# What Explains Minimal Usage of Minimum Tillage Practices in Zambia? Evidence from District-Representative Data

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Working Paper No. 82

March 2014

Indaba Agricultural Policy Research Institute (IAPRI)
*Lusaka, Zambia*

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## ACKNOWLEDGEMENTS

The authors are grateful to USAID through the Food Security Research Project III and Indaba Agricultural Policy Research Institute (IAPRI) for financing this study. Technical support from IAPRI researchers is greatly appreciated. We are also grateful to Peter Aagard and the Conservation Farming Unit for the useful comments and facilitating fieldwork in Choma and Petauke districts. Thanks to Aslihan Arslan for useful discussions on the topic and for involving IAPRI in international outreach activities associated with this research. We are also thankful to Nicole Mason for very useful comments and suggestions provided on an earlier draft of this paper, and to Patricia Johannes for formatting and editing.

The views expressed or remaining errors and omissions are solely the responsibility of the authors and do not necessarily reflect the opinions of IAPRI or any other organization.

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## EXECUTIVE SUMMARY

Conservation farming practices are widely considered to be important components of sustainable agricultural development in Sub-Saharan Africa because of their potential to increase farm productivity and incomes while maintaining or improving soil quality and reducing vulnerability to variable climatic conditions. However, despite major efforts over the past two decades to promote adoption of conservation farming (CF) practices such as ripping and planting basins in Zambia, as of 2012 only a small proportion of small and medium-scale farmers used these practices as main tillage methods at field level. Using farm data from the Crop Forecast Surveys, which were conducted annually from 2008 to 2012 and are statistically representative at the district level, results show consistently low use rates for both ripping and planting basins. There is a slightly upward but quite variable trend over the five-year period considered in the study. Roughly 51,000 farmers (3.9% of all small and medium scale farmers in the country) used ripping and/or planting basins in 2012, up from 24,000 (1.8%) in 2008. In terms of individual CF practices, 39,000 farmers (3.0%) used planting basins in 2012, up from 17,000 (1.0%) in 2008. Roughly 12,000 farmers (less than 1.0%) used ripping in 2012 compared to 7,000 (0.5%) in 2008. We find somewhat higher use rates in lower rainfall agro-ecological zones 1 and II compared to agro-ecological zone III. These findings raise puzzling questions: why does minimum tillage use remain so low despite major efforts to promote it and despite evidence that the use of CF practices substantially raises crop yields and area cultivated? Addressing this question is the main objective of this study.

To identify household and community factors associated with use and non-use of planting basins, ripping, and either planting basins and/or ripping (also called minimum tillage in this report), two econometric models were applied. The seeming unrelated bivariate probit model was estimated to identify the factors influencing farmers' decisions to use ripping and planting basins, while controlling for endogeneity of CF promotion programs operating in certain areas. Double hurdle models with the use of the control function to control for endogeneity of CF program placement were used to determine factors influencing land sizes farmers cultivated using specific minimum tillage practices. Results suggest that the occurrence of floods and droughts in the previous season significantly reduced and increased, respectively, the likelihood of farmers using planting basins and ripping as well as the amount of land cultivated using these practices in the current season. These results suggest that farmers are perceiving ripping and planting basins to be effective responses to drought and low soil moisture conditions, while they perceive these practices less helpful in the face of flooding and waterlogging conditions. However, more research is required to assess whether these practices actually help farmers smooth out the yield instability caused by climate variability.

The use of ripping is found to be positively and significantly associated with male-headed households, age of the household head, and landholding size. Further, age of the household head and landholding size had significant and positive effects on the use of planting basins, while having a male household head had a significant and negative effect on the use planting basins. However, all of these variables had a very small absolute influence on whether or not households used these minimum tillage practices, since such a small proportion of households used them. These household attributes had much greater effects on the amount of cultivated land under these practices. For example, among households using ripping and/or planting basins, a one-hectare increase in landholding size owned by a household will lead to a 0.49 and 1.12 hectares increase in land cultivated under planting basins and ripping, respectively. Being in a district where the Conservation Farming Unit (CFU) operates

significantly increased the probability of a household using ripping and significantly increased land cultivated using ripping.

Additionally, results show that being in districts that recorded cattle diseases of economic importance over the last 10 years (2012 going backwards) significantly reduced the field area that was ripped. Concerted efforts to address cattle disease outbreaks may support a sustained increase in the use of draft powered ripping in Zambia. Equally, there is need to support mechanized ripping as an alternative.

To gain more insights into the low use of minimum tillage practices amongst smallholder farmers in Zambia, key informant interviews and focus group discussions were conducted in three districts where Crop Forecast Survey (CFS) data indicated that minimum tillage use rates had reached relatively high levels (over 10% use) before reverting back to very low levels in subsequent years. Among the reasons suggested by farmers for low and variable use rates for planting basins and ripping were: high labor requirements for planting basins; trade offs between dry season land preparation and other non-farm income generating activities; the lack of access to finances required to purchase the requisite tools, herbicides and implements for various CF technologies; poor selection criteria for project beneficiaries; and poor exit strategies by CF projects. The practice of giving handouts in the form of farm inputs, implements, and foodstuffs by projects/programs promoting CF was identified as one of the causes of variable use rates observed over time. In such a setting, farmers' use of CF technologies may represent a *quid pro quo* arrangement where they are required to practice some form of CF in order to receive material support. Disadoption may follow the next year if the material support is discontinued. While development facilitators may argue for *smart* startup subsidies, focus group results suggest that failure to continue receiving the subsidy is associated with disadoption. These qualitative methods underscored how the institutional settings of programs/projects promoting CF play a pivotal role in farmers' uptake of these technologies.

Six main conclusions are drawn from these findings:

i. Despite having been actively promoted for several decades, minimum tillage use in Zambia remains quite low, with less than 5% of smallholder farmers using ripping or planting basins. Use rates are generally below 10% even in the top ten districts where CF programs have been active for many years. Use rates appear to be increasing slightly between 2008 and 2012, but the trend is highly variable.
ii. Major reasons forwarded for the continued low use of CF practices include incompatibility with the resource base of some farmers, high labor requirements for some practices, and tradeoffs between competing needs for various farmer resources.
iii. There is need to revolutionize development facilitation in the area of CF and design extension programs that provide farmers with incentives to adopt CF practices based on underlying economic viability rather than on the basis of gifts in exchange for adoption. The culture of giving handouts should be discouraged; beneficiary selection needs to be carefully considered and exit strategies should be built in right from the start of 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 roles of providing linkages and building capacity.
iv. Because the previous season's rainfall significantly influences farmers' use of minimum tillage practices in the current season; more support should be given to institutions gathering and disseminating weather information to guide farmers' decisions regarding tillage methods.

v. Since results also show that incidences of animal diseases significantly affect use of ripping which is dependent on animal draught power; there is need to support programs addressing animal disease outbreaks and those linking farmers to use of tractor-drawn rippers and zero tillage planters as alternatives to animal draught-powered ripping.
vi. Because our data set is only able to address whether or not households use particular CF practices and not the reasons why they disadopt, there is need for more in-depth analysis of the reasons for disadoption, and a better understanding of whether and/or how to support farmers in making these practices more productive and lucrative

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| | |
|---|---|
| APEs | Average Partial Effects |
| CA | Conservation Agriculture |
| CAP | Conservation Agriculture Program |
| CF | Conservation Farming |
| CFS | Crop Forecast Survey |
| CFU | Conservation Farming Unit |
| CSA | Climate Smart Agriculture |
| CSO | Central Statistical Office |
| FGD | Focus Group Discussion |
| GART | Golden Valley Agricultural Research Trust |
| hh | headed households |
| IAPRI | Indaba Agricultural Policy Research Institute |
| IV | instrumental variable |
| MACO | Ministry of Agriculture and Cooperatives |
| MAL | Ministry of Agriculture and Livestock |
| MT | minimum tillage |
| SEAs | Standard Enumeration Areas |
| SEEV | suspected endogenous explanatory variable |
| SSA | Sub-Saharan Africa |
| SUBP | Seemingly Unrelated Bivariate Probit |
| USAID | United States Agency for International Development |
| ZMD | Zambia Meteorological Department |
| ZNFU | Zambia National Farmers Union |

# 1. INTRODUCTION

Conservation agriculture, or conservation farming (CF) as it is often called in Zambia, is widely believed to have potential for achieving sustainable agricultural productivity growth(Haggblade and Tembo 2003; Baudron et al. 2007; Giller et al. 2009; Baudron et al. 2012; Arslan et al. 2013; Grabowski and Kerr 2013). CF is also believed to have solid potential for stabilizing crop yields in variable rainfall conditions. Additionally, CF provides a clear pathway towards agricultural intensification for improved food security amid heightened environmental challenges and population increase (Thierfelder and Wall 2010; Friedrich, Derpsch, and Kassam 2012; Verhulst et al. 2012) and offers potential pathways to reconcile biodiversity conservation and agricultural productivity (Baudron et al. 2009; Baudron and Giller 2014). Although often defined in different ways, CF generally refers to agricultural management practices that prevent or reduce both land and water resources degradation, and enhance farm productivity in an environmentally sustainable manner (Baudron et al. 2007).

Development of CF in Zambia can be traced to the 1980s when government, the private sector, and donors started promoting CF as an alternative set of agronomic practices for Zambian smallholders (Haggblade and Tembo 2003). The CFU of the Zambia National Farmers Union (ZNFU) and the Golden Valley 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 currently 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 initially promoted on the premise that they would improve crop yields since they had the potential to rejuvenate soils. However, more recently, these CF practices are increasingly seen as potential adaptations to climate change and variability.

There is a dearth of reliable nationally representative empirical evidence on adoption and impact of CF in Zambia. Available evidence is based on case studies and seasonal snapshots (except for a recent study by Arslan et al. (2013)). Some of this evidence estimate yields gains of between 50-100% and 40-60% for maize and cotton, respectively, for farmers who use CF technologies (Haggblade and Tembo 2003; Haggblade, Kabwe, and Plerhoples 2011). Actual estimates of the numbers of farmers practicing particular CF technologies vary depending on the source of the information. Haggblade and Tembo (2003) provide some of the oft-used estimates in Zambia. They estimated that 20,000-60,000 smallholder farmers used some form of CF in the 2001/2 season. This estimate increased to about 120,000 during the 2002/3 season (roughly 12% of all smallholder farmers in Zambia during that year) because of increased donor involvement following the severe drought experienced in the 2001/2 agricultural season. Further estimates indicate that about 75,000 – 150,000 smallholder farmers used some form of CF in the 2003/4 agricultural season, again because of increased donor support (Haggblade and Tembo 2003). In terms of the specific CF technologies, estimates suggest that about 8% (63,350) and 13% (3,000) of the small scale and medium scale farmers, respectively, used planting basins during the 1999/2000 agricultural season. However, as the authors acknowledge, this wide range of estimates may be misleading due to possible errors in the data used in the analysis (Haggblade and Tembo 2003, page 16). Additionally, Kabwe and Donovan (2005) suggest that 7% of the smallholder farmers used planting basins in both the 2001/2 and 2002/3 agricultural seasons. In addition to the above estimates, wide variations are extant in reported CF adoption or use rates. For example, Arslan 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 also they found a 95% dis-adoption rate for the country over the same period. Using data from the 17 districts covered by the Conservation Agriculture Program (CAP) in Zambia, CFU estimated an increase in the proportion of farmers using minimum tillage to 12% in 2009/10 agricultural season (up from 2% in 2006/7). Nyanga, Johnsen, and Kalinda (2012) estimated CF adoption rate within the CAP at 71%. Grawboski et al. (forthcoming) estimate 13% adoption of CF on cotton plots owned by smallholder farmers compared to 21% on plots owned by cotton lead farmers. As can be seen from the foregoing, estimates of CF adoption or use vary widely, depending on the source. Such reported differences are common in much of Sub-Saharan Africa (SSA) region; see Giller et al. (2009) for a detailed discourse on the subject and there are no universally accepted determinants of adoption but except that uptake of CF will be affected by locale specific characteristics (Knowler and Bradshaw 2007)

Most of the aforementioned estimates are either quite outdated now or are based on single-season snap shots in selected regions or agricultural season(s) without a reliable representative picture at the national scale. Further, available empirical analysis of CF in Zambia are based on small samples (see for example Haggblade and Tembo 2003 (sample size for the econometric analysis); CFU various years (Nyanga et al. 2011; Nyanga, Johnsen, and Kalinda 2012; Grabowski et al. forthcoming)). With rainfall becoming increasingly more variable in Zambia (Chabala, Kuntashula , and Kaluba 2013), we would expect adoption or use of CF technologies to be on the increase if it were feasible for farmers to profitably utilize these practices. Therefore, understanding CF use rates over the more recent time horizon and using data that are statistically representative at both national and district levels may be illuminating. Additionally, given the massive investments into CF promotion by both government and cooperating partners and the current impetus towards climate-smart agriculture (CSA) and sustainable agricultural intensification, both of which are based on CF, it is important to assess the trends and determinants of CF use in Zambia while paying particular attention to estimation issues that may confound the results

The current study addresses these issues by using pooled cross sectional Crop Forecast Survey (CFS) data collected annually by the Central Statistical Office (CSO) and the Ministry of Agriculture and Livestock (MAL) for the period 2008 to 2012. The CFS data are considered representative of small- and medium-scale farming conditions at the national, provincial, and district levels and hence provide the most accurate and most comprehensive estimates to date of CF use rates in Zambia, including within districts where CF has been most activity promoted. Rainfall data were obtained from *dekad* growing season rainfall data collected by the Zambia Meteorological Department (ZMD). This study focuses on planting basins and ripping, two of the main elements of CF minimum tillage.[1] For purposes of this study, a farmer is considered to have used minimum tillage (MT) when he/she uses either planting basins and/or ripping.[2] We focused on MT because it is the basis for both CF and CSA. Understanding the trends in use of the minimum tillage practices can help extensionists and training practitioners better understand how farmers are responding to MT technologies

[1] Zero tillage is the other main minimum tillage practice generally considered to be a part of *conservation farming*. Zero tillage is excluded from this analysis because survey respondents were found to confound it with chitimene (a slash and burn shifting cultivation) system during data collection.
[2] Throughout this study, the main variable in the survey data that was used to calculate use rates was the main tillage method applied by households in each field.

and promotion programs, and whether possible modifications in the programs or the technologies themselves should be considered.

