FACTORS INFLUENCING ADOPTION OF MINIMUM TILLAGE RIPPING AND ANIMAL DRAUGHT POWER AMONG SMALLHOLDER FARMERS IN ZAMBIA

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DECLARATION

I, Isabel Chalendo Sakala declare that this thesis:

a) Represents my own work;
b) Has not previously been submitted for a degree at this or any other University; and

c) Does not incorporate any published work or material from another dissertation.

Signed…………………………………………….

Date……………………………………………….

CERTIFICATE OF APPROVAL

We do hereby declare that this thesis by Isabel Chalendo Sakala, represents her own work and effort under our guidance. We are satisfied that it should be allowed to be presented to the Graduate Studies for examination.

Sign …………………………… Date. …………………………

Thomson Kalinda, Ph.D. **Main Supervisor**

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ABSTRACT

Conservation Farming (CF) practices and Animal draught power (ADP) have been promoted for years in Zambia and the rest of sub-Sahara Africa. CF has the potential to improve soil quality and raise farm incomes despite the variable climatic conditions. ADP is considered the least expensive form of mechanisation among smallholder farmers who cannot afford tractors. This study focused on the determination of the factors affecting the adoption of minimum tillage technology of ripping (MTR) and ADP among smallholder farmers in Zambia. It uses panel data from the Rural Agricultural Livelihoods Survey (RALS) conducted by the Indaba Agricultural Policy Research Institute (IAPRI) in 2012 and 2015 in Zambia. The pooled sample used in the current study consists of 14,213 households broken down as 7,130 and 7,083 for the RALS of 2012 and 2015 respectively.

The study also examined the extent to which adopters of MTR use ripping with ADP. Moreover, the Correlated Random Effects (CRE) estimator was used to estimate the unconditional average partial effects (APEs) in order to explore the within and between household effects on the hectares ripped. This analysis paved way for more robust results and determined the changes in the hectares ripped within a given household overtime and between households in a given period. These unconditional APEs were then compared with the unconditional APEs from the pooled estimator, that is, without the CRE estimator.

Descriptive statistics indicated that use of ADP, ADP hire, partial CF adoption and non-adoption of CF changed between 2012 and 2015 by 40.3 to 43.8%, 16.8 to 19.8%, 6.2 to 5.8% and 89.8 to 89.2% respectively. This showed an increase in ADP use and ADP hire but reduction in partial CF. Gender aspects indicated that females hired ADP more than men while more men used ADP than women.

Factors found to positively influence the adoption of ADP include male headed households, labour availability, ownership of a ripper and access to loans. Compared to those with no education, Primary, secondary and tertiary education of the household head had negative effects on the adoption of ADP. The distance to nearest seller of veterinary products also had a negative effect on the adoption of ADP. For farmers that adopt MTR and use ADP, ownership of a ripper, distance to the nearest seller of veterinary products, CF advice, price of fertilizer per kg and loan access were positive. Moreover, the age, labour availability, hectares cultivated, Tropical livestock units and distance to the nearest agro dealer had negative effects on the adoption of MTR for farmers with ADP. For the extent of adoption of ripping for farmers with ADP, the CF advice, hectares cultivated and the gender of the household head had positive effects while the distance to the nearest agriculture camp office, and primary education had negative effects. The pooled triple hurdle model was less robust compared to the CRE triple hurdle model. All variables used in this analysis were found significant in determining the mean level of adoption on the hectares ripped. However, variables that were important for policy formulation included the hectares cultivated, loan access and ownership of a ripper, which positively affected the mean level of adoption on the hectares ripped. Moreover, recommendations are that promotions of ADP and MTR should be intensified and incentives to be introduced, especially for female farmers, to have access to loans from stakeholders and lending agencies in the agriculture sector, hire or own rippers, hire ADP, and increase the hectares cultivated.

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LIST OF ABBREVIATIONS

ADP	Animal Draught Power
CA	Conservation Agriculture
CFU	Conservation Farming Unit
CRE	Correlated Random Effects
CSO	Central Statistical Office
FAO	Food and Agriculture Organization of the United Nations
FISP	Farmer Input Support Programme
FRA	Food Reserve Agency
GART	Golden Valley Agriculture Research Trust
GRZ	Government of the Republic of Zambia
IAPRI	Indaba Agricultural Policy Research Institute
IFAD	International Fund for Agricultural Development
MAFF	Ministry of Agriculture, Food and Fisheries
MACO	Ministry of Agriculture and Cooperatives
MAL	Ministry of Agriculture and Livestock
MDG	Millennium Development Goals
MSU	Michigan State University
MTT	Minimum Tillage Technologies
MTR	Minimum Tillage Ripping
NAP	National Agricultural Policy
RALS12	Rural Agricultural and Livelihoods Survey of 2012
RALS15	Rural Agricultural and Livelihoods Survey of 2015
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Units
UN	United Nations
USDA	United States Department of Agriculture
WFP	World Food Program
WB	World Bank
ZARI	Zambia Agricultural Research Institute
ZNFU	Zambia National Farmers' Union

CHAPTER ONE

INTRODUCTION

1. Background

Production of farm produce by smallholder farmers in Zambia is characterised by issues of low productivity. Most of these smallholder farmers are poor and experience challenges of decreasing land productivity (Mwale, 2002). This decreased land productivity is attributed to poor agronomic practices such as conventional tillage, and poor farming systems associated with government policy of subsidising chemical fertilizers (Kabamba & Kankolongo, 2009). Crops grown using conventional tillage have produced lower yields than those cultivated using conservation farming (Haggblade & Tembo, 2003). The issue of low productivity still remains a major concern and efforts have been made to curb this issue through the promotion of Conservation Agriculture (CA) in many African developing countries in order to reduce poverty levels and food insecurity (Nyanga, 2012). Conservation Agriculture or Conservation Farming (CF)[1] as it is commonly known in Zambia, is claimed to be the solution to the problems associated with soil degradation and agricultural productivity (Giller *et al.*, 2009).

CF promotions in Zambia begun approximately in the late 1980s and early 1990s (Haggblade & Tembo, 2003; Ng'ombe & Kalinda, 2015). Donor financed Non-governmental organisations such as the Co-operative League of the United States of America (CLUSA) and private companies such as Dunavant, came on board in the promotion of CF in the late 1990s and early 2000s. The government of the Republic of Zambia joined in the promotion of CF in the mid 1990's through the Ministry of Agriculture and Cooperatives (MACO). Other stakeholders that joined in these promotions include the Conservation Farming Unit (CFU) under the Zambia National Farmers' Union (ZNFU), the Soil Conservation and Agro-forestry Extension Project (SCAFE) and the Golden Valley Agricultural Trust (GART). All these stakeholders had the objective of disseminating information on CF and thus increase adoption.

[1] Note that throughout this paper Conservation Agriculture will be referred to as Conservation Farming

CF involves three key practices, which are minimum tillage dry-season land preparation with minimal soil disturbance of 15%, crop residue retention and nitrogen-fixing crop rotations (CFU, 2007a, 2007b). Farmers practicing minimum tillage in combination with only one of the other two key practices (crop residue retention or legume-cereal crop rotations) are classified as partial CF adopters. On the other hand, full CF adopters are those that practice the three aforementioned key practices of CF (Zulu *et al.*, 2016). The three most commonly practiced minimum tillage technologies (MTT) in Zambia include zero tillage, hand hoe planting basins, ox-drawn and tractor drawn ripping using a ripper.

However, most smallholder farmers have limited access to farm machinery such as tractors and thus, most use oxen for ripping or ploughing the fields. Studies have indicated that although use of ripping is limited by costs of equipment (rippers), ripping (both ox- drawn and tractor drawn) has shown some marginal increase in adoption, 0.5% to 1% between 2008 and 2012 (Hambulo, 2014). Grabowski *et al.*, (2014), found that ripping among cotton farmers in Eastern province of Zambia increased from 3% in 2002 to 8% in 2011. This shows that a substantial number of CF adopting farmers are ripping and using Animal Draught Power (ADP), whether owned, borrowed or hired.

Moreover, since both MTT and ADP use have potential benefits, there is an urgent need to explicitly determine the factors influencing the adoption of ADP and conditional on this, the adoption and extent of adoption of Minimum tillage ripping (MTR). There is also need to determine the factors influencing the adoption of these technologies for both adopters and non-adopters. This was the major focus of this research.

1.1 Problem Statement

A number of studies done worldwide indicate that significant agricultural transformation has occurred through the adoption of new and improved farm technologies (Gabre-Madhin *et al.,* 2002). Adoption of technologies seems to substantially raise productivity and farm incomes (Feder *et al.*, 1985; Sunding & Zilberman, 2000).

There have been vast promotional activities to encourage use of ADP and CF by the government of the Republic of Zambia and stakeholders. These include Land o' lakes and Heifer International for ADP and cattle ownership and Conservation Agriculture Scaling Up (CASU) and Conservation Farming Unit (CFU) for CF adoption. Adoption of ADP stands at 36.5% nationally (RALS, 2015) and statistics from the Living Conditions Monitoring Surveys indicate an increase in the number of cattle keeping households over the years. Despite vast promotions of CF adoption, adoption rates are still minimal, about less than 5-15% nationally (Ngoma *et al.*, 2014). While evidence suggests that more than one third of farmers use ADP as a source of power for land preparation, it is still not clear why adoption of ripping, has remained low, as low as 2% nationally (RALS 2015). This information is shown in Table 1. Since CF is touted to engender increased benefits to farmers, this study investigates the factors that influence adoption and extent of adoption of ripping for users of ADP and also analyses the factors that influence the hectares ripped for small holder farmers.

Table 1. Adoption of Tillage Practices and Cattle Ownership by Province in Zambia

	CENT	C/B	EAS	LUA	LUS	MUC	NOR	N/W	SOU	WEST	NAT
Mechanical power adoption	2.1	1.6	0.5	0.4	10.4	0.7	0	0.1	1.1	1.1	1.8
ADP adoption	67.6	17.3	56.6	0.3	39.4	0.9	7.6	3.6	93.8	60.2	36.5
Ripping	3.2	2.4	4.2	0.3	2.8	0.8	0.8	0.2	3.1	0.3	2
Cattle ownership	36.9	13.3	47.1	2	26.2	10.3	8	13.2	58.7	41.6	31.1

Source: RALS 2015

Studies done on ADP adoption (Okello *et al*., 2015, Guthiga *et al*., 2007) and Minimum Tillage Technology (MTT) adoption (Arslan *et al*., 2013, Ngoma *et al*., 2014) have shown that these technologies significantly increase productivity and raise farm incomes of smallholder farmers. However, these studies have separated the adoption of these technologies. They do not consider the adoption of MTR conditional on the adoption of ADP. Moreover, they do not take into account the factors influencing the adoption of these technologies for both adopters and non-adopters, that is, they do not determine the mean level of adoption among the whole population.

