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Factors affecting the choice of conservation agriculture practices adopted by smallholder cotton farmers in Zimbabwe

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Conservation agriculture (CA) has been widely promoted in Zimbabwe as an antidote to non-viable agricultural production and continual land degradation. However, the adoption process had been quite slow and has not yet entered into the exponential uptake phase. This study aimed at identifying factors that influence the level of adoption of CA components. A cluster analysis from results of a household survey administered to 146 households in Muzvezve II, Kadoma District, Zimbabwe identified five dominant CA strategies (clusters) practiced by cotton growing farmers. A multinomial logit model revealed that the choice of CA components adopted is positively influenced by farmer's age, formal education, access to extension services, labour, animal draught power availability and land size. The empirical results suggests that, to promote adoption of a complete package of CA policies that increase access to formal education and extension of CA should make strategic intervention through innovative methods of farmer to farmer extension services. Promotion of longer-term and effective CA can only be accomplished through targeting young educated farmers. It is of paramount importance as well to address the main factors leading to non-adoption and slow adoption such as labour and animal draught power availability.

Key words: Cluster analysis, household survey, non adoption, strategic intervention, multinomial logit.

INTRODUCTION

Significant initiatives have been undertaken to improve the livelihoods of smallholder farmers in southern Africa through conservation agriculture (CA) (ZCATF, 2009). These farmers generally have problems with non-viable agricultural production, characterized by low yields, ongoing land degradation from soil erosion, nutrient depletion and global depression of crop prices (prices of cotton in particular) (Marongwe et al., 2011). Low production levels have further threatened the livelihood security of these farmers compelling them to engage in

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unsustainable soil and crop management practices (Theodor and Kassam, 2011). For example in Zimbabwe, cotton yield fell from 503 kg ha^{-1} in 1980 to 243 kg ha^{-1} in 2012 (USDA, 2012). The fall in production has been mainly attributed to poor husbandry practices and recurrent droughts (Hassan and Nemachena, 2008). Economic crisis over these years have also affected crop production further, thus deepening the livelihood insecurity of these farmers (FAO, 2012). Many studies have highlighted the potential of CA in addressing these livelihood security challenges, while improving soil and water management (Kassam et al., 2009; Guto et al., 2011).

In Zimbabwe cotton is the second most important export crop after tobacco even though it is faced with global competition (UDSA, 2012). Approximately 99.2% of the crop comes from smallholder sector (Poultron and Mhlambo-Hanyani, 2009). Cotton is one of the main sources of cash income to meet household financial expenditures in cotton production areas in Zimbabwe (James, 2006). However cotton production contributes significantly to land degradation through cultivation practices as well as intense consumption of soil nutrients (Gwenzi et al., 2009). Empirical studies have shown that CA offers a possible solution to land degradation which is being experienced in cotton production areas and other marginal areas in Zimbabwe (Thierfelder and Wall, 2011). Conservation agriculture is a sustainable method of farming that comprises of three main principles which are:

(1) Minimum mechanical soil disturbance,
(2) Maintaining at least 30 % of the soil covered using crop residues and
(3) Growing crops in rotation sequences or associations (Kassam et al., 2009; FAO, 2012).

The benefits of CA are increased infiltration of rain water in the soil and protection of soil against soil erosion through mulching and minimal soil disturbance. The soil fertility is also expected to increase through organic matter build up from crop residues, use of legumes in crop rotations and increased fertiliser use efficiency through precise application (Dercon et al., 2010; Johansen et al., 2012). It is believed that CA offers a means to increase labour productivity and ensuring higher and more stable crop yields at reduced production costs.

Conservation agriculture package, promoted in Zimbabwe consists of the following components, as adopted from Protracted Relief Program (2005):

(a) Winter weeding: This should be done soon after harvesting in May/June. The importance of weeding before land preparation is to ensure that the plot is weed-free at basin preparation, conserve moisture and also to prevent the dispersal of weed seeds.
(b) Digging planting basins: Planting basins are holes dug in a weed-free field into which a crop is planted and are prepared in the dry season from July to October.
(c) Application of crop residues: Crop residues (at least 30% soil cover) are applied on the soil surface in the dry season, soon after harvesting.
(d) Application of manure: The application of both organic manure/composts is recommended soon after land preparation.
(e) Application of basal fertilizer: Inorganic basal fertilizer is also applied soon after land preparation before the onset of the rains.
(f) Application of topdressing: Nitrogen fertilizer is applied to crops between 3 and 6 weeks after crop emergence soon after the first weeding.
(g) Timely weeding: Farmers are encouraged to weed in a timely manner (that is, when the weeds are still small) so as to prevent the weeds from setting seed.
(h) Crop rotation: Involves alternating crops of different families such as legumes and cereals every season.