The study objectives were fourfold:

i. To examine trends and spatial patterns in the use of planting basins and ripping from 2008 to 2012 at national, provincial and district levels;
ii. to determine factors influencing farmers' decisions to use planting basins and ripping;
iii. to determine the influence of rainfall shocks on farmers' decision to use planting basins and ripping; and
iv. to determine factors affecting how much land farmers cultivate using minimum tillage practices.

The remainder of the paper is organized as follows: Section 2 presents a review of relevant literature; data and methods are presented in Sections 3 and 4; results and discussions are presented in Section 5 while the study concludes in Section 6 and summarizes key findings.

## 2. LITERATURE REVIEW

Because CF was initially promoted exclusively as a package for land management, much of the literature reviewed relates to adoption and impact of CF among smallholder farmers in Zambia. However, in the wake of illuminating evidence showing CF technologies as potential mitigation and adaptation options to climate change, there is increased interest in studying and promoting CF technologies as promising adaptations to climate change. Not much work has been done on the latter in Zambia.

The study by Haggblade and Tembo (2003) on the development, diffusion and impact of CF in Zambia is among the pioneering empirical works on the subject in Zambia. 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 yields 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. Yield gains related to using CF practices in cotton are also reported in Haggblade, Tembe, and Donovan (2004).

In order to shed additional light on yield gains from using CF practices, Haggblade, Kabwe, and Plerhoples (2011) unpacked the above analysis and quantified yield, area and income gains possible under CF for resource-poor cotton growing households. Using plot-level data from 5,100 farms and 16,600 cultivated plots from the CSO's 2004 supplemental survey and a linear programming optimization model, they found that CF can increase crop income by about 85% among the poorest category (those without access to any cash inputs) of smallholder cotton farmers. They also found that smallholder farmers can increase their area under cultivation from an average of 1.1 hectares under conventional hand hoe to about 1.5 hectares under hand hoe CF. This is because CF reallocates heavy land preparation labor to the dry season thereby relieving the peak-season labor bottlenecks that typically constrain area cultivated under rainfed hand hoe agriculture.

Further, results from Haggblade, Kabwe, and Plerhoples (2011) indicate that farmers using purchased input packages costing up to US $60 per season can double crop income under hand hoe CF using household labor only. Additionally, this study suggests that use of herbicides to cut peak season labor requirements has the potential to enable farm households to treble their crop incomes compared to low-input conventional tillage, and at the same time increase area under cultivation to an average 2.7 hectares. A caveat is in order here as noted in Haggblade and Tembo (2003); while CF was found to confer yield gains, this was achieved at greater costs at initial stages because CF technologies involve additional labor costs for farmers, especially in the initial stages which involve digging basins in addition to weeding. However, the upside to this is that labor costs related to CF tend to decline over time because farmers go back to the same planting stations (Haggblade and Tembo 2003; Haggblade, Kabwe, and Plerhoples 2011). Additionally, there is also empirical evidence suggesting that labor requirements under CF may be daunting especially where herbicides are not used (see Giller et al. (2009) and that such labor requirements have gendered impacts because field operations such as weeding are generally undertaken by women(Nyanga, Johnsen, and Kalinda 2012).

Available empirical national evidence on the adoption of CF technologies in Zambia indicate 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, Tembo, and Donovan 2004; Arslan et al. 2013; and Nyanga et al. 2011). Evidence indicates that incentives for adoption of 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 Zambian farmers who perceive that climate is changing are more likely to use CF tillage practices (Nyanga, Johnsen, and Kalinda 2012). The literature also suggests that farmers will be more willing to adopt CF technologies based on the potential financial gains from using CF. Haggblade, Tembo, and Donovan (2004) assessed financial incentives for adoption of CF practices in Zambia by comparing increased input costs with increased value of output. It was found that while many CF adopters reported increase in yield, very few of them were alive to the fact that achieving such output gains was associated with high inputs costs. Using gross margins analysis, they found that CF can prove financially profitable to individual households across a range of locations and technologies but they were quick to mention that given the paucity of empirical literature, it was difficult to generalize such findings.

Not much work has been done in Zambia assessing the sustained adoption of CF technologies in Zambia, except for the study by Kabwe and Donovan (2005). Their study focused on the sustained use of CF practices among small and medium scale farmers. Using a panel of 5,342 households from two surveys carried out for the 1999/2000 and 2002/03 agricultural seasons, their results show that farmers are more likely to use and sustain CF practices that are closer to traditional cropping systems (such as the traditional zero tillage method) than the main CF technologies which require radical changes to farming systems. This finding suggests that CF technologies that do not require a total transformation of farming practices were more likely to succeed. It was also found that the Ministry of Agriculture and Cooperatives (MACO), as it was called then, was the most important supplier of advice on CF practices to farmers. Farmer to farmer interaction was also found to be an important source of information on CF technologies. In terms of adoption and disadoption dynamics, their results show that an average of 3% and 97% of smallholder farmers sustained use and disadopted, respectively, planting basins across all agro ecological zones in Zambia. However, as the authors noted, use of descriptive statistics limits applicability of the findings in this study. Although they use panel data, a multivariate analytical framework would have been more insightful. Using similar dataset as in Kabwe and Donovan (2005) but panel waves for 2004 and 2008, Arslan et al. (2013) used panel data econometrics techniques to assess adoption and intensity of adoption of CF in Zambia, and 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 adopt CF.

Using a household survey of 469 farmers under CAP promoted by the CFU, Nyanga et al. (2011) assessed farmers' perceptions of climate change and conservation agriculture in 12 districts of Zambia.[3] Study results show that farmers perceive various changes in climate and

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

that they are increasingly 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 Conservation Agriculture (CA) practices. However, only 8% of the farmers indicated recognizing CA practices as adaptation strategies to climate change. Similar results are reported in Ngoma (2012) where it was found that about 5% of the smallholder farmers in Eastern and Southern Provinces used minimum tillage. Although informative, the study by Nyanga et al. (2011) has limitations. Firstly, like most other studies on CF in Zambia (with the exception of Arslan et al. 2013), this was a case study of 12 districts where CF has been highly promoted. Therefore inferences from such a study cannot be generalized to the entire country because of low external validity. Secondly, the bivariate analysis undertaken in this study cannot be relied upon to provide conclusive evidence of the underlying relationships among variables. It is not possible, for example, to explicitly control for other intervening variables in such analytical settings. Additionally Nyanga, Johnsen, and Kalinda (2012) studied factors influencing adoption of CF and land put under CF in Zambia. They found that trainings, previous experience in minimum tillage, membership to farmer organizations (social capital), and ownership of tillage equipment, farm size, and access to herbicides significantly increased the likelihood of adoption and land size under conservation agriculture. CF basins were found to increase the labor burden for women in terms of weeding compared to their male counter parts who are more involved in animal draft powered ripping than hand hoe basins. This study was based on a sample of 415 households within CFU operation areas. The current study complements findings in Nyanga, Johnsen, and Kalinda (2012) by using more robust analytical methods and covering the whole country.

In addition to disparities in terms of numbers of farmers using CF as reported by different studies, impact of CF amongst adopter/users is highly contested in much of the region, see Giller et al. (2009); Anderson and Giller (2012); Grawboski and Kerr (2013) for detailed discussions. What is important to note here is that there appears to be a disagreement between what CF promoters report as adoption rates and impact, and estimates from nationally-representative data. CF promoters report higher adoption rates and impact than what is reported in empirical studies. Empirical work advance many reasons for low uptake of CF in SSA. These include the impracticalities of implementing mulching amid low crop productivity (resulting in low stover) and competing uses of crop residues for livestock feeding, and lack of land use rights and existence of communal grazing during off-season periods. A recent comparative analysis of CA and ploughing among cotton farmers in Zimbabwe found that CA offered minimal benefits over ploughing in the short term (Baudron et al. 2012). Further, adoption of CF may also be hindered by gender issues, for example when men seek to substitute male activities such as ripping with traditional female activities such as increased weeding (Andersson and Giller 2012). Lack of access to credit required to purchase requisite inputs (hybrid seed, fertilizers, herbicides) and implements have been cited as impediments to adoption and uptake of CF in much of SSA. However, there seems to be some level of consensus that CF has *potential* to significantly improve productivity among smallholder farmers in SSA (Haggblade, Tembo, and Donovan 2004; Haggblade, Kabwe, and Plerhoples 2011; Friedrich, Derpsch, and Kassam 2012) and that reported use rates in the past few years have been largely overestimated.

It is apparent from the literature reviewed that despite massive investments towards promotion of CF in Zambia; much of the evidence on its impact is contestable because it is either based on small samples or field trials (which differ from practical farmers' situations) or simply impressionistic. As such, we cannot say with certainty whether the use of minimum tillage practices have increased or decreased at national level over the years or even in the few focal areas where CF has been most actively promoted. This study was undertaken to fill this knowledge gap.

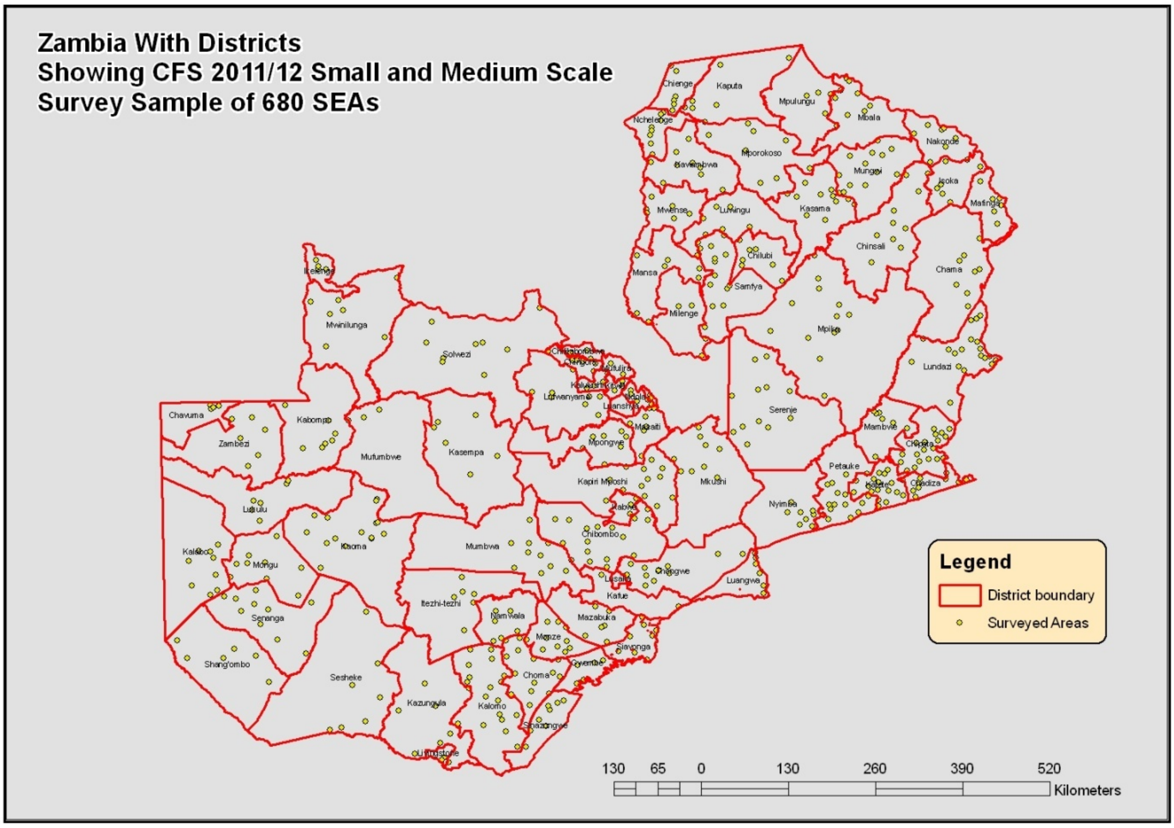
# 3. DATA

Data for this study were primarily drawn from the annual CFS conducted by MAL and CSO. We used data for the period 2008 to 2012. Other data used in the study are dekad (10-day period) rainfall data covering the 1997/98 to 2010/11 growing seasons and collected from 36 weather stations by the Zambia Meteorological Department. Focus group discussions were held in Chama, Choma, and Petauke districts to supplement these data. Additionally, key informant interviews were held with the Conservation Farming Unit (which is the leading institution promoting CF in Zambia) and with officials from MAL. CFS data is collected using face to face interviews where enumerators physically visit all sampled households to administer questionnaires. These enumerators are trained enough to be able to capture the exact tillage methods reported by farmers. Further, the enumerator reference manuals have detailed explanations on all tillage methods including pictures.

