Title: Adoption intensity of conservation agriculture in the Masvingo district of Zimbabwe

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Abstract

Conservation agriculture (CA) has been promoted among smallholders in Zimbabwe as a way of addressing the challenges associated with poor soil fertility, low yields, and insufficient rainwater. The technique was introduced to smallholders as a hand-hoe based technology where farmers had to prepare planting basins during the dry season, retain at least 30% soil cover, and rotate crops. The expected benefits for adopters include improved and more stable crop yields, and higher returns to inputs used in farming. Despite its claimed advantages, smallholder adoption rates of CA have remained low. Previous research has not fully explored the factors that explain low uptake, nor has it developed measures that take into account its incomplete adoption. This study investigates factors influencing the use of CA and the intensity of its uptake amongst 237 smallholders sampled in the Masvingo district of Zimbabwe. The intensity of uptake was measured using an index that accounted for the number of CA components used, and the rate and extent of their application. The determinants of use and intensity were identified using a double hurdle model. Although most smallholders implemented the reduced tillage component of CA, only a few implemented all the three components. The participation of females in decision making, experience with CA technology, and farm size all had a positive impact on current use of CA. Distance from town and ownership of an ox-drawn plough impacted negatively on the intensity of its uptake.

Key words: Conservation agriculture, smallholders, adoption, food security

1 Introduction

Conservation agriculture (CA) has been promoted in many parts of Southern Africa as a means of addressing land degradation and other crop production challenges faced by smallholders (Andersson & D'Souza, 2014; Knowler & Bradshaw, 2007; Mazvimavi, 2011). Significant investment and resources have been channelled towards supporting and upscaling CA technology among smallholders in developing countries (Ndlovu, Mazvimavi, An, & Murendo, 2014). The technology and practices associated with CA have been interpreted and defined differently in different contexts. For this study, we refer to CA as a farming technique that is based on the integrated management of soil, water and biological resources through: i) minimum disturbance of soil (limited or no till), ii) permanent soil cover (usually using crop residues), and iii) crop rotation (Giller, Witter, Corbeels, & Tittonell, 2009).

Empirical studies have shown that the impact of CA on smallholders has been undermined by low adoption rates, and findings on the reasons for low adoption are mixed (Andersson & D'Souza, 2014). Kassam, Derpsch, and Friedrich (2014) estimate percentages of cropland under no-till to be approximately 69%, 57% and 15% for Oceania (Australia and New Zealand), South America and North America respectively. In Africa, the authors report an estimate of 0.3% of arable land under no-till. Most empirical studies of CA adoption measured the uptake and practice of CA as a binary variable, assuming CA to be an indivisible technology. However, in reality small farmers often apply only one or two of the three principles (Giller et al., 2009; Mazvimavi & Twomlow, 2009; Pannell, Llewellyn, & Corbeels, 2014). The selection and uptake of specific CA components, and their intensity, differs among individuals.

Farmers choose components of CA according to their perceptions of feasibility, cost and benefits given external factors like the institutional and natural environment. In some areas it is relatively easy to apply certain components but difficult to implement others (Giller et al., 2009; Pannell et al., 2014). For example, farmers in Zambia were found to use relatively less mulch and crop rotation (Arslan, McCarthy, Lipper, Asfaw, & Cattaneo, 2014). Similar findings were reported in Zimbabwe (Pedzisa, Rugube, Winter-Nelson, Baylis, & Mazvimavi, 2015a). Studies that rely on just one component, (e.g. minimum disturbance / basin digging) to measure the uptake of CA ignore the reasons why farmers do not adopt the other components, or why some components may be sub-optimally applied. Gershon, Just and Zilberman (1985) emphasise the importance of developing measures that account for different levels of uptake.

Given that there are inconclusive findings on adoption levels and that findings on factors influencing uptake are mixed, the goal of this study is to generate information that will help decision-makers to assess the value of promoting CA amongst smallholders in Zimbabwe. Most empirical studies on the uptake of CA by smallholders have focused on factors affecting adoption. Very little work has been done on factors that influence levels of use. This research has three main objectives. The first objective is to construct an index that captures the degree and extent of specific CA techniques applied by smallholders. The second objective is to identify factors (including exposure to CA support) that influence adoption of specific CA components in a sample of Zimbabwean smallholders. The third objective is to investigate factors that explain the level of CA uptake as measured by the index scores computed for sampled households using a double-hurdle adoption model.

2 Conservation agriculture and adoption – a review of relevant literature

Non-government organisations (NGOs) have taken the lead in promoting CA as a hand-hoe based technology where farmers had to prepare planting basins during the dry season (minimum disturbance) and retain at least 30% soil cover (Mazvimavi & Twomlow, 2009). Crop rotation was also encouraged as part of the technology (Giller et al., 2009). NGOs initially targeted vulnerable farmers, who were defined as families that faced challenges in meeting their basic livelihood needs and had constraints in obtaining inputs in a cost-effective manner (Mazvimavi & Twomlow, 2009; (Andersson & D'Souza, 2014). CA allows farmers to rely less on draught power for planting and addresses problems associated with labour availability and input use (Giller et al., 2009; Kassam et al., 2014; Mazvimavi, 2011; Mazvimavi & Twomlow, 2009).

In Zimbabwe, smallholders were initially provided with free inputs to encourage the adoption of CA technology so that its effects could be measured. Smallholders in Zimbabwe allocate most of their resources to the production of staples, and consume most of the staples they produce (Johansen, Haque, Bell, Thierfelder, & Esdaile, 2012). Cash earnings from the sale of surplus products tend to be trivial and, in the virtual absence of off-farm earnings, smallholders confront severe liquidity constraints. This reduces their ability to invest in new technologies, particularly in cases were the technology does not provide immediate benefits (Shiferaw & Holden, 1998). The temporary provision of free inputs was considered necessary to overcome risk aversion and liquidity constraints that inhibit the adoption of CA technologies.

