Adoption of Conservation Agriculture Technologies by Smallholder Farmers in the Shamva District of Zimbabwe: A Tobit application

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Abstract
Conventional agricultural practices such as the use of the moldboard plough are no longer sustainable due to their extensive soil degradation effects. As a panacea, several Conservation Agriculture (CA) technologies have been promoted to improve soil structure and water conservation. However, adoption of these technologies has been resisted by smallholder farmers and identifying causes of the low adoption rates to facilitate intervention strategies remains a challenge to development practitioners. Using data from 100 farmers, this paper uses a Tobit application to assess the underlying factors important in determining farmers' adoption of zero-tillage, crop rotation and contour ridging technologies. Empirical results suggest that adoption and use intensity of each of these technologies is affected by a set of distinct household factors. There is also evidence to show complementarities in adoption and use of these technologies, suggesting the need to tailor awareness and promotional strategies depending on the technology in question and socio-economic background of target farmers.

Key words: Conservation Agriculture (CA), Conventional Farming (CF) technology, Tobit Model, Adoption

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1. Introduction

Traditionally, smallholder farmers in Africa just are accustomed to practicing conventional farming (CF), which involves disturbing the soil through ploughing, discing, harrowing and many other tilth conditioning operations (Mashingaidze and Mudhara, 2005). It is generally believed that CF creates a favourable soil structure for seedbed preparation, controls proliferation of weeds, and increases mineralization of soil organic matter but inevitably compacts the soil, promotes salinization, accelerates soil erosion and depletes the soil of organic matter and nutrient content (FAO, 2001a; FAO, 2001b). CF has been observed to cause soil losses of up to 150 tons per ha annually (Knowler and Bradshaw, 2007; Pier et al., 2002, FAO, 2001b). As a panacea to problems caused by CF, many agricultural scientists have advocated for the use of conservation agriculture (CA) technologies. However, these technologies have been less widely adopted (Garcia-Torres et al., 2003; Fowler and Rockstrom, 2001; Derpsch, 2003; Hobbs, 2006). This study aims to analyze factors that hinder the adoption of CA technologies in the Shamva district of Zimbabwe.

CA, which consists of (i) minimum soil disturbance which basically means no soil inversion by tillage, (ii) soil surface cover with crop residues and/or living plants, and (iii) crop rotations, has been referred to as a "unifying label" for a variety of integrated soil and water management practices and agricultural resources (Knowler and Bradshaw, 2007 and Kaumbutho and Kienzle, 2007). It is believed to offer the means to prevent further destruction of the soils, increase rainwater use efficiency, labor productivity and ensuring higher and more stable crop yields at reduced production costs.

CA practices attempt to achieve at least a 30% ground cover using growing crops or dead mulch in order to protect the soil physically from sun, rain and wind and to feed soil biota contrasting with CF which emphasizes the need for a clean seedbed without crop residues (Erenstein, 2003). Unlike in the case of mechanical tillage which disturbs this process, the soil micro-organisms and fauna take over the tillage function and soil nutrient balancing. The crop rotation component is designed to avoid disease and pest build up from the crop residue. As documented by FAO (2001a & b), Hobbs (2006), and Wall (2007), CA ensures improved water infiltration and soil surface aggregation as well as reduced soil erosion and compaction. In addition, biological tillage is promoted, surface soil organic matter and carbon contents increased, soil temperatures moderated and weeds suppressed. Proponents of CA sometimes argue that only when a number of agronomic management practices are applied simultaneously does CA become profitable, environmentally beneficial and ensures sustainable agricultural production in the short and long term (Hamblin, 1987; Unger and Fulton, 1990; Derpsch, 1999; Gowing and Palmer, 2007; Bollinger *et al*., 2006; FAO, 2001b).

In Brazil and Australia, CA technologies have been widely adopted on a range of soil types, environments and crops (Wall, 2007). In contrast, CA dissemination in Africa has been met with some resistance (Feder *et al*., 1985). Where adoption has been observed, not all components have been adopted due to bio-physical factors (soils, climate, and topography), socio-economic factors, institutional factors and technology characteristics (Baudron et al., 2007; Shetto and Owenya, 2007; Kaumbutho and Kienzle, 2007; CIMMYT, 1993; Langyintuo and Mekuria, 2005; FAO, 2001b). Place and Dewees (1999) noted that the bio-physical requirements for successful adoption of CA technologies are “in general well described in common manuals and relatively easy to verify”. It is the social, economic and cultural characteristics of would be adopters that are more intricate and hence limiting to the dissemination and adoption of new CA technologies.

