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ABSTRACT

This study used nationally representative pooled cross-sectional household data to assess determinants of farmers' decisions to use minimum tillage and how much land is cultivated using minimum tillage between 2008 and 2012 in Zambia. Empirical results from the Double Hurdle model show that age of the household head, landholding size, incidences of flood and droughts in the previous season significantly influence the probability of farmers using minimum tillage and the amount of land they cultivate under minimum tillage. For example, results show that increasing landholding size owned by households by 1 hectare would on average increase land cultivated under minimum tillage by 0.03 hectares. This result suggests that increasing landholding sizes among farmers provides them with more flexibility in making conservation farming decisions. We also found robust evidence suggesting that farmers in the current season would reduce the amount of land put under minimum tillage following a season with floods. We also found that farmers are more likely to use minimum tillage in the current season following a season with droughts. These results seem to suggest that farmers are using conservation farming practices in response to rainfall variability. Findings of this study underscore the importance of improving land access for smallholder farmers and timely gathering and disseminating of weather information in order to facilitate farmer's decision to adopt conservation farming practices.

Key words: Minimum Tillage, Determinants, Double Hurdle Model, Zambia, Smallholder farmers

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1.0 INTRODUCTION

Conservation agriculture (CA) or conservation farming (CF) as it often called in Zambia has potential for attainment of sustainable agriculture development and ensuring food security in Sub Saharan Africa. Although defined differently, CF technologies involve agricultural management practices that prevent or reduce both soil and water resources degradation while at the same time enhancing farm productivity that is environmentally friendly (Baudron *et al*., 2007).

Development of CA in Zambia can be traced to the 1980s when a coalition of stakeholders including government, private sector and donor communities started promoting CF as a new and alternative package of agronomic practices for Zambian smallholders (Haggblade and Tembo, 2003). Stakeholders like the Conservation Farming Unit (CFU) of the Zambia National Farmers Union (ZNFU) and the Golden Agricultural Research Trust (GART) are among the most notable private sector actors that initiated, and have consistently promoted CF in Zambia. Several non-governmental organizations have promoted or are promoting CF technologies in Zambia. CF technologies practiced in Zambia involve: dry-season land preparation using minimum tillage methods (zero tillage, ripping and/or planting basins); retention of crop residue from prior harvest; planting and input application in fixed planting stations; and crop rotations (Haggblade and Tembo, 2003; Baudron *et al*., 2007). These CF practices were promoted on the premise that they would improve crop yields since they had the potential to rejuvenate soils.

Available national evidence on adoption and impact of CF in Zambia estimate yields gains of between 50-100% and 40-60% for maize and cotton farmers, respectively, who use CF technologies (Haggblade and Tembo, 2003; Haggblade and Plerhoples, 2010). Aslihan *et al.*, (2013) estimated an increase in adoption of CF by smallholder farmers to 14% in 2008; up from 8% in 2004 in Eastern province, but they also estimate a 95% disadoption in 2008, compared to 2004. Based on the 17 districts covered by the Conservation Agriculture Program (CAP) in Zambia, CFU estimates an increase in the proportion of farmers using minimum tillage to 12% in 2009/10 agricultural season (up from 2% in 2006/7). However, these figures are mere estimates based on snap shots of situations in selected regions and/or agricultural season(s). This makes inferences from such studies questionable. Further, studies on extent of CF adoption have applied the Tobit model (Haggblade and Tembo, 2003 and Aslihan et al., 2013) which estimates participation and extent of participation simultaneously and assumes that the two processes are determined by similar processes, when in fact they may not.

Despite focusing mainly on impact and/or adoption of CF based on snapshots; available empirical analyses of CF in Zambia are limited mainly due to small samples used (Haggblade and Tembo, 2003; Haggblade and Plerhoples, 2010; Donovan and Kabwe, 2005; ZNFU/CFU; Nyanga et al., 2011; Ngoma et al., 2012). As a result, some fundamental questions around CF still remain unanswered in Zambia. For example, how are the trends in adoption/use[1] planting

[1]CF use and adoption are used interchangeably in this study

basins, and ripping (here after also called minimum tillage[2] (MT)) over the last few years? What factors influence farmers' decisions to use specific MT technologies and the amount of land they cultivate under MT? The current study was designed to answer these questions.

The study objectives were twofold; 1) to determine factors affecting smallholder farmers' decisions to use minimum tillage, and 2) to determine factors affecting the extent of minimum tillage use by smallholder farmers

2.0 LITERATURE REVIEW

Perhaps, the study by Haggblade and Tembo (2003) on the development, diffusion and impact of conservation farming in Zambia is the pioneer or among the first empirical works on the subject in the country. Using a household survey of 125 farms in Central and Southern Provinces during the 2001/2 cropping season, they found that, on average, hand-hoe CF farmers produced higher yield gains in both maize and cotton. Early planting, water harvesting, greater precision in input use in basins and use of hybrid maize seed were found to account for much of the reported yield gains among maize farmers. Since cotton farmers use standard input packages, the observed yield gains among CF cotton farmers was attributed to the water harvesting, precision and timeliness of the CF system. Yields gains related to using CF practices in cotton are also reported in (Haggblade et al, 2004).