## 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 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, 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 was available for about 63,000 households. The map in Figure 1 below highlights the extent covered by annual crop forecast surveys in Zambia; this is an example from the 2011/12 survey.

**Figure 1. Map Showing Location of Standard Enumeration Areas Covered in 2011/12 Crop Forecast Survey**




Source: CFS 2012.

## 4. ANALYTICAL FRAMEWORK AND ESTIMATION STRATEGY

Both descriptive statistics and econometrics modeling techniques were used to achieve the study objectives. For objective 1, descriptive statistics presented as counts and/or percentages in tables and/or graphs were used to show trends in use of planting basins, and ripping at national, provincial and district levels over the five-year period. Econometric modeling was employed to address the other three objectives aimed at determining factors influencing minimum tillage use, extent of use, and the influence of rainfall shocks on use.

We used the Seemingly Unrelated Bivariate Probit (SUBP) model to determine factors influencing farmers' uptake of planting basins, ripping and minimum tillage in general (whereas before, minimum tillage is defined as use of ripping, and/or planting basins). The SUBP model can be motivated from the following two unobserved latent variables,

$$\begin{aligned} y_1^* &= \mathbf{x}_1\beta_1 + \varepsilon_1 \\ y_2^* &= \mathbf{x}_2\beta_2 + \varepsilon_{2.} \end{aligned} \qquad (1)$$

Where the errors $\varepsilon_1$ and $\varepsilon_2$ are normally distributed with mean 0 and variance 1 (~ N (0, 1)), with a correlation $\rho$ = corr ($\varepsilon_{1,}$ $\varepsilon_{2)}$. We observe the two binary variables under the following conditions

$$y_1 = \begin{cases} 1\, if\;\; y_1^* > 0 \\ 0\; if\;\; y_1^* < 0, \end{cases} \; and \;\; y_2 = \begin{cases} 1\, if\;\; y_2^* > 0 \\ 0\; if\;\; y_2^* < 0. \end{cases} \qquad (2)$$

A priori, we would expect that use of CF practices is positively related to the location of CF promotion programs (for example, CFU). However, there may be *program placement effects*, i.e., the programs are selected to operate in particular areas based on agro-ecological conditions, convenience to promoters, both of which are not observed in available survey data. In such a case, including a right-hand side variable that specifies whether major CF promotion programs were operating in the area would result in endogeneity problems. Therefore, we are faced with a case where there is a binary suspected endogenous explanatory variable (SEEV). This presents a special case when the dependent variable in the analysis is also a binary variable. Applying models that assume exogeneity for all explanatory variables leads to biased estimates. Common approaches for correcting endogeneity in cross sectional data using instrumental variable (IV) regression or 2 stage least squares (2sls) – which require either a continuous dependent variable or a continuous SEEV – are not necessarily suitable in this case. The SUBP model is the best suited estimation option because it explicitly models the binary nature of an endogenous covariate using an appropriate IV given that the dependent variable is also binary (Wooldridge 2010).

Following Woodridge (2010), we specify the seemingly unrelated bivariate probit model in general terms as

$$\begin{aligned} y_1 &= 1[\mathbf{x}_1\beta_1 + \alpha_1 y_2 + \varepsilon_1 > 0] \\ y_2 &= 1[(\mathbf{x}_2\beta_2 + \varepsilon_2 > 0], \end{aligned} \qquad (3)$$

Where $y_1$ is binary variable taking the value of 1 if the household practiced ripping, planting basins and/or minimum tillage. $y_2$ is the binary endogenous variable taking 1 if CFU has operations in that district. $\varepsilon_1$ and $\varepsilon_2$ ~ N (0, 1). $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are vectors of covariates in equation 1 and 2, respectively. $\beta_1$ and $\beta_2$ vectors of parameters to be estimated. In the $y_2$ equation we included an IV – being in a district where Dunavant operates (*ddunavt*) – as an IV for being in a district where CFU has operation. Note that this IV was not included in the structural equation and this was our identification strategy. Further, we evaluated the relevance of *ddunavt* as an IV using a Linear Probability Model and results were highly statistically significant (p=0.000). Empirical results confirmed that the CFU dummy was endogenous to farmers' choices of ripping and minimum tillage but not planting basins (see the likelihood ratio test results for $\rho=0$ below Table 6). Although we could not test for instrument validity because our model is just identified, *ddunavt* is a very strong IV with an F- statistic > 4,000 against the benchmark F - value of 10 for any IV to be considered strong enough.

APEs from the bivariate probit model were calculated and their significance levels determined using the bootstrap routine with 200 replications. If $\rho = 0$, the model collapses to 2 separate binary probit models, otherwise there are efficiency gains from conducting a joint Maximum likelihood estimation (MLE) for $\alpha_1$ and $\beta_1$ within the bivariate probit setup (Woodridge, 2010, page 594). The likelihood functions for the equations in (3) are defined for 4 possible outcomes which can be denoted by $y_{11}$ (when $y_1 =1$ and $y_2 =1$), $y_{10}$, $y_{01}$ and $y_{00}$. For the case when $y_1 =1$ and $y_2 =1$, the likelihood function is given as;

$$\ell = \frac{1}{\Phi(\mathbf{x}_2\boldsymbol{\beta}_2)} \int_{-x_2\beta_2}^{\infty} \Phi[(\mathbf{x}_1\boldsymbol{\beta}_1 + \alpha_1 y_2 + \rho_1 z)/(1-\rho_1^2)^{1/2}]\phi(z)dz. \tag{4}$$

Where Z in the integral is a dummy argument of integration. The likelihood function for $y_{01}$ is 1- equation (4). While the likelihood function for P($y_1=1|y_2=0,\boldsymbol{x}$) is

$$\ell = \frac{1}{1-\Phi(\mathbf{x}_2\boldsymbol{\beta}_2)} \int_{-\infty}^{-x_2\beta_2} \Phi[(\mathbf{x}_1\boldsymbol{\beta}_1 + \alpha_1 y_2 + \rho_1 z)/(1-\rho_1^2)^{1/2}]\phi(z)dz. \tag{5}$$

Taking the log of the likelihood functions of the 4 possible outcomes of ($y_1, y_2$) gives the log likelihood function for maximum likelihood estimation of the model. All other variables are as defined before while Φ is the standard normal cumulative distribution function and ϕ is the standard normal density function.

Turning to the fourth objective of determining use of, and amount of land cultivated using minimum tillage practices; we used the Double hurdle (DH) model, with a modified control function approach. The model estimates two decision processes namely; 1) determinants of the probability of a household practicing minimum tillage (participation); and 2) the determinants of the amount of land that a household puts under a particular MT practice. This method was chosen because MT use is not very common among farmers and hence we had pile ups of observations at 0 leading to a corner solution outcome. Tobit models are often used with corner-solution outcomes, but such models estimate the determinants of the probability of participation and extent of participation simultaneously. Estimation of a single set of parameters implies an assumption that coefficients on the probability of participation and extent thereof, are equal, which may not always be reasonable (Lin and Schmidt 1984). Our double hurdle model is comprised of the following two stages as shown below. Stage 1 is a participation probit equation while stage 2 is a truncated normal regression model;

Stage 1: $P(D_i > 0 \mid \mathbf{x}) = \mathbf{\Phi}(\mathbf{x}\gamma)$

Stage 2: $E(y_i / \mathbf{x}, y > 0) = \mathbf{x}\beta + \sigma\lambda(\mathbf{x}\beta / \sigma)$ (6)

where $D_i$ takes the value of 1 if the household used planting basins, ripping and minimum tillage (MT), respectively ; $y_i$ is the amount of land put under each of these MT practices; $\boldsymbol{X}$ is the vector of explanatory variables postulated to influence participation and magnitude of land put under each practice, respectively, and is the same for both stages; $\boldsymbol{\gamma}$ is the vector of coefficients associated with $\boldsymbol{X}$ in the first stage; and $\boldsymbol{\beta}$ is the vector of coefficients associated with $\boldsymbol{X}$ in the second stage. $\lambda = \phi(.)/\Phi(.)$ is the inverse mills ratio and $\sigma$ is the variance.

The log likelihood function for the double hurdle model is expressed as follows:

$$\ell(\gamma, \beta, \sigma) = 1(y_i \ = 0 \log[1 - \Phi(x_i\gamma)] + 1(y_i > 0)\log[\Phi(x_i\gamma)] + 1(y_i > 0)\{-\log[\Phi(x_i\beta / \sigma)] + \log \phi[y_i - x_i\beta / \sigma)] - \log(\sigma)\} \quad (7)$$

Estimation of the double hurdle consists of obtaining values of $\beta$, $\gamma$, and $\sigma$ that maximize equation (7) and this was done using maximum likelihood estimation in Stata statistical software. The only modification we made to the DH model was that we first estimated a reduced form probit model of being in a CFU operation district and then obtained generalised residuals that were later included as additional covariates in the MT equations. Similar methods were used in (Ricker-Gilbert, Jayne, and Chirwa 2011). The significance of these residuals both tests and controls for endogeneity of being in a CFU operation on uptake of MT. IV requirements in the reduced form equation were met as described above under the SUBP model.

Average Partial Effects (APEs) from equations in (6) follow from the standard probit and truncated normal regression models. However, the overall unconditional APEs can be calculated using equation (8) below, some modifications are possible depending on whether $x_j$ is a continuous or binary variable.

$$\frac{\partial E(y \mid x)}{\partial x_j} = \gamma_j \phi(x\ \gamma)(x\ \beta + \sigma\lambda(x\beta / \sigma)) + \Phi(x\ \gamma)\beta_j \{(1 - \lambda(x\beta / \sigma)(x\ \beta / \sigma + \lambda(x\beta / \sigma)))\} \quad (8)$$

Where $\phi$ and $\Phi$ are probability density and cumulative density functions, respectively.

We used both the Delta method and Bootstrapping to compute APEs and obtain correct standard errors for the double hurdle model. Bootstrap standard errors with 200 replications are reported. Readers are referred to (Burke 2009) for details on implementation of the double hurdle estimation using the *craggit* command and on using the delta method and bootstrapping to obtain APEs in Stata.

### 4.1. Description of Variables Used in the Models

The dependent variables for the econometric models applied in this study are *use of planting basins*, *use of ripping*, *use of minimum tillage* and *land cultivated (in hectares) with a particular MT method*. Since our dependent variables are all technology adoption, they are thought to be affected by similar covariates (Feder, Just, and Zilberman 1985). The choice of explanatory variables included in the models was based on data availability and literature. But as pointed out in the literature review section, there are no universally acceptable covariates in the literature that are thought to influence uptake of CF technologies.

*Sex* 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. We expect male-headed households to be more likely to adopt CF 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. 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 CF tillage methods because of the labour and planting intensities required to properly utilise these technologies.

*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 specific MT 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 them, and what climatic variables to include. As in many other technology adoption studies, see for instance (Deressa et al. 2009; Gbetibouo 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 factors, we defined 4 different variables related to rainfall. First, we calculated long run average rainfall defined as average rainfall over the past 10 year period, starting from the previous year, which we then used in generating the rainfall deviation variables described below.

We then computed both positive and negative absolute rainfall deviation variables, defined as the positive and negative differences between last season's rainfall amount *(t-1)* and the long run average rainfall. In years in which rainfall is less (more) than the 10-year average, the positive (negative) deviation variable is given a zero value. Years of large positive (negative) deviations are indicative of flooding/waterlogging (drought). The fourth rainfall variable used in the study is the prior year's rainfall stress which represented the total number of 20 day periods that recorded rainfall amounts of less than 40mm within a growing season (definition provided by the Zambian Meteorological Department). All rainfall variables used in the analysis are lagged because farmers would not know at planting time the rainfall amount for that growing season.

*A priori*, we expected long-run average rainfall and positive rainfall deviations to negatively influence use of either planting basins or ripping since these are also water retention technologies. The negative rainfall deviations and rainfall stress variables were expected to increase use of planting basins and/or ripping. Also, we expected the presence of CFU in a district to have positive effect on use of MT practices. Further we included a dummy *cattle_d* =1 if the district recorded animal diseases of economic importance over the last 10 years and 0, otherwise.[4] We expected this dummy to negatively affect use of ripping which predominantly uses animal draught power and hence its use in the ripping model only.

All the variables described above are summarised in Table 1 below.

