

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

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Accepted Version

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Lalani, B., Dorward, P. and Holloway, G. (2017) Farm-level economic analysis - is Conservation Agriculture helping the poor? *Ecological Economics*, 141. pp. 144-153. ISSN 0921-8009 doi: <https://doi.org/10.1016/j.ecolecon.2017.05.033>
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To link to this article DOI: <http://dx.doi.org/10.1016/j.ecolecon.2017.05.033>

Publisher: Elsevier

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

2 Baqir Lalani^{a,*}, Peter Dorward^a, Garth Holloway^a

3 ^{a*}Corresponding author: Natural Resources Institute, University of Greenwich, Medway

4 Campus, Central Avenue, Chatham Maritime, Kent, ME4 4TB, UK,

5 B.Lalani@greenwich.ac.uk

6 ^aSchool of Agriculture, Policy and Development, University of Reading, Whiteknights, PO

7 Box 217, Reading, Berkshire, RG6 6AH,United Kingdom, p.t.dorward@reading.ac.uk,

8 ^aSchool of Agriculture, Policy and Development, University of Reading, Whiteknights, PO

9 Box 217, Reading, Berkshire, RG6 6AH,United Kingdom, garth.holloway@reading.ac.uk

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11 **Highlights**

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

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

49 **Keywords:** Conservation Agriculture, farm-level economics

50

51 **1. Introduction**

52 Conservation Agriculture (CA) is now practiced worldwide across all continents and
53 ecologies including on various farm sizes from smallholders to large scale farmers (Friedrich
54 et al., 2012). It is defined as the simultaneous application of three principles, namely minimal
55 soil disturbance, permanent organic soil cover (covering at least 30% of the cultivated area)
56 and the use of rotations and/or associations involving at least three different crops (FAO,
57 2015). In Sub Saharan Africa, conventional tillage practice which is primarily practiced
58 through the application of hand-hoe or plough has resulted in severe soil erosion and loss of
59 soil organic matter (SOM) which has been further exacerbated through the practice of slash
60 and burn cultivation (Rockström et al., 2009; Thierfelder et al., 2012). Despite enthusiasm
61 from proponents the adoption of CA has, however, remained fragmented throughout the
62 region (Giller et al., 2009; Rockström et al., 2009).

63
64 There still exists a polarised debate, particularly in Sub-Saharan Africa, surrounding the
65 merits of CA as an alternative to conventional tillage based farming. The debate has largely
66 centred around the farm level costs/benefits, including the time horizon of benefits actually
67 accruing, labour requirements and in particular whether CA requires the additional need of
68 high inputs such as fertilisers and herbicides to be profitable (Giller et al., 2009;
69 Rusinamhodzi et al., 2012). Significant yield benefits and/or improvements to gross margins
70 due to higher labour productivity have been found in a number of circumstances relative to
71 conventional agriculture (Mazvimavi, and Twomlow, 2009; Ndlovu et al., 2014; Thierfelder
72 et al., 2014a; Mupangwa et al., 2016) though fertilisers (organic/inorganic) are used in these
73 comparisons and seen as an important addition. Likewise, Thierfelder et al. (2014b) showed
74 that there can be benefits in the first few seasons under CA including significant yield
75 benefits, however, these are site specific which may also require ‘appropriate fertilisation’ in

76 order 'to become significant'. Vanlauwe et al. (2014) argued that a fourth principle should be
77 used to define CA (i.e. the appropriate use of fertiliser) due to low yields and the competing
78 needs for crop residues thereby resulting in sub-optimal application for soil cover. Thus, it is
79 argued that adequate fertiliser application would simultaneously enhance crop productivity
80 and organic residue availability. Sommer et al. (2014a) in contrast argue that fertiliser
81 application should not be an additional principle but rather an additional practice as they
82 argue that the application of (inorganic or organic) fertiliser is crucial to making CA work.
83 However, this may not be the case for all soils and agro-ecosystems as improvements to
84 productivity have been found under CA relative to conventional agriculture with very small
85 amounts of residues applied (e.g. Sommer et al., 2014b). Moreover, sound nutrient
86 management in any production system is a 'good practice' but should not be considered as a
87 principle of CA (Sommer et al., 2014a) given there are also instances where mineral fertiliser
88 applications have not resulted in higher yields and where soils are unresponsive (Tittonell and
89 Giller 2013).

90

91 Others have argued that CA has not benefited the poorest farmers (Nkala, et al., 2011). Giller
92 et al. (2015) more recently argued that CA is likely to 'remain beyond the grasp of
93 smallholders' that lack adequate mechanisation, animal traction or herbicides. Considering
94 maximisation of all production factors (including labour and land) and reducing the risk to
95 the whole-farm is considered important for farmers (Giller et al., 2015). In addition, there has
96 been scant research in the Sub-Saharan African region on smallholder farms that delves into
97 farm- level economic analysis of CA with appropriate sophistication (Pannell et al., 2014).

98

99 A wide ranging review of previous farm-level economic studies has been discussed in depth
100 by other authors in this journal (Pannell et al., 2014). They conclude that there are key

101 deficiencies in much of the economic analysis, to date, including a lack of consideration of
102 the time lags, discount rates, appropriate opportunity costs for labour (particularly as farm
103 labour is not often monetised) and crop residues. Moreover, omission of the role of risk and
104 uncertainty in farm level economic analysis is widespread (Ngwira et al., 2013; Pannell et al.,
105 2014; Thierfelder et al., 2016).