This study contributes to the body of literature, through improving of likely shortfalls and adding more value, to the understanding of what drives adoption of MTR[2] and ADP in Zambia in the following ways. Firstly, a model of the ripping adoption decision conditional on adoption of ADP was done. Secondly, the intensity of ripping (proportion of total area cultivated that is prepared using ripping) was estimated conditional on the decision to adopt ripping and ADP. Thirdly, this study went a step further by including the factors that affect adoption of these technologies by including the entire population of adopters and non-adopters because factors that encourage adoption for adopters could also induce non-adopters to adopt these technologies. Most of the previous studies done on ADP and Minimum tillage adoption have mainly focussed on the decision to adopt only, excluding non-adopters and inferences made from the models used may not generalise to the entire population since potential adopters are left out. Fourthly, this study used panel data and the CRE estimator to control for household heterogeneity, creating room for more robust results.

1.2 Objectives of the Study

1.2.1 General Objective

The main aim of the study was to determine the factors associated with farmer decisions to adopt ripping and extent of ripping conditional on the adoption of ADP and to further determine the factors driving the mean level of adoption of these technologies for the entire population of adopters and non-adopters.

1.2.2 Specific Objectives

i To determine the factors affecting adoption of ADP by smallholder farmers in Zambia.

ii To identify factors that affect the adoption of ripping conditional on adoption decision of ADP by smallholder farmers in Zambia.

iii To determine the intensity of adoption of ripping (proportion of total area cultivated that is prepared using ripping) for farmers that adopt ADP and ripping.

[2] In this paper, Minimum Tillage Ripping (MTR) will be used interchangeably with ripping.

iv To determine the factors that influence the change in the mean level of adoption (hectares ripped) for the whole sample, irrespective of whether the farmer adopted ADP or ripping.

1.3 Research Questions

i What farmer characteristics and on-farm characteristics affect the adoption of ADP?

ii If farmers adopt ADP, what are the factors that affect the adoption of ripping and the extent of adoption of ripping?

iii What factors drive the adoption of ADP, ripping and the extent of ripping for the whole population of adopters and non-adopters.

iv What factors determine the change in the unconditional expected value of a given determinant on the hectares ripped?

1.4 Justification of the Study

Since minimum tillage technologies have been shown to increase yields, if all recommendations are followed, and livestock ownership, cattle in particular, has a wide range of benefits, there is need to determine the factors affecting adoption of the two technologies. From literature, the use of ripping minimum tillage technology has gained popularity among small holder farmers. However, there has been no study done to determine the factors influencing the conditional adoption of the two technologies, considering also, the factors driving adoption for the whole sample of adopters and non-adopters.

This study focussed on the determination of factors influencing the adoption of ADP and conditional on this, the adoption of ripping and the extent of adoption of ripping. It also went a step further by determining overall, the factors driving adoption of these technologies by including non-adopters in the analysis. Knowledge on the factors influencing this adoption will help to recommend workable strategies that will enable policy makers to formulate policies that will not only encourage adopters to increase the extent of adoption, but also induce non-adopters to adopt these technologies. All in all, inferences made from this research will be more accurate to represent the adoption decision of these technologies for the entire population. Adoption will allow farmers to keep cattle for ADP use and raise income through hiring out services and sell of cattle products such as milk, meat, manure and the like. Adoption will also encourage high productivity of farming overtime, through use of less labour intensive methods of ripping and ripping services.

1.5 Organisation of the Thesis

The rest of this thesis is organized as follows. Chapter 2 presents an overview of conservation agriculture and ADP in Zambia. Chapter 3 presents the literature review and starts with the theoretical framework of adoption of a technology and further presents more insight on the previous research studies on ADP and CF practices. The research methodology is presented in Chapter 4. Chapter 5 presents the results and discussion and Chapter 6 presents the conclusion and recommendations based on the findings of this study.

CHAPTER TWO

OVERVIEW OF CONSERVATION AGRICULTURE AND ANIMAL DRAUGHT POWER IN ZAMBIA

2.0 Introduction

This chapter begins with an overview of conservation agriculture in Zambia and discusses the different conservation farming practices, the promotions done on conservation farming and the benefits of practicing Conservation farming. It further presents the overview of draught animal mechanisation and the livestock sector in Zambia.

2.1 Overview of Conservation Agriculture in Zambia

According to the Food and Agriculture Organisation of the United Nations (FAO), conservation agriculture (CA) or conservation farming (CF)—as it is commonly known in Zambia—can be defined as “a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment” (FAO, 2007a). The developments of widespread adoption of mechanized CF practices in North and South America created a route for trial in Africa with ox- and human-powered CF systems (Bolliger *et al*., 2006; Twomlow & Hove, 2006). CF in Zambia aims to sustainably improve productivity and food security by combining several practices that mainly concentrate on minimum tillage such as dry-season land preparation using minimum tillage systems; crop residue retention; seeding and input application in fixed planting stations; and nitrogen-fixing crop rotations; and reduction in quantity of mineral fertilizer (CFU, 2007a, 2007b). For hand hoe farmers, CF revolves around dry-season preparation of permanent planting basins. For farmers using oxen, CF technology involves dry-season ripping, normally with a ripper (Haggblade & Tembo, 2003).

Ripping is done in the dry season or after early showers but before the onset of the main rains. An oxen-drawn “tine” is drawn through the soil to rip the top soil open. The tine must penetrate a good depth of 15cm or more to break the hard-pan. If the soil is very compact or if communally grazed cattle have trampled the field and the furrows need to be re-opened, the farmer might need to rip the same lines twice. The same rip lines are supposed to be re-opened year after year. This method is fast and less labour intensive compared to ploughing but requires that the farmer has access to a ripper and oxen. Fertilizer or manure and lime are applied in the ripped furrows after the second ripping is done. This also helps to dilute the clay, helping to prevent the formation of a hard-pan, thus ensuring ripping gets easier in future years. Seeds are planted along the lines with spacing dependent on the crop.

Ripping has a lot of advantages over ploughing in that it is cheaper, faster and oxen are put to better use. There is early planting and yields are higher than in normal ploughing. There is also less soil disturbance, preventing soil erosion. This technique can serve as a potential for service provision as a business through hiring out of oxen and rippers (CFU, 2017).

Figure 1: Farmer Ripping the Field

Source: CFU and CSA Handbook, 2017

There have been a number of promotions of CF by international and national organisations in Africa so as to curb the issue of low productivity (IIRR & ACT 2005; Giller *et al*., 2009; Mazvimavi, 2011). The promotion of CF started as a response to low agricultural productivity on degraded soils, which was thought to be caused by intensive tillage, lack of soil cover and burning of crop residue (Baudron *et al*., 2007). In Zambia, CF practices started in the late 1980s to early 1990s (Haggblade & Tembo, 2003; Ng'ombe & Kalinda, 2015).

Conservation farming has a lot of potential benefits, that is, it improves water infiltration and reduce soil erosion, improves soil aggregation, reduces soil compaction and increases surface soil organic matter (CFU, 2017).

2.2 Overview of Draught Animal Mechanisation in Zambia

Animal draught power refers to the muscle power of draught animals used for pulling agricultural implements, hauling carts, giving motive power to devices such as water pumps, cane and seed crushers, and electricity generation equipment (Ramaswamy, 1994). Animals commonly used for draught power in Zambia include cattle and donkeys though buffalos, horses and camels are used in other countries. Use of draught animals has been a cultural practice in Zambia. It was modified by the earlier European settlers in the colonial times. This technology was considered suitable for the smallholder farmers as a step ahead of the hoe. The highly mechanised farming practise developed was reserved for the European settlers and big private estates. Before Zambia gained independence, most of the implements were imported, making the local blacksmith tools and implements such as hoes, spears axes and the like, less competitive. Importation of these implements was done inconsiderate of training blacksmiths on development and repairing of the imports. There was an invasion of foreign farm machinery and local blacksmiths could not compete due to lack of skill. As a result, the introduction of draught animal mechanisation could not be supported by the blacksmiths and local farmers, posing as a constraint to the development of draught animal mechanisation.

In 1987, a project called the Animal Draft Power Research and Development Project at the Magoye Research Centre was introduced by government in order to pave way for the development of implements and up the use of animal draught power. Before 1995, animal draught power development was channelled through the public sector with the Ministry of Agriculture, Food and Fisheries (MAFF) being in charge of policy development, co-ordination, implementation and monitoring of activities.

In 1992, the Agricultural Sector Investment Programme (ASIP) was initiated as a reformation of the agriculture sector to pave way to the private sector, farmer organisations and Non-Governmental Organisations to play a role in the development of agriculture. A major element of the national exercise to reform the agricultural sector, termed the Agricultural Sector Investment Programme (ASIP) and initiated in 1992, recognised the role that the private sector, farmer organisations and NGOs play in agricultural development (Sprenkels & Mwenda, 2000). There have been a number of promoters who have come on board to encourage cattle keeping and ADP use. Some of these include Heifer Project International and Land O' lakes. However, keeping cattle comes with its own challenges of disease outbreaks caused by ticks and tsetse-borne pathogens, lack of available feed and environmental concerns of over utilisation of grazing areas (too many cattle for the amount of fodder available), lack of access to credit and veterinary services, and lack of animal drawn implements and spares used especially in the deepest rural areas. There is an urgent need to address these challenges to encourage adoption of ADP by farmers country wide.

2.3 Overview of the Livestock Sector in Zambia

The Livestock and fisheries sector contribute about 35% to the total agriculture GDP. Livestock contributes about 6% of smallholder household income through sales and consumption (RALS 2012). The sector has experienced steady growth in recent years with beef and dairy products growing around 7% and 10% annually, respectively (Chapoto *et al.*, 2017). There has been an upward trend in the population of livestock from the past years to date. This is shown in the Table 2.

Despite this growth, the sector has experienced a number of challenges which include: low productivity as a result of in-breeding, poor pasture management, lack of technology extension support and disease outbreak, poor control mechanisms and poor infrastructure (Lubungu, 2013).

Table 2. Population of Livestock by Year

YEAR	CATTLE	GOATS	PIGS	SHEEP
2001	1,489,728	1,179,301	492,465	51,336
2004	2,392,893	1,740,329	615,514	111,156
2006	2,610,000	2,108,000	814,000	116,000
2008	2,8115,583	2,420,077	1,016,199	157,535
2015	2,856,000	2,408,000	1,132,000	103,000

Source: CSO/FSRP (2001, 2004, 2008); LCMS (2006,2015)

Statistics from the Living conditions monitoring survey (LCMS) of 2015 show that Western province has the highest number of agricultural households owning cattle at 84.4% followed by Southern province (73.6%), Central province (64.5%), Eastern province (58.7%) and then Lusaka Province (44.7%). These statistics show that the majority of agricultural households own cattle which is a source of income and wealth for the owning households.