[4] These districts were 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 | | | | | Source |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 10th | 25th | 50th | 75th | 90th | |
| Dependent Variables | | | | | | | | | |
| pl-basins | Use of Planting basins | [0,1] | 0.02 | - | - | - | - | - | |
| Ripping | Use of ripping | [0,1] | 0.01 | - | - | - | - | - | |
| MT | Use of minimum tillage (i.e., either planting basins or ripping) | [0,1] | 0.03 | - | - | - | - | - | CFS[1] |
| land_pbcult | Land under planting basins | hectare | 0.02 | 0 | 0 | 0 | 0 | 0 | |
| land_rpcult | Land under ripping | hectare | 0.02 | 0 | 0 | 0 | 0 | 0 | |
| land_mtcult | Land under minimum tillage | hectare | 0.04 | 0 | 0 | 0 | 0 | 0 | |
| Independent Variables | | | | | | | | | |
| Male-headed hh | Male-headed households (1=male) | [0,1] | 0.82 | - | - | - | - | - | CFS |
| 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 | ZMD[2] |
| Ddunavt | Districts where Dunavant Cotton has operations (1= yes) | [0,1] | 0.34 | - | - | - | - | - | Dunavant |
| dcfu | Districts where Conservation Farming Unit has operations (1= yes) | [0,1] | 0.23 | - | - | - | - | - | CFU[3] |
| Land_size | Total land size owned by households | hectare | 3.60 | 0.41 | 1.00 | 2.02 | 4.05 | 7.50 | CFS |
| 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 | ZMD |
| 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 | ZMD |

| **Variable Name** | **Definition** | **Units/ Values** | **Mean** | **Percentiles** | | | | | **Source** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 10th | 25th | 50th | 75th | 90th | |
| Table 1 Con't. | | | | | | | | | |
| 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 | - | - | - | - | - | Personal Interview with a Vet Doctor |
| Aer2a | Households in aer2a is agro-ecological zone 2 with clay soils and annual rainfall between 800 – 1000 mm (1=yes) | [0,1] | 0.23 | - | - | - | - | - | CFS |
| Aer2b | Households in aer2b is agro-ecological zone 2 with sandy soils and annual rainfall between 800 – 1000 mm (1= yes) | [0,1] | 0.13 | - | - | - | - | - | CFS |
| Aer3 | Households in aer3 is agro-ecological zone 3 with > 1000mm of rainfall per year (1=yes) | [0,1] | 0.39 | - | - | - | - | - | CFS |

Source: Authors' computations from CFS and ZMD data.
Note: [1]CFS – Crop Forecast Survey; [2] ZMD – Zambia Meteorological Department; [3] CFU-- Conservation Farming Unit.

# 5. RESULTS AND DISCUSSIONS

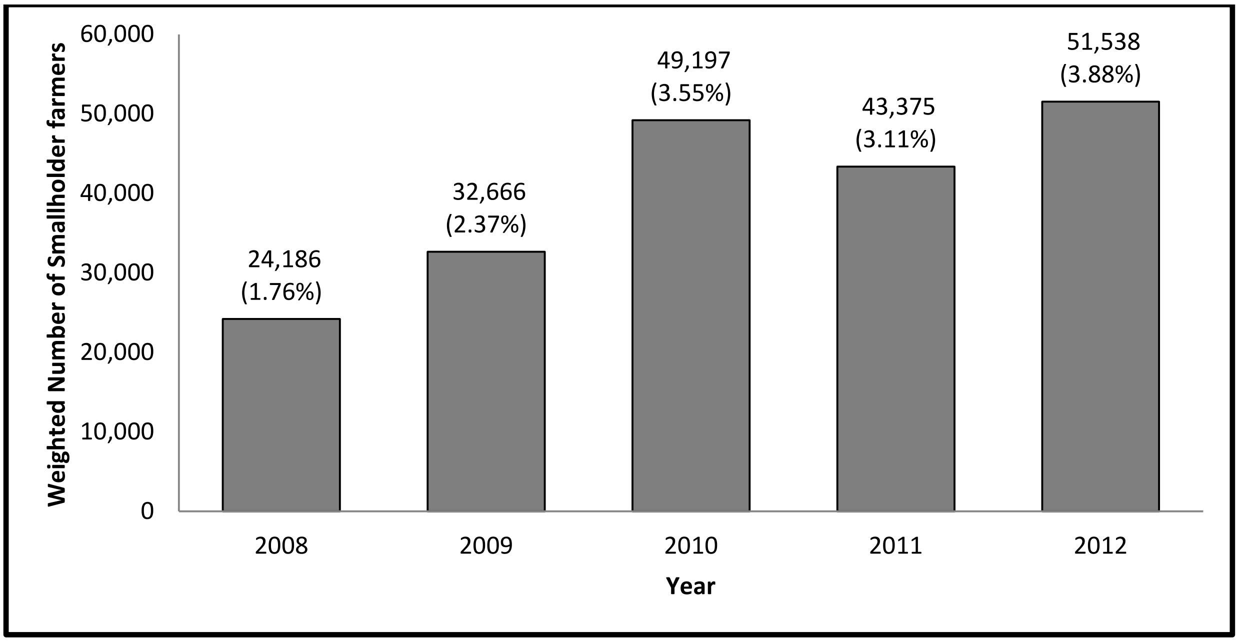
## 5.1. Descriptive Results and Discussions

### *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 as the main tillage method on any field crop captured under CFS, results show that an estimated 51,000 farmers representing 3.9% of the smallholder farmers' population used MT in 2012, up from 24,000 (1.8%) in 2008 (Figure 2). Suffice to mention here that we do not use data on zero tillage in this study because it was loosely defined in crop forecast surveys to include traditional farming practices such as Chitemene and a local traditional variant of hand hoe zero tillage, both of which do not represent CF zero tillage in essence.

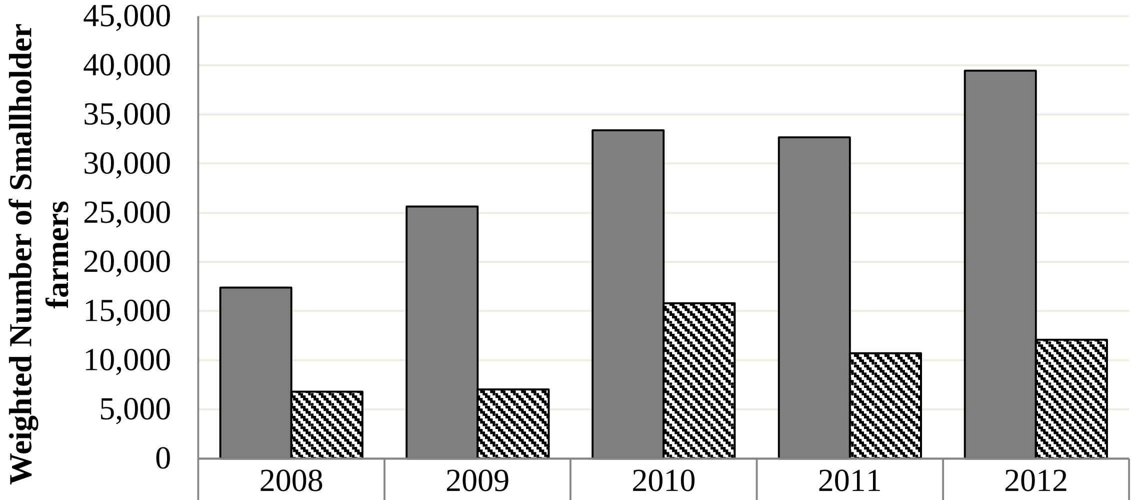
In terms of the individual CF practices, Figure 3 shows that the estimated number of farmers using planting basins and ripping increased from 17,000 (1%) to 39,000 (3%), and 7,000 (0.5%) to 12,000 (1%), respectively, between 2008 and 2012. Over this period, use of planting basins more than doubled while use of ripping only increased marginally.

**Figure 2. Trends in the Total Weighted Numbers of Smallholder Farmers Using Ripping and/or Planting Basins by Year from 2008-2012 in Zambia**




Source: Authors' computations from CFS 2008-2012.

**Figure 3. Trends in Weighted Total Number of Smallholder Farmers Using Planting Basins and Ripping by Year from 2008-2012**



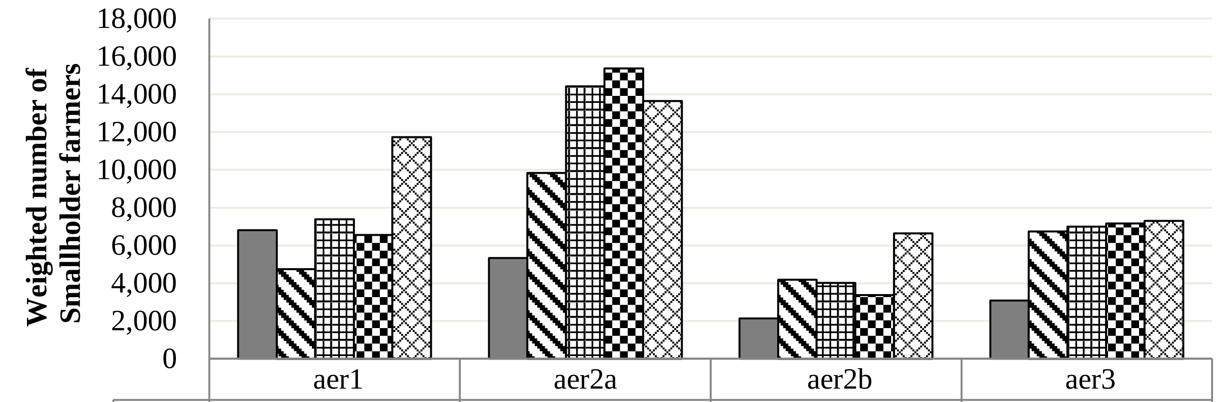

| | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|
| Basins | 17,394 | 25,650 | 33,386 | 32,676 | 39,466 |
| Ripping | 6,792 | 7,017 | 15,811 | 10,699 | 12,072 |

Source: Authors' computations from CFS 2008-2012.

Additionally, use rates for both planting basins and ripping dipped between 2010 and 2011, before picking up again between 2011 and 2012 (Figures 4 and 5). Ostensibly, there must have been a shock in 2010 which led to the decline in use of MT. Results from Focus Group Discussions (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 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 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. Similar results are reported by others (see Haggblade and Tembo 2003), where farmers respond to CF projects/programs and implement some form of CF for only as long as project/program support continued.

As expected, use of planting basins and/or ripping was more prevalent in the low rainfall agro ecological zones 1, 2a, and 2b. However, and perhaps in stark contrast to conventional views of CF in Zambia, results show that only a slightly smaller proportion of farmers used planting basins and ripping in the high rainfall areas of agro ecological zone 3 between 2008 and 2012.

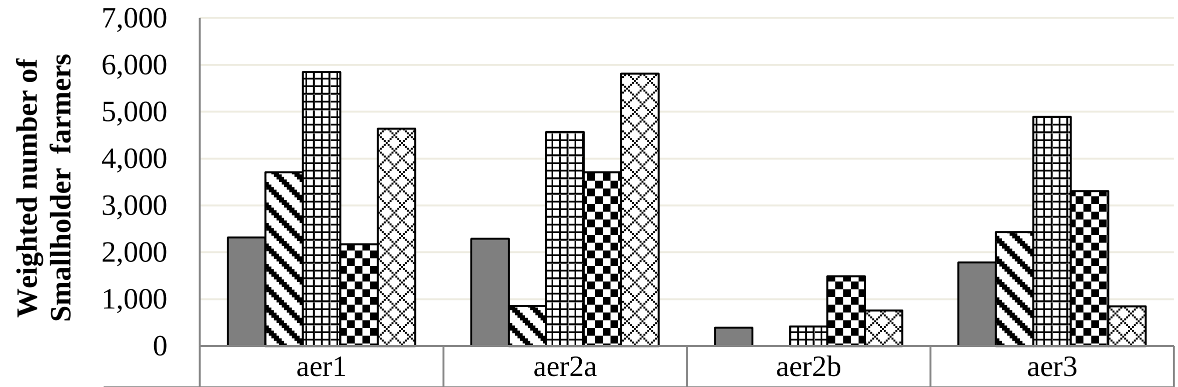
**Figure 4.Trends in Use of Planting Basins by Agro-ecological Zone[5] and by Year from 2008 to 2012**




| | aer1 | aer2a | aer2b | aer3 |
|---|---|---|---|---|
| 2008 | 6,810 | 5,329 | 2,137 | 3,092 |
| 2009 | 4,753 | 9,837 | 4,192 | 6,740 |
| 2010 | 7,383 | 14,423 | 4,025 | 6,998 |
| 2011 | 6,557 | 15,372 | 3,372 | 7,161 |
| 2012 | 11,739 | 13,646 | 6,640 | 7,299 |

Source: Authors' computations from CFS 2008-2012.