106

107 A further criticism of much of the literature on CA has also been directed to the multitude of
108 on-farm/on-station experiments which may not appropriately reflect farmers' realities (Soane
109 et al., 2012). Though there are benefits from conducting rigorous studies through either on-
110 farm or on-station experiments; a number of authors have suggested that farm-level data (i.e.
111 from large scale household surveys) is needed to better analyse the impact of CA in different
112 contexts (Ngwira et al., 2013; Pannell et al., 2014; Dalton et al., 2014; Carmona et al., 2015;
113 Mafongoya et al., 2016). This criticism applies to much of SSA, including Mozambique
114 where considerable attention has been given to research on CA systems in recent years
115 (Nkala et al., 2011; Nkala, 2012; Famba et al., 2011; Grabowski and Kerr, 2014; Thierfelder
116 et al., 2015; Nyagumbo et al., 2015; Thierfelder et al., 2016). Most of these studies have
117 focused on-farm level experiments whilst some have focused on farm-level economics
118 (Grabowski and Kerr, 2014). These have not addressed risk analysis or on-farm level
119 economic analysis through large scale household surveys. Moreover, specific research
120 relating to CA in Cabo Delgado (Northern Mozambique where this study is based) on farm-
121 level economics is limited and/or has not been documented through peer-reviewed research to
122 date.

123 In this study we use elements of the economic model framework presented by Pannell et al.,
124 (2014) to address some of the key concerns raised in the literature. Similar research has also
125 been reported in this journal which also explored the economics of Conservation Agriculture,

126 including using certainty equivalents and considering risk, but did not consider different
127 wealth categories (Tessema et al., 2015). The aim of this study is to better help understand
128 whether CA provides an attractive option for the farmers within this case-study region when
129 all known economic considerations are addressed. Given research, extension and
130 development efforts in general are also focussed throughout the region on reaching the
131 poorest, we also use this cohort to explore farmers' net returns under various risk levels and
132 crop mixes used. The description of the model and approach is presented in Section 2 and the
133 model and results in Section 3. Section 4 provides discussion and conclusions to the paper.

134

135 *1.1 Background of study area*

136 Cabo Delgado is the northernmost province situated among the coastal plain in Mozambique.
137 The majority of inhabitants, within the province rely on subsistence agriculture (mainly
138 rainfed agriculture). Conventional agriculture practices (including slash and burn) are still
139 pervasive and mainly done through ploughing by hand-hoe or animal traction.

140

141 Mozambique consists of ten different agro-ecological regions (R1-10). These have been
142 grouped into three different categories which are based in large part on mean annual rainfall
143 and evapotranspiration (ETP). First, the highland category represents high rainfall regions
144 (>1000mm, mean annual rainfall) with low evapotranspiration and correspond to R3, R9 and
145 R10. The medium altitude category in contrast (R7, R4) corresponds to areas with mean
146 annual rainfall ranging between 900-1500mm and medium level of ETP. Finally, the low
147 altitude category (R1, R2, R3, R5, R6, R7, R8) are hot with comparatively low rainfall
148 (<1000mm mean annual rainfall) and high ETP (INIA, 1980; Silici et al., 2015). The Cabo
149 Delgado province falls within R7, R8, and R9. The particular district under study (Pemba-
150 Metuge) is situated within R8; distribution of rainfall is often variable with many dry spells

151 and frequent heavy downpours. The predominant soil type in R8 is Alfisols (Maria and Yost,
152 2006). These consist of soils with predominantly red clay texture which are deficient in
153 nitrogen and phosphorous (Soil Survey Staff, 2010).

154

155 A recent study using the human development poverty index ranks Cabo Delgado as the
156 second poorest province in Mozambique (INE, 2012). The province also has one of the
157 highest rates of stunting in the country (Fox et al., 2005). Other issues such as the high
158 population growth rate in Mozambique further exacerbate the poverty nexus. Within the
159 study district (Pemba-Metuge), current projections show that the population will more than
160 double by 2040 (INE, 2013).

161

162 *1.1.1 Conservation Agriculture in Cabo Delgado*

163 CA adoption in recent years has been stimulated in the province largely with the support of
164 the AKF-CRSP (Aga Khan Foundation Coastal Rural Support Programme), which has been
165 promoting CA in the province since 2008. AKF's approach has differed to other NGOs in the
166 region as provision of incentives such as vouchers/subsidies or inputs such as herbicides,
167 chemical fertilisers and seeds in order to stimulate adoption have not been provided. Farmer
168 Field Schools have been established within each of the districts and helped to encourage
169 adoption of CA among farming households. Given the lack of draft and mechanical power in
170 Cabo Delgado, manual systems of CA have been promoted such as the use of a dibble stick
171 which is a pointed stick used to open small holes in crop residues for planting seed. Micro-
172 pits are often also used in the early years of CA to break soil compaction and are the most
173 commonly used system in the region. These are similar to basins used elsewhere in Sub-
174 Saharan Africa and originate from the Zai pit system used in the Sahel (e.g. Thierfelder et al.,
175 2016). These. AKF- CRSP has promoted the use of micro pits (35cm long x 15cm wide x

176 15cm deep). It should be noted that these differ to some forms of conservation farming
177 systems used in Zambia and Zimbabwe that require regular soil-tillage inside the basins i.e.
178 minimum tillage systems where tilling is done inside the basins using discs or tines in order
179 to create a seedbed (e.g. Kassam and Brammer, 2016). Finally, the use of jab planters have
180 also recently been promoted in the region.