Given the promotion of CA by NGOs, the number of farmers practicing some form of CA in Zimbabwe increased from less than 20,000 households in the 2006/07 cropping season to approximately 120,000 households in the 2009/10 cropping season (Mazvimavi, 2011). In 2010/11, there were approximately 300,000 households practicing CA, of whom almost 40% were spontaneous adopters who did not receive free inputs. However, despite a relatively high reported number of households implementing CA, the area under CA has remained low. As of the 2010/11 season, CA was implemented on 141,334 hectares, representing approximately 5% of the area allocated to maize (Marongwe, Nyagumbo, Kwazira, Kassam, & Friedrich, 2012).

Furthermore, the adoption of mulching and crop rotation practices remained low due to competing uses for crop residues and preferences to grow staple cereals over legumes (Mazvimavi, 2011; Pannell et al., 2014). Additional constraints to adoption include increased demand for labour, weed control (Nyamangara et al., 2014), lack of knowledge, perceived complexity of the technology, inappropriate tools and lack of herbicides (Johansen et al., 2012), and inadequate technical support (Giller et al., 2009; Mazvimavi & Twomlow, 2009).

Ngwira, Johnsen, Aune, Mekuria, and Thierfelder (2014) studied CA adoption and the extent of adoption in Malawi using the two-step Heckman procedure to address sample selection bias. They found that the use of hired labour, belonging to a farmer group, and cultivating a larger area increased the chances of adopting CA. The extent of adoption was positively affected by larger areas of cultivated land, farmer experience, and the location of the farmer. Working in farmer groups makes it easier to share information, and it is less time consuming for extension personnel to provide services to a group. Farmers who work in groups can also pool their experience and share the labour burden, for instance, by collectively digging seed basins for each group member. Peer effects can play a role in influencing behaviour. Farmers in a group can influence one another to adopt technologies.

Ngwira et al. (2014) measured the intensity of CA as the percentage of land allocated to CA techniques and did not consider variations within the technology. Although the authors indicated that farmers in Malawi who practice CA apply all three components in most cases, this measure of intensity ignores the potential variation within each component as farmers are likely to apply varying levels of each component. Improving the measure of CA uptake and intensity by accounting for variation within each component should provide more accurate information about the determinants of adoption. In addition, measuring intensity as the percentage of land cultivated using CA ignores the extent of adoption. Farmers scoring the same level of intensity (percentage) could be practicing CA on very different areas of land. Standardizing the area may help to address this weakness. A recent study by Pedzisa, Rugube, Winter-Nelson, Baylis, and Mazvimavi (2015b) attempted to measure the intensity of adoption in Zimbabwe. They used count regression analysis to investigate the factors that influence the intensity of use as measured by the number of CA components practiced by each farmer. This approach also fails to accurately measure the intensity of CA adoption as it does not consider the extent of CA adoption.

The inconclusive findings may reflect inadequate measurement of uptake and omission or lack of variation in key explanatory variables. Moreover, previous studies on CA adoption were conducted at a time when NGOs were still actively promoting CA by providing free inputs. This most likely distorted the determinants of its adoption and the levels of its uptake. In addition, some studies did not explicitly indicate which of the components (no till, mulching, and crop rotation) were used to measure CA. Reported adoption rates may therefore be misleading. This study intends to improve upon past studies of CA adoption by developing an index of CA adoption that accounts for the number of CA components used and the rate and extent of their application. Factors explaining the use and intensity of CA uptake by smallholders in the Masvingo district of Zimbabwe are then identified using a double hurdle regression model.

3 Research methodology

3.1 Study area, sampling design and data collection

The study was conducted in Ward 14 of Masvingo district between October and December 2015. The ward is located 60 km south east of Masvingo town, near Lake Mutirikwi/Kyle of

Zimbabwe (Figure 1). The largest part of the district is classified as semi-arid, and normally receives annual rainfall ranging between 450 to 650mm between October and April (Moyo et al., 2012). Smallholders in the study area are predominantly subsistence farmers. In rare cases, they produce a marketable surplus which may be sold or stored for future consumption. Farmers in the study area rely heavily on rain fed agriculture (Johansen et al., 2012; Moyo et al., 2012).

3.2 Research design

Households were selected using a multistage sampling technique. Table 1 summarises information about the ward, its villages, and its estimated population, as well as the breakdown of the sampling criteria used in study villages. This information was obtained from local leaders (village heads and ward councillor) with the assistance of the local agricultural extension personnel. The ward had a total of nine villages with an estimated population totalling 1726 households. Based on this population pool, the first stage of sampling involved the selection of three villages with probability proportionate to size (PPS), where size was measured by the number of households estimated in each village. PPS controls for differences in the size of the villages. The villages that were selected were Zano, Rukovo, and Mudare. A list of all households was then constructed for each of these selected villages. In the second stage of sampling, households were selected randomly from each list at a constant rate of 40%. Using PPS at the first stage of sampling and a constant sampling rate at the second stage implies that households enter the sample with equal probability. Consequently the sample is representative of the population and can be analysed as if it were a simple random sample, i.e. no weighting is required to compute unbiased estimates of population statistics. A total of 240 farmers were selected and interviewed.