**Figure 5. Trends in Use of Ripping by Agro-ecological Zone and by Year from 2008 to 2012**




| | aer1 | aer2a | aer2b | aer3 |
|---|---|---|---|---|
| 2008 | 2,319 | 2,293 | 389 | 1,787 |
| 2009 | 3,711 | 855 | 0 | 2,436 |
| 2010 | 5,847 | 4,571 | 420 | 4,892 |
| 2011 | 2,177 | 3,711 | 1,489 | 3,309 |
| 2012 | 4,636 | 5,818 | 758 | 848 |

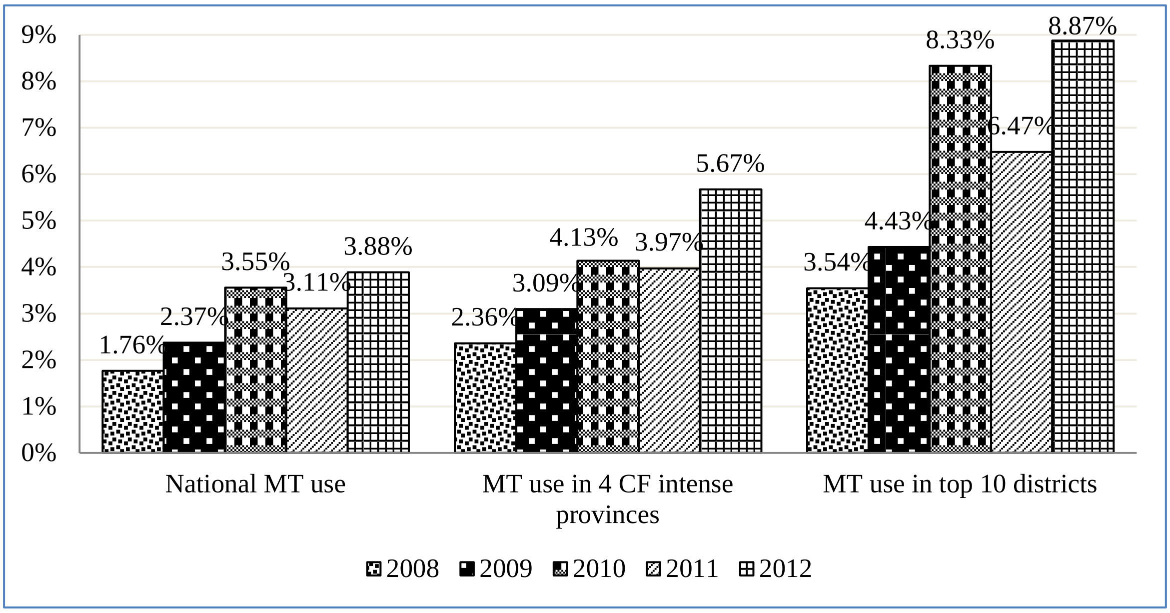
Source: Authors' computations from CFS 2008-2012.

[5] aer1 is agro-ecological zone 1 with < 800mm of rainfall per year; aer2a is agro-ecological zone 2 with clay soils and annual rainfall between 800 – 1000 mm; aer2b is agro-ecological zone 2 with sandy soils and annual rainfall between 800 – 1000 mm & aer3 is agro-ecological zone 3 with > 1000mm of rainfall per year.

Having identified the extent of MT practices used in each agro-ecological zone, we went a step further to compare average MT use rates at national level, in the four provinces where CF has mostly been promoted in Zambia[6] and in the top ten districts, ranked according to the average number of farmers who used minimum tillage between 2008 and 2012, (Figure 6). For each category, there are five bars representing MT use per year. The most salient observation is that use rates for MT are very low even in the provinces and districts where CF has been most actively promoted. On a positive note, we find an upward trend in use rates of minimum tillage between 2008 and 2012 across all the three sub samples shown in Figure 6. For example in 2012, results show that about 6% and 9% of the smallholder farmers in the top four provinces and the top ten districts used planting basins and/or ripping. These findings indicate that, at least in areas where CF is being promoted, use rates are rising over time and may be in the double-digits within a few years if current trends continue.

On average, the four CF-intense provinces and the top ten districts accounted for about 65% and 55%, respectively of all smallholders in Zambia using CF practices. However, these areas also accounted for a large proportion of the national smallholder population in the country. As shown in Table 2, four CF-intense provinces and the top ten districts accounted for about 50% and 26%, respectively, to the total population of smallholder farmers per year.

**Figure 6. Trends in the Percentage of Farm Households Using Minimum Tillage at National Level, in the Top Four Provinces and Top Ten Districts with the Highest Prevalence of Minimum Tillage Usage, by Year**




Source: Authors' computations from CFS 2008-2012.

[6] Includes Lusaka, Eastern, Southern, and Central Provinces.

**Table 2. Crop-growing Smallholder Population and Minimum Tillage Use at National Level, in the Four CF Intense Provinces and in the Ten CF Districts, by Year**

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Percentage (%) minimum tillage use | | |
| Year | Population of smallholder households growing crops | Population in four CF-intense provinces | Population in top ten districts | Households using MT, National | Households using MT, top four provinces | Households using MT, top ten districts | National level MT use | MT use in four CF-intense provinces | MT use in top ten districts |
| 2008 | 1,373,281 | 673,674 | 337,048 | 24,186 | 15,893 | 11,943 | 1.76 | 2.36 | 3.54 |
| 2009 | 1,378,302 | 688,080 | 383,927 | 32,666 | 21,278 | 17,007 | 2.37 | 3.09 | 4.43 |
| 2010 | 1,384,591 | 680,818 | 350,957 | 49,197 | 28,142 | 29,227 | 3.55 | 4.13 | 8.33 |
| 2011 | 1,395,050 | 694,722 | 373,720 | 43,375 | 27,595 | 24,198 | 3.11 | 3.97 | 6.47 |
| 2012 | 1,327,040 | 661,512 | 355,308 | 51,538 | 37,502 | 31,521 | 3.88 | 5.67 | 8.87 |

Source: Authors' computations from CFS 2008-2012.

We further break down MT use in Table 2 above to show the contribution of the four CF intense provinces and the top ten districts to national MT use. Columns 1- 4 show the year and smallholder populations nationally, in the four provinces and in the top ten districts. Columns 5-7 show MT use at national level, and in the four provinces and top ten districts while columns 8 –10 show estimated proportions of smallholder farmers that used minimum tillage over the total smallholder population at national, in the four provinces and the ten top districts. In summary, results show that less than 5% of the smallholder farmers in Zambia used MT over the five years considered in this study. Further, results also show that even in the four CF intense districts and in the ten districts with highest MT usage; use rates are still less than 10%. These findings are rather startling and would inevitably beg the question, "Why is MT use so low in Zambia even after more than two decades of actively promoting the practices?" We explore answers to this and other relevant questions in sub section 5.1.3.

*5.1.2. Provincial and District Level Trends in Use of Minimum Tillage among Smallholder Crop Farmers in Zambia from 2008-2012*

With national level trends well covered above, the next stage was to take the analysis to provincial and district levels. The aim in this part of the analysis was to identify provinces and districts where use of MT was most variable between 2008 and 2012. Table 3 below presents results for each province by year. Columns 1- 4 show province, year, total crop agricultural households, and the total number of households that used ripping and/or basins. Columns 5-7 show the percentages of households that used a particular CF practice per province per year. A similar table (although not reported) was generated at district level. Disuse is defined in this study as a reduction of more than 40% in the number of farmers using a particular CF practice from one year to another. Provinces that showed marked rates of dis-use are greyed in the table below for the relevant years.

**Table 3. Total Weighted Number of Smallholder Farmers Using Planting Basins and/or Ripping by Year from 2008-2012**

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|
| | | | | % of smallholder farmers using specific practices per year | | |
| **Province** | **Year** | **Total crop agricultural households** | **Number using basins and/or ripping** | **Basins and/or ripping** | **Planting basins** | **Ripping** |
| Central | 2008 | 172,949 | 2,709 | 1.57 | 1.21 | 0.35 |
| | 2009 | 165,584 | 5,642 | 3.41 | 3.29 | 0.12 |
| | 2010 | 174,330 | 4,888 | 2.80 | 2.48 | 0.32 |
| | 2011 | 162,582 | 5,183 | 3.19 | 2.40 | 0.79 |
| | 2012 | 154,988 | 5,365 | 3.46 | 2.60 | 0.86 |
| Copperbelt | 2008 | 84,340 | 1,093 | 1.30 | 0.38 | 0.92 |
| | 2009 | 84,034 | 1,493 | 1.78 | 1.77 | 0.01 |
| | 2010 | 99,299 | 3,078 | 3.10 | 2.61 | 0.49 |
| | 2011 | 95,538 | 1,919 | 2.01 | 1.36 | 0.65 |
| | 2012 | 70,309 | 1,590 | 2.26 | 1.34 | 0.92 |

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|
| | | | | % of smallholder farmers using specific practices per year | | |
| **Province** | **Year** | **Total crop agricultural households** | **Number using basins and/or ripping** | **Basins and/or ripping** | **Planting basins** | **Ripping** |
| Table 3 con't | | | | | | |
| Eastern | 2008 | 280,656 | 8,082 | 2.88 | 1.68 | 1.20 |
| | 2009 | 288,604 | 9,368 | 3.25 | 2.56 | 0.69 |
| | 2010 | 277,467 | 12,140 | 4.38 | 2.42 | 1.95 |
| | 2011 | 281,972 | 16,782 | 5.95 | 5.04 | 0.91 |
| | 2012 | 263,603 | 19,450 | 7.38 | 4.81 | 2.57 |
| Luapula | 2008 | 121,766 | 1,237 | 1.02 | 0.65 | 0.37 |
| | 2009 | 140,500 | 2,131 | 1.52 | 1.37 | 0.15 |
| | 2010 | 134,224 | 5,181 | 3.86 | 1.11 | 2.76 |
| | 2011 | 130,191 | 4,296 | 3.30 | 1.60 | 1.70 |
| | 2012 | 128,992 | 2,564 | 1.99 | 1.86 | 0.13 |
| | 2008 | 41,202 | 1,567 | 3.80 | 3.19 | 0.61 |
| Lusaka | 2009 | 40,657 | 2,030 | 4.99 | 4.57 | 0.43 |
| | 2010 | 41,701 | 5,575 | 13.37 | 11.55 | 1.82 |
| | 2011 | 47,116 | 2,388 | 5.07 | 4.78 | 0.29 |
| | 2012 | 37,146 | 2,258 | 6.08 | 3.68 | 2.40 |
| Northern | 2008 | 234,621 | 1,530 | 0.65 | 0.61 | 0.04 |
| | 2009 | 233,178 | 5,188 | 2.23 | 1.43 | 0.79 |
| | 2010 | 241,711 | 2,909 | 1.20 | 1.06 | 0.14 |
| | 2011 | 252,305 | 4,694 | 1.86 | 1.18 | 0.68 |
| | 2012 | 261,168 | 8,183 | 3.13 | 3.11 | 0.02 |
| North Western | 2008 | 104,098 | 1,834 | 1.76 | 1.20 | 0.56 |
| | 2009 | 96,357 | 1,252 | 1.30 | 0.91 | 0.39 |
| | 2010 | 94,434 | 2,163 | 2.29 | 1.57 | 0.72 |
| | 2011 | 93,746 | 1,663 | 1.77 | 1.56 | 0.22 |
| | 2012 | 73,764 | 450 | 0.61 | 0.56 | 0.05 |
| Southern | 2008 | 178,867 | 3,536 | 1.98 | 1.69 | 0.29 |
| | 2009 | 193,236 | 4,237 | 2.19 | 1.04 | 1.15 |
| | 2010 | 187,320 | 5,538 | 2.96 | 1.13 | 1.82 |
| | 2011 | 203,052 | 3,241 | 1.60 | 0.93 | 0.67 |
| | 2012 | 205,775 | 10,428 | 5.07 | 4.11 | 0.96 |
| Western | 2008 | 154,783 | 2,599 | 1.68 | 1.59 | 0.09 |
| | 2009 | 136,152 | 1,323 | 0.97 | 0.97 | 0.00 |
| | 2010 | 134,104 | 7,724 | 5.76 | 5.43 | 0.33 |

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|
| | | | | % of smallholder farmers using specific practices per year | | |
| **Province** | **Year** | **Total crop agricultural households** | **Number using basins and/or ripping** | **Basins and/or ripping** | **Planting basins** | **Ripping** |
| Table 3 con't | | | | | | |
| | 2011 | 128,549 | 3,208 | 2.50 | 2.02 | 0.47 |
| | 2012 | 131,294 | 1,250 | 0.95 | 0.80 | 0.15 |
| **National** | **2008** | **1,373,281** | **24,186** | **1.76** | **1.27** | **0.49** |
| | **2009** | **1,378,302** | **32,666** | **2.37** | **1.86** | **0.51** |
| | **2010** | **1,384,591** | **49,197** | **3.55** | **2.41** | **1.14** |
| | **2011** | **1,395,050** | **43,375** | **3.11** | **2.34** | **0.77** |
| | **2012** | **1,327,040** | **51,538** | **3.88** | **2.97** | **0.91** |

Source: Authors' computations from CFS 2008-2012.

At provincial level, Eastern, Southern, and Lusaka provinces were identified as having had higher levels of variability based on the number of farmers who used particular CF practices from one year to another. A closer look at results in Table 3 shows that the number of farmers who used ripping in Eastern Province declined from 1.0% in 2008 to 0.7% in 2009. For Southern Province, results in Table 3 show a decline in the number of farmers that used planting basins and ripping from 2008 to 2011. The percentage of farmers who used planting basins reduced from 2.0% in 2010 to about 0.6% in 2011. Further, results show a major decline in use rate for planting basins to 5% in 2011, down from 12.0% in 2010 in Lusaka province. Use rates for ripping reduced to 0.3% in 2011 from 2.0% in 2010 over the same period in Lusaka province.