In Zimbabwe, some components of CA, such as crop rotation and intercropping are being practiced by farmers while others such as zero tillage and mulching are new introductions by development agents and partners. The objectives of this paper are to identify the components of CA technologies that are adopted by farmers in the Shamwa district of Zimbabwean analyze factors that influence farmers' adoption decisions. The findings will assist governments, Non-Governmental Organizations (NGOs) and other development partners involved in the development and promotion of CA technologies to design appropriate intervention that will help increase the adoption rates of CA technologies among farmers in similar ecologies in Africa.

The rest of the paper is organised as follows: Section 2 briefly describes the CA technologies modelled in this paper followed by a description of the research methodology and analytical methods in Section 3. Section 4 presents and discusses the empirical results followed by the concluding remarks and policy implications of the findings in Section 5.

2. Evolution of CA in Zimbabwe

Conservation farming has increasingly gained recognition in southern Africa as package of technology interventions that are meant to conserve of soil water, nutrients and farm power (Kizito et al., 2007). Nyagumbo I, (2004), contends that the advent of CA in Zimbabwe was as early as the 1950s in the form of reduced tillage systems such as wheel track planting, rip on row into crop residues, rip and disk and direct seeding into residues combined with the use of herbicides for weed control. Zimbabwe, then Rhodesia, was under economic sanctions and this move was driven by the need for reduced machinery wear and fuel costs. More elaborate work on CA systems for smallholders were further evaluated and promoted in the 1980s. Some of these techniques include no-till tied ridging; mulch ripping; no till strip cropping; clean ripping; hand-hoeing or zero till; tied furrows (for semi-arid regions) and open plough furrow planting followed by mid season tied ridging. These have frequently been promoted in combination with mechanical structures such as: graded contour ridges; dead level contour ridges with crossties (mainly for semi-arid regions); infiltration pits dug at intervals along contour ridge channels; fanya juus (for water retention in semi-arid regions); vetiver strips and broad based contour ridges (mainly used on commercial farms) (Twomlow et al., 2008; Mashingaidze et al., 2006, Nyagumbo 1998*)*

Since the 2003/2004 crop season, the International Maize and Wheat Improvement Centre (CIMMYT) in collaboration with many of its partners in Zimbabwe, Zambia, Malawi and Tanzania, have been engaged in the development, evaluation and promotion of CA technologies in smallholder maize-based systems. They promoted the use direct seeders and rippers which are implements that lead to zero or minimum disturbance of the soil, crop rotation, maintenance of a soil cover, intercropping, and contour ridging. The project supported with funds from the German Federal Ministry for Economic Cooperation and Development (BMZ) and the International Fund for Agricultural Development (IFAD). In Zimbabwe, the project particularly targeted emerging commercial maize farmers who had ample financial resources and draft power to invest in no-till equipment that is animal drawn such as the direct seeders. Practices described below form part of a system of integrated soil and water management technologies that are promoted under CA.

Zero-tillage, also known as no-till or direct drilling, was first developed in North and South America to combat soil degradation (Bolliger et al., 2006). It involves sowing seed and applying fertilizer on previously unprepared soils by creating a narrow trench or bend or applying directly onto the stubble of the previous crop (Bollinger et al., 2004; Dumanski et al., 2006). The only tillage operations are low-disturbance seeding techniques for application of seeds and fertilizers directly into the soil. Zero-tillage gradually increases organic matter content of the soil due to reduced erosion thereby increasing yields and the amount of crop residue added to the soil surface in the long term. It is also known for improving soil structure, reducing labor and fuel needs and hence increasing farm profit margins (Bollinger *et al*., 2004). Farmers were encouraged to use specialized direct seeding equipment, an ox-drawn planter or a manual jab planter as well as the *Magoye* ripper and *Palabana* sub soiler in order to achieve zero/minimum tillage (Nhamo, 2007). A direct seeder can cut through crop residues, making a furrow into which seed and fertilizer are dropped mechanically at the required rates. A ripper is used to rip into the soil making a single furrow where seeds and fertilizers can be placed manually (Siziba, 2008).