Farmers owning cattle use it as animal traction when cultivating either using a plough or ripper. This is less labour intensive. A comparison of the LCMS of 2004 and 2015, on the other hand, shows an increase in the number of agriculture households owning cattle from 225 859 to 974 730.

CHAPTER THREE

LITERATURE REVIEW

3.0 Introduction

This chapter starts with a discussion on the theoretical framework on the adoption of agricultural technologies, and goes a step further to present the insights from literature on the adoption of ADP and conservation technologies. It also presents the conceptual framework of the study.

3.1 Theoretical Framework on Adoption of Agricultural Technologies

Theoretical studies on adoption of agricultural technologies are many and different. In the studies reviewed, the adoption of a given technology is in one way or another, linked to information acquisition involving the particular technology, a notion supported by many earlier studies (Nkamleu *et al.*, 1999; Tecklewold *et al.*, 2000; Nkegbe *et al.*, 2011).

Binary-choice, discrete or dichotomous models are usually used to evaluate the farmer's adoption decision of agriculture technologies. These models are based on the assumption that farmers are faced with a choice between two alternatives of adoption or non-adoption of the technology. This choice depends on identified characteristics (Pindyck & Rubinfeld, 1997). The decision made by farmers whether to adopt a particular technology or not depends on the utility derived from the technology (the von Neumann-Morgenstern's utility theory). A technology 2 (T_2) is preferred to technology 1 (T_1) as long as the utility derived from technology 2 is greater than that from technology 1.The utility function ranking the i_{th} farmers' preference for technologies is represented as follows (Rahm & Huffman, 1984):

$$U(N_{Ti}; A_{Ti}) \quad \dots\dots\dots\dots\dots\dots\dots\dots \quad (1)$$

Where utility U depends on a vector N_{Ti} describing the distribution of net returns for technology T_j and a vector A_{Ti} corresponding to other attributes associated with the technology T_j. The variables N_{Ti} and A_{Ti} are not observable, but a linear relationship is postulated for the i_{th} farmer between the utility derived from the T_j technology and a vector of observed farm and farmer characteristics X_i and a zero mean random disturbance term

$U_{Ti} = X_{iT} + \mu_T$ ………………………(2)

where T = 1, 2 and i = 1, 2, ….n.

As mentioned, the i_{th} farmer adopts T_2 if U_{T2} is greater than U_{T1}
A qualitative variable Y can represent the farmer's adoption decision.

Y =1 if $U_{T2} > U_{T1}$ and new technology T_2 is adopted replacing T_1

Y = 0 otherwise ………………………..(3)

The probability that Y is equal to one is expressed as a function of farmer characteristics:

P_i = Pr (Y = 1) = Pr ($U_{T1} < U_{T2}$)

Pr ($\chi_i \alpha_1 + \mu_{1i} < x_i \alpha_2 + \mu_{2i})$

x Pr [$\mu_{1i} - \mu_{2i} < x_i(\alpha_2 - \alpha_1)$]

Pr ($(\delta_i < x_i \beta) = F(x_i \beta)$ …………………(4)

Where:

Pr (.) is a probability function**,**

$\delta = \mu_{1i} + \mu_{2i}$ is a random disturbance term

$\beta = \alpha_2 - \alpha_1$ is a coefficient vector and;

$F(x_i\beta)$ is a cumulative distribution function for δ calculated at $x_i\beta$

The marginal effect of a variable X_j on the probability of adopting new technology can be calculated by differentiating P_i with respect to X_j :

$\partial P_i / \partial X_{ij} = F(X_i \beta) . \beta_j$ ……………………… (5)

Where f (.) is the marginal probability density function of δi and j = 1, 2,……n is the number of explanatory variables.

The general form of the univariate dichotomous choice model is expressed as:

$P_i = P_i (Y_i = 1) = G(X_i, \theta)$ where i = 1, 2, ….n. ………………………. (6)

Equation (6) states that the probability that the i_{th} farmer will adopt the technology is a function of the vector of explanatory variables X_i and unknown parameter vector θ.

The Probit model was used to estimate the probability of adopting a given technology because it incorporates nonlinear maximum-likelihood estimation. Probit analysis accounts for heteroscedasticity of the error terms and restricts predictions to lie between 0 and 1 range. The probability of a farmer adopting or not adopting improved technology in the Probit model is defined in terms of an index that takes on any value between negative infinity and infinity. This index is converted into probability values by using a standard cumulative normal distribution and this transformation guarantees that all corresponding probability values are confined between 0 and 1 (Pindyck & Rubinfeld, 1997, Maddala G., 1983). The functional form is represented as follows:

$$P_i = F(Z_i) = \frac{1}{(2\pi)^{0.5}} \int \exp^{-\mu^2/2} d\mu$$ ………………. (7)

Where $Z_i = x_i\beta + \mu$

An estimated β value in a Probit model does not give the change in the dependent variable, due to a unit change in the explanatory variable. This effect is obtained by computing the partial derivative of the Prob ($Y_i = 1$) with respect to β. More insight on the Probit analysis in relation to the adoption of ADP and ripping is presented in chapter 4.

3.2 Insights from Literature

There have been a number of studies done on MTT and ADP adoption though not many recent studies have been done on adoption of ADP.

3.2.1 ADP Adoption

Results from a study by Savadogo *et al*., (1998) on the adoption of improved land use technologies to increase food security in Burkina Faso compared results in two zones, Sudano Sahelian and the Guinea zones. Results from the Probit regression showed that non-farm income and size of household had positive impact on the adoption of animal traction technology. The results further indicated that probability of adoption increased substantially from households with little non- farm income and small farms to households with more non-farm income and large farms. The results also suggest that non-farm income is the most important liquidity source for investment in animal traction and the main source of cash income.

Results from a study by Mbata, (2001) on the determinants of animal traction adoption in Lesotho indicate that adoption of animal traction is sensitive to both sociological and economic factors, the most significant being the number of work animals and farm income, respectively. The study further recommended advancement of credit to poor farmers in order to motivate animal traction adoption and resultantly increase farm output and income.

Guthiga *et al*., (2007), in Central Kenya addressed the question of whether ADP increases economic efficiency of smallholder maize farmers using the Cobb-Douglas unit output price frontier. Out of the sampled 80 farmers, 57% used ADP and 43% did not. The results indicated that farmers who used ADP had higher yields and operated at higher economic efficiency than those who used hand hoes. However, this study also indicated that affordability of the ADP technology, availability of appropriate implements and skills of use must be considered when promoting ADP technology adoption.

Cachomba *et al*., (2011), in Mozambique studied the determinants of animal traction adoption. Data from a nationally representative household survey of 2008 was used in the study and the Probit model was used to determine the factors that influence animal traction adoption in the southern and central provinces of Mozambique. The results showed that gender of the household head, livestock ownership, access to veterinary services and hiring seasonal labour are the key determinants of animal traction use. Recommendations from this study were that adequate agricultural credit and effective extension services should be provided and at the same time, enabling better access to both input and output markets in order to increase adoption of animal traction.

A study done by Makki *et al*., (2017), in West Kordofan State, Sudan, on factors affecting draught animal technology used a cross sectional survey design on a sample of 100 farmers. Data was collected using a structured questionnaire and analysed descriptively using SPSS. Dependency between the selected variables was tested using chi square test. The results indicated that draught animal traction users lacked confidence and trust in the staff responsible for technology transfer, training and extension. These draught animal users would rather learn about the technology from their peers rather that the people endowed with the responsibility to train them. The Factors found to influence adoption of draught animal traction were; production purpose, farm size, farmers' age and land ownership. Lack of financial resources, inaccessibility to service, poor technical know-how of the staff of training and extension authorities were pointed out as undermining factors to the adoption of draught animal traction. Recommendations from the study were that adoption rate of the technology can be improved by providing credit service and high quality training for optimal application of the technology.

These studies done on ADP use and adoption do not address the issue of how ADP adoption affects adoption of MTT of ripping. Some of them use descriptive analysis. This study will go a step further by determining how adoption of ADP affects adoption of MTT of ripping and intensity of ripping, using more robust econometric analysis, addressing the knowledge gap in literature.

3.2.2 Empirical studies on factors affecting the adoption of conservation technologies.

A number of adoption studies have been done to determine the factors affecting adoption of new technologies.

Recent studies conducted in Eastern Africa, designed to better understand key determinants of farm-level technology adoption/dis-adoption, revealed that the major reasons for technology non-adoption were: (1) farmer's unawareness of the improved technologies or a lack of information regarding potential benefits accruing from them; (2) the unavailability of improved technologies; and (3) unprofitable technologies, given the farmer's agro ecological conditions and the complex set of constraints faced by farmers in allocating land and labour resources across farm and off-farm activities (Doss, 2003).

Nkala *et al.,* (2011) also conducted a meta-analysis of CA which mainly focussed on the hindrances to successful implementation of CA projects in Southern Africa. The authors discuss such issues as the lack of infrastructure, insufficient involvement of farmers in the process, existing livestock management norms, imperfect input and credit markets and land tenure as obstacles that limit wide-spread adoption in Southern Africa. They also highlight that adoption in this region is mostly partial and underline the importance of defining adoption in this context not only as a binary outcome, but also as a continuous process. Primary constraints to adoption in Zambia are found to be the use of crop residues for other purposes (e.g. high opportunity costs), labour constraints and the limited potential to grow cover crops during the dry season. Among these constraints, many authors have argued that labour constraints, which manifest themselves during land preparation and weeding, are the most important (Baudron *et al*., 2007; Haggblade & Tembo, 2003; Umar *et al*., 2011; Mazvimavi, 2011; Vasanthakumar *et al*., 2017.)

Nasrin & Akteruzzaman, (2017), conducted a study in Bangladesh to delineate the status of adoption and the factors influencing adoption of CA technology practice. A total of 240 farmers were randomly selected for survey of which 120 were adopter and 120 were non-adopters from Durgapur upazila of Rajshahidistrict and Baliakandiupazila of Rajbari district. The results from the logit model indicated that farm size, family size, earning member, extension access and training facilities of the farmers significantly contributed the adoption of CA practice. The study recommended access to credit and a demonstration of the benefits of the adoption CA involving government and non- government organisations in order to expand CA practices.