Although there is a dearth of empirical national evidence on the adoption of CF technologies, available estimates indicated that between 20,000 and 60,000 farmers practiced some form of hand hoe CF basins during the 2001/02 season while an additional 4,000 used rippers (Haggblade and Tembo, 2003). The main incentives that are thought to drive farmers into adopting CF technologies are mainly related to financial, institutional and climatic factors (Haggblade and Tembo, 2003; Haggblade *et al.*, 2004, Aslihan *et al.*, 2013, Ngoma *et al.*, 2012 and Nyanga *et al.*, 2011). Literature shows that incentives for adoption of water-conserving minimum tillage CF technologies are strongest in Zambia's Agro-ecological Regions I and II where there is erratic rainfall and extensive plow-pan damage. There is also recent evidence suggesting that farmers who perceive climate change use CF tillage practices as adaptations in Zambia (Nyanga *et al.*, 2012). Further, literature also suggests that farmers will be more willing to adopt CF technologies based on the potential financial gains from using CF (Haggblade *et al.*, 2004).

Not much work has been done around assessing sustained adoption of CF technologies in Zambia, except for the study by Donovan and Kabwe (2005). Their study focused assessing on the sustained use of conservation farming practices among small and medium scale farmers.

[2] A household practices minimum tillage (MT) in this study when they use planting basins and/or ripping

Using a panel of 5,342 households from two surveys carried out for the 2000/2001 and 2002/03 agricultural seasons, their results show that farmers are more likely to use and sustain CF practices that are closest to traditional cropping systems than the main CF technologies. This finding suggests that CF technologies that don't require a total transformation of farming practices were more likely to succeed. In terms of adoption and disadoption dynamics, their results show that an average of 3% and 98% of small holder farmers sustained use and disadopted, respectively, planting basins across all agro ecological zones in Zambia. However, as the authors noted in their report, use of descriptive statistics limits applicability of the findings in this study.

Using the same dataset as in Donovan and Kabwe (2005), Aslihan *et al.,* (2013) used panel data econometrics techniques to assess adoption and intensity of adoption of CF in Zambia. Defining use of hand hoe, planting basins and/or zero tillage as CF1 and use of planting basins and/zero tillage as CF2, Aslihan *et al.,* (2013) found a CF disadoption rate of 95% between 2004 and 2008 nationally, adding that Eastern was the only province where CF adoption increased to 14% in 2008, up from 8% in 2004. They also found indirect evidence of synergies between CF adoption and adaptation to climate change by using rainfall coefficients of variations as determinants of farmers' decisions to use CF. They found no statistically significant effects of age, labor, and education on farmers' decisions to use "CF".

Using a household survey of 469 farmers under the Conservation Agriculture Programme (CAP) promoted by the Conservation farming Unit (CFU), Nyanga *et al.,* (2011) assessed farmers' perceptions of climate change and conservation agriculture in 12[3] districts of Zambia. Study results show that farmers perceive climate change and that they are using CF technologies to adapt. The pearson chi square test of independence and the paired t-test results found significant association between farmers' perception of changes in the frequency of droughts and floods, and their adoption of CA practices. However, only 8% of the farmers indicated recognizing CA practices as adaptation strategies to climate change. Similar results are reported in Ngoma *et al.*, 2012 where it was found about 5% of the smallholder farmers in Eastern and Southern Provinces used minimum tillage as adaptations to climate change. Although informative, this study by Nyanga *et al.,* (2011), has limitations. Firstly, like the other studies on CF in Zambia, this was a case study of 12 districts where CF has been promoted. Therefore inferences from such a study cannot be generalised to the entire country. Secondly, the bivariate analysis undertaken in this study cannot be relied upon to provide conclusive analysis of the underlying relationships among variables.

Further and still on climate change and CF, Ngoma *et al.,* 2012 studied climate change adaptation options among smallholder farmers in Eastern and Southern Provinces of Zambia. Using data from focus group discussions (FGDs) and a sub-sample of 2,540 farming households

[3] included Choma, Kalomo, Mazabuka, Monze, Sinazongwe, Chibombo, Chongwe, Kapiri Mposhi, Mumbwa, Chipata, Katete and Petauke

from the 2008 Supplemental Survey, they found that 53% of the study sub sample adapted to climate change in the 2006/07 agricultural season. The main climate change adaptation strategies included crop diversification, early planting, a combination of crop diversification and early planting, and minimum tillage. Results show that minimum tillage, defined as use of either planting basins, ripping and/or zero tillage, was used by 5% of the respondents as adaptations to climate change in the two Provinces. Farmer income, labor availability and climatic factors were found to significantly influence farmers' decision to use minimum tillage.

It is apparent from the literature reviewed above that despite massive investments going towards promotion of conservation farming in Zambia; much of the evidence on its impact is either based on small and non-national samples or based on a single or few seasons only. As such, we cannot say with certainty whether CF adoption or use has increased or indeed decreased at national level over the years, except for few districts/areas which are focal point places for promotion of CF. Even though use of panel data would suffice in the first best world scenario, reality has it that we could only access pooled cross sectional data and hence conduct analysis under the second best world scenario.

