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Farm-level economic analysis-Is Conservation Agriculture helping the poor?

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Highlights

- CA can be profitable without the use of external inputs.
- Labour and weeding time is reduced under CA without the use of herbicides.
- NPV analysis shows CA can have short-term and longer term benefits dependent on crop mix and opportunity cost of labour assumed.
- CA cropping options for the poorest farmers are preferred under risk neutral and extremely risk-averse scenarios.
- Probability of CA breaking even under the same crop mix is higher than under conventional for the poorest farmers.

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/on-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

1. 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 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 slash and burn cultivation (Rockström et al., 2009; Thierfelder et al., 2012). 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., 2012). Significant yield benefits and/or improvements to gross margins due to higher labour productivity have been found in a number of circumstances relative to conventional agriculture (Mazvimavi, and Twomlow, 2009; Ndlovu et al., 2014; Thierfelder et al., 2014a; Mupangwa et al., 2016) though fertilisers (organic/inorganic) are used in these comparisons and seen as an important addition. Likewise, Thierfelder et al. (2014b) showed that there can be benefits in the first few seasons under CA including significant yield benefits, however, these are site specific which may also require ‘appropriate fertilisation’ in order 'to become significant'. Vanlauwe et al. (2014) argued that a fourth principle should be used to define CA (i.e. the appropriate use of fertiliser) due to low yields and the competing needs for crop residues thereby resulting in sub-optimal application for soil cover. Thus, it is argued that adequate fertiliser application would simultaneously enhance crop productivity and organic residue availability. Sommer et al. (2014a) in contrast argue that fertiliser application should not be an additional principle but rather an additional practice as they argue that the application of (inorganic or organic) fertiliser is crucial to making CA work. However, this may not be the case for all soils and agro-ecosystems as improvements to productivity have been found under CA relative to conventional agriculture with very small amounts of residues applied (e.g. Sommer et al., 2014b). Moreover, sound nutrient management in any production system is a 'good practice' but should not be considered as a principle of CA (Sommer et al., 2014a) given there are also instances where mineral fertiliser applications have not resulted in higher yields and where soils are unresponsive (Tittonell and Giller 2013).

Others have argued that CA has not benefited the poorest farmers (Nkala, et al., 2011). Giller et al. (2015) more recently argued that CA is likely to 'remain beyond the grasp of smallholders' that lack adequate mechanisation, animal traction or herbicides. Considering maximisation of all production factors (including labour and land) and reducing the risk to the whole-farm is considered important for farmers (Giller et al., 2015). 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 (particularly as farm labour is not often monetised) 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/on-station experiments which may not appropriately reflect farmers' realities (Soane et al., 2012). Though there are benefits from conducting rigorous studies through either on-farm or on-station experiments; a number of authors have suggested that farm-level data (i.e. from large scale household surveys) 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 criticism applies to much of SSA, including Mozambique 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). These have not 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. Similar research has also been reported in this journal which also explored the economics of Conservation Agriculture, including using certainty equivalents and considering risk, but did not consider different wealth categories (Tessema et al., 2015). 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 Section 2 and the model and results in Section 3. Section 4 provides discussion and conclusions to the paper.

1.1 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 (including slash and burn) are still pervasive and mainly done through ploughing by hand-hoe or animal traction.

Mozambique consists of ten different agro-ecological regions (R1-10). These have been grouped into three different categories which are based in large part on mean annual rainfall and evapotranspiration (ETP). First, the highland category represents high rainfall regions (>1000mm, mean annual rainfall) with low evapotranspiration and correspond to R3, R9 and R10. The medium altitude category in contrast (R7, R4) corresponds to areas with mean annual rainfall ranging between 900-1500mm and medium level of ETP. Finally, the low altitude category (R1, R2, R3, R5, R6, R7, R8) 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 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 R8 is Alfisols (Maria and Yost, 2006). These consist of soils with predominantly red clay texture 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 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).