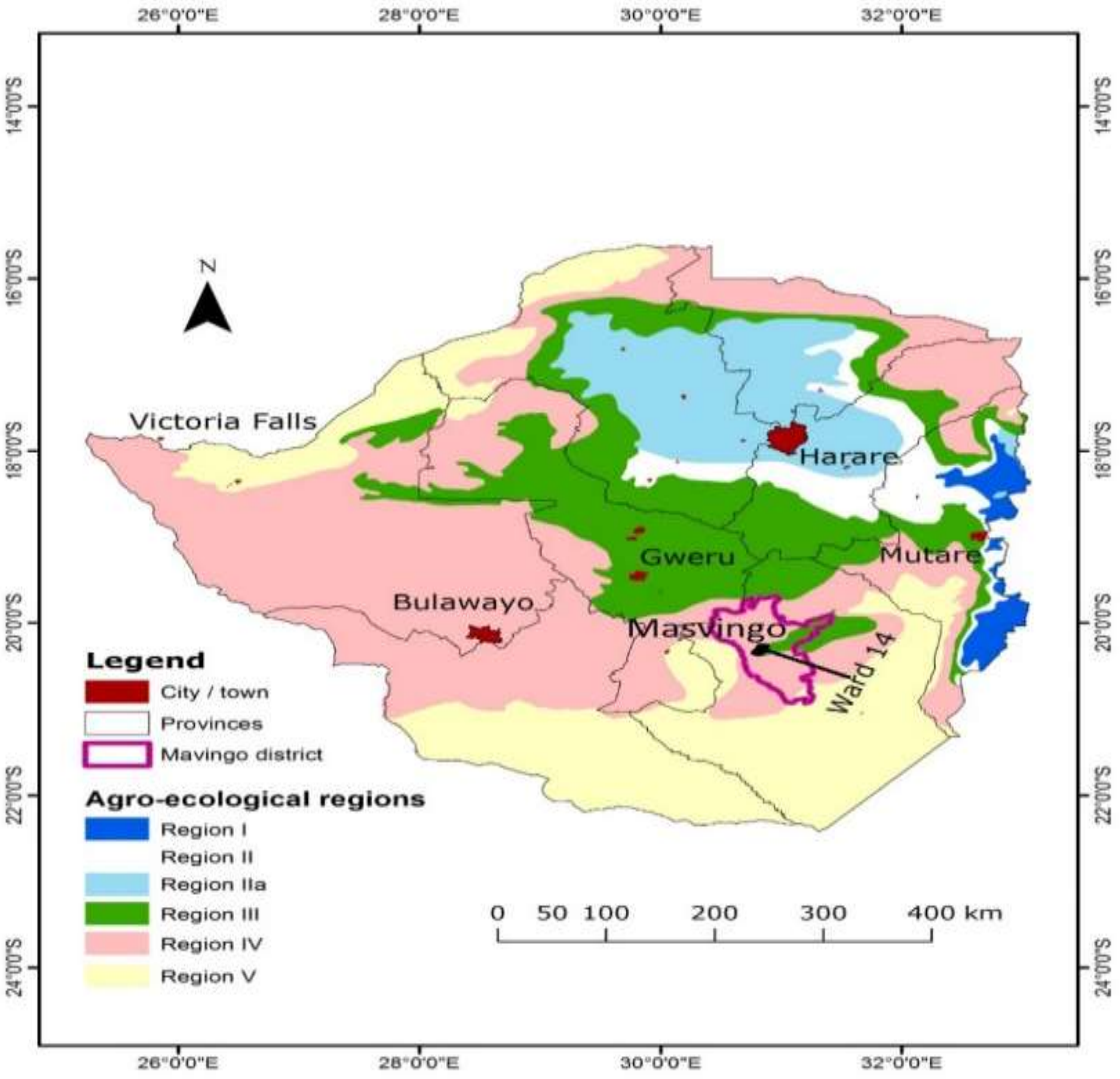

Figure 1: Map of Zimabwbe showing study area

Source: ICRISAT Matopos GIS unit (2015)

Table 1: Sampling technique

Ward 14 Villages	No. of HH	Cumulative Range	Random numbers	Actual No. of HH	Sample size[2]	Usable questionnaires
Cheure	170	1-170				
Madhiyo	216	171-386				
Zano[1]	160	387-546	437	160	64	63
Mashonga	155	547-701				
Matshokoto	124	702-825				
Maburamba	147	826-972				
Rukovo[1]	135	973-1107	1053	135	54	52
Makombe	319	1108-1426				
Mudare[1]	300	1427-1726	1562	305	122	122
Total	**1726**			**597**	**240**	**237**

[1] Selected villages, [2] 40% of households sampled in each selected village

3.3 Data collection

Data were captured using structured questionnaires, which were administered by three experienced enumerators using the local language (Shona) under the supervision of the researcher. The enumerators were trained by the researcher through an interactive approach for a period of one week, which enabled them to fully understand the questionnaire. After adequate enumerator training, the questionnaire was pre-tested with twelve respondents and necessary amendments were made. Interviews were conducted with the *de jure* household head. However, in cases where the *de jure* head was not available, the *de facto* household head was interviewed instead. In order to get accurate estimates of field sizes, each respondent's fields were measured by the researcher using a measuring wheel. In most of the cases, the fields were located next to homesteads and the researcher was able to measure fields and plots while the enumerators conducted the interviews. In rare cases where the fields were far from the homestead, arrangements to obtain area measurements in advance of the interview were made with the respondents. Questionnaires were then coded and data were captured using SPSS v.23. Out of the 240 completed questionnaires, 237 (Table 1) were deemed usable and only three were discarded as they had missing information. Dropped questionnaires belonged to respondents who did not till their fields during the 2014/15 season.

4 Analytical methods

Most of the adoption studies have used a binary variable to measure adoption and this made it appropriate to use logit or probit models. However, this approach does not capture intensity of adoption. The Tobit model is normally used to overcome this problem. Tobit estimation has been used where the variable is continuous with a censored limit. The model can be used to measure both adoption and intensity (Mazvimavi & Twomlow, 2009).

However, the Tobit approach assumes that the decision to adopt and the decision on levels of adoption are the same. Where adoption and intensity are assumed to be separate processes, then the two-stage Heckman procedure and double-hurdle approaches are more appropriate (Garcia, 2013). For this study, given that the index (CAI) used to measure adoption is continuous in nature, logit and probit models are not appropriate. Furthermore our CAI has positive values censored at zero; our CAI cannot be negative because farmers cannot negatively implement CA components. Ordinarily, Tobit models are used in such cases as they better handle censored data. However, we hypothesise that for each season the farmer has to first make a decision to use CA components, then decide on how intensively he or she is going to use the technique. Factors that affect the use of CA components may thus have a different impact on the two decisions made by farmers. For instance, a factor may positively affect adoption decision but negatively affect the intensity of adoption (Garcia, 2013). Tobit models are not able to sufficiently handle such scenarios.

This study thus uses a double hurdle model which allows us to separate the decision to participate and the decision made on intensity of practice. The double hurdle model assumes that an individual passes through two hurdles. The first hurdle is the decision of whether to implement CA or not, while the second hurdle is how much of a CA component to be used. The first hurdle uses a Probit regression, which takes 0 as the decision not to use a technology and other positive values as decisions to adopt. The second hurdle uses a Tobit regression model to determine factors that explain the intensity of adoption for individuals who decide to implement CA components (Garcia, 2013).