3.0 DATA

Data for this study were primarily drawn from the annual Crop Forecast Surveys (CFS) conducted by the Ministry of Agriculture and Livestock (MAL) and Central Statistical Office (CSO). We used data for the period from 2008 to 2012. Other data used in the study were dekad (10 day period) rainfall data covering the 1997/8 to 2010/2011 growing seasons and collected from 36 stations by the Zambia Meteorological Department. Focus group discussions were held in Chama, Choma and Petauke districts to supplement the CFS data. Additionally, key informant interviews were held with the conservation farming unit who are the leading institution promoting CF in Zambia and officials from MAL.

3.1. SAMPLING

Sampling for CFS has so far been based on the 2000 census of housing and population, except for the 2011/12 survey whose sampling was based on the 2010 census results. The sampling frame used consisted mainly of rural Standard Enumeration Areas (SEAs), but urban SEAs with 70% or more of their households engaged in agricultural activities were also included. A two-stage cluster sampling scheme was used. In the first stage, 680 SEAs were selected out of a total of 12, 789 SEAs nationwide using probability proportional to size (PPS), where the number of agricultural households was the measure of size. At the second stage of sampling, all household in selected SEAs were listed and agricultural households identified. To improve the precision of the survey estimates, the identified agricultural households were stratified into three (3) categories- A, B and C, on the basis of total area under crops; presence of some specified special crops; numbers of cattle, goats and chickens raised; and sources of income. Systematic sampling was then used to select a total of 20 households distributed across the three strata. This resulted in a total national sample size of 13,600 households per year and a total of 65,400 households over the 5 year period between 2008 and 2012. However, due to non-response and other challenges, usable data over the 5 year period represented 63,000 households.

4.0 METHODS

Since most households do not practice minimum tillage (MT), the dependent variable has a lot of zeros (98%) resulting into a corner-solution outcome. Ordinary least squares regression outcomes generate biased and inconsistent parameter estimates in this case. Tobit models are often used instead, but simultaneously estimate the determinants of the probability of participation and the magnitude of its effects. Essentially, tobit models assume that the coefficients on the probability and magnitude are equal, which may not always be reasonable (Lin and Schmidt, 1984).

To motivate the Cragg's Tobit alternative or Double Hurdle model, let Y_i^* be defined as a latent variable given as:

$$Y_i^* = \beta X_i + \varepsilon_i \sim Normal\left(0, \sigma^2\right) \tag{1}$$

Where X_i is the combined vector of household and climatic characteristics assumed to influence farmers' decisions to use minimum tillage, β is a vector of parameters to be estimated, and ε_i is the random error term, normally distributed with zero mean and constant variance. The relationship between the observed Y_i and the latent variable Y_i^* is expressed as follows:

$$Y_i = \begin{cases} Y_i^* \text{ if } Y_i^* > 0 \\ 0 \text{ if } Y_i^* \leq 0 \end{cases} \tag{2}$$

or alternatively, $Y_i = max\ (0, \beta X_i + \varepsilon_i)$.

The Cragg's Tobit alternative model (Cragg, 1971) presents a variation of the Tobit model which allows for separate estimation of the probability of participation and the amount of land under minimum tillage. Such two-stage models consist of both a probit and a truncated normal regression. In this study, the two-stage model is used to first estimate the determinants of household practicing minimum tillage and secondly to estimate the determinants of the amount of land they cultivated under minimum tillage. A household used minimum tillage if they cultivated any field with ripping and/or planting basins. The amount of land under minimum tillage is a summation of the land cultivated using ripping and/planting basins.

The Cragg's Tobit alternative model was applied in estimation of the determinants of the probability of a household practicing minimum tillage (participation) and the determinants of the extent of land that household put under a minimum tillage. The empirical model is specified as follows:

$$\text{Stage 1:} \quad P(D_i = 1 \mid X_i) = \gamma X_i + \mu_i \qquad (3)$$

$$\text{Stage 2:} \quad Y_i = \beta X_i + \varepsilon_i \qquad (4)$$

where D_i takes the value of 1 if the household practiced MT; Y_i is the amount of land put under MT; X_i is the vector of explanatory variables postulated to influence participation and magnitude of land put under MT, respectively, and is the same for both stages; γ is the vector of coefficients associated with X_i in the first stage; and β is the vector of coefficients associated with X_i in the second stage. Average Partial Effects (APEs) from the Double Hurdle Model were calculated using the Delta Method.

4.1. DESCRIPTION OF VARIABLES USED IN THE MODELS

The dependent variable for the econometrics model applied in this study is *use of minimum tillage* and *land cultivated under minimum tillage*. The choice of explanatory variables included in this study was based on data availability and literature.