Maintenance of a permanent or semi-permanent organic soil cover in the form of dry mulching or green cover crops throughout the cropping cycle helps to protect the soil from degradation. Three ways in which this can be achieved is by leaving previous crop anchored or loose after harvesting, growing a cover crop e.g. *Mucuna* which will be killed or cut to provide mulch and by applying external mulch from composts and manures (Hobbs et al., 2007; Nhamo, 2007). Mulching physically protects the soil from sun, rain and wind, intercepts energy of raindrops and run-off falling on a bare soil, moderates soil temperature, improves soil surface aggregation, promotes accumulation of organic matter and enhances biological activity within the soil. This results in improved infiltration of water, reduced water losses from the soil by evaporation, reduced soil loss through erosion and improved soil health through enhanced nitrogen mineralization, reduce weed infestation and improved soil nutrients (Hobbs et al., 2007; FAO, 2001b)

Drawing from Sullivan (2003), intercropping is the growing of two or more crops in proximity to promote symbiotic interaction between them. Crops can be grown in different spatial arrangements. Row intercropping involves growing two or more crops simultaneously with at least one crop planted in rows. Strip intercropping is when two or more crops are grown together in strips wide enough to permit separate crop production using machines but close enough for the crops to interact. Mixed intercropping is the growing two or more crops together in no distinct row arrangement. Relay intercropping is planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting.

Crop rotation, as outlined in (Chomba, 2004), involves alternating crops of different families like legumes and cereals every season or year. This practice breaks weed and pest life cycles and improves soil fertility by providing complementary fertilization to crops in sequence with each other which reduces the risk of crop failure (IIRR and ACT, 2005 and Sullivan, 2003). Crop rotation entails alternating diverse crops in the cereals and legumes family hence requires more diverse management skills coupled with soil and water conservation technologies.

Contour ridging is a soil and water conserving technique which involves construction of soil ridges which are usually 15 to 20 cm high across a slope that are meant to slow down water run-off hence improving filtration and reducing soil loss by erosion (IIRR and ACT, 2005 and UNEP, 1998). Farmers were also encouraged to plant early, use herbicides to control weeds and to apply basal and top dressing fertilisers timeously.

3. Methodology

3.1 Survey location and data collection

The survey villages are in the Shamva district of Mashonaland Central Province of Zimbabwe (Figure 1). Most areas in this province fall under agroecological region II and III which are intensive and semi-intensive farming areas respectively (FAO, 2001c).

<FIGURE 1 goes about here>

Data were collected from a sample of 100 farmers randomly selected from the district. Interviews were conducted between November and December of 2006 by trained enumerators under the supervision of CIMMYT and the Ministry of Agriculture staff. The structured questionnaires designed to capture households' demographic and socio-economic characteristics, access to and ownership of various livelihood assets, households' livelihood strategies and perceptions as well as use of CA technologies.

3.2 Empirical methods

Adoption of CA technologies has been defined in several ways depending on the nature of the technology in question. In this study, adoption refers to the decision by a farmer to use a particular CA technology component, a definition similar to that used by Feder *et al*., 1985. The extent of adoption is measured as the proportion of area the farmer commits to a particular technology.

Knowler and Bradshaw (2007) synthesized 23 published empirical studies on factors affecting adoption of CA technologies. In their paper, they outline the different analytical methods used to determine variables that were statistically significant in explaining adoption decisions.

The commonly used methods include those that show bi-variate associations e.g. correlation coefficients and chi-square. Multivariate regression models such as the ordinary least squares (OLS), limited depended models e.g. Logit and Probit and the censored models like the Tobit are also common. Where the dependent variable is categorical, taking values of 0 or 1, the Probit or Logit models are used (Park, 2005; Long, 1997, Langyintuo et al., 2000) but when it is continuous, a censored regression model is appropriate as the probit or logit models fail to differentiate between limit (zero or censored) and non-limit (continuous or uncensored) observations (Langyintuo et al., 2000).