Double hurdle models assume that error terms of the two regression models are not related. However, given the nature of the study, it may be possible to have sample selection bias. For instance, a certain class of farmers may choose to adopt a technology. Therefore, first we use the Heckman approach to test for sample selection bias. If selection bias is present, then the Heckman approach becomes an appropriate model to use. However, if the selection bias is absent, the double hurdle efficiently estimates the determents of CA adoption and intensity given than it better handles the zeros in the second hurdle.

5 Results and discussion

5.1 Household characteristics

In order to understand the average household in the study area, this section starts by presenting descriptive statistics before focusing on factors that influence adoption and intensity. Table 2 presents a summary of key descriptive statistics computed for all households (237) in the sample. On average, surveyed households had 5.4 members of whom half were children under the age of 16. Households were endowed with approximately 3.6 adult equivalent[1] workers. Very few (12%) hired farm labour and only three per cent pooled their labour with other households to share farm work. These characteristics may imply heavy reliance on family labour, including part-time contributions from school-going children.

Sampled households had an average of more than twenty years of farming experience using traditional farming methods, which includes the use of ox-drawn ploughs and hand hoes. Although conservation agriculture components (reduced tillage, mulch, and crop rotation) had been promoted in the study area for approximately ten years, there is considerable variation in farmer experience with each component. The survey revealed that the average household had applied reduced tillage for approximately 5.5 years, mulch for 1.1 years, and crop rotation for 7.6 years. While the longer time period for crop rotation is not surprising given that it was used prior to the introduction of CA, the data nevertheless suggests that an average smallholder does not take CA as an indivisible technology as desired by proponents, as there is wide variation in the applicability of individual components.

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[1] Adult equivalent = Number of adults + 0.5 (number of children (<12) + number of pensioners (>65)).

Table 2: Household characteristics (n=237)

Variable	**Mean**	**Standard error**
Household size	5.4	0.16
Number of males (adults ≥ 16 years)	1.3	0.06
Number of females (adults ≥ 16 years)	1.4	0.05
Number of children < 16 years	2.7	0.12
Mean family labour (adult equivalent[1])	3.6	0.08
Age of household head (years)	50.6	1.07
Mean education level of household head (years)	7.5	0.22
General farming experience of Household head (years)	21.3	1.02
Experience with reduced tillage / planting basins (years)	5.5	0.27
Experience with mulching (years)	1.1	0.18
Experience with rotation (years)	7.6	0.68
Mean household annual off-farm income in US$[2]	945.61	72.44
Percentage of male headed households	70.0	0.03
Male head responsible for cropping decision making (%)	51.1	0.03
Household heads that reside in homesteads (%)	87.8	0.02
Household that used hired labour for 2014/15 season (%)	12.2	0.02
Households that use collective labour (%)	3.0	0.21

[2] Annual off-farm income = Cash obtained from all off-farm sources including wage income, cash from petty trading, and remittances

Source: Sample survey data.

Household heads in the sample were relatively well educated with an average of 7.5 years of schooling. This suggests that farmers in the study area are potentially in a better position to understand and use new farming methods. It also makes it possible to use other forms of extension like flyers and pamphlets rather than only relying on traditional direct contacts. A majority (70%) of the households were male headed. Interestingly, however, males were not responsible for cropping decisions in almost 50% of the households. This contrasts with the view that African women provide labour for cropping activities like weeding while men make management decisions. An average household had an annual off-farm income of roughly US$945. This translates to nearly US$78 a month for an average family size of 5.4 persons. This is significantly below the official poverty line which was reported to be around US$481 per month for a family of five as of April 2016 (Zimbabwe National Statistics Agency, 2016). This implies that the average household has to get an economic value (through farm products consumed or revenue) equivalent to $410 from farm related activities to get closer to the official poverty line. Approximately 87% of household heads were residing on farm at the time of the survey. This suggests a lack of off-farm employment opportunities and emphasises the important role of agriculture as a livelihood strategy.

5.2 Land endowment, farming techniques, and crop production

The survey revealed that, on average, households had 1.6 hectares of arable land and cultivate roughly 1.2 hectares, leaving 0.4 hectares fallow (Table 3). As the study area is located near Lake Mutirikwi/Kyle, crops produced near the lake are frequently destroyed by hippopotamuses. Farmers with fields located near the lake often leave their plots fallow rather than risk crop losses. However, in other instances, farmers do not till all of their land due to a lack of adequate resources such as farm implements, labour, and inputs (Giller et al., 2009; Ndlovu et al., 2014). Only a few survey households (9.7%) indicated that they had a fenced field. Customary tenure systems often make it risky for household to rent unused land to potential users (Dengu & Lyne, 2007).

Table 3 Farm characteristics (N=237)

Variable	Mean	Standard error
Mean land endowment (hectares)	1.58	0.06
Mean area cultivated in 2014/15 season (hectares)	1.18	0.05
Mean area left fallow in 2014/15 season (hectares)	0.40	0.04
Distance from nearest town in km	61.21	0.59
Distance from government extension personnel in km	5.99	0.29
Mean tropical livestock unit (TLU)*	2.21	0.20
Percentage of households owning cattle	51.5	0.03
Percentage of households owing a mouldboard plough	43.5	0.03
Percentage of households with fenced plots	9.7	0.02
Receipt of CA inputs prior to 2014/15 season (%)	56.1	0.03
Receipt of CA extension prior to 2014/15 season (%)	70.5	0.03
Receipt of CA extension in 2014/15 season (%)	41.4	0.03
Receipt of extension from social networks in 2014/15 season (%)	62.4	0.03
Perception of CA benefits (dummy, 1 for positive, otherwise 0)		
Percentage of households that produced maize	100	-
Percentage of households that produced groundnuts	79	0.03
Percentage of households that produced bambaranuts	74	0.03

Source: Sample survey data

Approximately 50% of sampled households owned cattle while less than half of the sampled households (43%) owned a mouldboard plough. In this area, similar to other places in