Gender of the household head has been found to have different effects on adoption decisions at household level. While some studies found that female farmers were more likely to adopt conservation practices (Newmark et al., 1993 cited in Hassan and Nhemachena, 2008), others found that gender of the household head did not significantly affect farmers' decisions to adopt conservation measures (Bekele and Drake, 2003). We expect male headed households to be more likely to adopt MT technologies because they tend to have more social ties compared to their female counter parts. *Age* of the household head is used as a proxy for farming experience. The influence of age on farmers' choices of agricultural technologies has been mixed in literature. Some studies found that age had no influence on a farmer's decision to adopt agricultural technologies (Bekele and Drake, 2003). Others in Zambia found that age is significantly and negatively related to farmers' decisions to adopt planting basins (Chomba, 2004). Although, old age is associated with more experience, we expected young farmers to be more likely to adopt these MT tillage methods because of the labour and planning intensities required to properly utilise these technologies (Haggblade and Tembo, 2003).

Land size is a form of household wealth. Generally, it is believed that there is a positive relationship between amount of land holding size and the likelihood of adopting improved agricultural technologies (Hassan and Nhemachena, 2008). However, Chomba (2004) found that landholding size negatively influenced farmers' adoption of planting basins in Zambia. In this study, we expected access to land to have mixed effects on adoption or use of MT tillage practices. Although there is a growing recognition of the importance of climatic and environmental factors in influencing farmers' decisions to adopt agricultural technologies, there doesn't seem to be consensus on how to define, and what climatic variables to include. As in many other technology adoption studies (see for instance Deressa *et al.,* 2008; Ngoma *et al.,* 2012; Gbetibou, 2009) , this study included rainfall variables derived from rainfall records for an agricultural growing season spanning from November to March of every year. However, in recognition of the temporal nature of environmental/climatic matters, we defined 4 different variables related to rainfall. All rainfall related variables are lagged variables representing last years' situation because generally farmers do not know the rainfall amount pertaining to the current season at planting. We calculated long run average rainfall *(lravr)* defined as average rainfall over the past 10 year period, starting from the previous year *(t-1).* Rainfall deviations, either positive or negative are differences between last season's rainfall amount *(t-1)* and the long run average rainfall. If the difference is positive, this was indicative of floods and if negative, the rainfall deviation term was indicative of droughts. Last years' *(t-1)* rainfall stress variable represented the total number of consecutive 20 day periods that recorded rainfall amounts of less than 40mm within a growing season (definition provided by the Zambian metrological department).

Apriori, we expected long run average rainfall and positive rainfall deviations to negatively influence use of minimum tillage. The negative rainfall deviations and rainfall stress variables were expected to enhance use of minimum tillage. We included a set of dummies to reflect the influence of districts where Dunavnat has operations. *Ddunvt* =1 if dunavant operates in that district. Also included is a dummy *cattle_d*[4] =1 if the district recorded animal diseases of economic importance over the last 10 years and 0, otherwise. We expected this dummy to negatively affect use of minimum tillage which also uses animal draught power for ripping.
All the variables described above are summarised in Table 1 below.

[4] Included Choma, Namwala, Solwezi, Kabwe, Kazungula, Kalomo, Nakonde, Isoka, Chama, Mambwe, Lusaka, Siavonga, Monze, Mongu, Sesheke, Lukulu and Senanga districts

Table 1: Definition of variables used in the study

Variable Name	Definition	Units/ Values	Mean	Percentiles 10th	25th	50th	75th	90th
Male headed hh	Male headed households (1=male)	[0,1]	0.82	-	-	-	-	-
Age_hh	Age of household	years	45	28	34	43	54	66
Rain Stress	# of 20 day periods with less than 40 mm of rainfall	mm	0.76	0	0	0	1	3
Ddunavt	Districts where Dunavant Cotton has operations (1= yes)	[0,1]	0.34	-	-	-	-	-
LogLand_size	Log of total land size owned by households	hectare	1.01	0.22	0.38	0.63	1.13	2.00
Lravr	Lagged (t-1) past 10 year average rainfall	mm	989	735	840	967	1,160	1,219
PvtRainDev	Positive rain deviation (difference between last year's rainfall and the 10 year average rainfall amounts)-indicative of floods	mm	82	0	0	39	126	218
NgtvRainDev	Negative rain deviation (difference between last year's rainfall and the 10 year average rainfall amounts)- indicative of droughts	mm	-49	-168	-89	0	0	0
Cattle_d	Indicates district where cattle diseases of economic importance were recorded in the last decade (1= disease(e) recorded over the last decade)	[0,1]	0.23	-	-	-	-	-

5.0 RESULTS AND DISCUSSIONS

5.1. DESCRIPTIVE RESULTS AND DISCUSSIONS

5.1.1. National trends in use of ripping and/or planting basins among smallholder crop farmers from 2008-2012

Defining minimum tillage (MT) as either use of planting basins and /or ripping, results show that an estimated total of 51,000 representing 3.9% of the smallholder farmers population used MT in 2012, up from 24,000 (1.8%) in 2008. Over the 5 years, results show an increase in use of MT among smallholder farmers in Zambia. See Figure 1 below.

