of CA (i.e. all three principles) on part of your plot before using it on more of your land?	1. Yes	2. No		|___|
G2	Did you test any specific technique under CA like with micro-pit without micro pit?	1. Yes	2. No		|___|
G3	Were you convinced to test/experiment CA because your spouse told you too?	1. Yes	2. No		|___|
G4	Did you consult anyone before trying CA? e.g. AKF facilitator , friend/family	1. Yes	2. No		|___|
G5	Did you learn about CA through a group/association?	1. Yes	2. No		|___|
G6	When using CA did you observe changes on your farm which made you only use certain CA principles?	1. Yes	2. No		|___|
G7	Did you try CA on all of your farm without doing any testing/experimenting before?	1.Yes	2. No		|___|

SECTION H: Theory of planned behaviour (intention) (+2 to -2) (for all farmer categories)

No.	Question	Coding	Skip	Response
H1	How strong is your intention to use all three principles together of conservation agriculture on your farm over the next 12 months?	**1.**Very strong **2.** strong **3.** undecided **4.** weak **5.** very weak		|___|
H2	In your opinion how important would it be to use all of the principles of conservation agriculture on your farm over the next 12 months?	**1.**Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|
H3	How strong is your intention to use minimum/no tillage and or more (but not all) principles on your farm over the next 12 months?	**1.**Very strong **2.** strong **3.** undecided **4.** weak **5.** very weak	(if using all principle skip to H5)	|___|
H4	How important would it be to use minimum/no tillage and or more (but not all principles) on your farm over the next 12 months?	**1.**Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|
H5	How useful would it be to use all of the principles of conservation agriculture on your farm during the next 12 months?	**1.**Very useful **2.** useful **3.** do not know **4.** opposed **5.** very opposed		|___|
H6	How useful would it be to use minimum/no tillage or more (but not all) of the principles of conservation agriculture on your farm during the next 12 months?	**1.**Very useful **2.** useful **3.** do not know **4.** opposed **5.** very opposed	(if using all principles skip to H7)	|___|
H7	How difficult would it be to use all of the principles of conservation agriculture on your farm during the next 12 months?	**1.**Very easy **2.** easy **3.** do not know **4.** difficult **5.** very difficult		|___|
H8	How difficult would it be to use minimum/no tillage and or more (but not all) of the principles of Conservation agriculture on your farm over the next 12 months?	**1.**Very easy **2.** easy **3.** do not know **4.** difficult **5.** very difficult	If using all principles skip to next section	|___|

SECTION I: Attitudes (Outcome belief and evaluation of the outcomes) (scale +2 to -2)

The following are statements made by other smallholder farmers regarding using Conservation agriculture From your experience, could you indicate:

- **Whether you agree or disagree with each statement and**
- **How important each issue would be to you**

No.	Question	Coding	Skip	Response
I1	Using conservation agriculture increases yields compared to conventional agriculture	**1.** strongly agree **2.** Agree **3.** Not sure **4.** Disagree **5**. Strongly Disagree		|___|
I1.1	How important is the above statement to you?	**1.** Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|
I2	Using conservation agriculture requires less labour than conventional agriculture.	**1.** strongly agree **2.** Agree **3.** Not sure **4.** Disagree 5. Strongly Disagree		|___|
I2.1	How important is the above statement to you?	**1.** Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|
I3	Using Conservation agriculture improves soil quality.	**1.** strongly agree **2.** Agree **3.** Not sure **4.** Disagree 5. Strongly Disagree		|___|
I3.1	How important is above statement?	**1.** Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|
I4	Using conservation agriculture reduces weeds because of organic mulch retention	**1.** strongly agree **2.** Agree **3.** Not sure **4.** Disagree 5. Strongly Disagree		|___|
I4.1	How important is above statement to you?	**1.** Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|

I5	Using conservation agriculture increases pest because of organic mulch retention	**1.** strongly agree **2.** Agree **3.** Not sure **4.** Disagree 5. Strongly Disagree		|___|
I5.1	How important is the above statement to you?	**1.** Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|
I6	Using Conservation agriculture cannot be used on all soil types	**1.** strongly agree **2.** Agree **3.** Not sure **4.** Disagree 5. Strongly Disagree		|___|
I6.1	How important is the above statement to you?	**1.** Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|
I7	Conservation agriculture leads to benefits (i.e. increase in production) after the first year of using it and does not require waiting 2 or 3 years.	**1.** strongly agree **2.** Agree **3.** Not sure **4.** Disagree 5. Strongly Disagree		|___|
I8.1	How important is the above statement to you?	**1.** Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|
I9	Conservation Agriculture provides better yields in a drought year than conventional agriculture	**1.** strongly agree **2.** Agree **3.** Not sure **4.** Disagree 5. Strongly Disagree		|___|
I10	How important is the above statement to you?	**1.** Very important **2.** Important **3.** No opinion **4.** Not very important **5.** Unimportant		|___|

SECTION J: Sources of advices and information (subjective norm) (+2 to -2)

No.	Question	Coding	Skip	Response
J1	How likely is it that people you respect most would think you should use conservation agriculture over the next 12 months?	**1.** very likely **2.** likely **3.** do not know **4.** unlikely **5.** very unlikely		|___|

How motivated would be to follow the advice of the following regarding using conservation agriculture on your farm?