Zimbabwe, cattle are used as draught animals and play a significant role in smallholder farming. Farmers that own, or have access to, cattle and mouldboard ploughs are able to till larger areas of land and can also plant early, thus resulting in better use of limited rains (Mazvimavi & Twomlow, 2009). Reducing dependency on these scarce resources (draught animals and mouldboard ploughs) has been one of the major reasons for promoting CA among poor smallholders (Andersson & D'Souza, 2014). In addition to its use as draught power, livestock ownership signifies wealth. On average, households had 2.2 tropical livestock units (TLU). This is an index computed form weighting livstocked owned by each household. Cattle is assigned a weight of 0.7, while goats and sheep are assigned a weight of 0.1 (Jahnke, 1982)

When CA was introduced, smallholders were provided with free inputs to enable them to try the technology. More than 50% of surveyed farmers indicated that they received free inputs to use on their CA plots prior to the 2014/15 season. Seventy percent of the sampled farmers also mentioned that they received CA extension during the same period. CA extension was offered by government and NGO extension personnel. The uptake of CA during this period was most likely influenced by this subsidy, and adoption studies conducted then may have suffered from this bias. However at the time of this study, local NGOs had stopped providing free inputs and extension support. Instead, farmers had to obtain inputs from the nearest town (Masvingo), located approximately 61.2 km from an average household.

The public sector continued providing extension support to farmers after NGOs had left. Though extension advice is provided freely to farmers, not all farmers have access to this service. The survey revealed that less than 41% of the farmers indicated that they had obtained extension services on CA from government during the 2014/15 season. Unlike local NGOs, government extension officers use traditional methods of direct contact, which entails either visiting the farmer's field or gathering farmers at the ward centre. However, due to limited resources, extension officers may be unable to access farmers located farther from the ward centre. Similarly, farmers that are located further from the ward centre may find it difficult to attend the meetings. The t-statistics reported in Table 4 indicate that farmers located closer to extension officers were more likely to receive extension from government.

Table 4: Relationship between distance and receipt of extension

Variable	Mean distance from extension offices in km		t-statistic[1]
	Recipient	Non recipient	
Receipt of CA extension prior to 2014/15 season	5.2	7.8	-4.14 ***
Receipt of CA extension in 2014/15 season	4.1	7.2	-5.65 ***

[1] Test for differences in distance between households that received extension services , *** denotes significance at 1%

Source: Sample survey data

5.3 Area allocation, tillage systems, and crops grown

Farms in the study region are normally divided into smaller parcels (plots), so that an average 1.6 ha farm comprises of several plots that may be managed quite differently. The average plot size was 0.28 ha. Farmers could have a mix of plots under conventional tillage, conservation techniques, and other tillage systems like traditional digging using hand hoes. Conventional tillage refers to use of mouldboard plough, whether owned or leased. Under conventional tillage, the minimum disturbance principle is violated as farmers till the land before planting. However, it is still possible to apply other conservation techniques like mulching and crop rotation. Conservation agriculture (CA) refers to a tillage system based on the integrated management of soil, water and biological resources through the minimum disturbance of soil, permanent soil cover, and crop rotation (Giller et al., 2009; Kassam et al., 2014). Under CA, all the three components have to be implemented simultaneously in a single plot. Where one of the components is not implemented, then the farmer practise is not classified as CA but rather as conservation technique. In this regard, conservation techniques refers to a tillage system that implements reduced tillage (planting basins) as a mandatory component. Under conservation techniques, it is possible to implement only the reduced tillage component or in combination with other components (in this case mulch and crop rotation). This relaxes the strict definition of conservation agriculture which does not allow partial adoption. Introduction of the term conservation techniques enables the classification of actual farmer practice, which in some cases does not take all the three CA components. Tillage systems that do not fit under conventional tillage or conservation techniques were classified as other techniques. This accommodates all the farmer innovations of practices like digging the whole plot using hand hoe (violating minimum disturbance) or creating very small basins in a manner different from the standard CA planting basins.

An individual smallholder may produce a variety of crops on different plots. Sample households had a total of 995 cultivated plots, of which approximately 53% were planted to maize, 21% to groundnuts and 18% to bambaranuts. Other minor crops like finger millet, cowpeas, sorghum, beans, and sunflowers were rarely produced by farmers. These minor crops combined were found on just seven per cent of the cultivated plots (table 5). Most (66%) plots were tilled using conventional tillage (table 6). However, the data revealed considerable crop-level variation. For instance, more than 80% of groundnuts and 90% of bambaranuts were produced conventional tillage, while just over 50% of maize was produced using this tillage method. By contrast, conservation techniques were much more prevalent in maize production relative to other minor crops.

Table 5: percentage of crops grown in different plots (n=995)

Crop	Percentage of plots
Maize	53.3
Groundnuts	20.8
Bambaranuts	18.9
Finger millet (rapoko)	1.6
Cowpeas	1.5
Pearl millet	1.5
Sorghum	1.1
Beans	0.7
Sunflower	0.6

Source: Sample survey data

Table 6: Respondent use of tillage systems by crop type (% using)

Tillage systems	Crops grown in 995 plots				
	Maize (n= 530)	Groundnuts (n=207)	Bambaranuts (n=188)	Other crops (n=70)	All crops
Conventional	50.2	83.1	91.5	65.7	**65.9**
Conservation techniques	47.0	9.7	3.2	18.6	**28.9**
Other techniques	2.8	7.2	5.3	15.7	**5.2**

Source: Sample survey data

5.4 CA components used by smallholders in 2014/15 season

Table 7 provides insights on the frequency of use of different CA components by sampled smallholders for the 2014/15 season. Survey results revealed that nearly 50% of all plots in the sample were cultivated without any use of CA components. The remainder of the sample used one or more CA components. Reduced tillage on its own was used in 21.2% of cultivated plots, while crop rotation on its own was used in 19.4% of sampled plots. There were a few instances where farmers used a combination of CA components, these represented a minority of the sample households. A combination of reduced tillage and crop rotation was used in 7.9% of the sampled plots, while just 1.3% of the plots used all three components. Interestingly, plots that used all three CA components were marginally smaller than the sample average, suggesting that farmers applying CA could experiment with such practices on smaller plots or that resource constraints prevent their use on larger plots.