181

182 **2. Materials and Methods**

183

184 *2.1 Survey procedure*

185 This study is based on results from a survey of 197 farmers in the Metuge district, of Cabo
186 Delgado Province Mozambique administered in the summer of 2014. A multi-stage sampling
187 frame was employed to select the households from a list of local farmers provided by key
188 informants in each of the villages. From the thirteen total clusters (i.e. in this case villages
189 which were chosen based on whether the Aga Khan Foundation had initiated CA activities in
190 the respective villages) six communities were then chosen at random from this list and
191 households were subsequently selected randomly from the lists generated by key informants
192 in these villages using probability proportional to size (PPS sampling) (e.g. Turner, 2003).
193 Focus group discussions were also held with farmers in the study region to understand
194 perceptions among users and non-users.

195

196 *2.1.1 Variables and measurement*

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

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

205

206 Detailed farm budget data has been gathered which represents the whole farm i.e. all crops
207 grown (including seeding rate), size of cultivated area (and total land size), type of seed used,
208 the amount, if any, of inputs used e.g. manure, fertiliser/herbicides or compost and total
209 labour used (hired and family) during the cropping season measured in person hours i.e.
210 number of persons used multiplied by numbers of hours worked in a typical day for the task
211 multiplied by total number of days the task took.. The wet conditions may, however, have
212 differing effects for CA relative to conventional tillage. Yield is calculated by dividing
213 reported production by reported area for each crop. The area reported is also expressed in
214 hectares as this reflects the most familiar unit known to farmers. The aid of locally used
215 metrics of measurement e.g. baskets and buckets of different sizes have been used. A sample
216 of buckets and baskets, typically used by farmers, have been weighed for specific crops in
217 order to maintain consistency with appropriate conversion into kilograms, although we
218 acknowledge the limitations of this approach and of using reported area and production. The
219 Cabo Delgado region also experienced some flooding in mid-2014 which may provide a
220 further limitation particularly with estimating yields.

221

222 ***2.2 Adoption of Conservation Agriculture defined***

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

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

230 Partial CA practices are defined using the following criteria:

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

233 Conventional agriculture or No CA (as referred to in figures due to space requirements) users
234 are farmers practicing conventional tillage agriculture with the use of hand-hoe. They may,
235 however, be practicing intercropping and/or rotation, and growing up to three crops during
236 the season.

237

238 ***2.3 Model description and key assumptions***

239 Probabilistic cash flow analysis was used to create a stochastic model for net returns
240 (Richardson and Mapp, 1976). In our analysis the two most common crop mixes used by the
241 farmers surveyed have been used i.e. one model comparing CA and conventional for farmers
242 using the maize (*Zea mays* L.), cowpea (*Vigna unguiculata* L.) Walp) and cassava mix and
243 the other for farmers using the maize, cowpea, and sesame (*Sesamum indicum* L.) mix. We
244 have not simulated those using partial CA practices i.e. two crops or CA users using four
245 crops given the small numbers of observations for both. Thus our analysis is restricted to
246 comparing CA users (using the full package) i.e. three crops relative to conventional
247 agriculture users i.e. those using tillage with hand-hoe and not retaining crop residues as
248 mulch.

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

260 As outlined above the stochastic model for net returns developed was validated by comparing
 261 the stochastic means for each year of CA and conventional with their historic means using
 262 Student t-tests set at alpha 0.05. Each failed to reject the null hypothesis which signalled that
 263 the stochastic net returns assumed their original means and variability. The Box-M test has
 264 been used to test if the simulated data have a covariance that is statistically significantly equal
 265 to the historical covariance matrix. This also failed to reject the null hypothesis which
 266 signalled both were the same. Secondly, we calculate the Net Present Value (NPV), a widely
 267 used financial criterion, used in previous studies on the same topic (Pannell *et al.*, 2014;
 268 Knowler & Bradshaw, 2007; FAO, 2001). The NPV determines the present value of net
 269 benefits by discounting the benefits (B) and costs (C), that arise between the present and
 270 future time periods (T). The subscripts (t) denote a specific time period i.e. year and the
 271 discount rate is referred to as (r).

$$272 \quad NPV = \sum_{t=1}^T \frac{B_t - C_t}{(1+r)^t} \quad (1)$$

273 The NPV for the particular duration considered is thus calculated (based on random
 274 selections from the PDFs for the various years) through Monte-Carlo simulation (500
 275 iterations) using an excel Add-in Simetar©. We do not consider there to be any prior
 276 investment outlays for CA. Net returns (NR) are calculated by yield per hectare multiplied by
 277 price ($y \times p$) for all crops in the specific mix less full labour costs (hired and family) per
 278 hectare (l) and opportunity cost of mulch(m) per hectare (i.e. if applicable).

$$279 \quad NR = (y \times p) - (l + m) \quad (2)$$

280 These are presented in United States Dollars (USD) for ease of international/regional
 281 comparisons.¹ The model uses observations of farmers' in each year of CA use and therefore
 282 does not assume reductions in yield in the short-term or an increase in yield under CA after a
 283 10 year period as do Pannell et al. (2014). We do however, take the third year users' of CA as
 284 the most likely going forward i.e. we use the PDF for the third year to calculate the fourth
 285 year onwards given much of the CA literature states that benefits are found after the third
 286 year and yields are variable in the first few seasons (Thierfelder et al., 2014b).

287 Base case scenarios are presented under a 20% discount rate and use output prices at harvest
 288 reported by farmers and checked by key informant interviews. Furthermore, to account for
 289 farmers' different planning horizons NPV's are presented covering 3, 5 and 10 years.
 290 Sensitivity analysis is often used in order to examine the role of alterations to key parameters
 291 involved in the farm enterprise (Pannell, 1997). Pannell (1997) asserts that to be done
 292 effectively scenarios should be presented for each altered parameter individually. Moreover,
 293 high and low or maximum and minimum should be set for the altering of parameters or 'with'
 294 or 'without' a constraint that may bias the decision maker. Thus, a sensitivity analysis is also
 295 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.