In the current survey which assesses factors influencing the adoption and use of CA technologies, the proportion of crop area committed to the technology is used as the dependent variable. A censored regression model using the Tobit[1] specification was therefore used. The probability of adoption and the extent of use of zero-tillage, contour ridging and crop rotation were estimated simultaneously, consistent with Feder et al. (1985); Rahm and Huffman (1984); Langyintuo et al., (2003); and Waithaka et al., (2007).

[1] A full mathematical treatment of the Tobit model is not included in this paper as its usage is common in applied economics research. Thorough treatments of the model may be found in Greene (2000), chapter 20, pp. 896-951.

4. Results and discussion

4.1 Descriptive statistics on sampled households

Descriptive statistics presented in Table 1, show that the average household size is 7.2 and headed by the most elderly persons of an average age of 48 years and 16 percent of them are females. Formal educational attainment is about 6 years while on average, household heads spend about 20 years as the main decision maker of farming activities. When too old for any physical activities, headship is delegated to the next elderly person preferably a male. Only 7% of the household heads had leadership roles in their communities.

<TABLE 1 goes about here>

4.2 Awareness and use of CA technologies among sampled households

Since adoption of new technologies is a gradual process characterised by a sequence of stages hence there exist a time delay or lag, between farmers' initial awareness on a new technology and their subsequent decision to adopt this technology (Masuki et al., 2006). Farmers go through a transitional phases in adopting new technologies that they are introduced to. Introduction and awareness to these new technologies may be coordinated through extension efforts by private or public organizations or simply by observing other farmers already using the technology. Therefore, for the purpose of this paper, adopters are farmers that were using the technology at the time of the survey, whilst disadopters are those farmers who after using a particular technology for a while decided to abandon its use. Non-adopters are those farmers that never used a particular technology. Table 2 shows that for each of the CA elements reported, there are more farmers that are aware and have knowledge on technologies compared to those that had actually adopted. This disparity is explained by those farmers that are in the adoption lag period and those farmers that decide not to adopt at all.

A high proportion of farmers (90%, 84% and 78%) are aware of the principles of Crop rotation, contour ridging and zero-tillage, respectively and this is possibly due to extension support services from both government and NGOs (Langyintuo, 2005). Most farmers in the area practice rotation and contour ridging whilst about 35% practice mulching and zero tillage. Disadoption rate is relatively higher among zero-tillage farmers compared with other technologies. Clearly, Banner grass, tie ridging, stone terracing and strip cropping are amongst the least commonly adopted technologies.

<TABLE 2 goes about here>

4.3 Empirical adoption decision models

In this study, we model the adoption and use intensity of three dominant CA technologies observed in the study area, namely zero tillage, contour ridging and crop rotation. Factors considered important in determining their individual or joint adoption are discussed in the following sections.

4.3.1 Choice of variables for the empirical models

Table 3 describes all variables that have been used in the empirical model. Due to resource limitations and gender discrimination in extension message delivery female farmers are less likely to adopt CA technologies (Langyintuo and Mungoma, 2008). CA technologies are knowledge-intensive and hence complex technologies (Wall, 2007); therefore education level of household head is hypothesized to be positively associated with adoption. The likely effect of age of farmer on adoption decisions is mixed (Langyintuo and Mekuria, 2003). FAO (2001b) claim that age and or farmers' experience are very difficult factors to link with adoption of CA.

Adesina and Zinnah (1993), noted that younger farmers are more amenable to change old practices than older farmers because they tend to be more aware and knowledgeable about new technologies. Conversely, older farmers may be in a better position to adopt new technologies due to their comparative advantage in terms of capital accumulated, number of extension contacts/visits, creditworthiness etc. (Langyintuo and Mekuria, 2003).

<TABLE 3 goes about here>

Farmers with larger families are more likely to be better resource endowed than otherwise and hence more willing to try out new technologies. But in general, the impact of farm size on adoption is ambiguous. The slope of the farm is presumed to be positively associated with adoption of CA technologies (Tizale, 2007) due to its influence on erosion. Although CA elements are generally meant to save labor in the long run, labor requirements for the farm may actually increases in the short-term especially during weeding where zero tillage is practiced or during construction of contour ridges (IIRR and ACT, 2005). Therefore access to family labor is postulated to have a positive impact on adoption. Institutional factors such as number of extension contacts and membership of farmers' associations are also assumed to be positively related to adoption decisions.