To further explore the variations in MT use rates from year to year per district, we reproduced results in Table 3 but now at district level. We only report results for the top ten districts in Table 4. The districts were ranked based on the average number of households that used minimum tillage between 2008 and 2012. These results show average use rates for minimum tillage, planting basins, and ripping between 2008 and 2012. To give an idea of the variations in MT use rates at district level, the reader is drawn to selected statistics for Chongwe, Petauke, and Kaoma presented in Table 4 and Figure 7. Although variations are observed for most of the districts, we pick the three only for exposition purposes. Considering changes in use rates between 2010 and 2011, MT use rate in Chongwe was 7% in 2011, down from 20% in 2010 and it was 7% in Kaoma in 2011, down from 23% in 2010. Similarly, the use rate for ripping in Petauke was 0.5% in 2011 down from 3% in 2010. These variations were observed in most districts across the years and serve to show how variable the MT use rate was between 2008 and 2012 in Zambia. Figure 7 graphically presents use rate trends for each of the ten districts per year. See Table 4 and Figure 7 for additional details.

**Table 4. Use Rate Trends for Minimum Tillage, Planting Basins, and Ripping between 2008 and 2012 in the Top Ten Districts**

| | | | | % of smallholder farmers using specific practices per year | | |
|---|---|---|---|---|---|---|
| **District** | **Year** | **Total crop agricultural households** | **Number using minimum tillage** | **Minimum tillage** | **Basins** | **Ripping** |
| Chipata | 2008 | 59,466 | 1,290 | 2.17 | 1.44 | 0.73 |
| | 2009 | 67,177 | 3,782 | 5.63 | 5.55 | 0.08 |
| | 2010 | 67,967 | 950 | 1.40 | 0.73 | 0.67 |
| | 2011 | 67,601 | 5,793 | 8.57 | 7.82 | 0.75 |
| | 2012 | 61,495 | 4,477 | 7.28 | 6.13 | 1.15 |
| Lundazi | 2008 | 55,628 | 1,894 | 3.40 | 1.64 | 1.77 |
| | 2009 | 59,762 | 979 | 1.64 | 0.76 | 0.88 |
| | 2010 | 54,303 | 2,810 | 5.18 | 1.67 | 3.50 |
| | 2011 | 55,145 | 3,065 | 5.56 | 3.83 | 1.72 |
| | 2012 | 61,332 | 6,525 | 10.64 | 6.55 | 4.08 |
| Chongwe | 2008 | 22,721 | 782 | 3.44 | 2.35 | 1.09 |
| | 2009 | 23,061 | 1,633 | 7.08 | 6.47 | 0.61 |
| | 2010 | 23,581 | 4,814 | 20.42 | 17.42 | 3.00 |
| | 2011 | 25,636 | 1,917 | 7.48 | 7.00 | 0.48 |
| | 2012 | 21,653 | 1,574 | 7.27 | 3.82 | 3.44 |
| Petauke | 2008 | 46,956 | 1,879 | 4.00 | 2.25 | 1.76 |
| | 2009 | 58,154 | 1,293 | 2.22 | 0.99 | 1.23 |
| | 2010 | 53,276 | 2,508 | 4.71 | 1.28 | 3.43 |
| | 2011 | 56,614 | 2,625 | 4.64 | 4.12 | 0.52 |
| | 2012 | 50,989 | 2,116 | 4.15 | 1.54 | 2.61 |
| Kaoma | 2008 | 32,572 | 675 | 2.07 | 2.07 | 0.00 |
| | 2009 | 27,927 | 441 | 1.58 | 1.58 | 0.00 |
| | 2010 | 28,585 | 6,526 | 22.83 | 21.36 | 1.47 |
| | 2011 | 24,410 | 1,793 | 7.35 | 5.00 | 2.34 |
| | 2012 | 27,593 | 211 | 0.76 | 0.70 | 0.06 |
| Mumbwa | 2008 | 25,701 | 852 | 3.31 | 1.66 | 1.65 |
| | 2009 | 29,422 | 2,202 | 7.48 | 6.81 | 0.67 |
| | 2010 | 31,031 | 1,276 | 4.11 | 2.84 | 1.27 |
| | 2011 | 29,563 | 2,100 | 7.10 | 4.86 | 2.24 |
| | 2012 | 29,110 | 2,068 | 7.11 | 6.14 | 0.96 |
| Katete | 2008 | 42,717 | 537 | 1.26 | 0.59 | 0.67 |
| | 2009 | 41,657 | 262 | 0.63 | 0.55 | 0.08 |

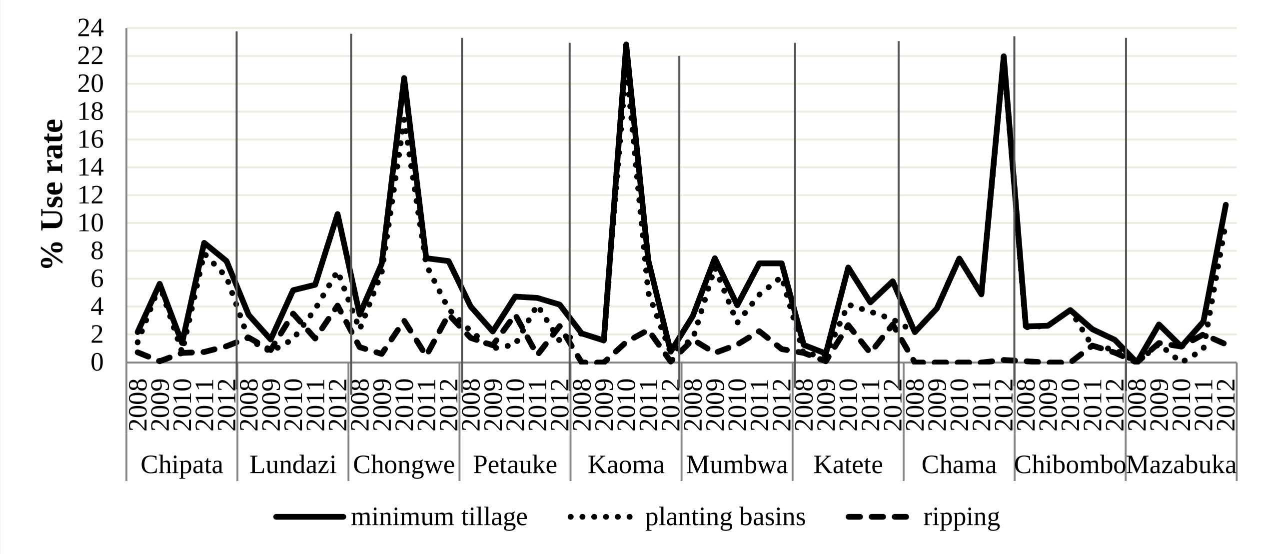
| | | | | % of smallholder farmers using specific practices per year | | |
|---|---|---|---|---|---|---|
| **District** | **Year** | **Total crop agricultural households** | **Number using minimum tillage** | **Minimum tillage** | **Basins** | **Ripping** |
| Table 4 con't | | | | | | |
| | 2010 | 39,666 | 2,698 | 6.80 | 4.14 | 2.67 |
| | 2011 | 39,358 | 1,697 | 4.31 | 3.63 | 0.68 |
| | 2012 | 45,659 | 2,657 | 5.82 | 3.09 | 2.73 |
| Chama | 2008 | 17,643 | 385 | 2.18 | 2.18 | 0.00 |
| | 2009 | 17,050 | 660 | 3.87 | 3.87 | 0.00 |
| | 2010 | 16,605 | 1,240 | 7.46 | 7.46 | 0.00 |
| | 2011 | 19,253 | 937 | 4.87 | 4.87 | 0.00 |
| | 2012 | 19,894 | 4,372 | 21.98 | 21.80 | 0.17 |
| Chibombo | 2008 | 50,065 | 1,298 | 2.59 | 2.52 | 0.08 |
| | 2009 | 49,814 | 1,317 | 2.64 | 2.64 | 0.00 |
| | 2010 | 53,261 | 2,003 | 3.76 | 3.76 | 0.00 |
| | 2011 | 47,521 | 1,130 | 2.38 | 1.16 | 1.21 |
| | 2012 | 43,126 | 697 | 1.62 | 0.92 | 0.70 |
| Mazabuka | 2008 | 27,841 | 0 | 0.00 | 0.00 | 0.00 |
| | 2009 | 25,088 | 682 | 2.72 | 1.31 | 1.40 |
| | 2010 | 25,868 | 293 | 1.13 | 0.00 | 1.13 |
| | 2011 | 26,855 | 788 | 2.93 | 0.93 | 2.01 |
| | 2012 | 39,863 | 4,514 | 11.32 | 10.03 | 1.29 |

Source: Authors' computations from CFS 2008-2012.

Use rate trends for the top ten districts are better visualized in Figure 7. For each district, use rate trends are shown over the five years (2008-2012) considered in this study. We separate districts by use of vertical lines in the *xy* plane.

A common pattern among all the top ten districts is the huge variations in use rates from one year to another. We observe substantial movement in use rates between 2009 and 2011 in almost all districts. The reasons for inter-year variability of MT practices in specific areas was the motivation for holding farmer FGDs in several of these districts; the findings of these FGDs are explored in 5.1.3. below.

**Figure 7. Use Rate Trends for Minimum Tillage, Planting Basins, and Ripping in the Top Ten Districts by Year**




Source: Authors' computations from CFS 2008-2012.

### *5.1.3. What Explains Low and Variable Use of Minimum Tillage in Zambia?*

In this sub section, triangulation techniques are used to help understand why there is low minimum tillage use in Zambia. Firstly, focus group discussion results from Choma, Chama, and Petauke districts are discussed. Secondly, results from key informant interviews with stakeholders involved in CF in Zambia are presented and discussed in the context of related applied studies from the region.

Focus group discussions were held with 69 farmers in Chama, Choma, and Petauke districts. These three districts showed variable use rates for minimum tillage over the five-year period considered in this study. One of the major reasons for low minimum tillage use rates was the high labor requirements of some practices like basins and the timing of activities. Farmers also highlighted lack of access to finances required to purchase the requisite implements (chaka hoes for basins, and oxen drawn implements for ripping), and inputs including herbicides, hybrid seed, and mineral fertilizers. It would appear here that just like many authors have alluded to in the past, CF is highly rewarding when used with appropriate implements and when combined with appropriate inputs, see (Haggblade and Tembo 2003; Giller et al. 2009; Haggblade, Kabwe, and Plerhoples 2011; Goeb 2013; Grabowski and Kerr 2013). However, if farmers cannot access such purchased inputs, chemicals, and equipment, they face many challenges including weed pressure, low yields, and high seasonal labor requirements. Equally, when farmers do not have access to finance to enable them acquire inputs and equipment, the result is low adoption or use rates. Unfortunately, this appears to be the case for a majority of the farmers in Zambia and much of Sub-Saharan Africa (Giller et al. 2009;  Haggblade and Tembo 2003; Grawboski and Kerr, 2013).

There is an exception for a few select farmers who are financed by NGOs. However, once project support is withdrawn, such farmers tend to revert to *business as usual* and return to their traditional non-CF farming ways. We are cognizant of compelling arguments from development facilitators that CF farmers may require some sort of start-up subsidies since they face resource constraints that otherwise preclude them from experimenting with CF practices. The major problem with such subsidies is that they have not been *smart-enough* and this has resulted in economic dependence by beneficiaries. The FGDs also indicated that the way project beneficiaries are selected at project start-up phase is as important as the way the project exits at the end of its term. It seems these two aspects have implications on whether farmers will take up CF practices or not and generally on technology diffusion. Farmers in all the three districts visited explained that poor selection of project beneficiaries makes most CF projects fail because they tend to pick *wrong agents of change* in the communities. One farmer in Choma district explained that if local people are not adequately represented at the time of selecting project beneficiaries, some form of self-selection from among the NGO-dependent farmers arises.[7] Equally, if a CF project fails to properly define and build in an exit strategy right from the start; farmers tend to be discouraged from practicing CF when the project exit plan is not known. In this situation, farmers explained that they tend to be uncertain of how long they can access project support in terms of extension support and other capacity building activities.

There is some level of consensus in the literature that the labor requirements associated with planting basins, for example, is one of the reasons that lead to minimal minimum tillage use in Zambia (Haggblade and Tembo 2003; Haggblade, Kabwe, and Plerhoples 2011). There is also recognition that smallholders face tradeoffs in allocating labor across various competing needs of alternative crop enterprises, technologies, and off farm activities. On one hand, Haggblade, Kabwe, and Plerhoples (2011) suggests that because most smallholder farmers do not have much off-farm income earning opportunities during the off-season, CF provides a means to deploy off-season labor to productive use and earn incomes required to finance agricultural production. However, farmers explained during FGDs that they value their off-season social interactions. The constraints on off-season labor availability may warrant further research.