296 30% respectively and for ‘with’ and ‘without’ labour scenarios given this is the primary cost
297 to farmers. These are similar discount rates to those used by Pannell et al. (2014) given that
298 the author also expressed concern over studies that have not used high discount rates.
299 Different prices for maize and labour which typified high and low prices were also used in
300 the sensitivity analysis. For the other crops i.e. cowpea, cassava and sesame we did not find
301 much variation in the prices thus we solve the model for a scenario with higher prices i.e.
302 assuming a 50% increase in price for these crops.

303 Crop grain to residue ratio using a 1:1 grain to residue ratio for maize and sesame and 1:1.35
304 for legumes i.e. cowpea and cassava foliage is used to calculate the opportunity cost of mulch
305 as feed. A detailed breakdown of the key assumptions and base case scenarios are presented
306 in Appendix A. ² A ‘shadow’ price for mulch is also constructed similar to the method used
307 by Thierfelder et al. (2016). This provided similar estimations to the costs from the grain to
308 residue ratio method thus we have retained the use of this method in our analysis.

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

313 ***2.4 Data analysis***

314 Data were analysed in SPSS version 21. Principal component analysis (PCA) was conducted
315 in order to establish a wealth index. A common method in a number of poverty studies is the
316 first principal component (PC1) which explained the majority of variance in the data is then
317 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.

318 to the level of wealth, taking three values referring to lower, middle and upper terciles.
319 Disaggregating by wealth using this method allowed for a comparison to be made for
320 households of similar level of resources including land and household size. Farmers' net
321 returns for those in the poorest tercile using the same crop mix were simulated using 500
322 iterations using the multivariate kernel density estimate (MVKDE) Parzen distribution which
323 provides the best solution for the use of sparse data (Lien et al, 2009; Richardson, 2006). The
324 net returns accounted for opportunity cost of mulch and full labour costs i.e. hired and family
325 labour.

326 A number of tools have been used to analyse risk. The first is Stochastic Efficiency with
327 respect to a function (SERF) which identifies and ranks certainty equivalents with respect to a
328 range of risk preferences (Hardaker et al., 2004). It has been argued as a more 'transparent'
329 method (allowing graphing of a number of risky alternatives simultaneously) compared to
330 pairwise rankings such as stochastic dominance (ibid). Certainty equivalents reflect the
331 amount of money where the decision maker is indifferent between the risky alternative and a
332 certain amount. This tool assumes a negative exponential utility function similar to Pendell et
333 al. (2007) and Fathelrahman et al. (2011) which are also the most common form used in
334 expected utility (Richardson, 2006). Furthermore, the SERF tool also accounts for risk and
335 uncertainty (i.e. absence of perfect knowledge or the decision maker having incomplete
336 information) together in its calculation of certainty equivalents.

337 Secondly, Stoplight probability charts are employed which do not require knowing the exact
338 risk preference of the decision maker and instead provides target probabilities for different
339 risky alternatives. It calculates the probability for instance of scenarios falling below a lower
340 target, exceeding an upper target and/or those falling between the lower and upper target
341 specified. Similar tools with the use of Simetar© have been used by other authors which
342 have explored the net returns of CA and conventional under different risk levels for farmers

343 in Malawi (Ngwira et al., 2013). The advantage of using the Stoplight chart for ranking risky
 344 alternatives is that enables the decision maker to specify their lower and upper targets (e.g.
 345 net returns) and then let them decide which scenario is best using a simple graphic. There is
 346 therefore no need to specify a specific risk aversion coefficient/utility function which
 347 ultimately simplifies analysis and allows the decision makers to approach decisions according
 348 to the specific context and ‘problem at hand’ (Richardson and Outlaw, 2008).

349

350 **3. Results**

351 *3.1 Summary statistics*

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

357

358

359

360 **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%

361 Source: Adapted from Lalani et al., (2016)

363 The majority of CA farmers use a three crop sequence during the growing season i.e. maize-
364 cowpea and cassava and maize-cowpea and sesame being the most common. Likewise, for
365 conventional farmers these are the most common three-way sequences.³ Conventional
366 farmers also just cultivate two crops such as maize and cassava in the growing season.
367 Although, the most common four-way crop mixes used by CA users are maize-cowpea-
368 pigeonpea (*Cajanus cajan* (L.) Millsp.) cassava (*Manihot esculenta* (L.) Crantz.) or maize-
369 cowpea-cassava-sesame, the survey results also showed that farmers were invariably using
370 the local varieties of crops (not ‘improved’ purchased hybrids) and/or were also not using
371 external inputs such as fertilisers, herbicides, pesticides, composts and/or manure.

372 **3.2 Economic model**

373 Net present values calculated from the stochastic model are shown for three planning
374 horizons for the maize cowpea and cassava crop mix under CA and conventional (Table 2
375 and 3). The base case assumptions assume crop prices at harvest and the most common wage
376 rate in the district (See Table A.1 in Appendix A).

377

378 Though neither of the options i.e. CA or conventional would be considered a profitable
379 endeavour when labour is costed i.e. NPV greater than zero, the NPV which is least negative
380 between the two would still be the preferred option. It shows that for the majority of
381 scenarios CA is preferred relative to conventional over the short and longer term, but less
382 preferred in the long run under the scenario of higher maize prices and high labour costs after
383 10 years.⁴ If one uses three years as the yardstick of the majority of resource-poor farmers’
384 planning horizons CA would be preferred. Interestingly, under a zero labour cost scenario CA

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.