1.1.1 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. 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. Farmer Field Schools have been established within each of the districts and helped to encourage adoption of CA among farming households. Given the lack of draft and mechanical power in Cabo Delgado, manual systems of CA have been promoted such as the use of a dibble stick which is a pointed stick used to open small holes in crop residues for planting seed. Micro-pits are often also used in the early years of CA to break soil compaction and are the most commonly used system in the region. These are similar to basins used elsewhere in Sub-Saharan Africa and originate from the Zai pit system used in the Sahel (e.g. Thierfelder et al., 2016). These. AKF- CRSP has promoted the use of micro pits (35cm long x 15cm wide x

15cm deep). It should be noted that these 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 (e.g. Kassam and Brammer, 2016). Finally, the use of jab planters have also recently been promoted in the region.

2. Materials and Methods

2.1 Survey procedure

This study is based on results from a survey of 197 farmers in the Metuge district, of Cabo Delgado Province Mozambique administered in the summer of 2014**.** 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 probability proportional to size (PPS sampling) (e.g. Turner, 2003). Focus group discussions were also held with farmers in the study region to understand perceptions among users and non-users.

2.1.1 Variables and measurement

The survey consists of several sections. The first 4 sections relate to household/farm characteristics, agricultural production practices, including plot level characteristics and previous use of CA. The next two sections refer to household assets and food and nutrition security. The final section contained questions dealing with the Theory of Planned Behaviour.

In addition, 14 key informant interviews and 2 focus group discussions (FGD) were carried out in three different villages from February to March, 2014. As the survey was performed as part of a larger research project, we only outline the measurement of those variables that were used in the analyses reported in this study.

Detailed farm budget data has been gathered which represents 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.. The wet conditions may, however, have differing effects for CA relative to conventional tillage. Yield is calculated by dividing reported production by reported area for each crop. The area reported is also expressed in hectares as this reflects the most familiar unit known to farmers. The aid of locally used metrics of measurement e.g. baskets and buckets of different sizes have been used. A sample of buckets and baskets, typically used by farmers, have been weighed for specific crops in order to maintain consistency with appropriate conversion into kilograms, although we acknowledge the limitations of this approach and of using reported area and production. The Cabo Delgado region also experienced some flooding in mid-2014 which may provide a further limitation particularly with estimating yields.

2.2 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 (as referred to in figures due to space requirements) 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.

2.3 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 have been used i.e. one model comparing CA and conventional for farmers using the maize (*Zea mays* L.), cowpea (*Vigna unguiculata* L.) Walp) and cassava mix and the other for farmers using the maize, cowpea, and sesame (*Sesamum indicum* L.) mix. We have not simulated 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 have been 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 has been 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 calculate the Net Present Value (NPV), a widely used financial criterion, used in previous studies on the same topic (Pannell *et al*., 2014; Knowler & Bradshaw, 2007; FAO, 2001). The NPV determines the present value of net benefits by discounting the benefits (B) and costs (C), that arise between the present and future time periods (T). The subscripts (t) denote a specific time period i.e. year and the discount rate is referred to as (r).

$$NPV = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t} \quad (1)$$

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 (NR) are calculated by yield per hectare multiplied by price ($y \times p$) for all crops in the specific mix less full labour costs (hired and family) per hectare (l) and opportunity cost of mulch(m) per hectare (i.e. if applicable).

$$NR = (y \times p) - (l + m) \tag{2}$$

These are presented in United States Dollars (USD) for ease of international/regional comparisons.[1] 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 (Thierfelder et al., 2014b).

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

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

30% respectively and for ‘with’ and ‘without’ labour scenarios given this is the primary cost to farmers. These are similar discount rates to those used by Pannell et al. (2014) given that the author also expressed concern over studies that have not used high discount rates. 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 foliage 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. [2] A ‘shadow’ price for mulch is 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.

Our model is thus based on farmers using 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.

2.4 Data analysis

Data were 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

[2] We consider cassava under legume for the purpose of valuing cassava foilage. ‘Green’ in the case of cowpea (referred to in Appendix) refers to leaves harvested mid- season before seed is harvested.

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 have been 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). 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 are employed 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).

