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The Indaba Agricultural Policy Research Institute (IAPRI) is a non-profit company limited by guarantee that collaboratively works with public and private stakeholders. IAPRI exists to carry out agricultural policy research and outreach, serving the agricultural sector in Zambia so as to contribute to sustainable, pro-poor agricultural development.

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EXECUTIVE SUMMARY

Conservation Agriculture (CA) has been actively promoted actively since the early 1990s among Zambian smallholder farmers as a practice that helps improve crop productivity, improve soil fertility, and mitigate against low and/or variable rainfall. However, nationwide survey data show that adoption rates by Zambian smallholder farmers have remained low, while dis-adoption is widespread despite years of promotion. Several empirical studies have investigated the determinants of adoption, dis-adoption, and non-adoption of CA with the focus being on human capital assets, farm assets, institutional factors, risks and economic factors, and climatic conditions. However, a household's decision to adopt CA and any other farm practice is influenced not only by these factors but may largely be driven by household social, cultural and traditional beliefs that are normally difficult to capture in household surveys. Differences in culture may explain differences in perceptions, approaches towards adoption, and diffusion of new technologies. This study attempts to further explore the relationship between household beliefs, community endowments and services, and CA adoption in Zambia.

Using 2015 nationally representative rural households survey data, we find that 8.8% of smallholder rural households practiced CA in 2013/14 agricultural season, with 3.7% adopting the full CA package (minimum tillage, maize-legume rotation and residue retention) and the remainder adopting partial CA (minimum tillage with either maize-legume rotation or residue retention). Notably, the adoption rates of CA have increased by 6.4 percentage points from 2010/11 agricultural season. The rates are even higher if we only consider AEZ I and II, which are the suitable CA zones, at 11.7% in 2013/14 agricultural season, with 4.8% adopting full CA and 6.9 adopting partial CA.

Follow-up qualitative interviews with different groups of farmers marginally suggested that social or cultural beliefs might be a hindrance to the adoption of CA. However, the econometric analysis results on the determinants of CA adoption in this study show that social factors, to some extent, play an important role in a household's decision to adopt CA in Zambia. The results also show that availability of CA support services such as spraying services at community level had positive effects on the likelihood of smallholder households adopting CA. Surprising, the availability of tractor hiring services in the community reduces the likelihood of CA adoption. This result is counter-intuitive in that mechanization is hypothesized to help deal with any drudgery that may be associated with adopting conservation farming. It is important to note that the results show that the available tractor hiring services are mostly utilized for plowing and that the majority of the households owning farming implements own plows instead of CA appropriate implements such as rippers. We get similar results for households owning draught animals.

Another striking finding relates to household farm size. Promoters of CA in Zambia have often focused on increasing CA adoption among households with small farms as compared to larger farmers. However, the results show that households cultivating larger pieces of land are more likely to adopt full CA than those cultivating smaller pieces of land, while landholding size did not seem to matter for the adoption of partial CA.

Previous studies have suggested that tenure security constrains farmers to make long-term productivity investments such as adopting CA. Our results are not conclusive to support these suggestions as we find that land tenure did not make a difference in a household's decision to adopt any tillage method used. Hence, variables instead of tenure security are more important to the household's decision on the type of tillage method to use. This does not mean to say that smallholder farmers are not risk averse especially when it comes to long-term productivity investments on land that they are not sure belongs to them. Last but not least, the

results show that bad weather enhances the likelihood of smallholder households adopting CA. Thus, an increase in the number of stress periods in the preceding season increases the household's likelihood of adopting CA in the current season. The implication of this finding is that CA can be promoted as a coping mechanism in light of recurrent weather variability.

Based on these findings, this study makes the following recommendations in order to increase the adoption rates of CA in Zambia:

1. *Social, Cultural Issues:* There is some evidence to suggest social and cultural factors may influence technology adoption. Therefore, before engaging in any promotion of CA, there is need to establish how these issues can influence the communities' decision-making towards the new practice. There is also need for extensive local consultation, to create an understanding of how best CA can be scaled up.

2. *Access to CA Implements:* Limited access to CA implements that reduce drudgery remains a challenge for adoption of CA. The use of draught and mechanical power can be used to address this, however, very few households own or can afford to purchase CA implements to use with their available mechanical power. Additionally, for households without tractors and/or animals, the available mechanization services at community level seem to effectively promote conventional tillage, a situation requiring immediate attention. Increasing availability and access to CA mechanical services and equipment/implements would surely go a long way in enhancing the uptake of CA in Zambia. This can be achieved in part through engaging actors with machinery hiring services into providing minimum tillage services. Further, the creation of an incentive structure to reward farmers who invest into CA implements should be considered.

3. *Tailored CA Promotional Packages:* Given that the factors influencing adoption of CA vary depending on whether a farmer adopts full or partial CA and the farmer type, it is imperative for CA promoters to tailor the CA package and promotional activities to take into account these factors.

4. *Market Access:* Related to access to CA services, promotion of CA should continue to be enhanced through improving farmers' access to input and output markets. Promotion of outgrower schemes and contract farming are sustainable market solutions that can be promoted to help farmers appreciate the benefits of CA, as well as make available mechanized CA services and extension to smallholder farmers. This approach would crowd in the private sector who would in turn help fill the gaps regarding input and output markets facing the smallholder farm sector.

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ACRONYMS

ACT	African Conservation Tillage Network
AEZ	Agro-Ecological Zone
CA	Conservation Agriculture
CASU	Conservation Agriculture Scaling Up
CFU	Conservation Farming Unit
CSA	Census Supervisory Area
CSO	Central Statistical Office
FAO	Food and Agriculture Organization of the United Nations
FDGs	Focus Group Discussions
Ha	Hectares
HH	Household
IAPRI	Indaba Agricultural Policy Research Institute
IIRR	International Institute of Rural Reconstruction
Km	kilometer
MoA	Ministry of Agriculture
PPS	Probability Proportional to Size
RALS	Rural Agricultural Livelihoods Survey
SEA	Standard Enumeration Area
TAMSAT	Tropical Applications of Meteorology using Satellite
USAID	United States Agency for International Development
ZMW	Zambian Kwacha

1. INTRODUCTION

Conservation Agriculture (CA) consists of a package of farming practices based on three main principles namely minimum mechanical soil disturbance; permanent organic soil cover; and crop rotation (FAO 2001; Haggblade and Tembo 2003). CA helps improve crop productivity, improve soil fertility, and mitigate against low and/or variable rainfall (Haggblade and Tembo 2003). In addition to its potential productivity and farm system resilience benefits, there is reason to believe that through the utilization of cover crops and crop rotation, CA practices can improve household agricultural nutrition levels and dietary diversity (Mayer 2015).