Lack of access to cash or credit may hamper smallholder farmers from adopting new technologies that require initial investments (Feder et al, 1985; Doss, 2004) and therefore its access is assumed to be positively associated with adoption. As outlined in Shiferaw and Holden (1998), livestock holdings may have an ambivalent effect on farmers' adoption decisions of technologies that protect environmental integrity of the soil. This is because access to livestock may differentially imply a lax on cash constraint and/or a sense of security which both enhance adoption of these technologies. Conversely, intensive animal husbandry may reduce demand for conservation agriculture technologies because crop production is a secondary enterprise hence low investment priority area. Therefore, number of cattle may have a positive or negative effect on adoption of these technologies.

Table 4 shows the estimated Tobit regression results and the marginal effects representing the expected change in the farmer's adoption decision and use intensity of contour ridging, zero-tillage and crop rotation. These results are discussed below under separate headings.

<TABLE 4 goes about here>

4.3.2 Adoption of zero-tillage

The results from the zero-tillage model suggest that labor capacity negatively and significantly affects the adoption and use intensity of the technology. This is consistent with findings by Baudron et al., (2007) who did a study in Zambia. They argued that due to the paucity of family labor, more farmers will likely turn to technologies that save labor like reduced tillage systems if they are accessible and affordable. However, this is contrast with the findings of Pandey and Mishra (2004) who found no association between adoption of zero tillage and the family's ability to access labor.

There is an inverse relationship between level of disposable income and adoption of zero-tillage implying that households with higher disposable income are less likely to adopt and intensify the use of zero-tillage than those with lower income. It is possible that richer farmers have a greater ability to hire tractors or other mechanical power to prepare their lands compared with the poorest ones who are more likely to opt for zero-tillage to reduce cost especially under conditions of high rental rates for mechanical power. However, the demand for weeding labor increases. Previous work by Haggblade and Tembo, 2003) in Zambia, estimates that a farmer can save up to 75% on operations costs per Ha if they adopt zero-tillage as opposed to conventional tillage methods.

There is a significant positive relationship between cattle ownership and adoption and use of zero-tillage. A unit increase in the number of cattle owned will increase the probability of adoption by the farmer. Since cattle ownership is normally associated with wealth in communal areas of Zimbabwe and other developing countries, farmers with cattle might be able to raise the initial investment capital required to purchase zero-tillage implements like direct seeders as well as herbicides for controlling weeds. This is consistent with findings in Pereira de Herrera and Sain, 1999. Another plausible explanation is that since livestock is a more secure form of investment or store of value cash needs (Tizale, 2007), the bigger the herd the more the labor and capital requirements for management purposes and hence the need to explore labor saving technologies (e.g. zero-tillage) in their farming activities.

As hypothesized, the land quality has important effects on the decision to adopt CA technologies. SLOPE, SANDY, CLAY all significantly affect the adoption of zero-tillage. A farmer is likely to adopt zero-tillage if their fields are sandy or clayey. Bohlinger et al. (2006), with reference to many sources, concluded that although zero-tillage in Brazil initially started with farmers that had medium textured soils, it had proven successful for wide ranging soils between 10% and 70% clay. Similar to the findings Marenya and Barret (2007) also conclude that farmers farming on sloppy terrain are more likely to adopt zero-tillage.

4.3.3 Adoption of contour ridging

Results from the contour ridging model suggest that male farmers are more likely to adopt and intensify the use of contour ridges compared to their female counterparts. In general, there is significant labor input into constructing and maintaining contour ridges making male headed households with comparatively better access to cash and labor to be more likely to adopt this technology than their female counterparts. This finding is similar with the observations by Marenya and Barret (2007).

Age of the farmer positively affects the use of contour ridging. A unit increase in the age of the farmer will increase adoption and use intensity of this technology. This finding is consistent with those of Pandey and Mishra (2004); Langyintuo et al, (2000) and Panin (1988) but is in contrast with the general belief that older farmers have shorter planning horizons and hence are more reluctant to invest in soil conservation technologies which take a long time before farmers realize the benefits (Tizale, 2007; Marenya and Barreta, 2007). A conceivable reason for this could be that with age comes experience, hence older farmers could be more cognitive of soil degradation in their fields hence are more receptive and keen to try new technologies that counteract the negative effects.