385 is still preferred over the short and longer term thus indicating that yield gains rather than
 386 yield dips in the first few seasons are possible with this crop mix.⁵

387

388 Moreover, to account for risk and uncertainty, certainty equivalents (not shown) were
 389 calculated using the Stochastic efficiency with respect to a function (SERF) tool in Simetar©.

390 The SERF ranks certainty equivalents relative to a range of risk tolerance levels from risk
 391 neutral to extremely risk averse. Thus zero is defined as risk neutral or the LRAC (lower risk
 392 aversion coefficient) and the URAC (upper risk aversion coefficient) is calculated using the
 393 formula of $4/\text{average wealth of the decision maker}$ (Hardaker et al., 2004; Richardson, 2006).

394 This formula was used in the first instance but did not provide appropriate looking certainty
 395 equivalent lines as the SERF lines became asymptotic to the X axis. An expert in simulation
 396 suggested using 0.00001 as the URAC equated with an extremely risk averse farmer based on
 397 the type of net returns under analysis and thus provided relatively flat CE lines and ensured
 398 the SERF lines did not become asymptotic to the X-axis (J. Richardson, personal
 399 communication). Thus, where shaded both risk neutral and extremely risk averse farmers'
 400 would find CA the preferred option. Likewise (where unshaded) and where conventional has
 401 the advantage it also had higher certainty equivalents under the same risk tolerance levels.

402

403

404 **Table 2 Net present value per hectare for CA and Conventional maize-cowpea and**
 405 **cassava mix for three different planning horizons using base case assumptions and**
 406 **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

407

408

409

410 **Table 3 Net present value per hectare for CA and Conventional maize-cowpea-cassava**411 **mix for three different planning horizons using base case assumptions with a 30%**412 **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

413

414 Net present values show that for farmers using the maize-cowpea-sesame mix conventional
415 agriculture would be preferred over the short and longer term planning horizons (Table 4 and
416 5). However, for farmers' with a high opportunity cost of labour CA especially under higher
417 discount rates i.e. CA would be preferred over the short to medium term (Table 5). In this
418 context where there is little off-farm income the high opportunity cost refers to the value of
419 time for alternative means. Whist CA is certainly not exclusive to the poor, there is wide
420 ranging literature on 'time use poverty' which is also referred to as 'household overhead'
421 especially in relation to Sub-Saharan Africa (Blackden and Wodon, 2008). Thus, it must be
422 noted that although there are few viable alternative economic opportunities (e.g. in this
423 district under study) the cost of time in the local context can be higher for certain households.
424 For example, women in particular are seen to have a higher opportunity cost of time than men
425 and may have to devote time to farm labour and other important activities within the

426 household such as having to look after children or perform other activities like fetching
427 water/firewood and caring for the sick etc. (ibid). Thus, farm practices which reduce the
428 amount of time needed for farm- labour may be attractive.

429

430 This does also raise an important question as to the sustainability of agriculture in these areas
431 particularly when many of the mixes lead to a negative NPV for instance. Although this is
432 associated to some extent with how labour (family labour in particular) is costed as
433 mentioned above there is also the issue of whether agriculture is a viable route out of poverty.
434 Harris and Orr (2014) argue in their study of crop production interventions that smallholders
435 in SSA are inhibited by small farm size and that due to limited access to markets and low
436 production levels net returns are not high enough to lift themselves out of poverty (unless
437 farm size can be expanded), however, the direct benefit is likely to be in the form of
438 improved household food security. Of course this begs the question of whether farm land can
439 be expanded without encroaching on non-agricultural land etc. but it does highlight the
440 benefits of such interventions to household food security and the need to experiment with
441 crop mixes that are likely to be most beneficial in enabling a move out of poverty. It should
442 also be noted that Harris and Orr's study did not include livestock or irrigated crops, and was
443 mainly limited to comparing net returns based on monetised values only. This may overlook
444 some potential benefits of increased production on households e.g. the knock on effects of
445 increased food security on nutrition and health; and the ability of some households to spend
446 less time during 'hungry' periods of the season working for other farmers, and therefore
447 having the scope to invest more labour in their own agricultural and non agricultural
448 livelihood activities.

449

450

451 **Table 4 Net present value per hectare for CA and Conventional maize-cowpea-sesame**
 452 **mix for three different planning horizons using base case assumptions and altered**
 453 **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

454

455

456

457 **Table 5 Net present value per hectare for CA and Conventional Maize-cowpea-sesame**
 458 **mix for three different planning horizons using base case assumptions with a 30%**
 459 **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

460

461 *3.3 A case study of the poorest*

462 Whilst the economic model presented is helpful in providing insight particularly with regards
463 to the early years under CA for different mixes it is unable to compare households of similar
464 resource-levels e.g. land size and household size. To account for this farmers' were grouped
465 into different wealth terciles using PCA. The descriptive statistics for the poorest group are
466 presented in Table 6. Within the poorest tercile CA households seem to be poorer (i.e. have
467 slightly larger household size, older household head etc.) than Non-CA households which
468 signals that adoption of CA is more likely among poorer households. This is triangulated by
469 the household poverty score which used similar questions to those of the household poverty
470 score card developed for Mozambique by Schreiner et al. (2013) to better categorise farmers
471 based on poverty level. These, for example, include questions on type of housing, specific
472 household assets etc. Thus, both conventional and CA farmers within this tercile are likely to
473 be in 'extreme poverty' according to this metric. Furthermore, farmers within this tercile

474 used family labour only (with no hired labour) and had virtually no off-farm income (Table
475 6).