These eight components include the three CA principles and five practices which are deemed good agronomic practices that support CA.

Though CA has a potential to address land degradation, which occurred as a result of unsustainable means of crop production in smallholder farming areas (Domas et al., 2009). Marongwe et al. (2011) noted that there are a number of socio-economic factors determine the adoption of CA by smallholder farmers in Zimbabwe. Despite the growing advocacy that CA offers many benefits to the vulnerable households in marginal environments in Zimbabwe, these technologies have been less widely adopted (Mazvimavi and Twomlow, 2009; FAO, 2011). Proponents of CA argue its benefits can be fully realized, when the complete set of agronomic management practices are applied simultaneously (Gowing and Palmer, 2008; Giller et al., 2009). Empirical evidence in southern Africa has shown variation in the farmers' adoption rate of CA technologies (Mazvimavi et al., 2008). Some farmers have adopted the complete package, others only partially while others have completely dis-adopted. Among the farmers who continue to practice CA, many have modified the package and generally adopted some components of the technology while leaving out other recommended practices (Mazvimavi and Twomlow, 2009).

Identifying the socio-economic factors that are likely to enhance or impede adoption of CA will assist policymakers and researchers in their planning and implementation of comprehensive CA. The overall objective of this study was to determine the socio-economic factors that influence the level of adoption of CA practices by cotton growing farmers in Kadoma District, Zimbabwe. Specific objectives of the analysis were to:

(a) Identify the level of CA practices adopted by smallholder cotton farmers.

(b) Explore the influence of socio-economic variables on the choice of different levels of CA practices.
(c) Provide recommendations on the most suitable CA strategies for cotton growing farmers.

METHODOLOGY

The study area

A survey was conducted in thirteen villages in Muzvezve II, Kadoma District which is situated in Mashonaland West Province, Zimbabwe. The geographical coordinates for the study area are 18° 31′ S; 29° 40″ E. Climatically, Kadoma District straddles Natural Regions IIa, IIb, and III with the study site being in Natural Region III according to the land classification in Zimbabwe (Vincent and Thomas, 1960). The study site is characterized by semi-intensive farming. The rainfall is erratic and fluctuates from season to season. The average rainfall is 650 to 800 mm year^{-1}. The erratic rainfall during the cropping season makes the crops vulnerable to seasonal and mid seasonal droughts which pose a risk to crop production. The minimum temperatures range from 10 to 14°C while the maximum temperatures range from 28 to 35°C.

The soils in the study area are classified as Usotropept (USDA) or Chronic Luvisol (FAO). In vlei areas the soils are heavier, black in colour and relatively more fertile. Land is individually owned and smallholder mixed farming predominates. Cotton (*Gossypium hirstum (*L.) and maize (*Zea mays* (L.)) are major cash crops while groundnuts (*Arachis hypogaea* (L)), cowpeas (*Vigna unguilata* (L)), beans (*Phaseolus vulgaris* (L.)), bambara nuts (*Vigna subterranean* (L)) are common food crops. Majority of the farmers keep cattle, goats and poultry as a source of livelihood.

Sampling procedure

A total of 146 households were interviewed using a structured questionnaire from thirteen villages in Muzvezve II ward, Kadoma. Stratified random sampling procedures were used to obtain unbiased, efficient and consistent estimates of the target population. Firstly, Muzvevzve II ward in Kadoma rural District was purposively sampled based on the number of farmers practicing CA. Secondly farm households were selected from the village sample frame using stratified random sampling. The sample size in each village was proportional to the village population size. Stratification was based on the number of years the farm households had been exposed to the CA technologies, proportion of area under CA, gender of the households head, number of year the household had been formed and living in the village and wealth status as measured by number of cattle owned and major farm equipment such as the moldboard plough. Additional data on CA adoption levels for each village, community based variables such as land use patterns and average proportion of land under these technologies were obtained from secondary data (reports) and key informant interview of different organizations working in the area such as FAO.