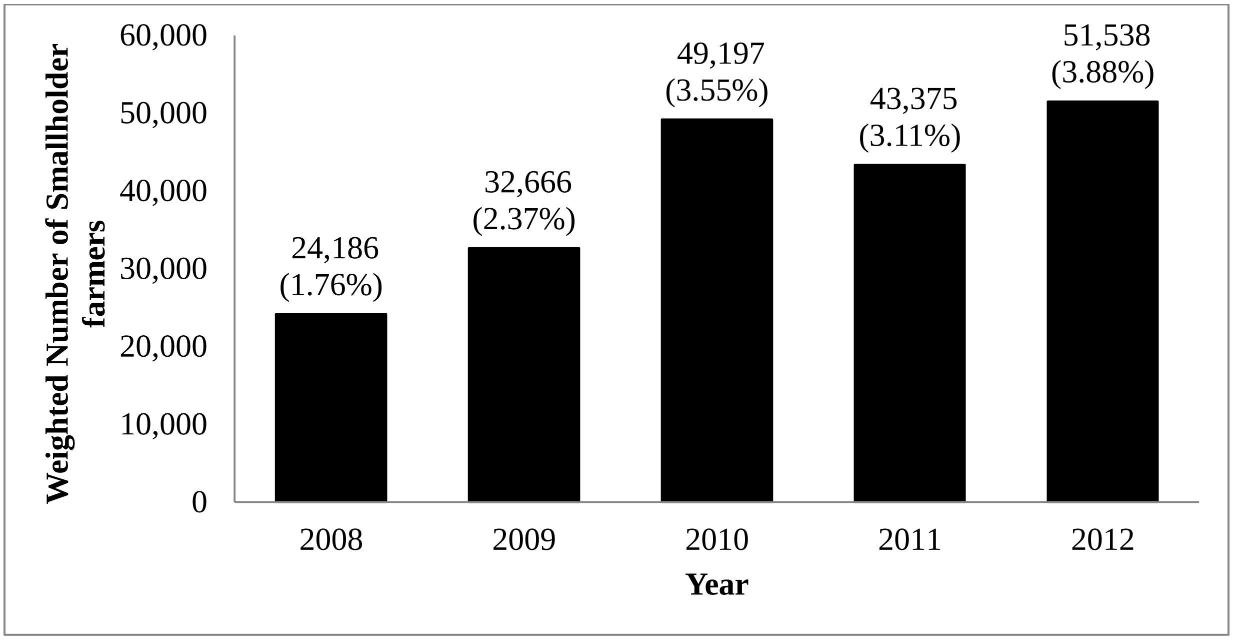

Figure 1: Trends in the total weighted numbers of smallholder farmers using ripping and/or planting basins by year from 2008-2012 in Zambia

We further show trends by individual practice in Figure 2 below, results show that use of planting basins consistently increased from 2008 to 2010 but use of ripping remained rather constant between 2008 and 2009 and only started to increase between 2009 and 2010. However use of both planting basins and ripping dropped between 2010 and 2011, before use of both practices showed uptrends between 2011 and 2012. Ostensibly, there must have been a shock in 2010 which led to the marked increase in use of MT.

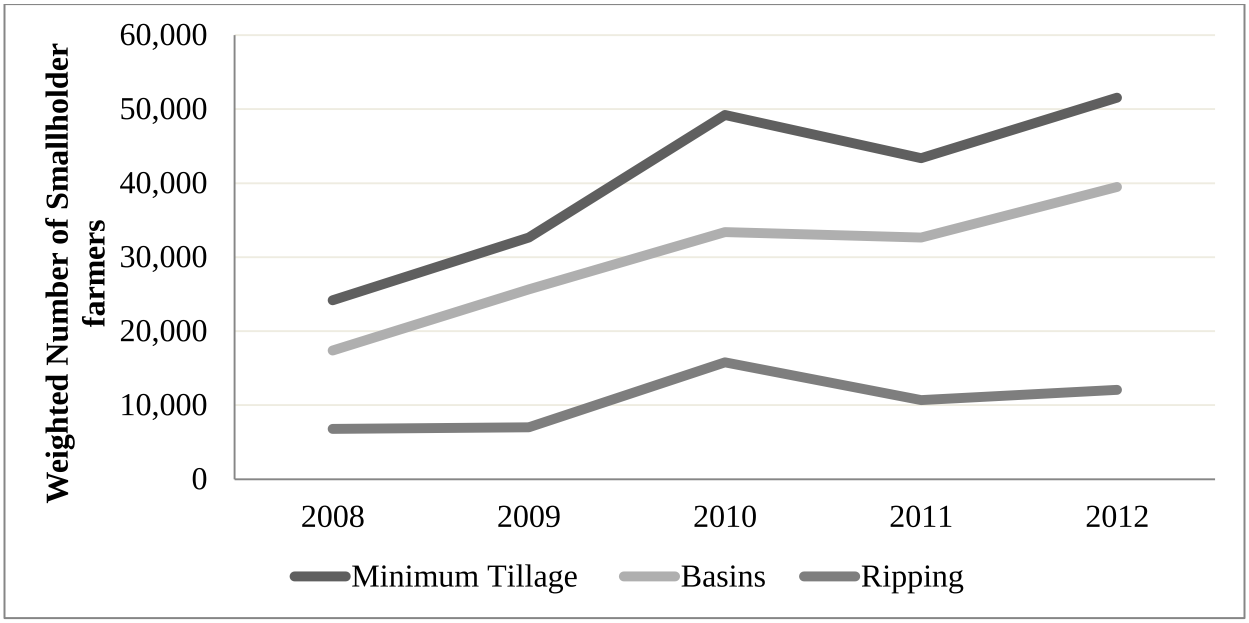

Figure 2: Trends in the numbers of smallholder farmers' use of planting basins and/or ripping by year from 2008-2012