As hypothesized, number of extension visits has a positive impact on adoption and use of contour ridges. This is because farmers get exposed to new information which reduces information asymmetry that characterize a new technology and hence farmers are more aware about it and more willing to take the risk of trying the new technology. Doss (2006) and

Haggblade and Tembo (2003b) also underscore the importance of extension services in enhancing adoption of new technologies.

Contour ridging may involve initial investment cost through hiring of manpower, tractors or draft power during the construction of the ridges. It was, therefore, not surprising to observe the significant and positive impact of disposable income on adoption and use of contour ridging at 5% level of error probability, consistent with CIMMYT (1993); Langyintuo and Mekuria (2005) and Marenya and Barret (2006).

Contrary to prior expectation, labor capacity negatively influences the probability of adopting contour ridging. On the other hand, adoption of contour ridging is negatively correlated with the education level of the farmer, similar to the findings of Gould et al, (1989) in Knowler and Bradshaw, (2007). This could be because contour ridging is not a complex technology and hence farmers with low education levels are more willing to uptake it compared to other knowledge-oriented technologies.

4.3.4 Adoption of crop rotation

Similar to the observation by Doss, 2006 and Marenya and Barreta (2006), a unit increase in labor capacity will increase a farmers' likelihood to adopt and use this practice. Since crop rotation involves diversifying crops, it is labor intensive hence the likeliness of households with more family labor to adopt such a technology.

Education level shows a positive correlation with adoption and use intensity of crop rotation. This suggests that farmers with higher levels of education are more likely to adopt crop rotation. This finding is consistent with Langyintuo and Mekuria (2005) who assert that educated farmers are better able to process information and search for appropriate technologies in the quest to alleviate their production limitations. Knowler and Bradshaw (2007) listed studies such as Rahm and Huffman (1984), and Shortle and Miranowski (1986), which reached similar conclusions.

<TABLE 5 goes about here>

4.3.5 Complementarities between adoption of CA technologies

Conservation agriculture is usually promoted as a package that includes different components or technologies. Although adopting all aspects of CA will generate full benefits of CA (Erenstein, 2003) it is difficult for farmers in developing countries to do so due to numerous factors outlined in Wall (2007), FAO (2001b) and Chomba (2007). Due to heterogeneity in farmers' socio-economic profiles, perceptions and livelihood objectives, different households tend to conveniently select and adopt different components of this package. Mazvimavi and Twomlow (2009) study on adoption of conservation farming contends that farmers tend to disassemble technology packages and adopt what they perceive as the most relevant components followed by additional components in time. Dumanski et al., 2006, cited as a major strength of CA, the step like implementation by farmers of complementary and synergetic practices that are meant to improve agricultural production. This section, using the regression results, highlights on how an increase in the area under one CA technology influences the adoption and extent use of another CA technology on farmers that adopt multiple technologies.

CA specialists contend that for farmers to fully realize the full extent of benefits of CA, they need to incorporate all three aspects (minimum tillage, surface soil cover and crop rotation). Survey results shows that only 20% of the farmers had adopted all three aspects at the time of the study. Crop rotation was shown to have a positive and significant correlation with zero-tillage. The results suggest that a unit increase in the area under rotation will result in an increase in the likelihood of adoption and extent of use of zero-tillage. There is also a positive and significant relationship between use of Crop rotation and adoption and extent of use of contour ridging. A unit increase in the area under rotation significantly increases the adoption and use intensity of contour ridges. Similarly, zero-tillage has a significant impact in the use adoption of crop rotation. A unit increase in the area under zero-tillage significantly increases the likelihood that a farmer adopts crop rotation and increase the extent of its use. Contour ploughing is also significantly linked with crop rotation. A unit increase in the area under contour ploughing will increase the adoption and use intensity of crop rotation.

Crop rotation seems to be the main technology that is linked to all other CA technologies. When soils are not inverted (through zero or minimum tillage) and residues are retained, crop rotation becomes a good option for the control of pests, diseases, and weeds because it interrupts the infection chain between subsequent crops (PACA, 2009). Communal farmers in the area, like in most parts of the developing world, do not have optimal access to herbicides due to economic inability and institutional failures in providing efficient input markets.