No.	Question	Coding	Skip	Response
J2	Government official " SDAE"	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J3	Other NGO e.g. umokazi	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J4	Radio	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J5	TV	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J6	Village facilitator AKF	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J7	Association/group	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|

J8	Farmer field school	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J9	Sibling	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J10	Spouse (husband or wife)	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J11	Self observation	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J12	Self initiative	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J13	Grandfather	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|
J14	Other experienced farms	**1.**Very motivated **2**. quite motivated **3.** Cannot say **4.** not very motivated **5.** not at all motivated		|___|

Indicate how strongly would the following encourage you to use conservation agriculture on your farm?

No.	Question	Coding	Skip	Response
K1	Government official ("tedau")	**1.**strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|

K2	Other NGO e.g. umokazi	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K3	Radio	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K4	TV	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K5	Village facilitator AKF	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K6	Association/group	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K7	Farmer field school	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K8	Sibling	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K9	Spouse (husband or wife)	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K10	Self observation	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K11	Self initiative	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|

K12	Grandfather	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|
K13	Other experienced farmers	**1**.strongly encourage **2**. encourage **3.** Cannot say **4.** discourage **5.** strongly discourage		|___|

Perceived behavioural control (+2 to -2)

The following are statements made by other smallholder farmers regarding using Conservation agriculture From your experience, could you indicate:

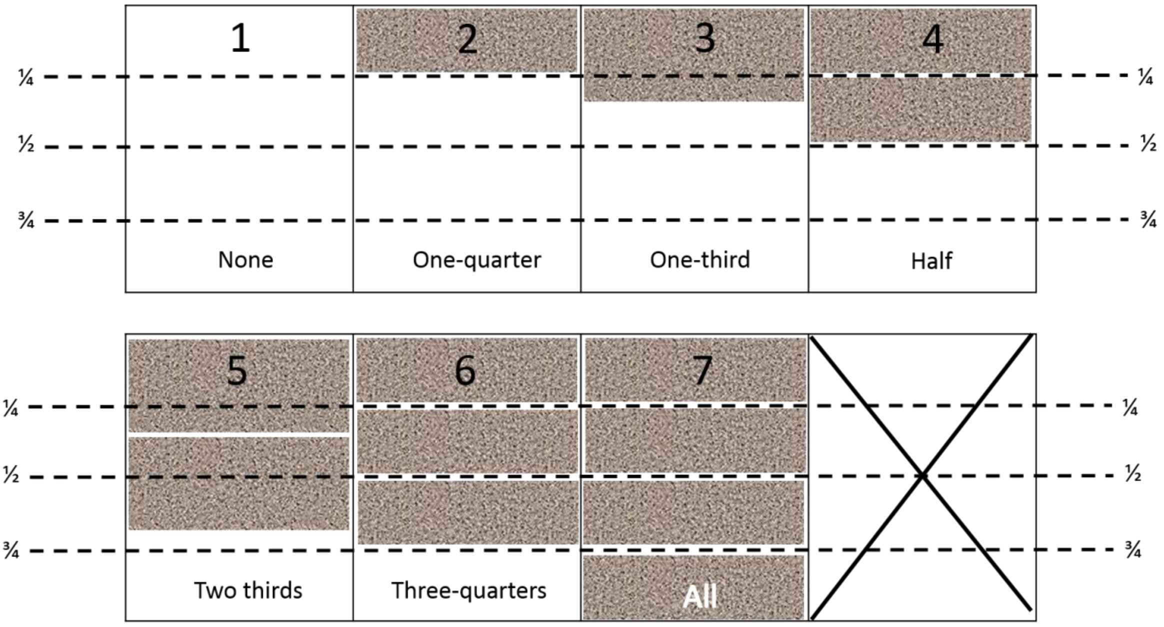
- **Whether you agree or disagree with each statement and**
- **How important each issue would be to you**

No.	**Question**	**Coding**	**Skip**	**Response**
L1	I expect I will have enough labour in the coming year to use CA on my land.	**1.** strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L1.2	Having enough Labour is important to be able to use CA	**1**.strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L.2	I expect I will have enough knowledge and skills to be able to use CA on my land.	**1.** strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L.2.1	Having enough knowledge and skills is important in order to practice CA	**1.** strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L3	I expect I will be part of a group/association that is involved in CA in the near future.	**1.** strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|

L3.1	Being part of a group association is important to the successful use of CA otherwise	**1**.strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L3.2	I expect to be able to use CA with the soil type I have	**1**.strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L4	Using CA on the Right soil is important with use of CA	**1**.strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L4.1.	I expect to be able to deal with pest issues that arise whilst using CA	**1**.strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L4.2	Having pests can limit the success of CA	**1**.strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L5	I expect to have to the appropriate mechanization to be able to expand my area on CA	**1**.strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|
L5.1	Having mechanization I would enable me to use CA on more of my land	**1**.strongly agree **2**. agree **3.** not sure **4.** disagree **5.** strongly disagree		|___|

Thank you for your time and your willingness to answer our questions

Machamba Proportion Guide (USE this to ask for amount they have done CA on each machamba and amount of mulching/groundcover they have put on each plot)


1
2
3
4
¼
½
¾
None
One-quarter
One-third
Half
5
6
7
Two thirds
Three-quarters
All