Data collection

Primary data collected include detailed household socio-economic characteristics, household resources, their sources of livelihood, exposure to economic and natural shocks and their mitigation strategies, access to financial and physical capital and institutional support. Households were also asked about crop and livestock production, were possible retrospective data for 2006 to 2007 season to 2008 to 2009 season were collected. Crop production information included crop area under different agricultural technologies and practices, input quantities and sources, quantity of each crop harvested and marketed. Primary data was complemented with secondary data from the ministry of agriculture at district level and FAO.

Data analysis

Descriptive analysis

Descriptive statistics was used to analyse quantitative data and results were presented.

Custer analysis

Cluster analysis a multivariate technique was used to group households based on similarities in their CA practices through maximizing within-group similarities and between-group differences (Kaufman and Rousseeuw, 2009). Clustering can provide information to better target interventions towards households with certain common characteristics, thereby increasing the efficiency of targeted interventions and other incentive structures towards the intended beneficiaries (de Janvry and Sadoulet, 2000). The identification of clusters is empirically based instead of guided by theory (Hair et al., 1998). The reasoning is that there are some latent common features that enable the agglomeration of individual observations into a smaller number of groups based on the similarity along particular, pre-determined dimensions of the individuals in each group. As agglomerative hierarchical cluster analysis can give rise to misclassification of observations at the boundaries between clusters (Wishart, 1999), *k*-means cluster analysis was used in the study. In *k*-means cluster analysis, observations are initially randomly assigned to each of the *k* cluster, and then reassigned using an iterative method to minimize within-cluster variance and maximize between-cluster variance (Wishart, 1999). The similarity measurement used was the Euclidian distance, and the centroid method of measuring similarity was employed because this method is more robust to outliers than most other hierarchical methods. The outcome of this cluster analysis was several clusters of households, within each cluster displaying a distinct CA choice.

Multinomial Logit

A multinomial logit model (MNL) was specified according to Hausman and McFadden (1984) and estimated to explain a household's choice of CA technologies. The farmer will choose certain components of CA technology only if the expected utility level of the chosen combination of technologies is greater than the utility obtainable for other available alternatives. Following Greene (2003), the MNL is specified as:

$$\ln (P_j/P_m) = \beta'_i X \qquad j = 1, 2 \ldots m-1 \qquad (1)$$

where ln = natural log, P_j is the probability that a given household falls into the jth cluster, P_m is the probability that a household falls in a benchmark cluster, X is the set of explanatory variables, and β' is the corresponding set of MNL regression coefficients to be estimated. The dependent variables in these equations are the log-odds ratios of being in cluster j versus being in cluster m (the benchmark cluster). A total of (m^{-1}) binary logit equations are estimated simultaneously in the MNL, and the sum of the *m* predicated probabilities is restricted to 1 (Greene, 2003). The probability of the ith household being in cluster j is computed as:

$$P_j = \frac{e^{\beta' jX}}{1 + \sum_{j=1}^{m} e^{\beta' jX}} \qquad (2)$$

The ith household's probability of inclusion in cluster *m* is estimated by

$$P_m = \frac{1}{1 + \sum_{j=1}^{m} e^{\beta' jX}} \qquad (3)$$

It is hypothesized in the MNL that the choice of a particular CA strategy (cluster) is a function of the Xs representing household resource endowments, community factors (access to extension, education) and institutional factors (extension services, training and material support through government and local NGOs).