Other researchers have found that the resultant increased weed pressure under CF has some *gendered* impacts. Nyanga, Johnsen, and Kalinda (2012) and Nyanga et al. (2011) found that the increased weed pressure resulting from using either basins and/or ripping (without herbicides) shifts the labor burden more towards women who are normally more involved in weeding activities compared to their male counterparts. FGD results also suggest that dynamics in minimum tillage use rates are related to changes in the number of project interventions promoting CF in different districts at a given time. Farmers explained that there was generally an increase in the number of projects promoting CF in most districts around the 2009/10 season, and hence the increase in the number of farmers using MT around those years in most districts (see Figure 7). Farmers and key informant interviews further revealed that the number of CF projects was at peak around the 2009/10 season but most of these projects began to wind down their activities by the 2010/11 season. Asked why this was so, farmers explained that it is easier for them to practice CF if they can easily access *extension advice* from project staff within their vicinity. The question that remains unanswered here is why farmers fail to sustain use of CF practices after project interventions.

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[7] FGDs revealed NGO-dependent farmers to refer to those dealing with multiple NGOs at the same time and usually deriving material benefits from each. Such farmers were referred to in a derogatory light and considered non-performers who were nevertheless among the most vocal and were sometimes able to present themselves as accomplished farmers and who became sought after to participate as lead farmers in multiple NGO conservation farming programs concurrently.

Drawing from literature (see Giller et al. 2009; Haggblade and Tembo 2003; Haggblade, Kabwe, and Plerhoples 2011; Grawboski and Kerr, 2013, Goeb 2013; Grawboski et al. (forthcoming); http://www.act-africa.org/ )), the following may serve as added explanations for low minimum tillage use:

- ✓ Most farmers are unable to use mulch as suggested by CF principles because of insecure land tenure (i.e., they have no exclusionary rights to their fields which are subjected to open grazing); low crop productivity which limits availability of crop residues; and competing uses for crop residues among fodder for livestock, household fuel and mulch.
- ✓ The 2 years of cereal - legume rotations proposed by CF have been found problematic in much of SSA because most farmers do not grow cereals and legumes on the same scale. Usually legumes are grown on smaller parcels of land compared to cereals. Very few farmers can afford the *1:1 matched rotations*, which is the ideal for maximum soil nutrient replenishment under CF.
- ✓ Giller et al. (2009) posit that because CF confers yield benefits over conventional tillage mainly over the long term and has limited short-term benefits, most farmers are reluctant to adopt the practices because they are interested in devoting their labor to activities that generate more immediate benefits. They emphasize that CF should be promoted as an activity that provides mainly medium- to long-term payoffs.
- ✓ If properly implemented, CF involves high cash costs and labor time, which most farmers cannot afford.
- ✓ Because adopters tend to adopt only a sub-set of the full set of practices, they may not attain the full potential benefits of CF.

**Table 5. Mean Values for All RHS Variables between Users and Non-users of Minimum Tillage between 2008 and 2012**

| | **Non Minimum Tillage users (MT=0)** | | | **Minimum Tillage users (MT=1)** | | |
|---|---|---|---|---|---|---|
| **Variable** | Observations | Mean | Standard deviation | Observations | Mean | Standard deviation |
| Male-headed household (=1) | 60973 | 0.82 | - | 1933 | 0.83 | - |
| Age of the hh head (years) | 60806 | 45.11 | 14.41 | 1927 | 46.16 | 14.17 |
| Land holding size (ha) | 60968 | 3.59 | 10.12 | 1935 | 4.43 | 14.90 |
| Positive rain deviation (mm) | 61024 | 0.08 | 0.12 | 1935 | 0.08 | 0.11 |
| Negative rain deviation (mm) | 61024 | -0.05 | 0.07 | 1935 | -0.05 | 0.07 |
| CFU has operations (=1) | 61024 | 0.32 | - | 1935 | 0.41 | - |
| Rainfall stress days (#) | 61024 | 0.76 | 1.20 | 1935 | 0.77 | - |
| dyear2 (=1) | 61024 | 0.20 | - | 1935 | 0.17 | - |
| dyear3 (=1) | 61024 | 0.20 | - | 1935 | 0.22 | - |
| dyear4 (=1) | 61024 | 0.20 | - | 1935 | 0.21 | - |
| Agro ecological zone 3 (=1) | 61024 | 0.39 | - | 1935 | 0.25 | - |
| Agro ecological zone 2a (=1) | 61024 | 0.23 | - | 1935 | 0.32 | - |
| Agro ecological zone 2b (=1) | 61024 | 0.14 | - | 1935 | 0.12 | - |
| Cattle disease (=1) | 61024 | 0.23 | - | 1935 | 0.23 | - |

Source: Authors' computations from CFS 2008-2012.

Before turning to the econometric results, Table 5 above presents summary statistics for all variables of interest between users and non-users of minimum tillage between 2008 and 2012 in Zambia. The left half of the table shows results for MT non-users.

Results in Table 5 indicate that users and non-users of minimum tillage between 2008 and 2012 were very similar in most respects. Both groups had similar mean age (45 vs. 46 years); 23% of each group had experienced cattle diseases of economic importance; the two groups experienced similar rainfall conditions and the number of rain stress days. The spread based on survey years and agro-ecological conditions was equally balanced. However, the users of minimum tillage had higher mean land holding sizes and there were a higher proportion of MT users in the CFU operational districts.

## 5.2. Econometric Results and Discussions

### *5.2.1. Factors Influencing Use of Planting Basins and Ripping by Smallholder Farmers between 2008 and 2012 in Zambia*

Table 6 below shows empirical results from the SUBP model. Columns 1-3 show APEs of the covariates on planting basins, ripping, and minimum tillage respectively. A few notes are in order before we proceed to discuss the results. Firstly, although we only show results for the interaction of negative rainfall deviation and being in agro ecological zone 2a; we had interactions of all other rainfall variables with different agro ecological zones but results were not statistically significant.

Results indicate that male-headed households were 0.4 percentage points more likely to use ripping, on average, than female-headed households. This seems like a small number, but given that only 0.91 percent of households used ripping, this means that male-headed households are 0.4/0.91 = 44.0 percent more likely to use ripping than female-headed households. By constrast, in terms of planting basins, male-headed households were 0.3 percentage points on average, less likely to use that specific practice. Similar results are reported in Nyanga, Johnsen, and Kalinda (2012) where it was found that men were less likely to adopt planting basins. This result has a somewhat intuitive explanation; since planting basins and ripping are hand hoe and ox/tractor driven, respectively, women are generally associated with hand hoe farm activities while their male counterparts are more associated with ox/ tractor drawn farming activities. Furthermore, results show that farmers with more farming experience, as proxied by age of the household head, were on average, more likely to use planting basins and/or minimum tillage *ceteris paribus,* and this is statistically significant at the 5% level, albeit the effect being minimal (0.01 percentage points). This result is in contrast to findings in Chomba (2004) and Arslan et al. (2013) who find that age significantly reduced and had no effect, respectively, on farmers' decisions to adopt CF. However, it can be conjectured from our finding that more experienced farmers are more likely to use minimum tillage practices in general.

Additionally, results suggest that an increase in landholding size (a measure of wealth) significantly increases the probability of farmers using planting basins, ripping and minimum tillage of either type by 0.2, 0.6, and 0.7 percentage points respectively. To put these results into context, given that only 3.88 percent of households used either type of minimum tillage in 2012, this means that an additional 2 hectares of land is associated with a 0.7*2/3.88 = 36.1 percent increase in the probability that a farmer will use minimum tillage on some part of his/her land. This finding suggests that the promotion of particular minimum tillage practices should be cognizant of the asset holding/wealth dynamics among smallholder farmers and tailor suitable technologies. Land issues were also found to influence farmers' ability to participate in agricultural markets and commercialization at large, see (Hichaambwa and Jayne 2012; Mason, Jayne, and Meyers forthcoming.).

**Table 6. Determinants of Use of Planting Basins, Ripping, and Minimum Tillage from the Bivariate Probit Model**

| | (1) | (2) | (3) |
|---|---|---|---|
| **Variables** | **Planting basins** | **Ripping** | **Minimum Tillage** |
| Male-headed household (=1) | -0.0027* | 0.0038*** | 0.0083** |
| | (0.0015) | (0.0015) | (0.0034) |
| Age of the household head (years) | 0.0001* | 0.0000 | 0.0001** |
| | (0.0000) | (0.0000) | (0.0000) |
| Land holding size (ha) | 0.0018** | 0.0060*** | 0.0065*** |
| | (0.0008) | (0.0009) | (0.0010) |
| Rainfall stress( # of 20 day periods with less than 40mm of rain | -0.0002<br>(0.0006) | -0.0004<br>(0.0006) | -0.0001<br>(0.0007) |
| Positive rain deviation (mm) | -0.0268*** | -0.0341*** | -0.0474*** |
| | (0.0069) | (0.0082) | (0.0078) |
| Negative rain deviation (mm) | 0.0110 | 0.0412** | 0.0276 |
| | (0.0131) | (0.0171) | (0.0187) |
| Agro ecological zone 3 (=1) | -0.0085*** | -0.0075*** | -0.0163** |
| | (0.0031) | (0.0026) | (0.0064) |
| Agro ecological zone 2a (=1) | 0.0096*** | -0.0060** | -0.0128*** |
| | (0.0025) | (0.0024) | (0.0044) |
| Agro ecological zone 2b (=1) | 0.0050 | -0.0050** | -0.0111** |
| | (0.0031) | (0.0020) | (0.0054) |
| CFU has operations | 0.0010 | 0.0328** | 0.0788*** |
| | (0.0048) | (0.0139) | (0.0279) |
| Agro ecological zone 2a * negative rain deviation (1, mm) | 0.0500***<br>(0.0183) | 0.0033<br>(0.0138) | 0.0454**<br>(0.0223) |
| Cattle disease (=1) | - | -0.0108*** | -0.0187*** |
| | - | (0.0030) | (0.0025) |
| Joint provincial dummy | 187.77*** | 77.51*** | 205.70*** |
| Joint year dummy | 168.72*** | 194.07*** | 171.75*** |
| Number of observations | 62,708 | 62,708 | 62,708 |
| Log Likelihood | -27,045.6 | -23,738.1 | -28,906.7 |
| Bootstrap replications | 200 | 200 | 200 |

Source: Bivariate probit model results based on CFS 2008-2012.
Notes: APEs with bootstrap standard errors in parenthesis; ***, **, * Significant at 1%, 5%, and 10% respectively; Base ag. Zone is 1 (<800mm); Base year: 2008.

Furthermore, compared to farmers located in agro-ecological zone1 (with <800mm annual rainfall), results suggest, as expected that farmers in agro-ecological zone 3 (with > 1000mm of rainfall annually) were less likely to use either basins and/ripping. Farmers in agro-ecological zone 2a were more likely to use planting basins but less likely to use ripping compared to those in agro-ecological zone 1. Farmers in zone 2b were less likely to use ripping and minimum tillage, relative to farmers in zone 1. This is as expected because agro ecological zone 1 covers much of Southern province where animal draught power and ripping are more prevalent than in agro ecological zones 2a and 2b.

With regard to climatic variability and its effect on the use of minimum tillage practices (planting basins and ripping); results indicate that an increase in incidences of droughts (negative rainfall deviations) significantly ($p<0.05$) increased the likelihood of farmers using ripping. Similar results are reported in (Ngoma 2012; Arslan et al. 2013). On the other hand, an increase in incidence of floods (positive rain deviation) significantly ($P<0.01$) reduced the likelihood of farmers using minimum tillage practices in response. A caveat on this result is that this does not necessarily imply that farmers would dis-adopt minimum tillage practices in the wake of floods, but merely shows the likely *tillage responses* by farmers in the current season following a season with floods. Baudron et al. (2012) found the opposite of our results in a relatively smaller geographic area, noting that CA was beneficial to cotton farmers in wetter years because it helped them shed water in order to avoid water logging. In addition, being in zone 2a and having experienced a drought incident in the preceding season (as represented by an interaction between zone 2a and negative rainfall deviation) increased farmers' probability of using planting basins and minimum tillage, but had no significant influence on the use of ripping.

Further, results suggest that farmers in districts where CFU operates were 3.3 percentage points, on average, more likely to use ripping, but the CFU dummy had no statistically significant influence on farmers' likelihood to use planting basins. Although CFU is *the kingpin of CF* in Zambia, they only operated in some parts of 17 out of the over 72 districts in the country then and so it is not unexpected that their footprint insofar as use of planting basins was not statistically significant at national level. However, CFU's efforts in promoting mechanized ripping and facilitation of provision of tractor ripping services seems to have had a significant and positive impact on uptake of ripping among smallholder farmers in Zambia. These efforts are, however, hampered by persistent cattle disease outbreaks. Results suggest that farmers in districts which recorded major cattle diseases over the last 10 years were about 1 percentage point, on average less likely to use ripping, *ceteris paribus*. Therefore, animal disease control and restocking programs are essentially a moral imperative given the foregoing.

Further, we found statistically robust influence of spatial temporal variables on farmers' decisions to use planting basins and ripping. Being in a particular province and in a given year significantly ($p<0.01$) influenced farmers' likelihood of using planting basins and/or ripping- see the provincial, and year - joint significance test results below Table 6.