3. Results

3.1 Summary statistics

Table 1 shows the summary statistics of the sample. Household sizes are quite high on average with low levels of educational attainment. Off-farm income is generally very low signifying the importance of agriculture in this region 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)
Household size	5.2 (2.4)
Sex of Household Head	Male 65%; Female 35%
Age of Household Head	62(27.9)

Marital status of Household Head	69 %= married, 2%= Divorced, 4%=Separated, 9%= Widowed and 16%=Single
Education of Household Head (i.e. grades completed 1-12)	2.4 (2.8)
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
Conventional	52
Current adoption	
Micro-pits with mulch and rotation/intercrop using at least 3 different crops	51%
Conventional 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%
Conventional (no mulch)	24%
Conventional (with mulch)	3%

Source: Adapted from Lalani et al., (2016) The majority of CA farmers use 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 are the most common three-way sequences.[3] Conventional farmers also just cultivate two crops such as maize and cassava in the growing season. Although, the most common four-way crop mixes used by CA users are maize-cowpea-pigeonpea (*Cajanus cajan* (L.) Millsp.) cassava (*Manihot esculenta* (L.) Crantz.) or maize-cowpea-cassava-sesame, the survey results also showed that farmers were invariably using the local varieties of crops (not 'improved' purchased hybrids) and/or were also not using external inputs such as fertilisers, herbicides, pesticides, composts and/or manure.

3.2 Economic model

Net present values calculated from the stochastic model are shown for three planning horizons for the maize cowpea and cassava crop mix under CA and conventional (Table 2 and 3). 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 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.[4] If one uses three years as the yardstick of the majority of resource-poor farmers' planning horizons CA would be preferred. Interestingly, under a zero labour cost scenario CA

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[3] Maize is often intercropped with cowpea and/or cassava where four crops are used under CA and this is usually done in sequence and/or rotation.

[4] Shaded sections highlight differences to the norm in each table i.e. where the other system is more profitable.

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.[5]

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. An expert in simulation 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

[5] 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.

	3 years	5 years	10 years	3 years	5 years	10 years
Base case	-300	-463	-686	-343	-487	-682
Maize high	-251	-395	-591	-276	-392	-550
Maize low	-315	-486	-718	-365	-518	-726
Zero Labour	242	329	448	213	303	425
Labour high	-845	-1264	-1834	-905	-1285	-1802
Labour low	-194	-310	-467	-235	-334	-469
50% increase in cowpea price	-245	-400	-609	-323	-457	-641
50% increase in cassava price	-264	-406	-600	-322	-457	-641

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	-253	-368	-490	-296	-396	-503

Maize high	-211	-313	-420	-239	-320	-406
Maize low	-267	-387	-514	-315	-422	-536
Zero Labour	210	271	336	184	247	313
Labour high	-721	-1015	-1326	-781	-1047	-1329
Labour low	-164	-245	-331	-203	-272	-346
50% increase in cowpea price	-206	-314	-429	-278	-372	-473
50% increase in cassava price	-224	-324	-430	-278	-372	-472

Net present values show that for farmers using the maize-cowpea-sesame mix conventional agriculture would be preferred over the short and longer term planning horizons (Table 4 and 5). 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. Whist CA is certainly not exclusive to the poor, 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 look after 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) argue in their study of crop production 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 mixes that are likely to be most beneficial in enabling a move out of poverty. It should also be noted that Harris and Orr’s study did not include livestock or irrigated crops, and was mainly limited to comparing net returns based on monetised values only. This may overlook some potential benefits of increased production on households e.g. the knock on effects of increased food security on nutrition and health; and the ability of some households to spend less time during ‘hungry’ periods of the season working for other farmers, and therefore having the scope to invest more labour in their own agricultural and non agricultural livelihood activities.

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	312	380	472	325	465	647
Maize high	439	542	682	437	658	923
Maize low	270	325	402	279	396	555
Zero Labour	916	1203	1594	959	1362	1909
Labour high	-299	-454	-664	-316	-449	-630
Labour low	428	539	688	447	635	890
50% increase in cowpea price	383	472	593	408	579	812
50% increase in sesame price	605	767	985	581	825	1156

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	279	327	377	280	376	477
Maize high	392	464	540	400	536	681
Maize low	242	281	323	241	323	410
Zero Labour	801	1002	1216	823	1109	1408
Labour high	-249	-357	-472	-273	-366	-464
Labour low	380	457	539	386	518	657
50% increase in cowpea price	341	403	470	352	472	599
50% increase in sesame price	536	649	768	501	672	853