The effect of a unit change in any of the X explanatory variables on the probability that the i^{th} household will choose a particular CA strategy is given by the marginal effect statistic (Greene, 2003), which is derived as follows:

$$\Delta P_j/\Delta X_i = P_j\ [\beta_j - \sum_{k=1}^{m} Pk\beta k] \qquad (4)$$

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

The socio-economic characteristics of the respondents are presented in (Table 1). About 61% of the households interviewed are less than 45 years old. Age has been found to be an important factor influencing adoption of farming technologies (Nwakor et al., 2011). Though more recently, there has been mixed findings on the effect of age on adoption of CA (Langyintuo and Mungoma, 2008; Mazvimavi and Twomlow, 2009). Adoption theories, for labour-intensive and complex technologies such as CA reiterate that for technologies to be successful should target young farmers (Defrancesco et al., 2008). Young farmers have been found to be more innovative and less risk averse than older farmers (Mazvimavi and Twomlow, 2009). About two thirds (65.8%) of the respondents had secondary education providing a good opportunity for successful extension campaigns and programs that seek to disseminate and promote adoption of any agricultural innovation, particularly soil and water conservation (Mupangwa et al., 2012). More than half of the households had medium sized households and farms, about 6 to 10 household members and farm sizes ranging between 4.45 to 6.67 ha, respectively.

Family members are the main sources of labour in rural areas of Zimbabwe, as some components of CA (digging planting and timely weeding) are laborious, large families or families with animal draught power are expected to be more innovative compared to small families or those without animal draught power. Additionally, large farms will also make more land available for CA and therefore adoption of the technology will not be perceived as a risk to household food security (Table 1).

Components of CA practices

Results from the descriptive analysis (Table 2) revealed that 63.5, 28 and 56.2% of the households practiced winter weeding, planting basin and crop residue application in the 2008 to 2009 season, respectively. Among the farmers, manure application and timely weeding were the most popular CA technologies. There has been a significant decrease of 13.1% in the percentage of farmers applying basal inorganic and top dressing fertilizers from 2007 to 2008 to 2008 to 2009 season. This significant change was attributed to the decrease in availability of free inputs both from non-governmental organizations promoting the technology and from central government (Mazvimavi and Twomlow, 2009). The scarcity of inorganic fertilizers and economic collapse during 2007 to 2008 to 2008 to 2009 seasons further constrained the use of fertilizers in the smallholder areas. Proponents of CA emphasize that for farmers to fully realize the benefits of this technology, they need to incorporate all the components of the package (Mupangwa et al., 2012). Giller et al. (2009) noted that adoption of CA in smallholder sector is characterised by partial adoption or referred to as 'distorted adoption'. Farmers tended to disassemble technology packages and adopt what they perceived as the most relevant components followed by additional components with time. Heterogeneity in resource endowments, livelihood objectives and risk perceptions explained the difference in components of the technologies adopted (Mazvimavi and Twomlow, 2009) (Table 2).

Conservation agriculture strategies

Five clusters or strategy dimensions of CA were identified and illustrated in Table 3. Cluster one which consisted of 7.5% (11) of the households, had 2 and 0.4 ha of their land under conventional agriculture, and planting basins as a component of CA, respectively. These farmers only practiced three components of CA consistently, namely application of basal inorganic, top dressing fertilizers and timely weeding. Cluster two composed 12 % of sampled households who practiced all the components of CA consistently. They are different from all the other clusters in that they had more land with planting basins, about 1.2 ha. Conversely they had less land under conventional

Table 1. Socio-economic characteristic of respondents of a household survey, in Kadoma District, Mashonaland West, Province, Zimbabwe, 2009.

Socio economic characteristics	Frequency	Percentage
Age of head of household (Years)		
<25	6	4.1
25-35	23	15.8
36-45	60	41.1
46-55	15	10.3
56-65	37	25.3
>65	5	3.4
Total	146	100
Marital status of head of the household		
Single	7	4.7
Married	112	76.7
Widowed	23	15.8
Divorced	2	1.4
Separated	2	1.4
Total	146	100
Years of formal education		
No formal Education	1	0.6
Primary education (1-7)	47	32.2
Secondary Education (8-13)	96	65.8
Tertiary Education (>13)	2	1.4
Total	146	100
Average number of people in a household		
≤ 5	24	16.4
6-10	67	45.9
11-15	31	21.2
16 -20	21	14.4
< 20	3	2.1
Total	146	100
Average area of cultivated land (Hectares)		
<0.8	5	3.4
0.8-1.6	63	43.2
1.82-2.4	70	47.9
2.6-3.23	6	4.1
3.4-4	2	1.4
Total	146	100
Mean number of cattle per household		
0	37	25.3
<5	55	37.7
5-10	38	26
11-15	15	10.4
>15	1	0.6
Total	146	100

agriculture. Cluster three consisted of 40 % of the sampled farmers who mainly practiced conventional agriculture, with timely weeding; application of basal inorganic and top dressing which are components of CA. Farmers in cluster four practiced all the components of CA except digging planting basins. Households in cluster

Table 2. Proportion of sample households practicing components of conservation agriculture in 2008 to 2009 agricultural season.