476

477

478 **Table 6 Characteristics (means) of CA and conventional farmers for poorest wealth**
479 **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)

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

482

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

486

487 **Table 7 Total person hours used per hectare by task for CA and conventional for**
488 **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

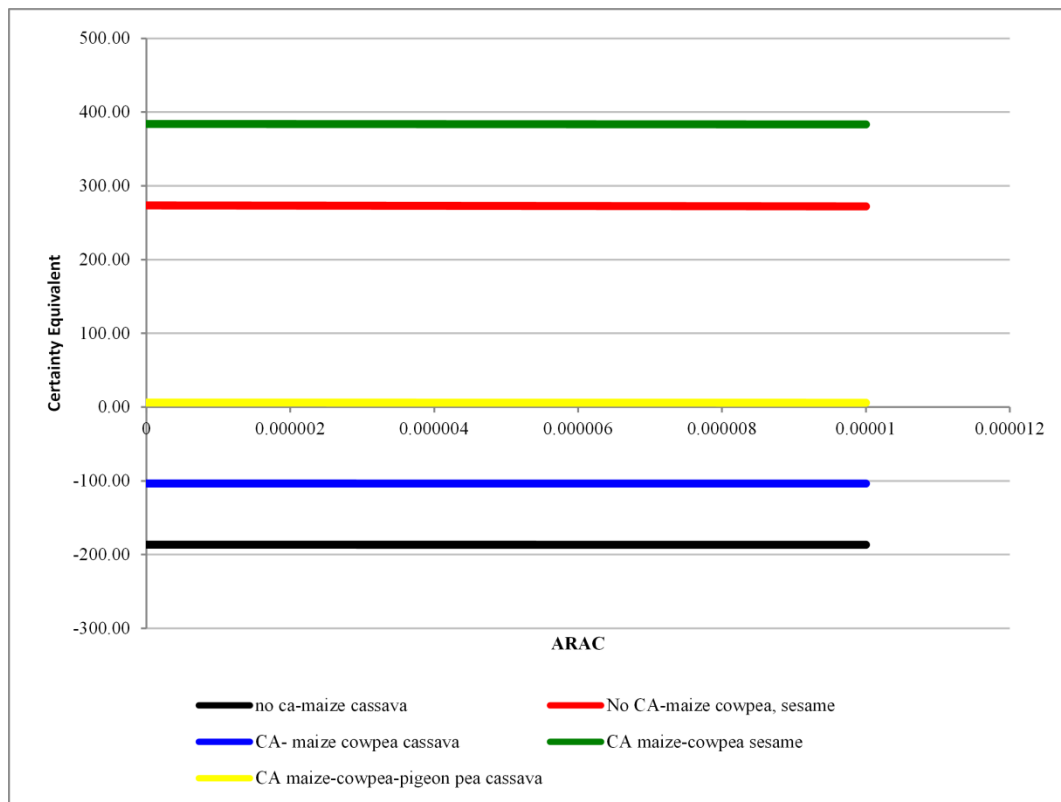
489 *significantly different between CA and conventional ($p < 0.10$)

490

491 **3. 4 Risk simulation analysis**

492 To examine under what circumstances CA is likely to be an attractive option for these
 493 farmers it is important to be able to compare farmers' actual net returns under the same crop
 494 mixes used and in accordance with different attitudes to risk and uncertainty as outlined
 495 earlier. Figure 1 shows the certainty equivalents (CE's) for the most frequent crop mixes used
 496 by the poorest farmers. The Absolute Risk Aversion coefficient (ARAC) shows a range of
 497 risk tolerance levels from risk neutral to extremely risk averse i.e. zero denotes risk neutral
 498 and 0.00001 extremely risk averse. It shows that over a range of risk aversion coefficients the
 499 CE's remain fairly constant as risk aversion increases. Thus farmers would have a higher CE
 500 under the maize-cowpea-sesame mix and would also prefer other crop mixes relative to the
 501 conventional maize-cassava mix being used. For example, both a risk neutral farmer and an
 502 extremely risk averse farmer using the CA four crop cassava mix would need to receive
 503 approximately a payment of 100 USD to be indifferent between the three crop cassava mix
 504 under CA and would further need to receive approximately 200 USD to be indifferent from

505 the conventional maize-cassava mix. For the maize-cowpea-sesame mix a risk neutral and
 506 risk averse farmer would need to receive a payment of roughly 100 USD to be indifferent
 507 between the higher ranked CA maize-cowpea sesame and conventional maize-cowpea
 508 sesame.



509

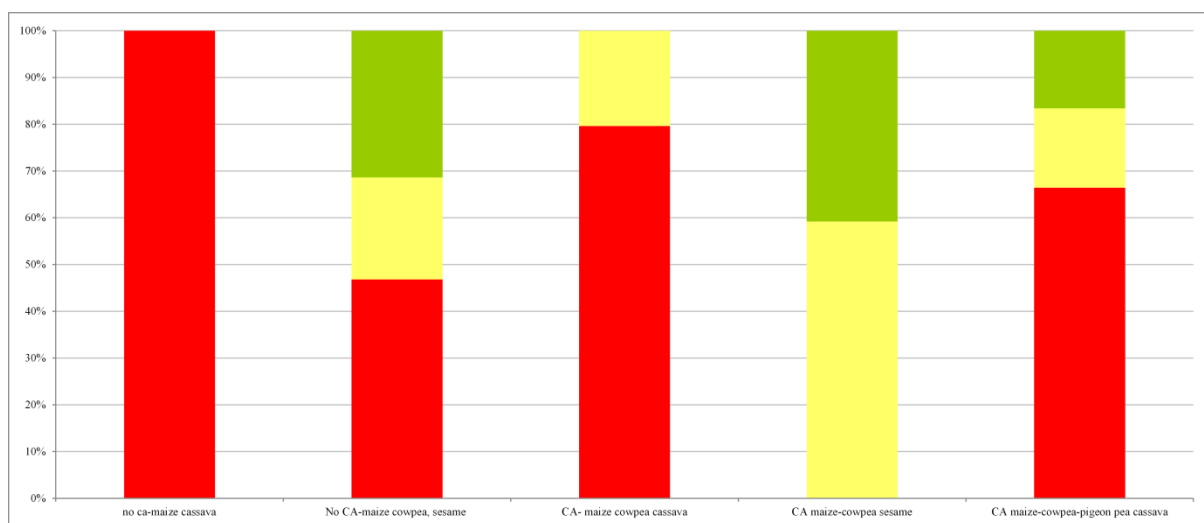
510 **Figure 1 Certainty equivalents (CE's) in USD for the most frequent crop mixes used by**
 511 **the poorest farmers under different risk tolerance levels**