Since the early 1990s, CA has been actively promoted by various stakeholders among Zambian smallholder farmers with the aim of increasing its uptake. However, despite the nearly two decades of promotion and evidence of yield benefits associated with CA, national adoption rates remain low, while dis-adoption is often widespread. A number of studies report less than 10% national adoption (Arslan et al. 2013; Ngoma, Mulenga, and Jayne 2014), and about 95% dis-adoption rates (Arslan et al. 2013). These national CA adoption rates have often been much lower than those reported by programs promoting CA in Zambia. For example, Kasanga and Daka (2013) reported 41, 29, and 16% adoption rates in high, medium and low concentration areas of CA promotion whilst Kabamba and Muimba-Kankolongo (2009), reported 10% of smallholder farmers adopting some of the CA technologies, and only 40.5% of small-scale farmers adopting minimum tillage systems. Although, the nationally representative surveys may slightly under represent CA farmers, the sampling methods used by those evaluating CA adoption rates in promotional areas may be put into question. This assertion is made due to the following observation; higher national adoption rates would require that the estimates of CA adoption be very close given that adoption rates are computed at field level among smallholder farm households. Also the definitions of CA has varied across these studies, adding to the varied CA adoption rates reported. These discrepancies have sometimes caused a rift between the researchers and the program implementers as funders are now beginning to question the efficacy of current promotion strategies and programs. There is, therefore, need for additional research to closely look at the determinants of CA adoption in Zambia.

Several empirical studies have been carried out to investigate the determinants of adoption, dis-adoption, and non-adoption of CA by smallholder farmers in Zambia (For example, Chomba 2004; Grabowski et al. 2016; Haggblade and Tembo 2003; Kabwe, Donovan, and Samazaka 2005; Ngoma, Mulenga, and Jayne; Ngombe et al. 2014; Nyanga, Johnsen, and Kalinda 2012). Most of these studies have focused on similar sets of variables that have been posited to influence CA adoption, for instance, human capital assets, farm assets, institutional factors, risks and economic factors, and climatic conditions. For instance, (Haggblade and Tembo 2003; Ngombe et al. 2014; Arslan et al. 2013; Chomba 2004) all examine human capital, farm assets, institutional factors, risks and economic factors and climatic conditions as factors that affect the adoption of CA and CA practices while (Grabowski et al. 2016) extended the set of variables to include community variables on buyers of the produce. The current debate about the factors associated with CA adoption in Zambia is now focused on other non-conventional variables not covered by prior studies. In particular, four issues and their relationship to CA adoption and dis-adoption are at the center of this discussion, more specifically; a) the role of social and cultural/traditional beliefs; b) role of household farm size; c) the role of tenure security and; d) the importance of the availability of supporting CA services in the rural communities. It is against this background that this study goes beyond prior studies by examining these factors that might influence a household's decision to adopt CA practices.

- *Social and Cultural/traditional Beliefs:* Indeed, the adoption of any new technology may be influenced by culture and traditional beliefs. For instance, people's culture and traditional beliefs may help or hinder efforts to promote CA (IIRR and ACT 2005). Differences in culture may explain differences in perceptions, approaches towards adoption, and diffusion of new technologies. In particular, we examine the relationship between cultural and traditional beliefs, as well as the household's heads parents farming history, and CA adoption in Zambia.

- *Farm Size:* Qualitative results show households with larger farm sizes are more likely to adopt CA than households with smaller household size. This holds true more so for full CA adoption as compared to partial CA adoption. This has put into question the current promotion strategy focusing on smaller farmers. Ceteris paribus, this study examined whether indeed farm size matters and the implications thereof.

- *Tenure Security*: Prior studies have suggested that tenure insecurity hinders adoption of new technology especially where the benefits accrue over time (Giller, et al. 2009; Peter Nkala et al. 2011; Kassie et al. 2012). Very few smallholder farmers in Zambia own land with title deeds. Instead, most of the land is under the customary tenure system, which may not provide farmers with an incentive to invest in long-term productivity-enhancing technologies such as CA. There are efforts to help farmers have tenure security through the introduction of a chief's certificate indicating ownership or usage (Honig and Mulenga 2015). However, we could not find any empirical evidence in Zambia, showing the relationship between CA adoption and ownership of a chief's certificate. Therefore, this study examines the relationship between access to a title and adoption of CA.

- *Provision of Services Supporting Households' Adoption of CA:* Households access to implements and other services that support the CA practices influence households decision to adopt CA (Nkala et al. 2011; Chomba 2004; Ngombe et al. 2014). Giller et al. (2009) asserts that access to equipment hiring services; could address labour constraints that have been highlighted as some of the reasons for the low adoption rates.

Results from the qualitative analysis from the Rural Livelihood Agricultural Survey (RALS) of 2015 (CSO/MAL/IAPRI 2015) to some extent support these findings. For example, a greater proportion of households in communities with chemical spraying services adopted CA than households in areas without such services. The results for the availability of mechanical services in the community seem to suggest otherwise. Ceteris paribus, we formally test the influence of the availability of these services in different communities on CA adoption.

A closer examination of the CA adoption in Zambia showed that the major constraining factor is the low adoption of minimum tillage (planting basins, ripping, and zero tillage). Results from RALS 2015 show that 49.9% and 63.3% practiced cereal-legume rotation and residue retention respectively, with only 10.6% practicing minimum tillage. However, it is pertinent to note that, to be considered a CA household, minimum tillage is a prerequisite; hence, the reported low CA adoption rates in the country. It is, therefore, important for this study to go a step further and examine the factors associated with the use of minimum tillage and make recommendations on how to increase the uptake of CA adoption in Zambia.

Using nationally representative rural farm survey data complemented by qualitative interviews with smallholders farmers, this study analyses the determinants of CA adoption in Zambia. The study provides empirical evidence to the emerging debate in Zambia regarding

CA adoption. Specifically, the study focuses on answering the following five research questions:

1. Do social and cultural factors influence adoption of CA in Zambia?
2. What is the relationship between access to farming/agricultural services at community level and adoption of CA?
3. How does a household's farm size influence adoption of CA and the type of CA adopted?
4. Does ownership of land title influence adoption of minimum tillage?
5. What explains the low adoption of minimum tillage in Zambia?

Results from this study provide empirical evidence to benefit the current debate, as well as help guide future CA promotional strategies. The rest of the study is organized as follows: Section 2 presents evidence on the adoption and dis-adoption of CA in Zambia. The data and methods used in the study are described in Section 3, and the econometric results of the study are presented in Section 4. Section 5 presents the conclusion and recommendations made by the study.

2. EVIDENCE OF CA ADOPTION AND DIS-ADOPTION IN ZAMBIA

Although, CA have been successfully adopted and adapted to local conditions by the commercial farmers in the last two decades (Derpsch and Friedrich 2009), adoption by smallholders more especially in Africa has lagged behind. CA adoption rates remain low, while dis-adoption have been widespread in most African countries (Derpsch and Friedrich 2009). Zambia is seen as one of the more successful countries in southern African regarding CA adoption (Haggblade and Tembo 2003). However, the adoption rates have not improved much over the years. CA has been promoted since the early 1990s, by development agencies in collaboration with the government as well as by private sector, especially among cotton farmers. The main objective of this support was to increase the knowledge and adoption of CA and associated agricultural practices. However, despite the continued promotion of CA, there has been a lot of debate in the country on whether the investment in CA has yielded the desired success in terms of the number of farmers adopting the practice.