A study by Belachew *et al.*, (2020) in the northwest Ethiopian highlands used a multivariate Probit analysis to determine the determinants of soil and water conservation practices. The joint probability of adopting the selected soil and water conservation practices was 14.2%. The results suggested that age, sex, education level, household size, livestock holding, land size, access to credit, access to extension service and training were significant factors that affected the adoption of soil and water conservation practices in the study area. The study further recommended the strengthening of the provision of formal and non-formal training and facilitate an effective extension service.

In Zambia, a study by Ngoma *et al.*, (2012), found that larger land holding was an important factor driving the adoption of Conservation Technologies. The study also hinted on the climate change scenarios, especially the erratic rain patterns, as a strong factor influencing farmers' decision to adopt Conservation technology methods, so that soil and water could be conserved sufficiently in the crop fields.

A study by Chomba (2004) in Eastern, Southern, Central and Lusaka Provinces of Zambia, found that household size and land size positively influenced adoption rates of CA practices during the1998–2000 seasons of the postharvest survey. He also found that distance to markets and extension services influence adoption decisions.

A study by Grabowski *et al.*, (2014) on the minimum tillage adoption among 135 000 commercial cotton farmers between 2002 and 2011 found that demonstration effects of lead farmers, availability of herbicides and long term extension effects influenced adoption of MTT. It was discovered that 13% of cotton farmers practised MTT in 2011 compared to 11% in 2002.

Nkhoma *et al.*, (2017) examined the adoption and impact of CA on crop productivity and income on farming households in Luapula Province of Zambia. This study used probit regression model to identify factors influencing adoption of CA among the smallholder farmers in the Province and results indicated that advice on CA and access to wetlands/dambos by households increased the probability to adopt CA. The study further recommended an increased access to quality extension services that incorporates promotion of CA practices among the smallholder farming households in the area.

This study contributes to the body of literature by improving our understanding of likely shortfalls associated with low adoption of MTT and ADP in Zambia. Specifically, adoption of MTT using ripping and intensity of ripping conditional on the adoption of ADP is examined in the present study. There was need to find out why farmers that have ADP do not adopt ripping which all the reviewed studies have ignored. Moreover, this study used panel data to control for household heterogeneity. To create room for more robust results, the correlated random effects estimator was used when generating the unconditional APEs.

3.3 Conceptual Framework

Based on the theoretical and empirical studies on the adoption of improved technologies, this study postulates that the adoption of ox drawn ripping is influenced by a number of independent variables that can be divided into four categories as shown in Figure 2. The first one being household characteristics (gender, age, education, labour availability). Secondly, farm characteristics (Ownership of productive assets (ripper, livestock), hectares cultivated, distance to the service providers (veterinary, agro-dealer, camp office). The third category are the institutional factors which include the extension advice on the technology, loan access and the price of inputs (fertilizer). The fourth category are the locational factors which include the province where the farm is found.

Adoption of agricultural technologies is influenced by several interrelated components within the decision environment in which farmers operate. Adoption of improved technology by farmers will depend on the benefits that the farmer derives from that technology and the awareness of the technology. The farmer will adopt the new technology only if the incentives outweigh the disincentives. Successful and continued adoption of the new technology depends on farmers' perception of the incentives and disincentives provided along with that technology. If perceived benefits are higher than the costs, farmers are motivated to adopt a technology as they expect high returns on investment. Thus, this study was guided by the utility maximization theory (the von

Neumann-Morgenstern's utility theory). The Utility theory has been used in appropriate technology adoption (Ogada, Mwabu, & Muchai, 2014; Borges, Foletto & Xavier, 2015).

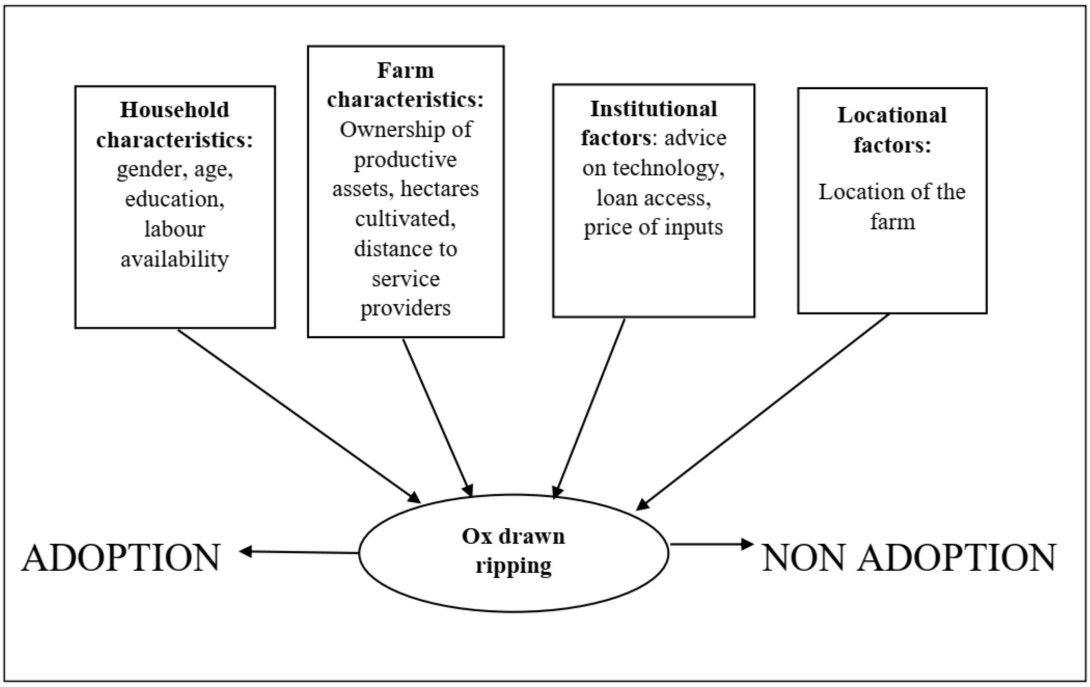

Figure 2: Conceptual Framework showing the Adoption of Ox-drawn Ripping

CHAPTER FOUR

METHODOLOGY

4.0 Introduction

This chapter begins with a description of the study area, data collection methods and the statement of the hypothesis. It then presents the theoretical framework of the triple hurdle model, the sample size selection, data analysis methods and the analytical framework.

4.1 Description of the Study Area and Data Collection Methods

This study is a panel study that encompassed all the provinces of Zambia. Zambia has a total number of 10 provinces. Secondary data was used from the Rural Agricultural Livelihoods Survey of 2012 and 2015 (RALS 2015) from Indaba Agricultural Policy Research Institute (IAPRI). This data was randomly collected across the country by IAPRI in collaboration with the Central Statistical Office (CSO) and the Ministry of Agriculture and Livestock (MAL). The RALS 2015 is a panel survey continuing from the RALS 2012 survey whose sampling frame was based on the 2010 Census of Housing and Population. The RALS 2012 survey was conducted between May and June, 2012 and covered 8840 households. The RALS 2015 survey was conducted between June and July, 2015, covering 9520 households. The RALS 2012 and 2015 surveys involved collection of information on demographic characteristics, crops, land use, assets, adoption of technologies, agriculture information, agroforestry, to mention a few.

4.2 Sample Size

The main objective of this study was to determine the factors influencing adoption of ADP and ripping among smallholder farmers in Zambia. In addition, the study was aimed at identifying and quantifying factors that affect the adoption of ripping conditional on adoption of ADP. The study also went a step further to determine the factors affecting the hectares ripped for the whole population of adopters and non-adopters of ripping, by determining the unconditional expected value of hectares ripped. For this reason, after data cleaning (some observation with missing values were dropped), all households were selected, with a sample size of 14,213 households, as 7,130 and 7,083 for the RALS of 2012 and 2015 respectively.

4.3 Statement of Hypotheses

The main hypothesis of this research was that selected farmer and farm characteristics, institutional factors and geographical location play a critical role in influencing farmers' decision to adopt ripping and the intensity of ripping conditional on the adoption of ADP. These selected farmer and farm characteristics, institutional factors and geographical location that play a critical role in influencing the adoption decision of ADP, ripping and the intensity of ripping for adopters can also influence non-adopters into adopting these technologies. The null hypothesis was that selected farmer and farm characteristics, institutional factors and geographical location do not play a significant role in influencing farmers' decision to adopt ripping and intensity of ripping conditional on the adoption of ADP.

4.4. Theoretical Framework for the Adoption of ADP and Ripping

4.4.1 The Triple Hurdle Model

To measure the factors influencing the adoption of ADP, ripping and extent of ripping, the triple hurdle model was used. The likelihood function for the triple-hurdle model is an integration of a Probit model in the first two hurdles and a lognormal model in the third hurdle. Studies that have similarly but not exactly used these hurdle models include Cragg's (1971) integration of the Probit and lognormal model, Bellemare & Barrett's (2006) integration of the ordered Probit and truncated normal model, and Burke *et al.*, (2015) integration of the Probit model in the first hurdle, an ordered Probit model in the second hurdle and two lognormal models in the third.

The full likelihood function for a probit-probit-lognormal hurdle model is[3]:

[3] The likelihood function for the triple hurdle model was derived with the help William Burke

$$f(w_1, w_2, y|\boldsymbol{x\theta}) = [1 - \Phi(\boldsymbol{x_1\beta})]^{1[w_1=0]}$$

$$* \left[\Phi(\boldsymbol{x_1\gamma})\left[[1 - \Phi(\boldsymbol{x_2\gamma})]^{1[w_2=0]}\left[\Phi(\boldsymbol{x_2\gamma})\frac{\phi[log(y) - x_3\delta]/\sigma}{y\sigma}\right]^{1[w_2=1]}\right]\right]^{1[w_1=1]} \quad \ldots(8)$$

Where;

$w_1 = ADP; \qquad w_2 = Ripping; \qquad y = Hectaresripped$

Where the dependent variables $w_1 = 1$ if the observation passes the first hurdle, and $w_1 = 0$ otherwise; $w_2 = 1$ if the observation passes the second hurdle, and $w_2 = 0$ otherwise; y is the continuous value that can only be non-negative if the observation passes both hurdles. The parameters $\boldsymbol{\beta}$ is the vector in the first stage, and $\boldsymbol{x_1}$ is the vector of determinants for w_1; given that $w_1 = 1$, $\boldsymbol{\gamma}$ is the vector of parameters in the second stage, and $\boldsymbol{x_2}$ is the vector of determinants for w_2; and given $w_1 = w_2 = 1$ (which is to say, given that y>0), $\boldsymbol{\delta}$ is the vector of parameters in the third stage, and $\boldsymbol{x_3}$ is the vector of determinants for y. For notational purposes, $\boldsymbol{\theta} = (\boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\delta})$ and $\boldsymbol{x} = (\boldsymbol{x_1}, \boldsymbol{x_2}, \boldsymbol{x_3})$. The function Φ is the standard Normal cumulative distribution, and ϕ is the standard Normal probability density function. σ is the standard deviation of the random variable y.