512 Similarly, Figure 2 shows probability of breakeven and target net return which in this case is
 513 the mean net return of all crop mixes plus one standard deviation. Green shows the
 514 probability of net income above the threshold of 353 USD (i.e. mean net income plus one
 515 standard deviation) and cautionary (light yellow) between 0 and the threshold of 353 USD.
 516 Red signals probability of a negative net income i.e. lower than 0 i.e. breakeven. In general,
 517 risk-averse farmers would prefer the outcome with the least red and most green (Richardson
 518 and Outlaw, 2007). However, the risk neutral to slightly risk averse farmer would prefer the

519 outcome with the most green (ibid). Thus the CA maize-cowpea-sesame mix provides the
 520 highest probability of net returns above the threshold of 353 USD and the least probability of
 521 a red outcome i.e. below the minimum threshold of breakeven. For example, farmers using
 522 the maize, cowpea and sesame mix would have a probability of 41% of achieving a net
 523 income higher than 353 USD and 59% for a net income between 0 and 353 USD. It would
 524 thus provide the best bet to breakeven for farmers. Interestingly, the least favoured mix would
 525 be the conventional maize-cassava mix which is unlikely to breakeven and almost certainly
 526 has net returns lower than breakeven.

527

528



529

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

533

534 **4. Discussion**

535 This study has investigated, using an economic model and risk analysis to what extent CA
536 relative to conventional agriculture (within the case study district of Metuge) is economically
537 viable. Whilst acknowledging there are limitations to our approach (e.g. small sample size for
538 certain crop mix simulations and cross-sectional data gathered for one season as opposed to
539 panel data over several seasons) the study is strengthened by having observations of farmers
540 using CA in each year of use i.e. first year, second year and third year. The economic model
541 finds evidence that under higher discount rates CA can be an attractive option relative to
542 conventional under a number of scenarios and, depending on crop mix, can even provide
543 yield benefits relative to conventional agriculture over the short and longer term. Equally, CA
544 may have lower yields than conventional agriculture users for other crop mixes. However,
545 CA may have the advantage for farmers with a higher opportunity cost of labour. Baudron et
546 al., (2016) similarly showed that reduction in labour is a major entry point for CA systems.

547

548 Thus, some conclusions seem plausible. Firstly, the different mixes used by farmers in this
549 study provide some indication that farmers may also have differing motivations when
550 approaching the use of CA e.g. primarily for yield but also for labour maximisation if they
551 are subsistence based (producing solely for consumption) which may be the case for cassava
552 based crop mixes, and labour maximisation if otherwise e.g. for those with a higher
553 opportunity cost of labour where farmers are likely to rely to a greater degree on purchasing
554 additional food to meet their household requirements.⁶

555

556 For example, those using the sesame mix invariably sold the sesame produced given its high
557 level of return whereas farmers using the various cassava mixes consumed all of their
558 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.

559 Appendix B) of the poorest farmers using the sesame mix, conventional farmers (i.e.
560 conventional) actually have the highest probability of achieving the highest net returns (i.e.
561 above 1000 USD MZN) relative to CA farmers using the same mix (See Figure B.2 in
562 Appendix B). It is thus the reduction in labour for this mix for CA farmers, which likely
563 provides the more stable distribution of net returns relative to conventional rather than higher
564 yields per se. This may also be the case for farmers using the four-way crop mixes (among
565 the poorest tercile) as opposed to two or three crops under conventional, as the labour
566 reduction, particularly during land preparation time under CA extends the cropping cycle,
567 essentially increasing the intensity of cropping which allows more crops to be grown in the
568 season and improves the overall economic returns (FAO, 2001). Thierfelder et al. (2016) has
569 also noted that CA will be attractive for poor farmers if there is focus on ‘energy efficient
570 cropping systems’ which provide benefits to both labour and returns for farmers.

571

572 Secondly, this study also supports the notion that CA can be a viable option for farmers
573 without the use of high inputs including labour, the need for new cultivars or use of
574 herbicides and fertilisers. Survey results, for instance, point to a reduction in weeding time
575 without the need for herbicides. This is in sharp contrast to previous research which suggests
576 that weeding time is likely to increase under CA without the use of herbicides (Giller et al.,
577 2009). The results are in line with those of Thierfelder et al. (2013) which suggest that hand
578 weeding is also an effective way to combat weeds without the need of herbicides. Thirdly,
579 CA is being used by and deemed to be an attractive option (based on farmers’ actual net
580 returns) for the poorest farmers for a variety of crop mixes and risk tolerance levels including
581 under extreme risk and uncertainty. This is contrary to previous farm-level economic analysis
582 which suggests that farming households with smaller plots of land are unlikely to find CA
583 (i.e. the full package) attractive (Pannell., et al 2014). The results do, however, support

584 findings elsewhere in Mozambique which suggests on smaller plots of land higher yields with
585 CA practices can be realised relative to conventional agriculture (Grabowski and Kerr, 2014).
586 Though the economic analysis did not account for the opportunity cost of mulch and only one
587 crop was used rather than at least 3 under CA by definition. Similarly, other on-farm
588 experimental studies such as by Thierfelder et al. (2013) have also illustrated that on small
589 plots of land all three principles of CA can be employed without fertiliser or herbicides being
590 used and can be beneficial for farmers.