Results from FGDs and key informant interviews suggest that the increase in use of MT up to the year 2010 may have resulted from an increased push from development cooperators at the time. The Conservation Farming Unit (CFU) for example scaled up their field training activities during the 2009/10 agricultural season by recruiting more field training officers and the Government supported Farmer Input Supply Response Initiative (FISRI) and the Conservation Agriculture Scaling Up Support program (CASSP) and several other CF projects were at peak around 2009/10 in most districts of the country. However, by 2011 we see that the numbers had receded to about 3%. This decline corresponds to the period when most of the CF projects started phasing out or had phased out. Much of the turbulences in use rates of MT across years are related to institutional settings of projects promoting CF in Zambia. Provision of material handouts as inducements to practice CF, poor beneficiary selection criteria and poor or lack of exit strategies by projects come out strongly as major factors causing variability in MT use rates among farmers. For example, it was explained that once projects stop providing material "incentives" such as agro inputs and food stuffs, farmers would also stop practicing CF and wait for the next project intervention.

5.2 ECONOMETRIC RESULTS AND DISCUSSIONS

5.2.1 Determinants of the probability to use minimum tillage and amount of land cultivated under minimum tillage among smallholder farmers between 2008 and 2012

Empirical results from the Double Hurdle Model are presented in Table 2 below. The Instrumental Variable for the CFU[5] dummy, "*ddunavt"* was also included as a covariate. Column 1 present's participation APEs and column 2 presents the unconditional or overall APEs based on the entire sample regardless of whether the household practiced any MT or not. The significance of all APEs reported in Table 2 was evaluated using the Delta method.

Results show that age of the household head, land holding size, incidences of droughts, being in a CFU operational area significantly increased the probability of farmers using MT. However, incidences of floods in the previous year significantly reduced the likelihood of farmers using minimum tillage this year.

On the extent of land under MT, results suggest that male headed households would on average increase land cultivated under minimum tillage by 0.05 hectares ceteris *paribus*. This is statistically significant at 5% level. This result tend to reflect the decision making power dynamics in households where in most instances, men have absolute control. Further, a unit increase in land owned by households was on average found to significantly increase amount of land cultivated with minimum tillage by 0.03 hectares. This finding seems to suggest that increasing land under the control of a household provides better leverage on farm decisions making. Further, results show robust evidence suggesting that farmers in the current season would increase and reduce the amount of land put under CF following seasons with droughts and floods respectively. A caveat is in order on these results. These results merely show farmers' likely tillage responses in the current season following flooding and / or droughts during last year's agricultural season.

Additionally, results suggest that being is districts where CFU has operations significantly increased the amount of land put under minimum tillage by 0.03 hectares *ceteris paribus*. We also found that being in a district which recorded major cattle disease outbreaks within the last 10 years (2012 going back) significantly reduced the amount of land under MT by about 0.01hectares. This finding has major implications on the success of MT in Zambia given that the country has witnessed recurrent animal disease outbreaks in the recent past. Despite the small magnitudes of influence, results show the extent to which various factors can lead to changes in amount of land cultivated under MT above and beyond the probabilistic effects of whether a household practices some form of MT or not. It is therefore imperative that these and other

[5] We tested and found that the CFU dummy was endogenous to the uptake of MT by farmers. We also tested and found that *"ddunvt"* indicating districts where Dunavant Cotton has operations in Zambia, was a good instrument.

salient issues are addressed if novel and new approaches such as the push of Climate Smart Agriculture are to succeed.

Table 2: Determinants of use of minimum tillage and the amount of land cultivated under minimum tillage by smallholder farmers

	(1)	(2)
	--------------Minimum Tillage---------------	
	Probability, D (Tier1)	Land cultivated using MT, Y(Tier2)
Variable description	Participation APEs	APEs on the unconditional expected value (overall)
Male headed household (=1)	0.0001	0.0052**
	(0.0018)	(0.002)
Age of household head	0.0001**	0.0000
	(0.0000)	(0.000)
Land size (ha)	0.0069***	0.0315***
	(0.0010)	(0.003)
Positive rain deviation (‘000mm)	-0.0416***	-0.0359***
	(0.0079)	(0.008)
Negative Rain Deviation (‘000mm)	0.0255**	0.0117
	(0.0118)	(0.217)
Agro ecological zone 3 (=1)	-0.0113***	-0.01865***
	(0.0039)	(0.005)
Agro ecological zone 2a (=1)	0.0059**	0.0007
	(0.0026)	(0.378)
Agro ecological zone 2b (=1)	0.0075*	-0.0603***
	(0.0041)	(0.004)
Dunavant has operations (=1)	0.0194***	0.0283***
	(0.0040)	(0.004)
Cattle disease (=1)	-0.0009	-0.0057***
	(0.0020)	(0.002)
Number of observations	*62,708*	*62,708*
Wald (χ^2)		*557.74*
Prob > χ^2		*0.000*
Log Likelihood		*-10,325.7*
Number of observation at corner		*61,204*