Table 7: Frequency of individual and combination use of CA component (%)

Component	% of plots (n=995)	Mean area (Ha)	Std error
No CA component	49.0	0.28	0.01
Reduced tillage	21.2	0.25	0.01
Crop rotation	19.4	0.30	0.02
Reduced tillage and crop rotation	8.3	0.27	0.03
Reduced tillage and mulch	0.8	0.24	0.09
All three components	1.3	0.23	0.05
All plots		**0.28**	**0.01**

Source: Sample survey data

The descriptive statistics in Table 7 gives insights on actual farmers practice. Only 1.3% of the plots were under CA on strict terms based on a rigid definition requiring the simultaneously use of all three components on one plot. The majority of the plots used less than three components implying varying levels of adoption which cannot be accurately measured by a binary variable. This justifies the need to develop a measure that can accurately quantify partial adoption. The next section presents the computation of the CA index that is used to determine the level of adoption for each sampled household.

6 Computation of the CA index (CAI)

In order to better understand the adoption of CA and the intensity of its uptake, we used our survey data to compute an index that takes into account the number of CA components applied, and the rate and extent of their application. The aim with the index is to improve our understanding of the nature of adoption, taking into account the possibility of incomplete or partial adoption.

Our CA index first considers the number of CA components implemented by the sample farmers. In the survey, we found that farmers practice reduced tillage (denoted as R), crop rotation (denoted as C), combinations of reduced tillage with crop rotation (R+C), reduced tillage with mulching (R+M), and the use of all three components (R+C+M). We seek to assign weights to these different CA components according to their perceived importance. However, to the best of our knowledge, there is no published work that decomposes CA into its component attributes. We applied an OLS regression model to the survey data to estimate weights for each component or combination of components. In Equation 1, we provide a regression model that relates maize yield (Y) to CA components, X, individually (R and C) and their combinations (R+C, R+M, R+C+M). The components are measured as dummy variables that take the value of 1 if the component was implemented, and 0 otherwise. In addition, α_r are the parameters estimated using OLS, and u_i is the error term.

$$Y_i = \alpha_0 + \sum_{r \in \{\mathrm{R}, C\}} \alpha_{ir} X_{ir} + \sum_{s \in \{R+C, \mathrm{R}+M, \mathrm{R}+C+M\}} \alpha_{is} X_{is} + u_i \qquad \text{………… (1)}$$

As expected, the regression results show that the application of different CA components have positive impacts on yield. However, out of the five potential combinations used by farmers, only three of these were statistically significantly (reduced till, reduced till plus crop rotation, and all three components combined) (table 8). From this regression, we took the standardized regression coefficients to compute the weights of the components and their interaction effects associated with use of a combination of components. To do this, we first divided each standardised coefficient by the sum of all standardised coefficients (0.686) for the five combinations to get the normalised interaction effects that add up to 1 (table 9).

Table 8: Contribution CA of components to maize yield

Combination of CA components	Coefficients	Standardised coefficient	
Reduced till only	647.52	0.248	***
Crop rotation only	245.64	0.067	
Reduced tillage and crop rotation	727.99	0.175	***
Reduced tillage and mulch	526.99	0.049	
All three components	1221.10	0.147	**
Constant	789.67		
F-statistic		8.187	***
Adjusted R^2		0.064	

*** and ** denotes 1 and 5% significance levels respectively

Table 9: Computed weights for different combinations of CA components

Combination of CA components	Standardized coefficient	Interaction effect	Assigned weights
Reduced till only	0.248	0.36	0.36
Crop rotation only	0.067	0.10	0.10
Reduced tillage and crop rotation	0.175	0.26	0.62
Reduced tillage and mulch	0.049	0.07	0.43
All three components	0.147	0.21	1
Total	**0.686**	**1**	

Source: Sample survey data

Next, we developed weights based on these normalized coefficients to compute the individual and combined effects of different practices. If more than one component is applied, an individual and interaction weight are combined. For instance, if a farmer practices only reduced tillage, we assigned a weight of 0.36. However, if the farmer combines reduced tillage with crop rotation, then we add an interaction effect of using both (0.26) to get a weight of 0.62. Note that we use the individual coefficient for reduced tillage instead of crop rotation as the former is statistically significant. Furthermore, attributing a greater weight for the reduced tillage component relative to other components has some logic given that it is a compulsory component that distinguishes between conventional and conservation techniques.

We then use the computed weights for the different CA components to develop an index at the plot level. The plot-level CA index is computed by multiplying the assigned weights of the components as computed above, the intensity of CA component use, the proportion of land allocated to the CA component(s), and the area of the individual plot relative to the size of the largest plot in the data set. Intensity is an index obtained from farmer perceptions in the survey, in which farmers were asked to rank themselves against the recommended rate of component use. Where a farmer assumes that they used the component as recommended by extension officers they were assigned a rate of 1. Intensity scores ranged from 0 to 1 and are assigned at a plot level. The plot level index scores are summed for each respondent to obtain household CAI. The equation for the CA index (CAI) is specified as:

$$CAI_i = \Sigma W_{ir} I_{ir} P_{ir} S_{ir} \qquad \text{……………} (2)$$

In equation (2), CAI is the computed conservation agriculture index for the i^{th} household and their r^{th} plot. W denotes the weight assigned to each component or a combination of components. I represents the intensity of CA component use as perceived by the farmer. P is the proportion of cultivated land allocated to different CA components, while S represents the area allocated to a CA component relative to the size of largest plot in the data set.

Table 10 provides an example of CA index computations for two sample farmers (A and B). We assume that farmer A cultivated a total area of 1 hectare, and farmer B cultivated a total area of 1.5 hectares. Each farmer has three plots. To obtain the index score for each farmer’s plots, we start by assigning the relevant component weights for each component used (column component weight on table 10). Next, we calculate the proportion of each plot (prop comp) relative to cultivated area. This aims at measuring the extent uptake of each component. However, the same score could be obtained for farmers practicing CA on very different areas. To control for this, each plot is standardised relative to the largest plot in the data set. This involved dividing each plot area by the size of the largest area in the data set to obtain a local scale measure. In our example, the largest plot is 0.8 hectares, and therefore we divide each plot by 0.8 to obtain our local scale measure. The index score at plot level will be equal to the product of component weight (W), intensity (I), proportion of area under CA component relative to cultivated land (P) and local scale (S). The plot index scores are then summed for each household to get the CAI. The summation of the plot index scores for each household was considered appropriate given that the computed index scores had been standardised using the using local scale measure. In the example, Famer A would thus have a CAI of 0.183 and farmer B would have a CAI of 0.210.