3.3 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 (means) of CA and conventional farmers for poorest wealth tercile (S.D)

	N	Household poverty score*	Age of HH Head	Household size	Off-farm income (1=yes,2 =no)	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	CA	36	344	189
preparation	Conventional	17	449	291
Weeding	CA	36	167*	117
	Conventional	17	263	220
Harvesting	CA	36	208	222
	Conventional	17	205	164
Total Person	CA	36	839	425
hours	Conventional	17	1013	470

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

3. 4 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 (ARAC) shows a range of risk tolerance levels from risk neutral to extremely risk averse 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 100 USD to be indifferent between the three crop cassava mix under CA and would further need to receive approximately 200 USD to be indifferent from the conventional maize-cassava mix. For the maize-cowpea-sesame mix a risk neutral and risk averse farmer would need to receive a payment of roughly 100 USD to be indifferent between the higher ranked CA maize-cowpea sesame and conventional maize-cowpea sesame.

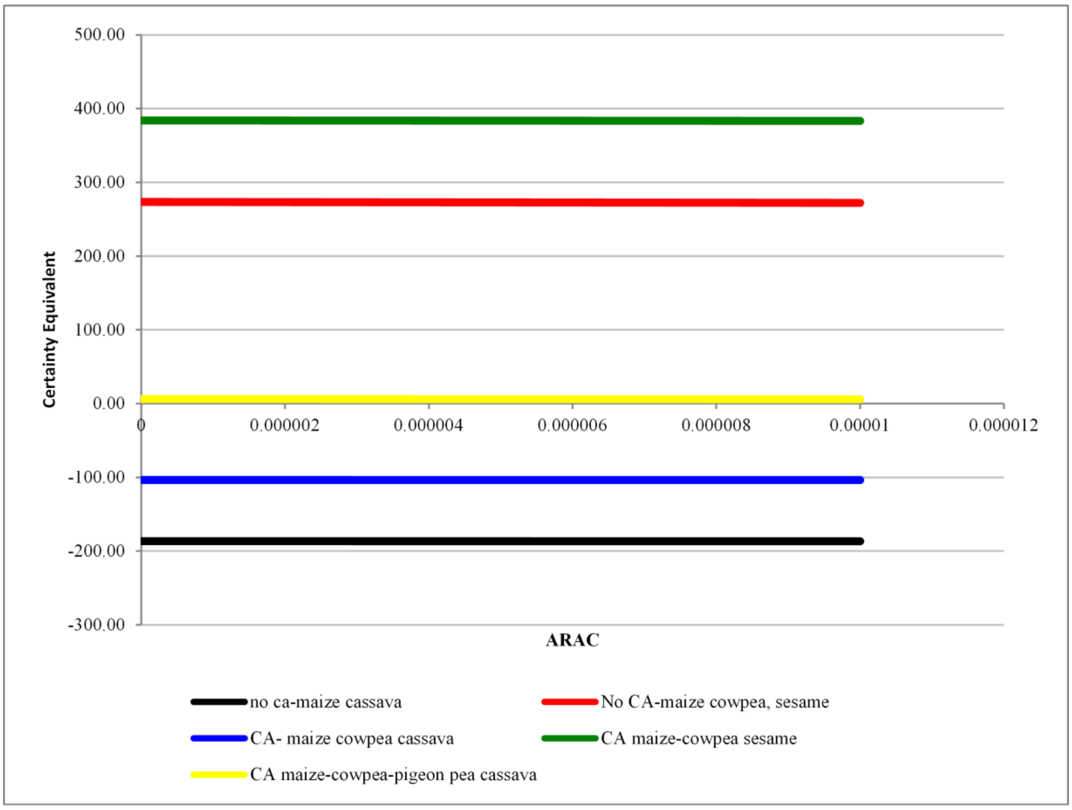

Figure 1 Certainty equivalents (CE's) in USD for the most frequent crop mixes used by the poorest farmers under different risk tolerance levels

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 the probability of net income above the threshold of 353 USD (i.e. mean net income plus one standard deviation) and cautionary (light yellow) between 0 and the threshold of 353 USD. 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). Thus the CA maize-cowpea-sesame mix provides the highest probability of net returns above the threshold of 353 USD 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 353 USD and 59% for a net income between 0 and 353 USD. 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.