591

592 Furthermore, the majority of households in this study are using micro-pits similar to basins
593 used elsewhere in Mozambique and Sub-Saharan Africa. An economic comparison of CA
594 under different CA systems (as would comparison with partial CA practices being practiced
595 in this study i.e. 2 crops) would also have been helpful in this regard. The site specific
596 attraction that some CA systems have may explain the higher rate of adoption of micro-pits in
597 this district (e.g. micro-pits are more commonly used in this district which is drier than other
598 regions in Mozambique and is thus likely to be more attractive than in wetter areas).
599 Qualitative information gathered from focus group discussions with farmers in the study also
600 suggested that in some areas of the study district, micro-pits were considered less favourable
601 among farmers because of waterlogging.⁷ For instance, research on CA elsewhere in
602 Southern Africa has shown high levels of water infiltration and soil moisture for crops which
603 is particularly beneficial during seasonal dry spells, however, waterlogging and nutrient
604 leaching may occur due to increased water infiltration which has a negative impact on plant
605 growth in particularly wet years (Thierfelder and Wall, 2009). Thus, it should be noted that
606 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.

607 (Mafongoya et al., 2016) whilst direct seeding is considered more attractive both in terms of
608 productivity and labour reduction in wetter regions (Thierfelder et al., 2016).

609

610 The study findings are also supported by other analysis of farmers' perceptions (i.e. for the
611 same cohort of farmers in this study) which uses a socio-psychological model to assess
612 farmers' intention to use CA (Lalani et al., 2016). Lalani et al. (2016) show through
613 regression estimates that farmers' attitude is the strongest driver of intention to use CA which
614 is mediated through key cognitive drivers such as increased yields, reduction in labour,
615 improvement in soil quality and reduction in weeds. Yield was found to be the strongest
616 driver to use CA followed by reduction in labour, improvement in soil quality and reduction
617 in weeds. Interestingly, the poorest farmers had the highest intention to use CA and found CA
618 the easiest to use compared to better-off farmers ($p < 0.05$). Of course farmers perceptions be
619 they through measurements based on farmer recall or a study of their motivations may not
620 align with experimental research findings. They do, however, provide an important indication
621 into the adoption process and thus allow an understanding of what farmers perceive to be
622 beneficial in their own contexts.

623 **5. Conclusion**

624 It is clear from this study that farmers can find CA attractive with the resources they have e.g.
625 local variety of seed, family labour and no external inputs. Thus the potential for CA to be of
626 benefit to the poorest in particular i.e. those with very small plots of land in similar
627 circumstances and farming systems should not be discounted. Nonetheless many farms would
628 benefit from support in terms of reducing the risk and uncertainty of using a 'new'
629 management system such as CA. The wide ranging support from NGOs in this regard (e.g.
630 Farmer Field Schools (FFS) and other support mechanisms to enhance farmer to farmer
631 exchange such as seed multiplication groups or associations) can reduce 'uncertainty' as

632 farmers learn about and observe what others are doing. Moreover, it has also been suggested
633 that certain factors which are most likely to have the strongest impact on reducing uncertainty
634 such as the reduction in labour associated with no-till should be the focus of extension
635 approaches related to CA (Pannell et al., 2014). Thus, social learning mechanisms play an
636 important role in this regard. Interestingly, FFS members found CA the easiest to use and had
637 stronger beliefs regarding the benefits of CA i.e. increased yields, reduction in labour etc.
638 (Lalani et al., 2016). Ward et al. (2016) recently suggested that rather than subsidies and
639 voucher programs being used as an incentive; ‘tailouring training and knowledge programs’
640 in relation to risk farmers face will be important in addressing adoption of CA.

641

642 In this regard, further research which combines farmers’ motivations and their risk
643 management strategies with more conventional economic/risk analysis would help to identify
644 different crop mixes/sequences for different conditions. Thus, there are likely to be cases
645 where conventional-tillage systems have short-term benefits which are more attractive
646 economically and factors such as soil erosion may have a bearing on long-term productivity
647 and economic returns which therefore favor CA or CA practices being used in the long run.
648 (Stonehouse, 1991; Fatherlrahman et al., 2011). Moreover, future research may also consider
649 the wider implications to society at large of different systems being used. For example, the
650 possibility that other benefits to society may not be quantified such as the potential of CA use
651 to increase carbon sequestration or reduce soil erosion which may improve water quality and
652 thus could warrant incentives (e.g. payments for ecosystem services) being provided to
653 farmers if the cumulative benefits to society are higher than conventional tillage systems and
654 where economic returns particularly in the short-term may be lower than conventional
655 systems (Ngwira et al., 2013).

656

657 **Acknowledgements**

658 The authors wish to thank the Aga Khan Foundation (Mozambique) for funding the
659 household survey component of this study. Our sincere thanks to Ms Faiza Janmohamed
660 (former Chief Executive Officer of Aga Khan Foundation, Mozambique), Professor Amir
661 Kassam and Jose Dambiro for their support in facilitating the completion of this study. We
662 are also extremely grateful to Professor James Richardson (Texas A&M University) for his
663 advice on conducting simulations using Simetar©.

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