5. Conclusion and policy recommendations

The main objective of this paper is to establish factors that affect adoption of crop rotation, contour ridging and zero-tillage practices in order to provide insights to researchers, extension agents and policy makers responsible for the development and promotion of appropriate intervention strategies. Despite many studies having confirmed the benefits of CA, it is very imperative that policy makers realize the effects played by various factors (e.g. farm, farmer, institutional and other exogenous factors) in conditioning farmers' decision to adopt these technologies.

The main finding is that there are no apparent common factors that determine farmers' decision to adopt the three technologies in the survey districts. Each technology is distinctly affected by a set of its own factors. Hence, there is need for development agencies to firstly target those farmers that have a appropriate socio-economic characteristics that favour adoption of the technology in question. Secondly awareness and promotional strategies should be tailored depending on whether the target farmers resemble factors for adoption or factors against adoption.

Empirical results show that variables like labor capacity, cattle ownership and disposable income have significant but contrasting effects on adoption decisions depending on the type of technology in question. The implication on development efforts is that it is recommended that extension workers undertake household labor profiling of the targeted survey sites to determine household labor supply and demand as well as whether the labor markets work effectively and the extent to which farmers are Willing To Pay (WTP) for hired labor.

Another major highlight of this paper is the apparent existence complementarities between different technologies. A potential strategy could be to promote CA technologies that that show some degree of complementarity as a package rather than independently. This may reduce the time required between when the farmer adopts the first technology and the subsequent adoption of other technologies and hence realising the full and extensive benefits of CA as a package. It is also important for stakeholder especially in the public sector to facilitate efforts that try to eliminate barriers and bottlenecks limiting farmers' access to credit services and markets for inputs and outputs.

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Table 1: Descriptive statistics by survey districts

	Shamva–Zimbabwe (N=100)
Household size	7.21 (1-34)
Males: ≥ 60 years	0.18 (0-1)
16-59yrs	1.55 (0-7)
≤ 15 years	1.55 (0-11)
Females: ≥ 60 years	0.26 (0-3)
16-59yrs	1.87 (0-7)
≤ 15 years	1.73 (0-15)
Female headed household (%)	16.00
Age of House Head (HH)	47.5 (18-86)
Years HH has been decision maker	19.52 (2-62)
Education level of HH in years	6.35 (0-13)
HH's farming experience in years	21.00 (2-62)
Leadership position in community (%)	6.00

Note: In parenthesis are the ranges

Table 2: Awareness and use of CA technologies in Shamva district (%)

CA practice	Awareness	Adopters	Dis-adopters	Non-adopters
Zero-tillage	78	36	26	38
Mulching	52	35	4	61
Contour ridges	84	73	3	24
Tie ridges	5	0	0	100
Potholing	17	4	4	92
Strip cropping	6	2	1	97
Rotation	90	76	8	16
Stone terracing	14	2	0	98
Vetiver grass	21	4	0	96
Banner grass	5	0	0	100
Total[2]	372	232	46	722

[2] Total exceeds 100% due to multiple responses

Table 3: Definitions and descriptive statistics of variables used in the Tobit model

Variable	Definition	Mean
	Dependent variables	
CNTPROP	Proportion of area under Contour ridges (in Ha)	0.55 (0.439)
ZERPROP	Proportion of area under zero-tillage (in Ha)	0.14 (0.290)
ROPROP	Proportion of area under rotation (in Ha)	0.61 (0.460)
	Farm and farmer factors	
GENDER$^{(+/-)}$	A binary variable with 1 if household head is a male and zero otherwise	0.84 (0.368)
AGEHH$^{(+/-)}$	Age of household head in years	47.46(15.069)
EDUCN	Years of formal education of household head	6.35 (4.473)
DISPINC	Household disposable income in Z$	8.17 (8.250)
MEUNIT	Household labor capacity	3.13(1.996)
TOTAREA	Total arable area (in Ha)	0.37 (0.485)
TLUNIT	Draft power capacity	282.32 (628.3)
CATTLE	Number of cattle	3.30 (3.672)
	Institutional factors	
ASSOCN	A binary variable with 1 if household head belongs to a farmers' association and 0 otherwise	5.88 (4.172)
CRED	Binary variable with 1 if household is a beneficiary of input credit support	4.05 (3.917)
EXTVST	A binary variable if household has extension contacts at least three times a year	0.31 (0.465)
	Bio-physical factors	
SLOPE	A binary variable with 1 if slope of field under CA technology is flat and zero if slopy	0.38 (0.487)
SANDY	A binary variable with 1 if soil texture of field under CA technology is sandy and zero if otherwise	0.36 (0.482)
CLAY	A binary variable with 1 if soil texture of field under CA technology is clay and zero if otherwise	0.05 (0.219)