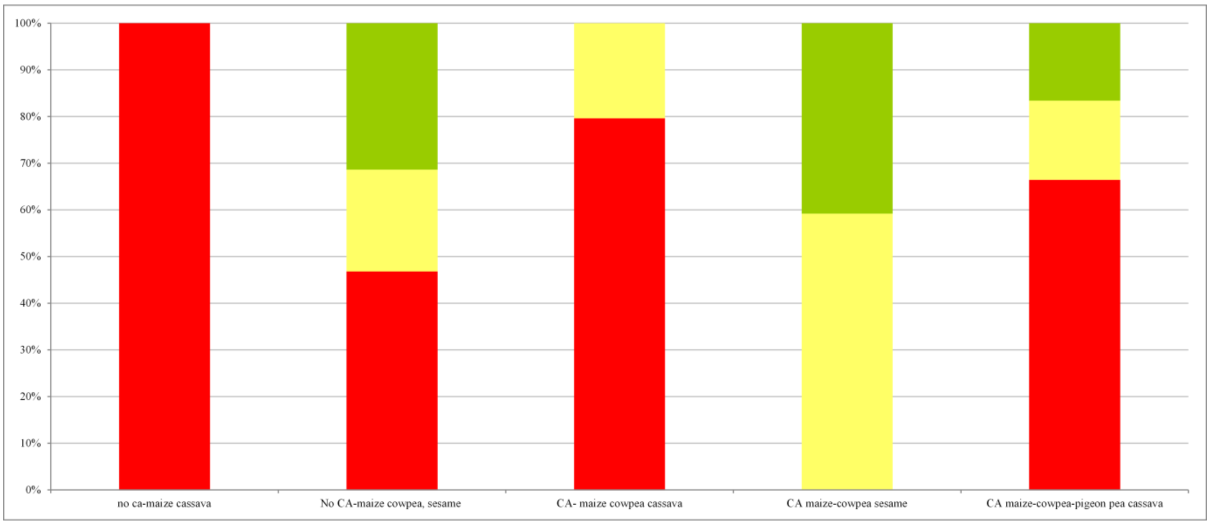

Figure 2 Stoplight probability chart showing probability (percentage) of achieving less than breakeven (i.e. zero) and target net return of 353 USD (mean plus one standard deviation) for different crop mixes for the poorest wealth tercile.

4. Discussion

This study has investigated, using an economic model and risk analysis to what extent CA relative to conventional agriculture (within the case study district of Metuge) 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. 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, CA may have lower yields than conventional agriculture users for other crop mixes. However, CA may have the advantage for farmers with a higher opportunity cost of labour. Baudron et al., (2016) similarly showed that reduction in labour is a major entry point for CA systems.

Thus, some conclusions seem plausible. Firstly, the different 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 for yield but also for labour maximisation if they are subsistence based (producing 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.[6]

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.1 in

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

Appendix B) of the poorest farmers using the sesame mix, conventional farmers (i.e. conventional) actually have the highest probability of achieving the highest net returns (i.e. above 1000 USD MZN) relative to CA farmers using the same mix (See Figure B.2 in Appendix B). It is thus the reduction in labour for this mix for CA farmers, which likely provides the more stable distribution of 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 returns for farmers.

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 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 which suggests on smaller plots of land higher yields with CA practices can be realised relative to conventional agriculture (Grabowski and Kerr, 2014). 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. 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.[7] 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). Thus, it should be noted that basins have been shown to be more productive and risk reducing in other dry climates

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

(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).

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 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. Interestingly, the poorest farmers had the highest intention to use CA and found CA the easiest to use compared to better-off farmers ($p<0.05$). 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.

5. Conclusion

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. Thus 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. Nonetheless many farms would benefit from support in terms of reducing the risk and uncertainty of using a 'new' management system such as CA. The wide ranging support from NGOs in this regard (e.g. Farmer Field Schools (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, social learning mechanisms play an important role in this regard. Interestingly, FFS 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. 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 therefore favor CA or CA practices being used in the long run. (Stonehouse, 1991; Fatherlrahman et al., 2011). 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).

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