#### 5.2.2. *Determinants of Land Size Cultivated under Planting Basins, Ripping, and Minimum Tillage among Smallholder Farmers between 2008 and 2012*

In this part of the analysis, we applied the control function- double hurdle model to assess determinants of the probability of using a given minimum tillage practice and how much land was cultivated under that practice. We first regressed the CFU dummy on all exogenous covariates and obtained generalized residuals that were included together with CFU dummy in the double hurdle model to control for endogeneity. Results in Table 7 are from three double hurdle models for use of planting basins (columns 1-3), ripping (columns 4-6), and minimum tillage (columns 7-9), as probit dependent binary variables coded (0/1). Truncated normal regression dependent variables are land in hectares cultivated under a given practice, all continuous with large pile ups at 0. Three APEs (from probit, truncated normal, and one from both probit and truncated normal regression) are reported for each model: participation APEs of whether the household practiced a particular CF practice or not (columns 1, 4, and 7); conditional APEs for those that practice MT (columns 2, 5, and 8) and unconditional or overall APEs (columns 3, 6, and 9) based on the entire sample regardless of whether the household practiced any MT or not. The significance of all APEs reported in Table 6 was evaluated using the delta method and bootstrapping to obtain correct standard errors. Model summary statistics are presented below the table.

Results suggest that male-headed households would on average increase land cultivated under planting basins and ripping by 0.002 hectares and 0.004 hectares respectively *ceteris paribus*, compared to female-headed households. While these effects are in the case of ripping statistically significant at1%, the magnitude of the effects is very small. We conclude that there is very little substantive difference in the size of land put under ripping between male and female-headed households overall.

Further, a unit increase in land owned was on average and overall found to significantly increase amount of land cultivated with planting basins and ripping by 0.014 hectares and 0.019 hectares, respectively. These effects increase to 0.49 and 1.12 hectares for basins and ripping, respectively, among households already using basins and ripping. Similar results are reported in Nyanga, Johnsen, and Kalinda (2012). This finding indicates that increasing land under the control of a household provides better leverage for a farmer to implement CF on some part of that land. Increased land use may be associated with other aspects of wealth and the ability to higher labor and adopt CF practices. There is a widely held view which suggests that more secure land tenure has potential to increase CF adoption and diffusion in Sub-Saharan Africa (see Giller et al. 2009). However, CFS data used in this study does not collect information on land tenure status, hence we could not investigate this view. Further, results suggest that farmers in the current season would increase (reduce) the amount of land put under planting basins and ripping in general, following seasons with droughts ( floods) respectively. These results merely show farmers' likely tillage responses in the current season following flooding and/or droughts during the previous season.

Additionally, results suggest that being is districts where CFU has operations significantly increased and reduced the amount of land put under ripping and planting basins by less than 0.01 and 0.03 hectares, respectively. Like in the previous section, these results again show a positive influence of CFU on farmers' uptake of ripping compared to planting basins. Similar observations are made in Grawboski et al. (forthcoming) where they posit that Zambia's experience with CF underline the importance of refining and testing technology packages for different environments and for farmers of differing resource endowments. We also found that being in a district which recorded major cattle disease outbreak within the last 10 years significantly reduced the amount of land under ripping. This finding indicates why cattle disease affects the success of CF in Zambia, given that at least ripping replies on draft power (see also Grabowski et al, forthcoming). Efforts aimed at controlling animal diseases by government and cooperating partners are timely and commendable.

**Table 7. Determinants of Use of Minimum Tillage, Planting Basins, and Ripping, and the Amount of Land Cultivated under Each CF Practice by Smallholder Farmers**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Planting Basins APEs | | | Ripping APEs | | | Minimum Tillage APEs | | |
| Variable description | **Probit (=1 if used basins)** | **Truncated normal regression (ha under basins)** | **Overall effects (ha under basins)** | **Probit (=1 if used ripping)** | **Truncated normal regression (ha under ripping)** | **Overall effects (ha under ripping)** | **Probit (=1 if used MT)** | **Truncated normal regression (ha under MT)** | **Overall effects (ha under minimum tillage)** |
| Male-headed household (=1) | -0.0025 | 0.1752*** | 0.0020 | 0.0031*** | -0.2062 | 0.0041 | 0.0003 | 0.1661** | 0.0055* |
| | (0.0015) | (0.0595) | (0.0020) | (0.0010) | (0.2598) | (0.0025) | (0.0018) | (0.0835) | (0.0033) |
| Age of household head | 0.0001 | -0.0015 | 0.0000 | 0.0000 | -0.0196*** | -0.0001* | 0.0001 | -0.0057** | -0.0001 |
| | (0.0000) | (0.0022) | (0.0001) | (0.0000) | (0.0055) | (0.0001) | (0.0000) | (0.0024) | (0.0001) |
| Land size (ha) | 0.0023*** | 0.4870*** | 0.0136*** | 0.0049*** | 1.1201*** | 0.0194*** | 0.0071*** | 0.7461*** | 0.0318*** |
| | (0.0008) | (0.0836) | (0.0023) | (0.0005) | (0.2170) | (0.0029) | (0.0009) | (0.1002) | (0.0032) |
| Positive rain deviation(‘000mm) | -0.0286*** | 0.4754* | -0.0165** | -0.0245*** | -0.4401 | -0.0478*** | -0.0500*** | 0.3453 | -0.0499*** |
| | (0.0064) | (0.2534) | (0.0083) | (0.0050) | (0.9454) | (0.0124) | (0.0081) | (0.3153) | (0.0165) |
| Negative Rain Deviation (‘000mm) | 0.0441*** | -0.7163 | 0.0259** | 0.0134* | 3.0830* | 0.0532** | 0.0573*** | -0.0641 | 0.0674** |
| | (0.0112) | (0.5203) | (0.0127) | (0.0074) | (1.7553) | (0.0212) | (0.0132) | (0.6134) | (0.0279) |
| Agro ecological zone 3 ( =1) | -0.0047 | -0.1191 | -0.0044 | -0.0101*** | -0.6604 | -0.0164 | -0.0123*** | -0.3783* | -0.0181** |
| | (0.0034) | (0.3038) | (0.0071) | (0.0022) | (0.6054) | (0.0165) | (0.0039) | (0.1989) | (0.0072) |
| Agro ecological zone 2a ( =1) | -0.0011 | -0.3143 | -0.0082 | -0.0036** | -0.3657 | -0.0072 | -0.0059** | -0.2398 | -0.0118 |
| | (0.0026) | (0.2039) | (0.0050) | (0.0016) | (0.4311) | (0.0056) | (0.0029) | (0.1849) | (0.0084) |
| Agro ecological zone 2b ( =1) | 0.0040 | -0.3329*** | -0.0654 | -0.0060*** | 0.5153 | 0.0140 | -0.0008 | -0.3722*** | -0.0685** |
| | (0.0030) | (0.1063) | (0.0488) | (0.0012) | (0.9063) | (0.0159) | (0.0033) | (0.1281) | (0.0270) |
| CFU has operations (=1) | -0.0087*** | 0.0921 | -0.0297*** | 0.0039*** | 0.0450 | 0.0072*** | -0.0047** | 0.1719** | -0.0004 |
| | (0.0015) | (0.0765) | (0.0062) | (0.0012) | (0.2098) | (0.0027) | (0.0019) | (0.0876) | (0.0034) |
| Cattle disease (=1) | - | - | - | -0.0035*** | -0.1345 | -0.0074** | -0.0003 | -0.1273 | -0.0043 |
| | - | - | - | (0.0009) | (0.2518) | (0.0029) | (0.0019) | (0.0912) | (0.0040) |
| *Residuals* | -0.0329*** | -0.4425 | -0.0422*** | -0.0063* | -2.8500** | -0.0383*** | -0.0416*** | -0.5005 | -0.0659*** |
| | (0.0059) | (0.3790) | (0.0105) | (0.0037) | (1.1553) | (0.0138) | (0.0067) | (0.4360) | (0.0184) |
| *Loglikelihood* | | -7,422.85 | | | -4,024.16 | | | -7,398.71 | |
| *Observations at corner* | | 61,604 | | | 62,353 | | | 61,204 | |
| Observations | 62708 | 1,348 | 62,708 | 62708 | 604 | 62,708 | 62,708 | 1,927 | 62,708 |

Source: Double hurdle model results based on CFS 2008-2012.

Notes: Bootstrap standard errors in parenthesis obtained after 200 replications;***, **, * significant at 1%, 5%, and 10% respectively.

## 6. CONCLUSIONS AND POLICY IMPLICATIONS

This study used pooled cross sectional data from crop forecast surveys to examine trends in, and determinants of farmers' use of minimum tillage (ripping and planting basins) between 2008 and 2012 in Zambia. Using a nationally and district level representative datasets from the crop forecast surveys conducted by the Central Statistical Office and Ministry of Agriculture and Livestock and *dekad* rainfall data from the Zambia Meteorological Department for the past 2 decades, we found that the number of farmers using basins and/or ripping doubled between 2008-2012, and a similar trend was observed for individual practices (ripping and basins separately). However, the percentage of smallholder farmers using these practices is still low at about 3% for planting basins and 1% for ripping. We also found that ripping and planting basins were used by farmers in all the four agro ecological zones in Zambia, although use rates were higher in agro-ecological zones I and II. However, the main conclusion is that a very small percentage of Zambian farmers (under 5%) are employing either ripping and/or planting basins as main tillage methods at field level throughout the 2008-2012 period. Even in the top ten districts with the highest use rates, we find less than 10% of the smallholder farmers used basins or ripping over the five years considered in this study.

Generally, there appears to be an upward but somewhat volatile trend in use rates for ripping and planting basins across the five years considered in the study. Eastern, Lusaka, and Southern provinces seem to explain much of the changes in use rate for both ripping and planting basins across all years. Results from focus group discussions held in Choma, Petauke and Chama districts suggest that the main cause of the variable use rate trends for ripping and planting basins could be linked to farmers' resource constraints, labor intensity associated with planting basins, lack of access to finance to purchase requisite inputs (fertilizers, hybrid seed and implements), and labor conflicts between off season activities and dry season CF practices. Changes in the number of interventions promoting CF in a given district at a particular time also contributed to the variable and low CF use rates. We find higher use rates corresponding to years when they were more project interventions and vice versa. The practice of giving handouts in form of agro inputs/implements and food stuffs by project/programs promoting CF was the main factor which caused farmers to discontinue use of such practices once such support is withdrawn or waned. Because most projects require farmers to practice some form of CF as a pre-requisite to receive *material support*, some farmers fail to develop a sense of ownership in the adoption of whatever conservation practices they may be implementing. These anecdotal findings from focus group discussions may warrant consideration of design changes in how NGOs and other CF program/project implementers select farmers to work with.

Findings indicate that age of the household head, and land holding size significantly increased the likelihood of farmers using ripping and planting basins *ceteris paribus*. However, male-headed households were on average less (more) likely to use planting basins (ripping). This result is perhaps reflective of the weed - labor burden associated with use of basins and especially that weeding is mostly done by women folk.

Further, results from the seemingly unrelated bivariate probit model suggest that incidences of floods and droughts in the previous season significantly reduced and increased, respectively, the likelihood of farmers using planting basins and ripping in the current season. Similar results are obtained from the double hurdle model with regards to land cultivated using minimum tillage. These results seem to suggest that farmers are using CF practices in response to rainfall variability, however, more research is required to assess whether using CF practices is effective in reducing the variability of crop yields across years caused by rainfall variability.

Additionally, empirical results from both seemingly unrelated bivariate probit and the double hurdle models show that increasing landholding size owned by households would increase the likelihood to use CF practices and the area cultivated using these practices. Results also indicate that being in a district where CF unit has operations significantly increased land cultivated using ripping, but significantly reduced land under planting basins. This result reflects that CFU is more influential in farmers' uptake of ripping compared to basins. Further, we also found evidence suggesting that being in districts which recorded cattle diseases of economic importance over the last 10 years (2012 going backwards) significantly reduced the likelihood to use ripping and the land cultivated under ripping. There is therefore need for consented efforts in addressing cattle disease outbreaks and giving more support to mechanized ripping initiatives in Zambia.

In summary, the main conclusions from this study are:

1. Despite having been actively promoted for several decades, minimum tillage use in Zambia remains quite low, with less than 5% and 10% of smallholder farmers using ripping or planting basins at national level and in the top ten districts. However, use rates appear to be increasing slightly between 2008 and 2012, but the trend is highly variable.
2. There is need to revolutionize development facilitation in the area of CF and design extension programs that provide farmers with incentives to adopt CF practices based on underlying economic viability rather than on the basis of gifts in exchange for adoption. The culture of giving handouts should be discouraged; beneficiary selection need to be carefully considered and exit strategies should be built in right from the start of 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 roles of providing linkages and building capacity.
3. Because the previous season's rainfall significantly influences farmers' use of minimum tillage practices in the current season; more support should be given to institutions gathering and disseminating weather information in order to provide better information to guide farmers' decisions regarding tillage methods.
4. Since results also show that incidences of animal diseases significantly affect use of ripping which is dependent on animal draught power; there is need to support programs addressing animal disease outbreaks and those linking farmers to use of tractor drawn rippers and zero tillage planters as alternative ways to implement ripping.
5. Some of the constraints to usage of CF practices as identified in the focus group discussions could not be tested empirically in our econometric analysis due to lack of data. Therefore, there is a need to initiate a more detailed nation-wide survey of farmers capable of better identifying the factors associated with adoption and dis-adoption of CF practices, the payoffs to using these practices under prevailing smallholder farming conditions, and how to support farmers in making these practices more productive and lucrative.

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