As discussed earlier, conflicting adoption and dis-adoption rates have been reported by various studies, adding to the debate. The high rates of adoption from project reports based on estimates from few districts were criticised as it was not clear how the results could be extrapolated to be nationally representative. Despite the continued debate, stakeholders have been able to come together to objectively investigate why CA adoption rates are much lower in nationally representative survey data. The emerging evidence is that the major constraint is the low rates of adoption and high dis-adoption rates of minimum tillage (planting basins, ripping, and zero tillage), a prerequisite for a household to be considered a CA household. Kabwe, Donovan, and Samazaka (2005) show that on average only 3% of the smallholder farmers used planting basins consistently, while 97% dis-adopted planting basins across all agro-ecological zones in Zambia. Arslan et al. (2014) using longitudinal data and econometrics techniques to assess adoption and intensity of adoption of CA in Zambia, found dis-adoption rate of 95% between 2004 and 2008 nationally, except Eastern Province where CA adoption increased to 14% in 2008, up from 8% in 2004. Ngoma, Mulenga, and Jayne (2014) found a 4.4% minimum tillage use rate nationwide in 2013/14 agricultural season and about 8% in provinces that have a long history of intensive CA promotion.

The literature on CA highlights a number of key reasons for the low CA adoption rates and the relatively high dis-adoption rates. In Zambia, the evidence indicates that adoption is highly sensitive to promotional activities and positively correlated with CA projects (Grabowski et al. 2016). Farmers tend to respond to the presence of CA projects and implement some form of CA for only as long as project support (mostly in the form of input subsidies) is provided. The fact that dis-adoption increases when projects end raises concerns about the sustainability of the CA promotional strategies. The adoption of CA has also been shown to be strongest in Zambia's Agro-ecological Regions (AEZ) I and II where there is erratic rainfall and extensive plow-pan damage (Ngombe et al. 2014). There is also recent evidence suggesting that Zambian farmers who perceive that climate is changing are more likely to use CA tillage practices (Mulenga and Wineman 2014; Nyanga, Johnsen, and Kalinda 2012).

There is evidence to suggest that a new technology is usually more likely to be adopted if it is not too radical. Ngoma, Mulenga, and Jayne (2014) shows that Zambian farmers are more likely to use and sustain CA practices that are closer to traditional cropping systems (such as the traditional zero tillage method) than other CA practices which require radical changes to farming systems. Other studies also show that very few farmers can afford the initial high input costs associated with CA implementation despite being aware of the benefits (Giller et al. 2009). Even if some CA projects provide start-up support in the form of inputs, such

support is usually too small in value and over too short a period (on average two seasons) for the farmers to be able to graduate and self-finance their future CA activities (Ngoma, Mulenga, and Jayne 2014). Additionally, there is also empirical evidence suggesting that labour requirements under CA may be daunting especially where herbicides are not used (Giller et al. 2009), and that such labour requirements have gendered impacts because field operations such as weeding are generally undertaken by women (Nyanga, Johnsen, and Kalinda 2012).

To gain more insights about CA adoption in Zambia this study used mixed methods, incorporating both quantitative and qualitative methods. To begin with, descriptive analysis was done to show the bivariate relationship between CA adoption and different households' characteristics. This was followed by qualitative interviews with farmers and finally this study utilized econometric methods to examine the determinants of CA adoption in the country. Table 1 shows the percent of households using different CA practices. The results show that nationally only 10.6% reported using minimum tillage[1] in the 2013/2014 agriculture season, an increase of 7.8 percentage points from the 2010/2011 agriculture season. However, in the suitable AEZ's[2] 14.3% used minimum tillage in the 2013/2014 agricultural season an 11.3 percentage point increase from the 2010/2011 agriculture season. Crop rotation and residue retention remained relatively high at 49.9% and 63.3% respectively in the 2013/2014 agriculture season. While *full* CA (i.e minimum tillage, maize-legume rotation and residue retention) and *partial* CA (minimum tillage with either maize-legume rotation or residue retention) adoption was 3.7% and 5.1% nationally and 4.8% and 6.9% in suitable zones in the 2013/2014 agriculture season respectively.

In terms of the bivariate relationships between CA adoption and household characteristics, the results show that age, education level of the head of the household, household size, household farm size, and household income level have a positive correlation with respect to the rates of adoption. Furthermore, the results suggested that cultural and traditional beliefs might play a role in the adoption of CA. For example, the bivariate results show that the proportion of farmers not adopting CA is higher among the farmers who believe that witchcraft and prayer are more important than hard work for one's success.

Table 1. Percent of Households Using CA Practices

	2012		2015	
	National	Suitable Zones	National	Suitable Zones
Number of Households	1,380,409	838,472	1,472,886	838,472
Minimum Tillage (%)	2.8	3.0	10.6	14.3
Planting Basins/Potholes (%)	1.0	0.7	3.8	5.3
Zero Tillage (%)	1.0	0.9	4.1	4.9
Ripping (%)	0.8	1.3	3.4	4.8
Crop Rotation (%)	49.0	46.1	49.9	47.6
Crop Residue Retention (%)	60.9	62.6	63.3	58.5
Full CA adopters	1.3	1.3	3.7	4.8
Partial CA adopters	1.1	1.2	5.1	6.9

Source: CSO/MAL/IAPRI 2012/2015. Note: All the mean value differences between the two years are statistically significant different at 5%.

[1] Data on the type of tillage method used was collected at plot level, and from this we were able to determine which households used minimum tillage.

[2] CA is most suited for AEZ I, IIa and IIb. Therefore, we base our analysis on these zones, excluding AEZ III.

Interviews through focus group discussion with farmers showed that the main reasons for non-adoption and dis-adoption of CA were; lack of/withdrawn input support, problems with weeds/poor access to herbicides, intensive labour demands for minimum tillage practices, and limited local consultation/understanding of the CA promotional projects. These results are indicative of some of the factors that might influence adoption of CA. These findings are also supported by Arslan et al. (2013); Ngoma, Mulenga, and Jayne 2014; and Ngombe et al. 2014, where they find that household size, age, and income level have a positive influence on adoption of CA.

Other studies also found various factors affecting CA adoption, for instance, Haggblade and Tembo (2003); Chomba (2004); Kabwe, Donovan, and Samazaka (2005); and Arslan et al. (2013), found that access to extension services and households membership in farmer groups were significant in explaining adoption of CA. Households who had access to such services are more likely to adopt CA practices. Ngoma, Mulenga, and Jayne (2014); Ngombe et al. (2014); Haggblade and Tembo (2003); and Arslan et al. (2013), on the other hand, found that the various AEZs were significant in determining the adoption of CA. Apart from the AEZ, drier weather conditions were also found to significantly affect CA adoption (Ngoma, Mulenga, and Jayne 2014; Arslan et al. 2013). Access to secure land tenure has also been found to significantly affect a farmers decision to adopt CA practices (Kassie et al. 2012; Haggblade and Tembo 2003). This is mainly because the benefits of CA are long term in nature. Therefore, farmers are more willing to invest in such technology if there is assurance that the land they are investing in is secure.

This study examines the determinants of CA by expanding on the work of existing studies through the inclusion of variables that were previously not included their econometric analyses. In particular, we focus on the relationship between social factors, availability of agricultural services, tenure security innovations, and household farm size.

3. DATA AND METHODS

3.1. Data

The data comes from nationally representative longitudinal data from more than 7,000 households in 442 standard enumeration areas (SEAs)[3] in rural Zambia surveyed in 2012 and 2015. The survey was carried out by the IAPRI in collaboration with the Central Statistical Office, and Ministry of Agriculture. The first survey wave (CSO/MAL/IAPRI 2012) was administered to 8,840 households in 442 SEAs. A follow-up survey of the same households was conducted in May/June 2015, and a total of 7,254 were re-interviewed. The RALS 2012 sampling frame was based on information and cartographic data from the 2010 Zambia Census of Population and Households. The census questionnaire included a question on whether the household engaged in agricultural activities (crop growing, livestock and poultry raising, and fish farming), as well as check items, to identify the specific crops grown and animals raised by the household. Households were included in the sample only if they were found to cultivate crops or raise livestock. The reason for excluding the non-agricultural households was to improve the efficiency of the sampling frame for crop and livestock production and other agricultural characteristics.