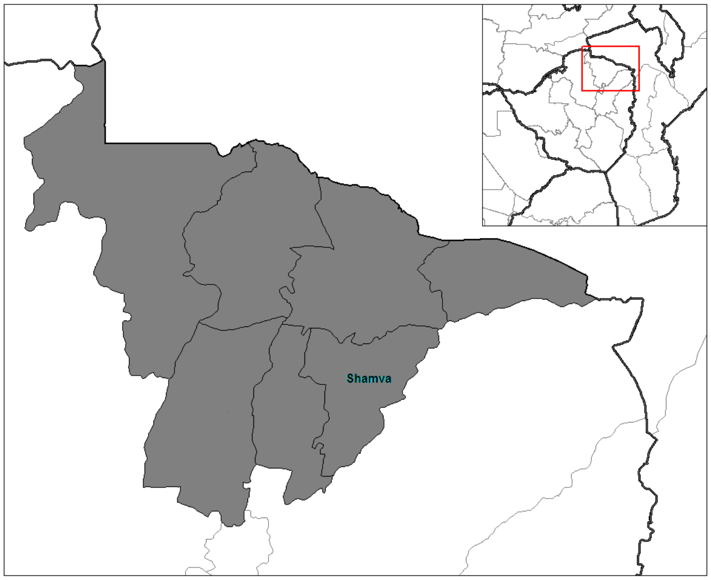
Note: Standard deviations in parenthesis

Table 4: Estimated marginal effects from the standard Tobit model results

Variable	Zero-tillage	Contour ridging	Crop rotation
GENDER	-0.064	0.459**	-0.259
	(0.300)	(0.213)	(0.314)
AGEHH	-0.005	0.010*	-0.008
	(0.009)	(0.005)	(0.007)
EDUCN	-0.008	-0.037**	0.048**
	(0.027)	(0.017)	(0.022)
MEUNIT	-0.225***	-0.041**	0.053**
	(0.076)	(0.017)	(0.022)
CATTLE	0.119***	0.026	-0.027
	(0.043)	(0.019)	(0.027)
TOTAR	-0.077	0.034	0.027
	(0.063)	(0.039)	(0.054)
INPCRD	0.781***	-0.140	0.031
	(0.258)	(0.144)	(0.198)
DISPINC	-0.002**	+0.001**	0.000
	(0.001)	(0.000)	(0.000)
ASSCN	0.089	-0.154	0.052
	(0.243)	(0.169)	(0.230)
EXTVST	-0.009	0.028***	-0.020
	(0.012)	(0.010)	(0.015)
SLOPE	-0.937*	0.097	-
	(0.498)	(0.230)	
SANDY	0.982*	-0.220	-0.002
	(0.510)	(0.219)	(0.200)
CLAY	0.700**	0.185	-0.409
	(0.345)	(0.288)	(0.395)
ROPROP	0.703**	0.561***	-
	(0.314)	(0.146)	
CNTPROP	0.048	-	0.787***
	(0.303)		(0.234)
ZERPROP	-	-0.016	0.662**
		(0.257)	(0.326)
Log likelihood	-18.544	-36.476	-48.125
LR chi^2	57.00***	33.51***	23.00*
Psuedo R^2	0.5101	0.3148	0.1929

Note: Standard errors in parenthesis; ***, **, * denote variable significant at 1%, 5% and 10% level of probability error respectively; LR chi2 denotes the likelihood ratios; Psuedo R2 denotes proportion of variation in the dependent variable that is explained by changes in the independent variable

Figure 1 Map showing selected survey district



Source: http://en.wikipedia.org/wiki/Image:Mashonaland_Central_districts.png