Taking the log of this, the log-likelihood function for any given observation (i), is:

$\ell_i(\boldsymbol{\theta})$

$$= log\{1 - \Phi(\boldsymbol{x_{1i}\beta})\}, \qquad if\ w_1 = 0$$

$$= log\{\Phi(\boldsymbol{x_{1i}\beta})[1 - \Phi(\boldsymbol{x_{2i}\gamma})]\}, \qquad if\ w_1 = 1\ \&\ w_2 = 0$$

$$= log\left\{\Phi(\boldsymbol{x_{1i}\beta})\Phi(\boldsymbol{x_{2i}\gamma})\left[\frac{\phi[log(y_i) - x_{3i}\delta]/\sigma}{y_i\sigma}\right]\right\}, \quad if\ w_1 = 1\ \&\ w_2 = 1 \quad \ldots..(9)$$

This yields the following key probability equations:

$\Pr(w_{1i} = 0|\boldsymbol{x_{1i}}) = 1 - \Phi(\boldsymbol{x_{1i}\beta})$

$\Pr(w_{1i} = 1|\boldsymbol{x_{1i}}) = \Phi(\boldsymbol{x_{1i}\beta})$

$\Pr(w_{1i} = 1, w_{2i} = 0|\boldsymbol{x_{1i}}, \boldsymbol{x_{2i}}) = \Phi(\boldsymbol{x_{1i}\beta})[1 - \Phi(\boldsymbol{x_{2i}\gamma})]$

$\Pr(w_{1i} = 1, w_{2i} = 1|\boldsymbol{x_{1i}}, \boldsymbol{x_{2i}}) = \Phi(\boldsymbol{x_{1i}\beta})\Phi(\boldsymbol{x_{2i}\gamma})$

and the following key expected values. First, the conditional expected value of y:

$$E(y_i|y_i > 0, \boldsymbol{x_{3i}}) = \exp\left(\boldsymbol{x_{3i}\delta} + {\sigma^2}/{2}\right)$$

and the, so called, unconditional expected value of *y*:

$$E(y_i|\boldsymbol{x_i}) = \Phi(\boldsymbol{x_{1i}\beta})\Phi(\boldsymbol{x_{2i}\gamma})\exp\left(\boldsymbol{x_3\delta} + {\sigma^2}/{2}\right)$$

The marginal effect of a variable, x_k (if it is an element of $\boldsymbol{x_1}, \boldsymbol{x_2}\ and\ \boldsymbol{x_3}$) on the unconditional expected value of *y* is:

$$\frac{\partial E(y_i|\boldsymbol{x_i})}{\partial x_k} = \beta_k\phi(\boldsymbol{x_{1i}\beta})\Phi(\boldsymbol{x_{2i}\gamma})\exp\left(\boldsymbol{x_3\delta} + {\sigma^2}/{2}\right)$$

$$+ \gamma_k\Phi(\boldsymbol{x_{1i}\beta})\phi(\boldsymbol{x_{2i}\gamma})\exp\left(\boldsymbol{x_3\delta} + {\sigma^2}/{2}\right)$$

$$+ \delta_k\Phi(\boldsymbol{x_{1i}\beta})\Phi(\boldsymbol{x_{2i}\gamma})\exp\left(\boldsymbol{x_3\delta} + {\sigma^2}/{2}\right)$$

When the explanatory variables include quadratic terms, the marginal effect is slightly different. For example, if $\boldsymbol{x_{1i}\beta}$=$\beta_1 x_1 + \cdots + \beta_k x_k + \beta_{q1}x_q + \beta_{q2}x_q^2$ (and x_q is similarly included as a quadratic term in $\boldsymbol{x_2}$ and $\boldsymbol{x_3}$), then the marginal effect of x_q on the unconditional expected value of *y* is:

$$\frac{\partial E(y_i|\boldsymbol{x_i})}{\partial x_q} = (\beta_{q1} + 2\beta_{q2}x_{qi})\phi(\boldsymbol{x_{1i}\beta})\Phi(\boldsymbol{x_{2i}\gamma})\exp\left(\boldsymbol{x_3\delta} + {\sigma^2}/{2}\right)$$

$$+ (\gamma_{q1} + 2\gamma_{q2}x_{qi})\Phi(\boldsymbol{x_{1i}\beta})\phi(\boldsymbol{x_{2i}\gamma})\exp\left(\boldsymbol{x_3\delta} + {\sigma^2}/{2}\right)$$

$$+ (\delta_{q1} + 2\delta_{q2}x_{qi})\Phi(\boldsymbol{x_{1i}\beta})\Phi(\boldsymbol{x_{2i}\gamma})\exp\left(\boldsymbol{x_3\delta} + {\sigma^2}/{2}\right) \text{ ....(10)}$$

The marginal effect of a variable on other probabilities and expected values can be similarly derived.

4.5 Data Analysis

In this study, SPSS software package was used for data processing and descriptive statistics while Stata 14 package was used for econometric analysis. The three-stage model (triple hurdle) was used in the analysis.

4.6 Analytical Framework

4.6.1 Factors Influencing Adoption of ADP and Ripping

To measure the factors influencing the adoption of ADP and ripping, the first hurdle included the 'selection' equation which measured the decision to adopt ADP or not. The second hurdle included the decision to adopt Ripping or not, on condition that the household adopts ADP, and the third hurdle will be the extent of ripping measured by the area under ripping.

This will be given as:

Hurdle 1------------ $\Pr(ADP > 0 \mid X) = F(X_1\gamma)$ ……………….(11)

Hurdle 2 -------------- $\Pr(RIP > 0 \mid ADP > 0) = F(X_2\delta)$ ………(12)

Hurdle 3------------ $E(Y_i \mid X, Y > 0) = X\beta + \sigma\lambda\left(X\beta/\sigma\right)$ ………..(13)

Where;

ADP and RIP takes the value of 1 if the household used ADP and ripping respectively; Y_i is the amount of land put under the minimum tillage practice of ripping. X is the vector of explanatory variables hypothesised to influence participation and is the same for the second and third hurdle but different from the first; γ is the vector of coefficients associated with X in the first hurdle; and δ is the vector of coefficients associated with X in the second hurdle. λ is the inverse mills ratio and σ is the variance. However, these hurdles were used to estimate both the conditional and unconditional Average Partial Effects.

Panel data was used of which one of the analytical benefits include the ability to control for unobserved time invariant individual household characteristics. Traditionally, control for these unobserved household heterogeneities is done by employing fixed effects (FE) and random effects (RE) estimators. However, these traditional estimators have their own weaknesses. The RE models assumes no correlation between unobserved heterogeneity and the observed explanatory variables in the model. If this RE assumption holds then cross-sectional analysis employing OLS estimation would also consistently estimate the model parameters (Wooldridge, 2010). Although FE model is attractive in that it allows arbitrary correlation between the unobserved heterogeneity and the observed explanatory variables, its major weakness is that the transformation it uses to remove the unobserved heterogeneity also removes all time invariant explanatory variables and this can be problematic especially if a researcher would like to obtain estimates on time constant covariates (Muricho, 2015).

The alternative method that provides the FE coefficients for time varying regressors is the Correlated Random Effects approach (CRE). The CRE, unlike fixed effects approach, allows one to estimate how important the persistent components of the covariates are, and also allows one to include time-constant covariates. The various subsets of results allow us to interpret the effect of a covariate both from changes within a given household and from differences between two households.

In this report, we use an approach that preserves the advantages of FE estimation while also allowing inclusion of time-constant covariates. The approach dates back to Mundlak (1978) and was extended by Chamberlain (1982, 1984). The so-called "Mundlak-Chamberlain Device" is an example of a CRE approach. Specifically, one models the relationship between the unobserved heterogeneity ψ_i and the observed explanatory variables. To construct the Mundlak-Chamberlain devise, the panel average variables of selected time varying variables were computed based on the two panel periods. These panel average variables were added in the first, second and third hurdle models as additional explanatory variables. This is modelled as follows.

Let X denote the 1×K set of all time-varying explanatory variables, excluding time invariant variables. For each cross-sectional observation i, let $\overline{X}_{it}$ be the 1 × K vector of time averages, with j_{th} entry

$$\overline{X_{ij}} = T^{-1}\sum_{t=1}^{T} X_{itj} \text{ ……………………… (14)}$$

According to Mundlak (1978), there is a linear relationship between the unobserved heterogeneity ψ_i and the time averages, which can be written as;

$$\psi_i = \delta + \overline{X}_i \lambda + m_i \text{ …………………….. (15)}$$

Where:- δ is a scalar; $\overline{X}$ is the averages of time varying explanatory variables λ is a vector of coefficients to be estimated m_i is the error term which Mundlak (1978) assumed to have zero mean conditional on the entire history of the covariates $(X_{i1}, X_{i2}, ..., X_{iT})$ i.e. the error term m_i is uncorrelated with X_{it} for all t and therefore X_i. The model for the CRE analysis including the time constant variables will be as follows:

$$Y_{it} = \alpha_t^* + X_{it}\beta + \overline{X}_i \lambda + Z_i \gamma + m_i + \varepsilon_{it} \text{ ………………….. (16)}$$

Where the scalar, δ, is absorbed into the intercept term such that $\alpha_t^* = \alpha_t + \delta$. Y_{it} is the outcome variable, Z_i is a vector of time invariant explanatory variables. The time constant projection error term m_i is assumed to have a zero mean and uncorrelated with the explanatory variables in the model. The assumption behind the idiosyncratic error term ε_{it}, is the 'strict exogeneity' assumption. This means that the idiosyncratic errors are not correlated with any of the explanatory variables in all time periods. The β, λ and γ are parameters to be estimated. According to Schunck (2013) and Burke & Jayne (2014), β are interpreted as "within-household" or "within-cluster" effect. These "within-household" estimates are similar to the FE estimates meaning that these coefficients are the effect of a given time varying variable's effect of deviation from its overall average or "permanent" level (Burke & Jayne 2014). These coefficients therefore, can simply be interpreted as the effect of a deviation within a given household. Moreover, λ and γ are interpreted as "between-household" or "between-cluster" effects and are unchanging for each household across the panel period. For a detailed understating on derivation and interpretation of "within" and "between" estimates, see Schunck (2013) and Burke & Jayne (2014).

4.6.2 Selection of Variables

The explanatory variables hypothesised to influence the adoption of ADP and ripping from literature are shown in the Table 3. These variables were captured in the RALS 2012 and 2015 datasets. A positive sign implies that there is a positive relationship between the independent variable and the dependent variable. Increase in the variable will increase the adoption rate and the opposite relationship exists if the sign of the independent variable is negative.