A stratified three-stage sample design was used. The census supervisory areas (CSAs) were primary sampling units selected with probability proportional to size (PPS) at the first stage, where the measure of size was based on the total number of households in the CSA. At the second sampling stage, one SEA was selected with PPS within each sample CSA. This resulted in a similar dispersion of the sample and probabilities of selection as if the SEAs had been selected directly at the first sampling stage. Within each selected SEA, all households were listed and stratified by size for selecting the sample households at the last sampling stage.

Households were classified into small- and medium-scale farming households, defined as those cultivating areas less than five hectares and between 5 and 20 hectares, respectively. Households cultivating more than 20 hectares were classified as large-scale farmers and were not included in this survey. Since smaller households vastly outnumber the larger ones, the survey over-sampled the medium-scale farming households to ensure adequate inclusion of the larger households in the survey. A weighting procedure was formulated for the sample estimates from RALS to be representative of the population of small to medium scale farmers. These sampling weights were multiplied with sample descriptive estimates.

RALS surveys provide reliable estimates at both provincial and national levels except for the Eastern province, whose estimates are statistically valid at the district level as well. We used a balanced panel of 6,989 crop-producing households in both 2010/11 and 2013/14 farming seasons In terms of CA adoption, we used household data from the 2013/14 agricultural season with lagged household factors (initial household conditions) from RALS 2012 used as explanatory variables. Hence, we assume that all the lagged household level variables used in our models are exogenous.

We also used other data sets to include variables that were not collected in the RALS data. Rainfall data from Tropical Applications of Meteorology using Satellite data (TAMSAT) (Tarnavsky et al. 2014) was used, as well as qualitative data from Focus Group Discussions (FGDs) to get more insight about CA adoption.

[3] Standard enumeration areas (SEAs) are the lowest geographic sampling unit in the Central Statistical Office's sampling framework for its annual Post Harvest Surveys. Each SEA contains roughly 15 to 20 rural households.

The Focus Group Discussions (FDGs) were held in selected districts in AEZ I, IIA and IIB in which CA has primarily been promoted though recent promotional activities have also covered AEZ III (the high rainfall zone in the northern parts of the country). The FGDs were complemented by key informant interviews at the national, provincial, district and sub-district levels, as well as direct observations. The districts that were covered were Sesheke, Sinazongwe, Choma, Monze, Kaoma, Mumbwa, Nyimba, Petauke, and Katete during the period February/March 2016. In each district, about two communities were purposively sampled based on consultations of the field teams with local key informants who included staff of the MoA (including CASU and CFU). Key factors used in their selection were participation in CA promotional activities, levels of adoption and the presence of either CFU or CASU. The participants included CA adopters as well as dis-/non-adopters. A total of 35 FGDs were held; 370 participants were involved of which 198 were male, and 172 were female.

3.2. Methods

To understand the factors affecting adoption of CA, the study used a mixed methods approach, employing both quantitative and qualitative methods. For the qualitative methods, FDGs were carried out to solicit information from smallholder farmers on the key drivers for adoption, dis-adoption, and non-adoption of CA among smallholder farmers in Zambia. Matrix scoring and/or pairwise ranking were conducted as a means to relatively weight the importance of issues brought out, in addition to being a tool to solicit group discussions during which interesting issues including quotes and examples were noted. During matrix scoring, participants were asked to distribute a given number of bean seeds or stones (about 50) across the issues/benefits/suggestions allocating relatively more where they felt the issue was more significant compared to the others. The participants were allowed to discuss as the exercise continued until they reached consensus. It was during these discussions that real quotes and examples of various issues were also noted.

The matrix scores were recorded after consensus was reached and these were analyzed at the group level (at which time these were reflected back to the groups for concurrence), at the community level (comparison between results from men and women groups), at district and AEZ levels. For each aspect, the scores for all the issues raised were totaled and the percentage share of each reflected its significance in that respect i.e., trends in CA adoption over a period of years from 1990 to 2015, benefits of CA adoption or reasons for dis-/non-adoption or suggestions for increased adoption.

On the other hand, the RALS data was used for carrying out the quantitative analysis, where we analyzed the determinants of CA adoption in Zambia. CA, as defined earlier consists of a package of farming practices based on three main principles namely: 1) minimum mechanical soil disturbance (minimum tillage); 2) permanent organic soil cover, and 3) crop rotation. Of these three practices, minimum tillage is considered the main principle in conservation farming/agriculture. Minimum tillage comprises of three tillage practices, namely: 1) planting basins/potholes; 2) zero tillage, which excludes the practice of *chitemene*[4]; and 3) ripping with either mechanical or animal power. For households to be considered a CA household, they had to be practicing minimum tillage with either crop rotation and/or crop residue retention.

[4] Chitemene is the cutting of trees and burning of the cut wood to generate mineral ash for incorporation into the soil. After a few days, farmers go in and just open the soil where the seed is to be planted.

In the analysis of the determinants of CA adoption, we classified households that use all three CA practises (minimum tillage, crop rotation, and residue retention) as *Full* CA adopters and households that use only two CA practises (minimum tillage with either crop rotation or residue retention) as *Partial* CA adopters. This is because factors affecting full CA adoption might not be the same factors affecting partial CA adoption. In addition, we also examined the factors that influence a household's decision to adopt minimum tillage practices. This is because minimum tillage was found to be the main limiting factor of low CA adoption in Zambia compared to the use of crop rotation and crop residue retention as secondary CA practices.

3.2.1. Estimation Strategy

Probit Model: We begin by modelling the factors influencing the decision to adopt general CA (i.e., regardless of whether it is full or partial CA) as well as minimum tillage (use of either planting basins, ripping or zero tillage), by using a probit model. This is a binary choice model where the latent model of adopting CA or minimum tillage is specified as:

$$Y_{it} = X_{it}\beta + \varepsilon_i \quad i=1, 2..., N; =1 \tag{1}$$

$$\varepsilon_{it} = \alpha_i + \mu_{it} \tag{2}$$

Where Y_{it} =1, if i adopts, 0 if otherwise.

Multinomial Logit: We also estimate the factors affecting full and partial CA adoption and the individual minimum tillage practices (planting basins, ripping and zero tillage) by employing a multinomial logit model. Multinomial logit regressions are commonly used in the analysis of categorical dependent variables with more than two response categories, in our case the adoption of partial CA, full CA or conventional farming and the adoption of planting basins, ripping, zero tillage or conventional tillage. The multinomial logit model determines the probability that household i adopts one of the j outcomes above. This probability is given by:

$$Prob(Y_i = j) = \frac{e^{\beta'_j x_i}}{\sum_{k=0}^{j} e^{\beta'_j x_i}}, j = 0,1 \dots, j \tag{3}$$

Where $Y_i$is the farming practice adopted by household i, β'_k are the set of coefficients to be estimated and X_i is the set of explanatory variables, and;

$$Prob(Y_i = j) = \frac{e^{\beta'_j x_i}}{1+\sum_{k=0}^{j} e^{\beta'_j x_i}}, j = 0,1 \dots, j, \beta_0 = 0 \tag{4}$$

$Prob(Y_i = j)$ is the probability of being in each of the groups compared to the reference group. $Prob(0)$ is the probability of being in the reference group. When estimating the model, the coefficients of the reference group are normalized to zero. This is because the probabilities for all the other groups must sum up to unity (Greene 2002). In order to identify the model, one of the outcome variables e.g., full CA, partial CA or conventional farming has to be omitted and used as the reference, so only two distinct sets of parameters can be identified and estimated. For both models, we chose conventional farming and conventional tillage as the reference from which to compare all the other farming practice groups.