Components of conservation agriculture	Cropping Season (n=146)	
	2007/08 (%)	2008/09 (%)
Winter weeding	46.7	63.5
Planting basins	20	28
Application of crop residue	43.0	56.2
Application of manure	68.9	74.5
Application of basal inorganic fertilizers	77.4	64.3
Application of top dressing	79.6	71.7
Crop rotation	40.5	48.3
Timely weeding	92.5	95.9

Table 3. Clusters of conservation agriculture strategies practiced by survey households, Kadoma District, Mashonaland West, Province, Zimbabwe, 2009.

Agricultural management practices	Cluster 1 N = 11	Cluster 2 N = 18	Cluster 3 N = 57	Cluster 4 N =33	Cluster 5 N = 27
Average area under conventional agriculture (Hectares)	2	0.40	1.21	0.81	0.40
Average area of maize and cotton with planting basins (Hectares)	0.40	1.21	0	0	0
Application of cattle manure (dummy 1 = Yes, 0= No)	0	1	0	1	1
Application of inorganic basal fertilizers	1	1	1	1	0
Application of top dressing	1	1	1	1	1
Crop rotation practice	0	1	0	1	1
Winter weeding	0	1	0	1	0
Timely weeding	1	1	1	1	1

five were unique in that they had only an area proportional to 0.4 hectare under conventional agriculture, practiced timely weeding, manure and top dressing application as well as crop rotation consistently. The results of cluster analysis also confirms findings of Thierfelder et al. (2012) that different households tend to conveniently select and adopt different components of CA (Table 3)

Multinomial logit model determinants of CA components choices

A multinomial logit regression was applied to identify the main determinants of CA components choices from cluster analysis. The effect of coefficients was estimated with respect to cluster 2, (those households who had adopted all the eight components of CA package) as the base category. Therefore, the inference from the estimated coefficients for each choice category is made with reference to the base category. The model was tested for the validity of the independence of the irrelevant alternatives (IIA) assumptions using the Hausman test for IIA and the SUEST (Seemingly unrelated post-estimation procedure). Both test indicated that the multinomial logit specification was appropriate in modeling CA choices of the smallholder farmers in Kadoma rural. Both tests failed to reject the null hypothesis of independence of the CA options available to smallholder farmers. The likelihood ratio as indicated by the chi-square statistic was highly significant ($P<0.001$) suggesting that the model has a strong explanatory power (Table 4).

For cluster one contrast, the coefficients for age of the head of household, average land owned and draught power owned were positive and statistically significant. This suggested that the odds of being in cluster one relative to cluster two rise for those households with older household heads, more land and draught power. The results (Table 4) show that an increase in education level of the head of the household, extension service access, institutional membership and CA experience significantly reduce the likelihood of choosing cluster one relative to cluster two. A unit increase in number of years of schooling would result in 19% increase in the probability of being in cluster 2. These results have important policy implications to CA promoters that increase in formal education, and access to extension services increases the probability of adopting all the eight components of CA. They also confirm the findings from other studies that increased access to formal education and extension services enhance farmers' understanding and technical

Table 4. Multinomial Logit Estimates for the conservation agriculture practice choices of Kadoma, District rural farmers, Mashonaland West, Province, Zimbabwe, 2009.