In past studies, different factors that affect farmers' adoption decision have been documented (Nzomoi, 2007: Egyir, 2010; Odoemenem, 2010; Beltran *et al*. 2011). Age of the household head has been found to have both positive and negative effects. It is normally used as a proxy for farming experience. According to some studies, age was found to have positive influence on the adoption decision of new technologies by farmers (Egyir, 2010; Beltran 2011). Other studies found that age had a negative influence on a farmer's adoption decision of agricultural technologies (Odoemenem, 2010). Farmers of productive age are more receptive to change and are likely to adopt new technologies than their older counterparts. Young farmers are more likely to adopt these ADP and minimum tillage technologies because of the labour requirement needed for these technologies.

Females are more involved in small-scale farming activities than males (FAO, 1998). However, some studies by Beltran (2011) and Ghazalia (2013) have found that female-headed households have less access to productive assets than the male headed households and rarely make decisions on technology adoption. However, other studies (Newmark et al. 1993 cited in Hassan & Nhemachena 2008), found that females were more likely to adopt conservation farming practices. Male-headed households normally have more influence on the decision to adopt new technology. In situations where the male is the household head, female spouses have relatively lower ability to influence adoption decisions. This can also be applied to adoption of minimum tillage and ADP technologies. Females on the other hand are more active in farming activities than males (FAO, 1998). This owes to the fact that adoption decisions of these technologies can take either sign.

Education level of the household head is assumed to be a strong *apriori* indicator of ability to obtain, productively process and use information in a more useful and relevant way, eventually leading to the adoption of a new technology. In this study, the level of education was taken as a proxy for the effectiveness of human capital, that is the capability to quickly discover the importance and benefits of new technology adoption. Hence, adoption of ADP and ripping MTT by educated smallholder farmers'

Table 3. Factors Hypothesised to Influence adoption of ADP, Ripping and Intensity of Ripping

Variable name	Description and type of variable	Expected impact
Dependent variable: Adoption of ADP, Ripping and extent of Ripping		
Independent variables		
1.Household characteristics		
Gender of Household head	Male headed Household (=1, if male, 0 o/w)	+/-
No education	Uneducated household head (=1, if yes, 0 o/w)	Base education
Primary	Primary level of education of the head(=1, if yes, 0 o/w)	-
Secondary	secondary level of education of the head(=1, if yes, 0 o/w)	-
Tertiary	Tertiary level of education of the head(=1, if yes, 0 o/w)	+
Labour availability	Labour availability in terms of adult equivalent with age groups	+
Age of head	Age of the household head in years	-
Age squared	Age of the household head squared	
2. Farm characteristics		
Ownership of a ripper	Number of rippers owned (=1, if yes, 0 o/w)	+
Hectares cultivated	Hectares of land cultivated (Ha cult)	+
Tropical Livestock Units	Livestock units measured in terms of Tropical Livestock Units(TLU)	-
Distance to seller of vet products	Distance to seller of vet products (km)	+
Distance to Extension officer	Distance to extension officer (km)	-
Distance to nearest Agro-dealer	Distance to nearest Agro-dealer (km)	-
3. Institutional factors		
Receive CF advice dummy	Household receive advice on CF (receive=1, 0 o/w)	+
Loan access	Does the Household have access to loans(access=1, 0 o/w)	+
Price of fertilizer per Kg	Input Price of fertilizer per kg in Kwacha	-
4. Location of the farm		
Central province	Province where farm is. (Central=1, 0 o/w)	+/-
Copperbelt province	Province where farm is. (Copperbelt=1, 0 0/w)	+/-
Eastern province	Province where farm is. (Eastern=1, 0 0/w)	+/-

Variable name	Description and type of variable	Expected impact
Luapula province	Province where farm is. (Luapula=1, 0 0/w)	Base province
Lusaka province	Province where farm is. (Lusaka=1, 0 0/w)	+/-
Muchinga province	Province where farm is. (Muchinga=1, 0 0/w)	+/-
Northern province	Province where farm is. (Northern=1, 0 0/w)	+/-
North-western province	Province where farm is. (North-western=1, 0/w)	+/-
Southern province	Province where farm is. (Southern=1, 0 0/w)	+/-
Western province	Province where farm is. (Western=1, 0 0/w)	+/-

Note: The Variable Tropical Livestock Units was not included in the first hurdle of adoption of ADP but included in the last two hurdles of adoption of ripping and intensity of ripping respectively. The TLU conversion factors were: cattle=1, pigs=0.4, goats and sheep=0.2 and donkeys=0.6. The adult equivalent age groups and weights were: <10 years=0.6 for both males and females; 10 to 13 years=0.9 for male and 0.8 for female; >13 years=1 for males and 0.75 for females according to Storck *et al*, 1991.

result in improved crop productivity and production because they grasp the concepts of the new improved technology faster than uneducated farmers. The level of education was divided into four categories; no education, primary, secondary and tertiary. Hence, it is expected that a higher level of education will be positively associated with adoption. Nzomoi (2007) found similar results.

The importance of the adult equivalent variable is that it helps to explain the amount of labour supply for a particular farm household. This variable is calculated using the sex and age of the household. The value of the adult equivalents helps to evaluate whether the household is producing enough food to sustain the household. Some members of the household need more food than others and these variables help to assign that value (Beaver, 2016). It can be assumed therefore, that households with higher adult equivalents are more capable of providing the necessary labour that a new technology may demand. A farmer with a larger number of adult household members is more advantaged in terms of labour supply during land preparation and harvesting than otherwise. In this case, the adult equivalent is anticipated to be positive for the probability of adopting both or either technology. This is reported in many adoption studies (e.g., Chikoye (2004); Mohammad (2004); Gianessi (2011)).

Total livestock holding of the household is measured as a continuous variable in terms of Tropical livestock units(TLU). In general, it’s believed that wealth increases the ability to take risks. So the chances of a farmer with livestock to engage in technology adoption are much higher than the one without any. The contrast is that the same wealthier farmers, with livestock, may be unwilling to adopt Ripping MTT because they can have other uses for the animals. For example, draft power from donkeys and oxen can be used to weed, plough fields or even hiring out the animals. This is in line with results from Ngombe *et al*., (2014) that indicated that smallholder farmers that have livestock are less likely to adopt CF. Another issue can be that there is a competition of crop residues between mulch and feed. So the sign in this case can either be positive or negative. This was only included in the adoption of ripping and not the adoption of ADP equation.

Distance to seller of veterinary products will have a negative impact on adoption especially for the adoption of ADP. The further away the market is, the less likely that the farmer will adopt the technology. This is because the further away the seller of veterinary products is, the less likely that the farmer will have access to the necessary products needed for the technology to be effective, for example, drugs for livestock.

The distance to an agro-dealer follows the same argument. The further away the agro-dealer is located from the farmstead, the more unlikely the farmer will be willing to adopt the ADP and ripping MTT. The reverse is true, because the farmer can easily consult about the benefits of each technology and can ask any pertinent questions concerning the new technology. Hence, he/she can, for example, buy the inputs as an important labour-saving input. He/she can adopt the technology to promote long-term soil healthy and productivity.

As for the distance to the nearest camp extension officers, the further away the camp office is, the less the chances of advice and extension support to the farmers and vice versa. So the sign is negative.

Access to extension services, is an important source of information on farming practices. The more visits the farmer gets from extension officers, the more well-informed he becomes about latest technologies. Access to extension services was found to be positively associated with the likelihood of farmers becoming more willing to adopt technologies. But Bryan *et al.,* 2009, found that access to extension was insignificant to farmers' decision to adopt herbicides. Some previous work in sub-Sahara Africa pointed out that information acquisition and eventual adoption is influenced by farmers' characteristics (Nkamuleu, 1998). Owing to the frequency with which access to extension services has been quoted and the impact it has been showing in earlier work, it has been assigned a positive sign with the assumption that access to extension services has a positive influence. This is on the understanding that services from field extension broaden farmers' horizon of agricultural production opportunities and can, to a greater extent, offset lower levels of formal school education.

Access to financial empowerment such as loans can positively affect the adoption of a given technology. Ng'ombe *et al.* (2014) found that access to loans positively influenced the likelihood to adopt CF. Ownership of productive and labour saving implements such as rippers is expected to increase the likelihood of adopting CF. This expected result is similar with studies done by Chomba (2004), Umar *et al*., (2010), Mavunganidze *et al.*, (2013), and Lugandu, (2013) who found that ownership of productive assets increases the likelihood of adopting a given technology.

Climatic conditions, soil and other factors such as culture vary across different regions. For these reasons, this study made the hypothesis that farms found in different provinces, with different agro-ecological zones, perceive the adoption of ripping and ADP technologies differently. Variations in locations imply differences in farmers' perceptions on the adoption of these two technologies and consequently, their decisions to adopt their use. The importance of location, as a variable in technology adoption, is hinted by Bryan *et al.*, (2009).

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 Introduction

This chapter starts by presenting descriptive statistics of the characteristics of smallholder farm households in Zambia. These are categorized as the overall sample, ADP adopters and adopters of MTR. The three are described and discussed. This chapter then goes further to discuss the results of the pooled triple hurdle model and the CRE Triple hurdle model.

5.2 Descriptive Statistics

The descriptive statistics for the whole sample (14,213households) of 7,130 and 7,083 from RALS 2012 and 2015 respectively, are as shown in the Table 4.

From Table 4 the farmer and farm characteristics show that the labour availability had a mean of 4.99. The average age of the household head was 47 years. This means that most of the farmers were not very old. Results further revealed that 80% of the households were headed by males.

Education level of the head was divided into no education, primary, secondary and tertiary. About 58% of household heads attained primary education while only 26% and 4% attained secondary and tertiary education respectively. Only 22% of households had non-educated household heads. This shows that few farmers in this sample did attain tertiary education. On average, the hectares of land cultivated was 2.5 hectares. About 6% of households practised CF while 7% of households used MTR. Only 3% of households owned rippers while 13% owned trained oxen. The mean for Tropical livestock units was 3.86. Moreover, 18% of households hired ADP to use on their plots. On average, the net off farm income indicated a mean of 6,549.8 Zambian Kwacha for the whole sample. The longest distances from the nearest agro dealer, agriculture camp office and seller of veterinary products were 24, 45 and 36.94km respectively. The mean distances were 1.44km, 0.84km and 0.73km from the nearest agro dealer, agriculture camp office and seller of veterinary products respectively.

Institutional factors show that on average, about 28% of households received CF advice and 17% had access to loans. This shows that very few households received advice on CF technologies. Moreover, only a few had access to loans.