3.2.2. Variables Used in the Models

Based on CA literature, the factors affecting adoption of CA and CA practices were disaggregated into seven categories as follows: human capital assets, household/farm assets, institutional factors, social factors, market access, community assets, and climatic factors. Table 2 presents the descriptive statistics for all the variables used in this study.

Human Capital Assets: the decision to adopt any new technology is affected by a household and household heads characteristics (Arslan et al. 2013; Ngoma, Mulenga, and Jayne 2014; Grabowski et al. 2016). For instance, adoption of new technologies was influenced by the gender of the household head as well as the age of the household head. For example, Namonje-Kapembwa and Chapoto (2016) found that male-headed households are more likely to take up new technologies due to larger endowments compared to their female counterparts, while older household heads, on the other hand, are more likely to take up new technologies due to their farming experience. Household size which is used as a proxy for labour availability has been found to positively influence a households decision to adopt CA practices as CA is perceived to be labour intensive (Haggblade and Tembo 2003; Nyanga, Johnsen, and Kalinda 2012).

Household/farm Assets: Households access to productive farming assets has been found to positively influence adoption of new technology. For instance, households with more land are more likely to allocate part of the land to try new technologies. A priori, one would expect that households with larger landholdings would be more likely to adopt CA as compared to smaller households. Also, included in the models is the value of productive assets, which can be used to proxy household wealth.

Institutional Factors: Households with access to credit have more capital to be able to purchase implements needed for adoption of CA practices. In addition access to information through members belonging to a farmer group or being in a promotional area might positively influence adoption to CA**.**

Social Factors: Adoption of any new technology may be influenced by culture and traditional beliefs. Beliefs in supernatural powers have been said to influence a household decision-making process about new technologies. In this study, we use household belief in witchcraft and prayer as a proxy for household's belief in supernatural powers and the associated relationship with CA adoption. We examined how a household's belief in witchcraft and prayer as the key factors for success and its decision to adopt CA. The variables were collected during RALS 2015 based on a Likert scale of 1-5. Where 1 if the households strongly disagreed with the statement "people in this area use witchcraft to become successful" and "to be successful, prayer is more important than hard work", and 5 if they strongly agreed. We included the household responses as continuous variables in the econometric models as the intervals between each scale is assumed to be equal (Baggaley and Hull 1983; Maurer and Pierce 1998).

Furthermore, households distance from markets is hypothesized to influence CA adoption. Thus households closer to markets are more likely to adopt CA practices due to easy access to inputs and implements. This is the same for households with access to inputs and implements at the community level. Existing literature also shows evidence that CA is more likely to be practiced in lower rainfall or drought-prone areas (Haggblade and Tembo 2003; Gebremedhin and Swinton 2003).

Therefore, we included a variable capturing the number of rainfall stress periods[5] in the past agricultural season as a proxy for climatic conditions.

Table 2. Variable Description

Variables	Mean	Standard Deviation	Min	Max
Plot Level Characteristics				
Distance from homestead to plot (Km)	1.90	2.94	0	70.0
Tenure security (titled/chiefs certificate (=1)	0.05	0.22	0	1.0
Field is prone to erosion (=1)	0.28	0.45	0	1.0
Human Capital Assets				
Gender of Fields decision maker (1=female)	0.26	0.44	0	1.0
Gender of the HH^ head (1=female)	0.19	0.39	0	1.0
Age of field's decision maker	48.16	14.08	7.00	101.0
Education level of fields decision maker	5.88	3.79	0.00	19.0
Adult equivalents	5.38	2.40	0.31	21.3
Household/Farm assets				
Landholding Size (Ha)▪	2.02	2.35	0.03	45.0
Landholding Size squared (Ha)	9.59	41.02	0	2025.0
Productive assets (ZMK)*	15.49	1.81	0	23.3
Ownership of draught power (=1)*	0.42	0.49	0	1.0
Tropical Livestock Units	6.87	14.56	0	250.0
Ownership of cellphone (=1)*	0.58	0.49	0	1.0
Ownership of Radio/TV (=1)*	0.71	0.45	0	1.0
Institutional factors				
Access to credit (=1)	0.30	0.46	0	1.0
Membership in a farmer organization (=1)	0.56	0.50	0	1.0
Social factors				
Witchcraft not hard work can make you successful	2.76	1.38	1	5.0
Prayer not hard work can make you successful	3.25	1.45	1	5.0
Market access				
Distance to the nearest Boma (Km)	38.69	28.47	0	200.0
Community assets				
Availability of hiring Oxen Services (=1)	0.81	0.39	0	1.0
Availability of hiring tractor Services (=1)	0.25	0.43	0	1.0
Availability of hiring spraying Services (=1)	0.31	0.46	0	1.0
Climatic Factors				
Number of stress periods across months*	1.90	0.86	0	5.0
AEZ I (=1)	0.13	0.34	0	1.0
AEZ IIb (=1)	0.10	0.30	0.00	1.0

Source: Authors Computations. Ha=hectare, HH=Household, Km=kilometer, ZMK=Zambian Kwacha.

[5] Number of 20 day periods with less than 40 mm of rainfall.

3.2.3. Study Limitations

Although this study uses the CFU and CASU definition for CA, for both full and partial CA, we were unable to capture the full definition as defined by CASU. The CASU definition includes a time frame for a household to be considered as a CA farmer, i.e., *a minimum of three years*. Unfortunately, RALS data does not allow us to take into consideration this time frame. Instead, we will rely on farming methods reported by the farmers used during the 2013/14 agricultural season. In addition, some stakeholders questioned whether the farmers were able to accurately distinguish between zero tillage and chitemene (a slash and burn shifting cultivation). Enumerators were trained to probe the respondents whenever zero tillage was indicated as the tillage method. Pictorial props were used to aid farmers to choose the appropriate tillage method. In any case, over-representation of zero tillage by not excluding chitemene in the calculation of minimum tillage adoption does not lead to underestimation of the adoption rates but instead overstates the rates. However, the exclusion of AEZ III in our analysis further takes care of this worry as chitemene is mainly practiced in AEZ III.

4. RESULTS

4.1. Determinants of CA Adoption

Table 3 shows the empirical results from the field level probit and the multinomial logit models. Column A shows the probit results for adoption of CA in general (full CA or partial CA adoption) and columns B and C shows the multinomial logit results for full CA and partial CA, in relation to conventional farming. To begin this discussion, we first look at other variables that influence CA adoption before moving to the variables of interest as discussed earlier. We focus only on statistically significant factors.

The results indicate that plot level characteristics do matter in determining the adoption of CA; the likelihood of adoption of full CA reduces with increased distance to the plot and when fields are prone to erosion. The gender of the field's decision maker and years of education of the household head also matter in determining the adoption of CA. Female field decision makers are more likely to adopt CA. In terms of education level, the results show that more educated household heads have a higher likelihood of adopting CA, in particular, full CA compared to conventional farming. The level of education does not seem to matter for the adoption of partial CA compared to conventional farming.