Table 10: Computation of the index at plot level

Farmer	Plot	Total cultivated area (ha)	Area (ha)	Technique	Component weight	Intensity	Prop comp	Local scale measure	Plot level index
A	1	1	0.3	R &C	0.43	1	0.3	0.375	**0.070**
A	2	1	0.5	R	0.36	1	0.5	0.625	**0.113**
A	3	1	0.2	none	0	1	0.2	0.25	**0**
B	1	1.5	0.1	none	0	0	0.067	0.125	**0**
B	2	1.5	0.6	R+C+M)	1	0.7	0.4	0.75	**0.210**
B	3	1.5	0.8	none	0	0	0.53	1	**0**

7 Factors determining adoption, intensity, and extent of CA use

In this section, we report the results of our double hurdle model to investigate the factors that influence uptake of CA components and their level of use. The sum index scores from the previous section obtained for each farmer were regressed against household and farm characteristics. The first hurdles uses a binary variable for the adoption of CA components and assumes a probit model specified as:

$P(w=1/x) = \Phi(x\gamma)$ ……………(3)

In equation (3), we denote P as the probability, w the binary variable of CA components, Φ as the cumulative normal distribution, and x a set of farm and household characteristics that may influence adoption. The γ's represent the coefficients to be estimated.

The second hurdle is a Tobit regression model assuming a linear relationship between computed CA index (CAI) and observed farm and household characteristics. The model is specified as:

$Y_i = x\beta + \varepsilon_I$ ……………(4)

In equation (4), Y_i represents the level of intensity for the i^{th} household as measured by the computed index (CAI), x_i represents farm and household characteristics that may influence intensity levels, β are the estimated parameters, and ε_i is the error term.

Table 11 shows the list of variables used in the regression and their expected signs. Receipt of inputs in previous years is expected to influence adoption decision but not the intensity decision. On the other hand, the use of hired labour and access to agricultural extension are expected to influence intensity and not adoption. This is based on the notion that the adoption decision is made before the season begins, with events occurring during the season not altering the decision to adopt.

Table 11: Variables used in the regression model and expected signs

Variables that may influence adoption and intensity	Expected sign	
	Decision to adopt	Intensity level
Gender of decision maker (male =1, otherwise 0)	-	-
Education of decision maker in years	+	+
Household head reside on farm (yes=1, otherwise 0)	+	+
Total household labour (adult equivalent)	+	+
Distance to nearest town in km	-	-
Perception of CA long term benefits (positive=1, otherwise 0)	+	+
General farming experience	+	+
Number of years practicing basins	+	+
Number of years applying mulch	+	+
Number of years practicing crop rotation	+	+
Land endowment	+	+
Presence of fencing (yes=1, otherwise 0)	+	+
Ownership of ox-drawn plough (yes=1, otherwise 0)	-	-
Tropical livestock unit	+	+
Liquidity (US$)	+	+
Distance to government extension personnel in km^2	-	-
Receipt of CA inputs in previous years	+	
Use of hired labour in 2014/15 season		+
Receipt of agricultural advice from social groups 2014/15		+
Receipt of CA extension in 2014/15 season		+

The double hurdle model regression results are presented in Table 12. The model did not suffer from multicollinearity as the variance inflation factors (VIF) ranged between 1.12 and 1.97. Before running the double hurdle model, we applied the Hecknam two-step procedure to test for sample selection bias. We found no evidence of selection bias, with the inverse Mills ratio not significant at 10% (p = 0.28). A lack of severe selection bias suggests that the double hurdle would yield efficient estimates. The double hurdle regression model's Wald statistic was significant with at 1% suggesting a good model fit.

Table 12: Estimated double hurdle model for factors influencing uptake of CA and level of use

Variable	First hurdle	Second hurdle
Gender of decision maker	-0.7714 ***	-0.0899 *
Education of decision maker	0.0129	-0.0032
Household head reside on farm	-0.3835	0.0363
Total household labour	0.0870	0.0045
Distance to nearest town	0.0046	-0.0066 **
Perception of CA long term benefits	0.4071	0.0014
General farming experience	-0.0236 **	0.0023
Number of years practicing basins	0.2900 ***	0.0094
Number of years applying mulch	-0.0531	0.0112 *
Number of years practicing crop rotation	0.0319 **	-0.0035
Land endowment	0.4409 **	0.0046
Presence of fencing	-0.1226	-0.0276
Ownership of ox-drawn plough	-1.1782 ***	-0.1153 **
Tropical livestock unit	0.0115	0.0103
Liquidity	0.1086	0.0134
Distance to govt extension personnel	-0.0026 *	0.0004 *
Receipt of CA inputs in previous years	0.1456	-
Use of hired labour in 2014/15 season	-	0.0768
Receipt of agric advice from social groups 2014/15	-	0.0738 *
Receipt of CA extension in 2014/15 season	-	0.0391
Constant	-0.2430	0.0911
Wald statistic (17)	52.09 ***	
Number of observations	237	

***, ** and * denote 1, 5 and 10% significance levels respectively.

In Table 12, the first hurdle shows the factors that influence the decision to use CA components, while the second hurdle shows factors that influence intensity of use. The gender of the main decision maker had a significant, negative impact on both the decision to implement CA components and on the intensity of use. This suggests that households with male decision makers are less likely to adopt CA components. This can be attributed to the fact that CA was promoted as a hand hoe technique which is less attractive to males. On the other hand, the education level of the main decision maker and the availability of the household head on farm was not statistically significant in influencing either the adoption or the intensity decision. While the availability of labour had a positive relationship with adoption and intensity, it was also not statistically significant suggesting that it is a less binding factor for adoption and intensity. Similar findings are reported by Arslan et al. (2014). The use of hired labour for the 2014/15 season was also not a significant determinant of intensity. The availability of labour was expected to be an important factor given that labour constraints are reported as one of the major reasons for poor adoption of CA components.