Table 4. Descriptive Statistics of Sampled Households by Adoption of Animal Draught Power

VARIABLE NAMES	ANIMAL DRAUGHT POWER						
	Whole sample		**Adopters**		**Non adopters**		**T test and Chi-square test**
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	
Farmer and Farm characteristics							
Labour (Adult equivalent)	4.99	2.26	5.25	2.41	4.79	2.12	-11.87**
Age (years)	47.62	14.76	47.34	14.65	47.82	14.84	-1.89
Gender(=1 if male, 0 o/w)	0.80	0.40	0.82	0.38	0.79	0.41	29.89***
No education (=1 if yes, 0 o/w)	0.22	0.41	0.14	0.23	0.12	0.20	0.58
Primary education of head(=1 if yes, 0 o/w)	0.58	0.49	0.57	0.49	0.58	0.49	0.34
Secondary education of head(=1 if yes, 0 o/w)	0.26	0.44	0.26	0.44	0.26	0.44	0.38
Tertiary education of head(=1 if yes, 0 o/w)	0.04	0.19	0.03	0.18	0.04	0.19	5.82**
Hectares of land cultivated	2.48	2.55	3.40	3.17	1.82	1.70	-35.08**
Use of CF (=1, if yes, 0 o/w))	0.06	0.24	0.10	0.30	0.03	0.17	358.67***
Use ripping (=1, if yes, 0 o/w)	0.07	0.26	0.17	0.38	0.00	0.07	1400***
Own a ripper (=1, if yes, 0 o/w)	0.03	0.17	0.06	0.24	0.00	0.07	412.10***
Ownership of trained oxen (=1 if yes, 0 o/w)	0.13	0.33	0.28	0.45	0.01	0.12	2300***
Tropical Livestock Units (TLU)	3.86	10.94	7.43	14.72	1.28	5.78	-30.62***
Hire ADP (=1, if yes, 0 o/w)	0.18	0.39	0.43	0.50	0.00	0.00	4400***
Net off farm income(kwacha)	6549.8	25131.5	5884.8	20022.5	7032.1	28256.5	10.31**
Distance to nearest agro dealer(km)	1.44	1.73	1.42	1.42	1.45	1.92	1.11
Distance to nearest camp office(km)	0.84	1.31	0.78	1.12	0.88	1.43	4.88**
Distance to nearest Vet seller (km)	0.72	1.46	0.69	1.30	0.74	1.57	1.86
Institutional Factors							
Receive CF advice (=1, if yes, 0 o/w)	0.28	0.45	0.31	0.46	0.27	0.44	29.73***
Loan access (=1, if yes, 0 o/w)	0.17	0.38	0.25	0.43	0.11	0.32	452.86***
Location factors							
Central(=1, if yes, 0 o/w)	0.09	0.29	0.14	0.35	0.05	0.22	358.34***
Copperbelt(=1, if yes, 0 o/w)	0.07	0.26	0.03	0.17	0.11	0.31	307.28***
Eastern(=1, if yes, 0 o/w)	0.24	0.43	0.34	0.48	0.16	0.37	603.44***
Luapula(=1, if yes, 0 o/w)	0.10	0.29	0.00	0.04	0.16	0.37	1100***
Lusaka(=1, if yes, 0 o/w)	0.04	0.19	0.03	.181	0.04	0.20	5.50**
Muchinga(=1, if yes, 0 o/w)	0.07	0.26	0.01	.080	0.12	0.33	690.14***
Northern(=1, if yes, 0 o/w)	0.11	0.31	0.02	.149	0.17	0.38	799.32***
Northwestern(=1, if yes, 0 o/w)	0.07	0.26	0.01	0.09	0.12	0.32	628.65***
Southern(=1, if yes, 0 o/w)	0.12	.330	0.28	0.45	0.01	.114	2200***
Western(=1, if yes, 0 o/w)	0.08	.278	0.14	0.34	0.05	0.210	368.65***
Total Sample	**14,213**		**5,975**		**8,238**		

Mean differences between sub-samples tested by unequal-variance t test for continuous variables, Significance level ** = 5%

Persons chi square test of independence for categorical variables. Significance level ***=1%, **=5%

For the locational factors, the percentage distribution of households from all the provinces was as follows Central (9%), Copperbelt (7%), Eastern (24%), Luapula (10%), Lusaka (4%), Muchinga (7%), Northern (11%), North Western (7%), Southern (12%) and Western (8%). It could be observed that the highest number of households was from Eastern province followed by Southern and then Northern, with the least number of households coming from Lusaka province.

The Table 4 also shows descriptive statistics for adopters and non-adopters of ADP. The t test was done to determine whether there is a significant difference between the means of the two groups of adopters and non-adopters for continuous variables and the chi-square test was used for categorical variables.

From the farmer and farm characteristics, labour, measured using the adult equivalent, indicated that adopters had a mean of 5.2 compared to 4.8 for non-adopters. The mean age of the household age was almost the same for both groups, 47 for adopters and 48 for non-adopters. This was the same for the whole sample.

About 82% of households were male headed for adopters and about 79% were male headed for non-adopters. Attainment of primary, secondary and tertiary education for adopters was at 57%, 26% and 3% respectively. Moreover, 14% of adopters did not attain any education. Similarly, non-adopters no education, primary, secondary and tertiary education were at 58%, 26% and 4% respectively. Only 12% of non- adopters had no education. These statistics show that there were few adopters and non-adopters of ADP as the education level increased. Results also indicate that most farmers attained primary education. Adopters had more hectares cultivated compared to non-adopters with a mean of 3.4 hectares for adopters and 1.8 hectares for non-adopters. This is probably because adopters of ADP cultivate more land as a result of using animals with either a plough or ripper, making it less labour intense.

Among those practicing conservation farming, 10% and 3% were adopters and non-adopters respectively. Out of those that practiced ripping, 17% were adopters and only 3% were non-adopters and 6% of adopters owned a ripper on average. The mean for TLU was 7.43 for adopters and 1.28 for non- adopters indicating a greater number of livestock for adopters. Among those that adopted ADP, 43% hired ADP on average. The net off farm income average was ZMW5,885 for adopters and ZMW7,032 for non- adopters indicating that non-adopters had a higher net off farm income compared to adopters. The mean distances to the nearest agro dealer, agriculture camp office and seller of veterinary products were 1.4km, 0.8km and 0.7km for adopters and 1.4km,0.9km and 0.7km for non-adopters, respectively. There was not much difference in values for the mean distances for the adopters and non-adopters of ADP.

For institutional factors, on average, about 31% of adopters received advice on CF while 27% of non-adopters received CF advice. Moreover, 25% of adopters of ADP had access to loans while only 11% of non-adopters had access to loans.

Locational factors indicated that the percentage distribution of the households in the Provinces were as follows for adopters: Central (14%), Copperbelt (3%), Eastern (34%), Luapula (0%), Lusaka (3%), Muchinga (1%), Northern (2%), North-western (1%), Southern (28%) and Western (14%). It could be observed that the highest number of adopters was from Eastern province followed by Southern and Northern, with the least number of households coming from Luapula Province.

All characteristics observed for the t test portrayed differences between the two groups of adopters and non-adopters of ADP, except for age, distance to nearest agro dealer and distance to nearest seller of veterinary products. The chi square test results portrayed no significant differences between the two groups of adopters and non-adopters in no education, primary and secondary education. All other variables were significant for the chi square test.

Table 5 shows the descriptive statistics of adopters and non-adopters of MTR (Minimum Tillage Ripping). Farmer and farm characteristics show that on average, the labour availability, measured by the adult equivalent was approximately 5 for both adopters and non-adopters of MTR. The mean age of the household head was 44 for adopters and 47 for non-adopters. This means that the household heads were not very old. About 82% of households were male headed for adopters and about 80% for non-adopters. The four categories of education for MTR had similar results as those for ADP, indicating that the majority of farmers were in the category of primary education for both adopters and non-adopters. On average, households that attained no education, primary, secondary and tertiary education were about 12%, 58%, 26% and 4% respectively for non-adopters of MTR. The mean of the hectares cultivated was 2.97 hectares for adopters and 2.6 for non-adopters. This means that adopters of MTR cultivated slightly more land than non-adopters.

Moreover, about 13% of adopters owned rippers while only 2% of non-adopters owned rippers. This showed that there were farmers that owned rippers but did not use them.

Table 5. Descriptive Statistics of Sampled Households by Adoption of Minimum Tillage Ripping

VARIABLE NAMES	MINIMUM TILLAGE RIPPING						T test and Chi-square test
	Whole sample		Adopters		Non adopters		
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	
Farmer and Farm characteristics							
Labour (Adult equivalent)	4.99	2.26	4.83	2.23	5.00	2.26	2.334***
Age of the household head (years)	47.62	14.76	44.72	14.44	47.85	14.76	6.783***
Male headed household (=1, if male, 0 o/w)	0.80	0.40	0.82	0.39	0.80	0.40	0.13
No education (=1, if yes, 0 o/w)	0.22	0.41	0.13	0.34	0.12	0.23	0.58
Primary education (=1, if yes, 0 o/w)	0.58	0.49	0.57	0.50	0.58	0.49	0.44
Secondary education (=1, if yes, 0 o/w)	0.26	0.44	0.26	0.44	0.26	0.44	0.89
Tertiary education o (=1, if yes, 0 o/w)	0.04	0.19	0.04	0.19	0.04	0.19	0.75
Hectares of land cultivated	2.48	2.55	2.97	2.60	2.44	2.54	-6.38***
Own a ripper (=1, if yes, 0 o/w)	0.03	0.17	0.13	0.33	0.02	0.14	383.02***
Ownership of trained oxen (=1, if yes, 0 o/w)	0.13	0.33	0.19	0.39	0.12	0.33	46.59***
Tropical Livestock Units (TLU)	3.86	10.94	4.10	11.36	3.84	10.91	-0.70***
Hire ADP (=1, if yes, 0 o/w)	0.18	.387	0.77	0.42	0.14	0.34	2700***
Net off farm income (Kwacha)	6549.8	25131.5	5284	17580.6	6652	25642	12.443***
Distance to nearest agro dealer (km)	1.44	1.73	1.28	1.43	1.45	1.75	-4.54***
Distance to nearest camp office (km)	0.84	1.31	0.71	0.95	0.85	1.33	4.45***
Distance to nearest Vet seller (km)	0.72	1.46	0.89	1.28	0.70	1.48	3.59***
Institutional Factors							
Receive CF advice (=1, if yes, 0 o/w)	0.28	0.45	0.40	0.49	0.28	0.45	75.72***
Loan access (=1, if yes, 0 o/w)	0.17	0.38	0.29	0.45	0.16	0.37	109.08***
Location factors							
Central(=1, if yes, 0 o/w)	0.09	0.29	0.12	0.33	0.09	0.28	15.71***
Copperbelt(=1, if yes, 0 o/w)	0.07	0.26	0.04	0.19	0.08	0.27	23.76***
Eastern(=1, if yes, 0 o/w)	0.24	0.43	0.38	0.49	0.23	0.42	129.98***
Luapula(=1, if yes, 0 o/w)	0.10	0.29	0.01	0.08	0.10	0.30	105.02***
Lusaka(=1, if yes, 0 o/w)	0.04	0.19	0.04	0.21	0.04	0.19	1.05
Muchinga(=1, if yes, 0 o/w)	0.07	0.26	0.01	0.09	0.08	0.27	72.21***
Northern(=1, if yes, 0 o/w)	0.11	0.31	0.02	0.12	0.12	0.32	103.48***
Northwestern(=1, if yes, 0 o/w)	0.07	0.26	0.01	0.10	0.08	0.26	63.98***
Southern(=1, if yes, 0 o/w)	0.12	0.33	0.26	0.44	0.11	0.32	193.55***
Western(=1, if yes, 0 o/w)	0.08	0.28	0.11	0.32	0.08	0.27	12.24***
Total	**14213**		**1063**		**13150**		