Using adult equivalent[6] as a proxy for labour availability in a household, we find that households with larger number of adult equivalents are more likely to adopt CA compared to conventional farming. This result is consistent with other studies whose findings show that CA is labour intensive and requires that adopters have enough labour (Haggblade and Tembo 2003; Nyanga, Johnsen, and Kalinda 2012). This implies that CA promotion should be accompanied by technologies that help to mitigate household labour requirements especially for pot holing and weeding. Adoption rates are likely to increase if labour requirements and costs are comparable with conventional farming. The labor cost study done as part of this project shows that labour requirements are higher for CA compared to conventional agriculture, with CA labour costs being 28% more than labour costs under conventional farming.

Other variables that are positively associated with adoption of CA are; access to information through ownership of radio/television and membership in a farmer organization. On the other hand, households with a high value of productive assets (a proxy for wealth) were less likely to adopt CA, particularly partial CA compared to conventional farming.

[6] The household size is adjusted taking into account the age and gender of the household members

Table 3. Determinants of CA Adoption

Variables	All CA (A)	Full CA (B)	Partial CA (C)
Plot Level Characteristics			
Distance from homestead to plot (Km)	-0.0021	-0.0035***	0.0000
	(0.001)	(0.001)	(0.001)
Tenure security (titled/chiefs certificate (=1)	-0.0172*	-0.0074	-0.0126
	(0.010)	(0.005)	(0.010)
Field is prone to erosion (=1)	-0.0083	-0.0068**	-0.0034
	(0.006)	(0.003)	(0.005)
Human Capital Assets			
Gender of Fields decision maker (1=female)	0.0178*	0.0020	0.0145*
	(0.010)	(0.005)	(0.009)
Gender of the HH head (1=female)	-0.0059	0.0084	-0.0145
	(0.012)	(0.006)	(0.010)
Age of field's decision maker	0.0000	0.0001	-0.0000
	(0.000)	(0.000)	(0.000)
Education level of fields decision maker	0.0026***	0.0003	0.0025***
	(0.001)	(0.000)	(0.001)
Adult equivalents	0.0034***	0.0021***	0.0012
	(0.001)	(0.001)	(0.001)
Household/Farm assets			
Landholding Size (Ha)	0.0028	0.0078***	0.0022
	(0.003)	(0.002)	(0.003)
Landholding Size squared (Ha)	-0.0001	-0.0011***	-0.0000
	(0.000)	(0.000)	(0.000)
Productive assets (ZMK)*	-0.0015	0.0007	-0.0029*
	(0.002)	(0.001)	(0.002)
Ownership of draught power (=1)*	0.0045	-0.0100***	0.0153***
	(0.007)	(0.003)	(0.006)
Tropical Livestock Units	-0.0005**	-0.0003	-0.0003
	(0.000)	(0.000)	(0.000)
Ownership of cellphone (=1)*	0.0071	-0.0000	0.0065
	(0.006)	(0.003)	(0.006)
Ownership of Radio/TV (=1)*	0.0144**	0.0053*	0.0093*
	(0.006)	(0.003)	(0.006)
Institutional factors			
Access to credit (=1)	0.0124**	-0.0051	0.0156***
	(0.006)	(0.003)	(0.006)
Membership in a farmer organization (=1)	0.0386***	0.0099***	0.0295***
	(0.006)	(0.003)	(0.006)
Social factors			
Witchcraft not hard work can make you successful	-0.0076***	-0.0018*	-0.0066***
	(0.002)	(0.001)	(0.002)
Prayer not hard work can make you successful	0.0032*	-0.0024**	0.0061***
	(0.002)	(0.001)	(0.002)
Market access			
Distance to the nearest Boma (Km)	-0.0003**	-0.0001**	-0.0003*
	(0.000)	(0.000)	(0.000)
Community assets			

Variables	All CA (A)	Full CA (B)	Partial CA (C)
Availability of hiring Oxen Services (=1)	0.0123*	0.0017	0.0089
	(0.007)	(0.003)	(0.007)
Availability of hiring tractor Services (=1)	-0.0443***	-0.0120***	-0.0324***
	(0.007)	(0.003)	(0.006)
Availability of hiring spraying Services (=1)	0.0388***	0.0093***	0.0285***
	(0.006)	(0.003)	(0.005)
Climatic Factors			
Number of stress periods across months*	0.0181***	0.0033**	0.0148***
	(0.003)	(0.002)	(0.003)
AEZ I (=1)	-0.0683***	-0.0278***	-0.0497***
	(0.009)	(0.006)	(0.010)
AEZ IIb (=1)	-0.0043	-0.279***	0.0291***
	(0.012)	(0.023)	(0.011)
Observations	11,216	11,216	11,216

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Authors computations.

The results also show that household's access to credit significantly increases the likelihood of CA adoption. This finding is consistent with Kassie et al. (2012); and Ngombe et al. (2014). One of the main reasons highlighted for households dis-adoption and non-adoption of CA during FGDs was the lack of inputs due to liquidity limitations. Therefore, improving credit access will help deal with liquidity constraints as well as help farmers to embrace CA. The CA programs could also be linked to CA information services in order to continue helping farmers to take advantage of the benefits of CA.

As expected, we find that the probability of households adopting CA is higher if the SEA experienced longer drought periods in the past rainfall season. Thus, an increase in the number of rainfall stress periods in a month increases the likelihood of a household adopting CA in the next farming season. Ngoma, Mulenga, and Jayne (2014) and Arslan et al. (2013), also found similar results. In addition, the results show that being in AEZ I decreases the likelihood of adopting all CA types compared to being in AEZ IIa, while households in AEZ IIb are more likely to adopt partial CA and less likely to adopt full CA.

4.1.1. Do Social and Cultural Factors Influence Adoption of CA in Zambia?

Social and cultural factors have not been fully explored as determinants of CA adoption in other studies, even though literature shows that they may help or hinder efforts to promote CA. Using household's belief in witchcraft and prayer as proxies, results in Table 3 show mixed results hence not very conclusive. In terms of witchcraft, our results show that households who believe in witchcraft as being an important factor to make someone successful are less likely to all types of CA compared to those who believe otherwise. On the other hand, the results show that believe in prayer as being responsible for one's success instead of hard work reduces the likelihood of adopting full CA, but at the same time increase the likelihood of adopting partial CA. Although the results from the qualitative surveys did not cite social and cultural issues as one of the key factors influencing CA adoption in Zambia, the econometric results, especially on witchcraft, seem to suggest some influence through more research work is still required to be able to make conclusive recommendations.

Otherwise, there is some evidence to suggest social and cultural factors may influence technology adoption. If the results on witchcraft are substantiated by other studies, then it may be paramount to work with local leaders to tackle socio-cultural issues so that they do not impede CA adoption.

4.1.2. Does Access to Farming/Agricultural Services at Community Level Influence Adoption of CA?

Most rural farmers do not possess or afford to purchase implements and assets needed to switch to CA; however, having CA farming/agricultural services for farmers to hire in the community may help deal with this constraint. Surprisingly, we find that households that are in communities with tractor hiring services are less likely to adopt all CA types. The coefficients on all the variables are negative and statistically significant. Further inquiry with farmers revealed that the available services promoted conventional tillage than minimum tillage. Therefore, access to machinery without the right implements might not necessary boost adoption of CA.