*Notes: Standard errors in parenthesis; ***, **, * significant at 1%, 5% and 10% respectively;* ***D*** *is the probability of a household using minimum tillage and* ***Y*** *is amount of land in hectares cultivated using minimum tillage*

6.0 CONCLUSIONS AND POLICY IMPLICATIONS

We use nationally representative pooled cross-sectional household data to assess determinants of farmers' decisions to use minimum tillage and how much land is cultivated using minimum tillage between 2008 and 2012 in Zambia. Results generally show an upward but volatile trend in use rates for ripping and planting basins across the 5 years considered in the study. We found that an average of 51,000 (3.9%) smallholder farmers used minimum tillage in 2012, up from 24,000 (1.8%) in 2008. These changes in use rates were mainly attributed to intuitional arrangements besetting projects promoting conservation farming in Zambia.

Empirical results from the Double Hurdle model show that age of the household head, land holding size, incidences of floods and droughts significantly influence farmers' probabilities to use minimum tillage. We also found that increasing landholding size owned by households by 1 hectare would on average increase land cultivated under minimum tillage by 0.03 hectares, *ceteris paribus*. This result suggests that increasing landholding sizes among farmers provides them with more flexibility in making farming decisions. We also found that being in a district where conservation farming unit has operations significantly increased land cultivated using minimum tillage by 0.03 hectares. However, we also found robust evidence suggesting that being in districts which recorded cattle diseases of economic importance over the last 10 years (2012 going backwards) reduced land under minimum tillage by 0.01 hectares. There is therefore need for consented efforts in addressing cattle disease outbreaks and giving more support to mechanized ripping initiatives in Zambia. Results further show that being in a given agro-ecological zone influences both the decision to use minimum tillage and the amount of land cultivated using minimum tillage. For example, results show that farmers in agro-ecological zone 3 (with > 1000mm of annual rainfall) are 1.1 percentage points less likely to use minimum tillage and reduce land under minimum tillage by about 0.02 hectares We also found robust evidence suggesting that farmers in the current season would reduce the amount of land put under minimum tillage following a season with floods. Although insignificant, we also found that farmers are more likely to increase the amount of land cultivated using minimum tillage in the current season following a season with droughts. These results seem to suggest that farmers are using conservation farming practices in response to rainfall variability but more research would be required to directly assess whether using conservation farming practices smoothen out the yield turbulences caused by climate variability and change.

Given the foregoing findings, a number of policy implications can be drawn;

i. There is need to revolutionize development facilitation in the area of conservation farming and adopt more of market led approaches that ensure sustainability of interventions. The culture of giving handouts should be discouraged; beneficiary selection need to be improved and exit strategies should be built in right from the start of projects to ensure continuity of activities beyond the life span of these projects. One way this could be done is to allow the private sector to provide direct goods and services while the project implementers retain the role of providing linkages and building capacity. There are some successful models in this regard that can be scaled up.

ii. Results also show that incidences of animal diseases significantly affect use of minimum tillage, there need, therefore to support programs working to reduce animal diseases and those linking farmers to use of tractor drawn rippers and zero tillage planters as alternative ways to implement ripping.

iii. Since previous season's rainfall amount received significantly influences farmers' current farming decisions; more support should be given to institutions mandated with the responsibility of gathering and disseminating weather information. Rainfall data used in this analysis were collected from 36 met stations in some of the 72 districts across the country. For those districts that don't have met stations, rainfall values had to be imputed from nearby stations which in some instances may be more than 100km away. This would facilitate farmers' decision to adopt conservation farming and allow for more policy relevant research.

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7.0 REFERENCES

Aslihan, A., McCarthy, N., Leslie Lipper, L., Asfaw,S. and A, Cattaneo. 2013. *Adoption and Intensity of Adoption of Conservation Farming Practices in Zambia.* Joint FAO/? IAPRI working paper # 71, Lusaka.

Baudron, F., H.Mwanza, B.Triomphe, and M. Bwalya. 2007. *Conservation agriculture in Zambia: a case study of Southern Province.* African Conservation Tillage Network (ACT), Nairobi, Food and Agriculture Organization of the United Nations.

Bekele, W., and L.Drake. 2003. *Soil and water conservation decision behaviour of subsistence farmers in the Eastern highlands of Ethiopia: A case study of the Hunde-Lafto area.* Journal of Ecological Economics 46: 437–51.