The receipt of CA inputs in the past had a positive effect on adoption though it was not significant. This may indicate that the provision of inputs does not guarantee or sustain the adoption of technologies in later years. Earlier studies that were conducted when NGOs were still giving free inputs reported that receipt of inputs significantly influenced adoption (Mazvimavi & Twomlow, 2009; Pedzisa et al., 2015a). Given that at the time of this study, NGOs had stopped giving free inputs, we use the distance to the nearest market as a proxy for access to inputs. Though proximity to the market does not necessarily mean ability and wiliness to buy, it can be a good indicator about accessibility of inputs. We found that the distance from the nearest market (Masvingo town) was not a significant determinant of adoption, but had a negative, significant impact on intensity. Farmers who are located further away from the market are more likely to incur higher transport costs in acquiring inputs. This is exacerbated by the lack of infrastructure such as roads, in that the further a farmer is located from the main town, the more difficult it is to obtain inputs. Furthermore when CA was promoted, the use of complementary inputs like fertiliser was emphasized. This may influence farmers to assume that CA cannot be practised without using fertilisers.

Receiving CA extension from public extension workers during the current cropping season (2014/15) was positively related to intensity but not significant. This may reveal the public sector’s inefficiency in providing extension services due to resource constraints. Public extension usually relies on the direct contact method which entails visiting farmer fields or gathering them at the ward centre. Farmers may develop systems like social networks to counter the challenges faced in obtaining extension advice. The results further show that receiving agricultural advice from social networks significantly (albeit at a 10% significance level) influenced the intensity of use, suggesting that farmers may use this as an alternative source of agricultural extension. On the other hand, this may indicate that social networks if utilised can play and important role in knowledge dissemination, particularly were public extension services are constrained by lack of resources.

Experience with CA components was expected to have a positive impact on adoption and intensity of use. With more years of practicing CA, farmers likely gain knowledge and expertise. Furthermore, they are likely to make better judgements through conducting actual comparisons between the new technology and conventional techniques. In addition, some researchers argue that CA becomes easier with time (Mazvimavi & Twomlow, 2009). We expected that experience with reduced tillage technique would have a positive influence on adoption and intensity. However, the regression results revealed that the impact was significant only for the adoption decision. Those who have practiced reduced tillage for a long time are likely to continue practicing this component. This is consistent with findings by Pedzisa et al. (2015a). On the other hand, experience with basins did not have a significant impact on intensity, implying that experience with basins does not translate into adoption of other components. Similarly, the number of years practicing crop rotation has a positive, significant impact on adoption but negative, insignificant impact on intensity. Many farmers have practiced crop rotation on conventional plots. Crop rotation under conservation techniques may be undermined by differences in basin size and spacing for legume crops and cereal crops. If a farmer has to apply crop rotation on plots in which they practice reduced tillage (planting basins), they have to establish new basins with a different dimension requiring a new learning curve.

Contrary to expectations, experience with mulching was negatively related to adoption decisions, though this result was statistically insignificant. This can be attributed to the fact that some farmers who have never adopted mulch have adopted other CA components like crop rotation and reduced tillage. However, the regression results revealed those who have more experience with mulching are likely to be more intensive users of CA (applying more than one component). This may suggest that farmers who have more experience with mulch develop ways of handling the challenges associated with livestock that feeds on mulching material. Some farmers reported during data collection that they keep their mulch secure during the free grazing period and only apply mulch during the season when livestock is not permitted to graze from the fields.

Farmers with larger farms were more likely to adopt CA components, with regression results showing a positive, significant relationship. We attribute this to the fact that such farmers can better absorb risk and allocate a larger portion of their land to try new technology. However, land endowment did not have a significant impact on intensity. As expected, ownership of an ox drawn plough had a negative, significant impact on adoption and intensity. Farmers with ox drawn ploughs are more likely to use conventional tillage because it less labour demanding. On the other hand, livestock ownership and liquidity were positively related to adoption and intensity though were not significant. This may suggest that wealth as measured by livestock ownership and liquidity is a less binding factor in making adoption and intensity decisions.

The discussion and the results illustrate that household and farm characteristics have different effects on adoption decision and intensity decision. Modelling adoption and intensity as two-step process helped in better understanding factors that influence the two processes, and as a result, better conclusions and recommendations can be drawn.

8 Conclusions

Decomposing CA has made it possible to draw informed conclusions about actual farmer practice, adoption, and intensity levels. Farmers in the study area rarely implemented CA as an indivisible technology. Most of the farmers only implemented the reduced tillage component (basin digging) of CA. There were only a few instances where farmers implemented more than one component. Participation of females in decision making, experience with technology, and farm size all had positive, significant impacts on adoption. On the other hand, the intensity of adoption was positively and significantly influenced by participation of females in decision making, proximity of input markets, experience with mulching, and access to extension support. Ownership of a mouldboard plough had a negative, significant impact on both adoption and intensity,

Given these results, it is necessary to develop ways of addressing factors that constrain adoption. Efforts should be put in place to improve rural input and output markets. Local availability of inputs will ease the challenges faced by smallholder farmers in acquiring inputs. Improving output markets will make it possible for farmers to sell their produce in the event of surplus production thereby easing liquidity constraints. This will increase the chances of investment in agriculture and may have spillover effects given that the rural communities heavily rely on agriculture. There is also need for innovation in conservation practices that could allow the use of the mouldboard plough. Such technologies are likely to be more attractive to farmers who have draught power and those who own ploughs.

Efforts should be made in equipping government extension personnel with resources that will enable them to effectively reach out to farmers. However, there is also need to improve the extension methods used. Public extension personnel should be encouraged to use methods that encourage farmer participation. Encouraging participation can also make it possible to obtain perceptions and views from male decision makers who were less likely to adopt CA technology. This approach can set a good platform for getting effective feedback from farmers. In addition, it may be an ideal way of developing technologies that are appropriate for smallholders, given their operating environment and constraints faced. Extension officers should also identify and utilise existing social networks. This can reduce transaction costs incurred in disseminating information.

We emphasize that these results are specific to a particular ward of Masvingo district of Zimbabwe. The adoption trends found here may be different in other parts of the country. Factors identified in this study may have a different impact on adoption for different places, therefore it is crucial to conduct site specific studies. It may be worthwhile for future studies to use more robust approaches as found in this study to better estimate accurate adoption levels and intensity. Further research may also focus on investigation the impact of partial adoption on users and the environment.

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