Weeds and poor access to herbicides and limited knowledge of how to use herbicides were one of the main reasons pointed out during the FGDs for non-adoption and dis-adoption of CA. As expected, the results show that households that are in communities with the availability of spraying services for hire are more likely to adopt all CA types. This implies that availability and access to hiring services that support the CA practices enhances the household's decision to adopt CA.

4.1.3. Does Farm Size Influence Adoption of CA and the Type of CA Adopted?

The size of a households land might influence their decision to adopt new technologies. Households with larger farm sizes would be more likely to allocate part of their farms to try new agricultural technologies such as CA (Marenya and Barrett 2007). Promoters of CA in Zambia have often focused on increasing CA adoption among households with small farms compared to larger farmers. However, the results show that households cultivating larger pieces of land are more likely to adopt full CA than those cultivating smaller pieces of land, while landholding size did not seem to matter for the adoption of partial CA. The results also show that there is a non-linear relationship between land size and full CA adoption. Thus the probability of adoption increases with farm size up to 3.54 hectares after which the likelihood starts to decline. To understand why land size might affect the adoption of full CA, we turn to the results of the FGDs where farmers indicated that they were land constraints—this made it difficult for them to practice crop rotation, which is a requirement for full CA adoption. These findings suggest that the promotion of CA should be tailored to suit the household's landholding sizes. Also, given that the relationship between landholding size and CA adoption vary depending on whether a farmer adopts the full CA package or partial CA, it is imperative for CA promoters to tailor make the CA package and promotional activities to take into account these differences.

4.2. Factors Affecting Minimum Tillage Adoption

Minimum tillage is the core for CA adoption, and it has been seen as the limiting factor due to the low adoption rates, compared to the other practices (crop rotation and crop residue retention). We estimated the determinants of minimum tillage adoption by practice at field

level. Table 4. shows the probit results for adoption of minimum tillage in general (Column A) and the multinomial results for planting basins, ripping and zero tillage in columns B, C and D respectively.

The results show that a households decision to adopt minimum tillage is influenced by distance to the plot, labour availability proxied by number of adult equivalents present in the household, landholding size, ownership if draught power, access to credit, membership in a farmer organization, household belief in witchcraft and prayer, availability of hiring tractor and spraying services, number of stress periods across months and agro-ecological zones.

Our results show that tenure security (ownership of tittle) has no effect on a household's decision to adopt minimum tillage compared to conventional tillage. Even though not significant, we find a positive correlation with adoption of planting basins and ripping. These results are similar to those found by Ngombe et al. 2014, but contrary to other studies that have suggested significant effects of tenure on soil conservation practices (Gebremedhin and Swinton 2003; Giller 2009). We also find that having draught power, belief in witchcraft and not hard work for one's success and availability of tractor hiring services at community level reduces a household's likelihood to adopt minimum tillage.

On the other hand, the results show that availability of labour, larger land size, ownership of cellphone, access to credit, membership in a farmer group, and availability of hiring spraying services at community level increases the likelihood of minimum tillage adoption. The number of stress periods across months and being in AEZ IIb compared to AEZ IIa also increases the probability of adoption of minimum tillage, with Ngoma, Mulenga, and Jayne (2014) and Arslan et al. (2013), finding similar results.

Table 4. Determinants of Minimum Tillage Practices

Variables	Minimum Tillage (A)	Basins (B)	Ripping (C)	Zero Tillage (D)
Plot Level Characteristics				
Distance from homestead to plot (Km)	0.0032***	0.0010*	0.0016**	0.0009***
	(0.001)	(0.001)	(0.001)	(0.000)
Tenure security (titled/chiefs certificate (=1)	0.0100	0.0070	0.0058	-0.0022
	(0.017)	(0.015)	(0.009)	(0.007)
Field is prone to erosion (=1)	0.0070	0.0013	0.0123***	-0.0048
	(0.007)	(0.004)	(0.005)	(0.003)
Human Capital Assets				
Gender of Fields decision maker (1=female)	-0.0157	0.0033	-0.0251***	0.0026
	(0.011)	(0.007)	(0.007)	(0.006)
Gender of the HH head (1=female)	0.0080	-0.0042	0.0096	-0.0032
	(0.013)	(0.008)	(0.008)	(0.007)
Age of field's decision maker	0.0003	0.0003*	-0.0002	0.0002**
	(0.000)	(0.000)	(0.000)	(0.000)
Education level of fields decision maker	0.0011	-0.0004	0.0010*	0.0005
	(0.001)	(0.001)	(0.001)	(0.001)
Adult equivalents	0.0028**	0.0007	0.0016*	0.0005
	(0.001)	(0.001)	(0.001)	(0.001)
Household/Farm assets				
Landholding Size (Ha)	-0.0024	-0.0125***	0.0030***	-0.0058**
	(0.003)	(0.004)	(0.001)	(0.002)
Landholding Size squared (Ha)	0.0003**	0.0003***	-0.0000	0.0002***
	(0.000)	(0.000)	(0.000)	(0.000)
Productive assets (ZMK)*	-0.0016	0.0000	0.0038**	-0.0011
	(0.002)	(0.001)	(0.002)	(0.001)
Ownership of draught power (=1)*	-0.0147*	-0.0338***	0.0123**	-0.0084*
	(0.008)	(0.009)	(0.005)	(0.005)
Tropical Livestock Units	-0.0001	-0.0005	-0.0000	-0.0015**
	(0.000)	(0.000)	(0.000)	(0.001)
Ownership of cellphone (=1)*	0.0096	0.0084**	-0.0001	-0.0026
	(0.007)	(0.004)	(0.005)	(0.004)
Ownership of Radio/TV (=1)*	0.0032	-0.0002	0.0023	0.0045
	(0.007)	(0.004)	(0.005)	(0.003)
Institutional factors				
Access to credit (=1)	0.0172**	0.0024	0.0102**	0.0037
	(0.007)	(0.005)	(0.004)	(0.003)
Membership in a farmer organization (=1)	0.0354***	0.0102**	0.0247***	0.0027
	(0.007)	(0.004)	(0.006)	(0.003)
Social factors				
Witchcraft not hard work can make you successful	-0.0072***	-0.0012	-0.0025	-0.0042***
	(0.002)	(0.001)	(0.002)	(0.001)
Prayer not hard work can make you	0.0056**	0.0023*	0.0052***	-0.0028***

Variables	Minimum Tillage (A)	Basins (B)	Ripping (C)	Zero Tillage (D)
successful				
	(0.002)	(0.001)	(0.002)	(0.001)
Market access				
Distance to the nearest Boma (Km)	-0.0001	0.0000	-0.0003**	0.0000
	(0.000)	(0.000)	(0.000)	(0.000)
Community assets				
Availability of hiring Oxen Services (=1)	-0.0055	0.0012	0.0223***	-0.0090***
	(0.008)	(0.005)	(0.007)	(0.003)
Availability of hiring tractor Services (=1)	-0.0241***	-0.0128**	-0.0005	-0.0191***
	(0.008)	(0.006)	(0.005)	(0.005)
Availability of hiring spraying Services (=1)	0.0328***	0.0032	0.0148***	0.0084**
	(0.007)	(0.005)	(0.004)	(0.003)
Climatic Factors				
Number of stress periods across months*	0.0176***	0.0093***	-0.0007	0.0069***
	(0.005)	(0.003)	(0.004)	(0.002)
AEZ I (=1)	-0.0090	0.0168***	-0.0164*	-0.0091
	(0.010)	(0.005)	(0.009)	(0.006)
AEZ IIb (=1)	0.0410***	0.0426***	-0.0718***	-0.0269***
	(0.013)	(0.007)	(0.016)	(0.009)
Observations	11,216	11,216	11,216	11,216

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Authors computations

The other factors affecting the individual tillage practices included gender of the field decision maker, education level of the field's decision maker, fields being prone to erosion, belief in prayer for success than hard work, distance to the nearest Boma, and availability of oxen services at community level. Having fields that are prone to erosion increases the likelihood of adoption of ripping. Gender of the field decision maker does not influence the choice of the type of tillage method expect for ripping. The results show that male decision makers are more likely to adopt ripping compared to their female counterparts, perhaps due to males having larger assets base than females.