Burke,W.J. 2009. *Fitting and Interpreting Cragg's Tobit Alternative Using Stata.* The Stata Journal 9(4), pp. 584–592

Chomba N. G. 2004. *Factors Affecting Smallholder Farmers' Adoption of Soil and Water Conservation Practices in Zambia*. Masters' Thesis, Department of Agricultural Economics, Michigan State University. Available at http://www.aec.msu.edu/agecon/fs2/zambia/chomba_thesis_updated_version.pdf

Crop Forecast Surveys (2008-2011): *Crop Forecast Surveys for Small and Medium Scale farmers*. Central Statistical Office, Lusaka

Donovan, C. and S. Kabwe. 2005. *Sustained use of Conservation Farming Practices among Small and Medium Scale Farmers in Zambia*. Lusaka, IFPRI and FSRP - MSU. Available at (http://www.aec.msu.edu/fs2/zambia/index.htm)

Feder , G., Just, R.E. and D. Zilberman. 1985. *Adoption of Agricultural Innovations in Developing Countries: A survey*. Journal of Economic development and Cultural Change 33: 255-298.

Gbetibouo, G.A. 2009. *Understanding Farmers Perceptions and Adaptations to Climate Change and Variability; The case of Limpopo Basin, South Africa*. IFPRI Discussion Paper # 849. Washington, D.C.: International Food Policy Research Institute (IFPRI).

Haggblade, S. J., and C. Pherlopes. 2010. *Productive Impact of conservation farming on Smalloder cotton farmers in Zambia.* Working paper # 47, Lusaka, Zambia. Available at (http://www.aec.msu.edu/fs2/zambia/index.htm).

Haggblade, S. J., G.Tembo, and C.Donovan. 2004. *Household Level Financial Incentives to Adoption of Conservation Agricultural Technologies in Africa*. No 54466, Food Security Collaborative Working Papers, Michigan State University, Department of Agricultural, Food, and Resource Economics.

Haggblade, S., and G. Tembo. 2003. *Development, Diffusion and Impact of Conservation Farming in Zambia*. Lusaka, IFPRI and FSRP - MSU. Available at (http://www.aec.msu.edu/fs2/zambia/index.htm).

Hassan, R., and C.Nhemachena.2008. Determinants of African farmers' strategies for adapting to climate change: Multinomial Choice analysis. *African Journal of Agriculture and Resource Economics* 2: 82- 104.

Hichaambwa, M. and T.S. Jayne. 2012. *Smallholder Commercialisation Trends as Affected by Land Constraints: what are Policy Implications*? IAPRI working paper # 61, Lusaka. Available at (http://www.aec.msu.edu/fs2/zambia/index.htm).

Jain, S. 2006. *An empirical economic assessment of impacts of climate change on agriculture in Zambia,* . University of Pretoria, South Africa, CEEPA discussions paper.

Kabwe, S. 2012. *Trends in CF use among Cotton farmers in Zambia: 2002-2011*. Forthcoming IAPRI working paper.

Lin, T. and P. Schmidt. (1984), '*A test of the tobit specification against an alternative suggested by Cragg*', The Review of Economics and Statistics **66**(1), 174-177.

Mason, N.M, T.S. Jayne and R.B. Meyers. 2012. *Zambian Smallholder Behavioural Responses to Food Reserve Agency Activities*. IAPRI policy brief # 57. Available at (http://www.aec.msu.edu/fs2/zambia/index.htm).

Ngoma, H., L.D., Mapemba, G., Tembo and B., Maonga. 2012. C*limate change adaptation strategies by smallholder farmers in Eastern and Southern Zambia.* MSc. Thesis, University of Malawi, Bunda College of Agriculture.

Nyanga, P.H., F.H. Johnsen, J.B., Aune and T.H. Kalinda. 2011. *Smallholder Farmers' Perceptions of Climate Change and Conservation Agriculture: Evidence from Zambia.* Journal of Sustainable Development 4: 73-83.

Thierfelder, C. andWall, P. C.2010 *Investigating Conservation Agriculture (CA) Systems in Zambia and Zimbabwe to Mitigate Future Effects of Climate Change.* Journal of Crop Improvement, 24: 2, 113 — 121.

Wooldridge, J. M. 2002. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press.

Wooldridge, J.M. 2010. *Econometric Analysis of Cross Section and Panel Data,* 2nd Edition. Cambridge, MA: MIT Press

http://conservationagriculture.org/uploads/pdf/MIN-TILL-AND-ACCESS-TO-CARBON-MARKETS-22.4.12.pdf. Accessed on 09.03.2013

http://conservationagriculture.org/uploads/pdf/PROMOTION-AND-ADOPTION-OF-CF-IN-ZAMBIA.pdf .Accessed on 09.03.2013

http://conservationagriculture.org/uploads/pdf/MT-CT-CF-CA-DEFINITIONS-CFU-ZAMBIA.pdf .Accessed on 09.03.2013

http://conservationagriculture.org/uploads/pdf/CF-ADOPTION-STATISTICS-TO-2010.pdf. Accessed on 09.03.2013