Variable	Cluster 1 P1/P2			Cluster 3 P3/P2			Cluster 4 P4/P2			Cluster 5 P5/P2		
	Coefficients	Marginal effects	P-values	Coefficients	Marginal effects	P-values	Coefficients	Marginal effects	P-values	Coefficients	Marginal effects	P-values
Education (years)	- 2.756**	- 0.19	0.03	-1.893***	-0.107	0.005	3.549***	0.282	0.004	- 2.469***	- 0.165	0.0001
Age of head of household	1.082***	0.051	0.002	2.694***	0.22	0.001	- 0.972	-0.019	0.612	0.784	0.020	0.76
Average land owned (Hectares)	0.594***	0.037	0.007	0.253	0.001	0.522	- 4.118***	-0.367	0.0001	- 3.098***	- 0.249	0.005
Extension service	- 2.031*	- 0.22	0.069	0.994	0.006	0.23	1.436**	0.254	0.023	- 0.0616	- 0.001	0.92
Institutional Membership	-0.026**	- 0.008	0.041	0.828	0.003	0.48	0.015	0.0007	0.81	- 0.018	-0.0012	0.53
Draught Power	4.382***	0.314	0.005	2.933***	0.182	0.009	0.787	0.004	0.37	- 2.641**	-0.3008	0.033
Labour[a]	0.071	0.005	0.681	0.056	0.011	0.18	-1.629***	- 0.189	0.008	-2.044***	-0.2941	0.0021
Conservation farming experience	-0.421	- 0.0132	0.19	-0.744	0.002	0.27	- 0.948**	- 0.071	0.041	0.025	0.0092	0.591

*=significant at 10%, **=significant at 5%, ***=significant at 1%, Base category – Cluster 2 (households that adopted all the 8 components of CA), Number of observation 146, LR Chi-square 190.74***,Log likelihood 203.8,Overall % of households correctly predicted 61.7%. [a]Labour- consists of family labour available for general farm work, hired and exchange. Children ≤12 years, between 13 and 15- 0.2 and 0.4 conversion factors of man equivalent labour day were used respectively as recommended by the International labour law.

capability for CA practices (Teklewold and Köhlin, 2011). For cluster three, only increase in age of household head and draught power increased the probability of being in this cluster relative to cluster 2 while increase in education level of the household head decreased the probability of choosing that category. For cluster four formal educations and extension services had a positive and statistically significant coefficient, where-as land ownership, labour and CA experience had negative statistically significant coefficients. This implies that the probability of the sample households to be in this cluster relative to cluster 2 increased with education and extension contact while an increase in size of land owned, CA experience and labour availability reduced it. Finally the probability of being in cluster five relative to cluster 2 decreased with increased education, size of land owned, labour and draft power availability. This implies that resource constrained households, particularly physical and human capital were more likely to belong to this cluster. The MNL results confirm that adoption of all the eight CA components increased with a unit increase in number of years of education of the head of household except for cluster 4 were land and labour availability are the major limiting factors. The marginal values of education are negative for all clusters relative to cluster 2 except for cluster 4. Conversely all the clusters had positive marginal values for household head age and labour availability except cluster 4. It can be inferred from the results that households with more educated heads, more land and labour have better chances of adopting a higher proportion of CA components education for all clusters expect cluster 4, draft power for cluster 5 and labour availability for cluster 4 and 5. These results are consistent with Bandara and Thiruchelvam (2008) and Mangisoni et al. (2011) who assert that choice of CA components is positively influenced by farmer's formal education level, labour available and the land size. The study contributes to literature on adoption of CA in the smallholder African sector. The socio-economic factors and challenges identified in the study shows areas that needs to be addressed to promote widespread adoption of CA in the smallholder sector in Africa.

Conclusion

The study revealed that farmers disentangle the CA package and adopt what they perceive as the most relevant components. The cluster analysis identified five dominant CA strategies practiced by cotton farmers. A few farmers practiced all the eight recommended components of CA which are important for them to realize benefits of CA. Digging of plant basins as a component of CA was practiced by a few farmers while timely weeding was the most popular component practiced by most farmers. The empirical results from multinomial logit analysis showed that the choice of CA adopted is positively influenced by farmer's formal education, access to extension services, labour and animal draught power availability and land size. The farmer's decision to adopt components of CA was also conditioned by age. The results imply that, to promote adoption of a complete package of CA, policies that increase access to formal education and extension services should be apriority. Farmers perceived an increase in weeds and labour requirements in CA. In view of these findings it is recommended that all stakeholders involved in the promotion of CA should make strategic intervention through innovative methods of farmer to farmer extension services. Promotion of longer-term and effective CA can only be accomplished through targeting young educated farmers as well as addressing the main factor underlying non-adoption such as labour unavailability.

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