5. CONCLUSION AND RECOMMENDATIONS

CA has the potential to improve productivity, farm system resilience, and household's nutrition levels. Despite numerous years of active promotion in Zambia, the rates of adoption remain relatively low with relative widespread dis-adoption rates. Using nationally representative data, we find that in Zambia only 8.8% of smallholder households used CA in 2013/14 agricultural season, with full CA adoption at 3.7% and partial CA adoption at 5.1%, a significant increase from 1.3% and 1.1% in 2012 respectively. In order to understand the low rates of adoption, several empirical studies have been carried out to investigate the determinants of adoption, dis-adoption, and non-adoption of CA by smallholder farmers in Zambia. Most of these studies have focused on similar sets of variables that have been posited to influence CA adoption, for instance, human capital assets, farm assets, institutional factors, risks and economic factors and climatic conditions. The current debate about the factors associated with CA adoption in Zambia is now focused on other non-conventional variables not covered by prior studies. In particular, four issues and their relationship on CA adoption and dis-adoption are at the center of this discussion, a) the role of social and cultural/traditional beliefs; b) role of household farm size; c) the role of tenure security and; d) the importance of the availability of supporting CA services in the rural communities. This study, therefore, went beyond prior studies by examining these factors that might influence a household's decision to adopt CA practices.

The econometric analysis of the determinants of CA adoption shows mixed findings on social factors and the role they play in a household's decision to adopt CA. Findings indicate that belief in witchcraft as the main ingredient to success reduces the likelihood of adoption CA. While belief in prayer and not hardwork reduces full CA and increases partial CA adoption. The results on witchcraft suggest that whenever the CA technology is promoted, the social dynamics in the communities should be taken into account.

Supportive agricultural services availability in the community were also found to influence adoption of CA. Availability of community herbicide hiring spraying services significantly increased the likelihood of CA adoption. While the availability of tractor hiring services in the community reduced the likelihood of CA adoption. This was mainly attributed to the fact that such service promoted conventional tillage than minimum tillage. Therefore, mechanization without the right implements might work against the promotion of CA in the country.

Furthermore, the education level of the household head significantly increased the likelihood of CA adoption holding all other factors constant. This finding shows that households who are more educated can be used as focal points for disseminating information to other farmers. Another important finding requiring serious attention was that an increase in landholding size increased the likelihood of using CA up to about 3.54 hectares. Therefore, there might be need to relook at the current CA promotion strategy of promoting CA among smaller farmers. The returns to full CA adoption may be higher among bigger farmers because of the ability to rotate their crops as required for successful CA. Similar to other studies, access to credit, price information, membership in a farmer organization and past drought conditions increased the likelihood of a household adopting CA. The results did not show any differences in the choice of tillage methods by tenure status

All factors constant, the coefficients on the variable, *Field owned with title* were not statistically insignificant for all tillage practices. Suggesting that land tenure did not make a difference in terms of tillage method used. This does not mean to say that smallholder farmers are not risk averse especially when it comes to long-term productivity investments on

land that they are not sure belongs to them. However, the results suggest that other variables instead of tenure security are more important to the household's decision on the type of tillage method to use.

Based on these findings, this study makes the following the following recommendations:

- *Social, Cultural Issues:* There are usually some social and cultural/traditional issues in a community at play. Therefore, before engaging in any promotion of CA, there is need to see how these issues can influence the communities' decision-making towards the new practice. More concerted efforts by the research community, development partners, programme implementers, and extension officers need to be made to understand further how these social and cultural beliefs can be unraveled to enhance CA adoption. There is a need for extensive local consultation to create an understanding of how best CA can be scaled up. For instance, with the involvement of local traditional leaders, area specific socio-cultural issues can be tackled during CA training so that they do not impede its broad-based adoption.

- *Access to CA Implements:* Limited access to CA implements that reduce drudgery remain a challenge for adoption of CA. One way that this has been addressed is with the use of draught and mechanical power. However, very few households own or can afford to purchase any CA implements to use with their available mechanical power. Also, for those without tractors and/or animals, the available mechanization services at community level seem to effectively promote conventional tillage, a situation requiring immediate attention. Increasing availability and access to CA mechanical services and equipment/implements would surely go a long way to enhance the uptake of CA in Zambia. This can be achieved in part by encouraging owners of machinery hiring services to provide minimum tillage services. In addition, the creation of an incentive structure to reward farmers who invest into CA implements should be considered. For example, assessing government agricultural subsidy programs could be jointly done with CA adoption and associated extension packages.

- *Tailored CA Promotional Packages:* Given that the factors influencing adoption of CA vary depending on whether a farmer adopts the full CA package or partial CA and farmer type, it is imperative for CA promoters to tailor make the CA package and promotional activities to take into account these factors. A feasibility study may need to be carried out to assess the possibility of attaching productivity-enhancing technologies such as adoption of CA with government subsidy program. For example, CA adoption would be a pre-requisite for accessing government input support.

- *Market Access:* Related to access to CA services, promotion of CA should continue to be enhanced through improving farmers' access to input and output markets. Promotion of outgrower schemes and contract farming are sustainable market solutions that can be promoted to help farmers appreciate the benefits of CA as well as make available mechanized CA services and extension to smallholder farmers. This approach would crowd in the private sector who would help fill the gaps in terms of input and output market facing the smallholder farm sector. Also, facilitating access to inputs—for instance, legume seed, which is normally in short supply—would help to address this issue. Agro-dealers should be encouraged to stock legume seed; this is likely to be enhanced through the implementation of the e-voucher. Also, marketing of the farmer's output, mostly legumes, where markets are not available can be strengthened by engaging private players to engage CA farmers in outgrower contracts.

- *Extension and Access to Information:* Access to information remains a critical component in achieving broad-based adoption of CA. In areas where farmers had information on the benefits and the knowledge of implementing CA practices, adoption rates were higher. Therefore, there is need to enhance extension services nationwide. Pluralistic extension services need to be promoted where both government and the private sector provide extension services to farmers. Studies have shown that farmers are willing to embrace information and technologies that enhance their livelihoods; therefore, harnessing this potential in Zambia may help fill the public extension provision. To enhance the public extension systems, funding to the MoA's Extension Department needs to be increased, and the release of operational funds improved. Also, a deliberate strategy to make CA the primary extension message of the MoA at all levels—including national, provincial, district, and sub-district level—needs to be made, especially in the face of climate change.

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