Mean differences between sub-samples tested by unequal-variance t test for continuous variables, Significance level ** = 5%

Persons chi square test of independence for categorical variables. Significance level ***=1%, **=5%

There were 19% adopters of MTR that owned trained oxen and 12% for the non-adopters. However, the whole sample showed that very few farmers owed trained oxen, as low as 13%. On average, the TLU for adopters and non-adopters was 4.10 and 3.84 respectively. This shows that non-adopters had slightly more livestock than adopters of MTR. There were more adopters of MTR that hired ADP to use on their plots indicating about 77% of households, compared to 14% of the non-adopters on average. The net off farm income was, on average, similar between the two groups, being ZMW5,324 for adopters and ZMW5,606 for non-adopters. The distances to the nearest agro dealer, agriculture camp office and the seller of veterinary products on average were 1.3km,0.71km and 0.9km for adopters and 1.4km, 0.9km and 0.7 for non-adopters, respectively.

For the institutional factors, about 40% of adopters and 28% of non-adopters received advice on conservation farming, on average. Only 29% of adopters had access to loans while only 16 % of non-adopters had access to loans on average.

The Locational factors indicated that the percentage of the adopters from the provinces were: Central (12%), Copperbelt (4%), Eastern (38%), Luapula (1%), Lusaka (4%), Muchinga (1%), Northern (2%), North western (1%), Southern (26%) and Western (11%). It was observed that the highest number of adopters of MTR was from Eastern province followed by Southern and then Central province, with the least number of adopters coming from Luapula, North Western and Muchinga Provinces.

The t test results revealed that there were significant differences between the adopters and non-adopters of MTR for all variables. The chi square test portrayed significant results for all categorical variables apart from the three categories of education and one locational characteristic of Lusaka province.

Figure 3 shows that ripping use reduced from 5.3% to 2% between 2012 and 2015. The adoption of conservation farming portrays similar results with a decrease from 6.2% to 5.8% between the two years. The major reason for these results is not known, but farmers could have dis-adopted ripping and conservation farming in general. More analysis will be needed in order to determine why this is so. The use of ADP increased from 40.3% to 43.8% while the hire of ADP increased from 16.8% to 19.8%, respectively, between 2012 and 2015. This shows that there has been a slight increase in the use and hire of ADP. This may be because farmers find benefits from keeping cattle and hiring ADP for use on the farm, hence the adoption.

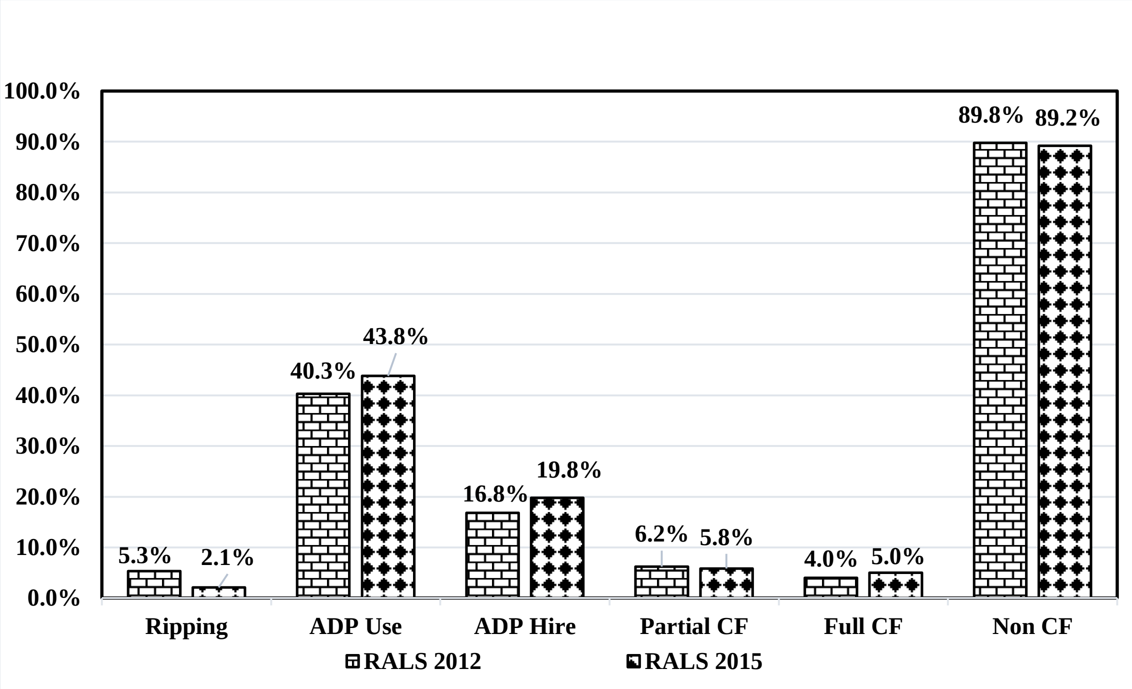

Figure 3: Statistics on Adoption of Ripping, ADP and CF by year

Source: Authors Own Computation; Data from RALS 2012 and 2015

5.3 Econometric Results

The econometric analysis for this thesis was done in stages. Firstly, the pooled triple hurdle model was run and the results presented in a table. This was done to show which variables were significant or not for each stage, without any conditions.

Secondly, the conditional average partial effects were computed and the triple hurdle model was run in such a way that the first stage was a Probit regression of adoption of ADP, the second stage was the Probit regression of the adoption of ripping on a condition that the farmer used ADP. The third stage was the lognormal regression for hectares under ripping for farmers that adopted ADP and ripping. The average partial effects were computed in order to determine the factors influencing the adoption of ADP, ripping on condition that a farmer uses ADP and the intensity of ripping if the farmer adopts ADP and ripping.

Lastly, in order to determine the factors influencing the adoption of ADP, Ripping and the hectares under ripping irrespective of whether the farmer adopted ADP and ripping, the pooled triple hurdle model and the Correlated Random Effects (CRE) Triple Hurdle Model was run. This means that factors that influence non-adopters to adopt these technologies were also determined since they were also included in the sample. The unconditional Average Partial Effects were computed for the pooled Triple hurdle model in order to determine the effect of a given determinant on the expected value of hectares under ripping, not conditional on using ADP or ripping. The unconditional APEs for the CRE triple hurdle model were computed. The CRE produces the between and within household effects of results which allow us to interpret the effect of a covariate both from changes within a given household (within effect) and from differences between two households (between effect). The results for the pooled and CRE triple hurdle model were then compared.

5.3.1 Triple Hurdle Model Results

Table 6 shows the results of the pooled triple hurdle model. Column (i) shows the results for Probit regression of the adoption of ADP while column (ii) shows the results for the Probit regression of the adoption of ripping. Column (iii) shows the results of the lognormal model for hectares under ripping. Negative signs for the coefficients mean that the variable has a negative relationship to the likelihood of adoption of ADP, ripping or hectares under ripping, respective of each stage. The reverse is true for positive signs of the coefficient estimates. The log likelihood was -9447.93 and the standard errors were in the parenthesis, with significance levels of 1%,5% and 10% being denoted by *, **, and *** respectively. To start with, a household being male headed had a positive relationship for all the three stages but was only statistically significant for the first stage of the adoption of ADP.

The labour availability was significant for all the stages but portrayed a negative relationship to the likelihood of adoption of ripping. The age of the household head had a negative relationship with the likelihood of adopting ADP and ripping, significant at 10% significance level, but a positive and insignificant relationship with the hectares under ripping. The square of the age was insignificant for all the three stages. The primary education variable had a negative relationship for all stages and was significant only for the first and third stage with 5% and 10% significance level respectively. This means that compared to those with no education, farmers with primary education were less likely to adopt these technologies.

Table 6. Pooled Triple Hurdle Model Results

	(i)	(ii)	(iii)
	Tier1	Tier2	Tier3
	ADP	Ripping	Ha under ripping
Variables	Probit	Probit	Lognormal
Farmer and farm characteristics			
Male headed household	0.108***	0.020	0.102
	(0.036)	(0.056)	(0.063)
Labour	0.015**	-0.041***	0.028**
	(0.007)	(0.010)	(0.013)
Age of head	-0.010*	-0.016*	0.013
	(0.006)	(0.009)	(0.010)
Age squared	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Primary education	-0.083**	-0.000	-0.135*
	(0.041)	(0.063)	(0.070)
Secondary education	-0.124**	-0.021	-0.052
	(0.048)	(0.072)	(0.079)
Tertiary education	-0.148*	0.129	-0.127
	(0.086)	(0.125)	(0.133)
Hectares cultivated	0.184***	-0.025***	0.236***
	(0.007)	(0.009)	(0.010)
Tropical Livestock Units		-0.017***	-0.003
		(0.002)	(0.002)
Ownership of a ripper	0.617***	0.873***	-0.495***
	(0.101)	(0.076)	(0.139)
Distance to vet seller	-0.046***	0.083***	-0.011
	(0.012)	(0.016)	(0.026)
Distance to agro dealer	-0.016	-0.061***	0.036*
	(0.010)	(0.017)	(0.022)
Distance to agric camp office	-0.001	-0.030	-0.031
	(0.012)	(0.022)	(0.028)
Institutional factors			
CF advice	-0.050	0.160***	0.143***
	(0.034)	(0.047)	(0.055)
Fertilizer price per kg	0.014	0.040**	
	(0.013)	(0.019)	
Loan access	0.066*	0.096*	-0.025
	(0.038)	(0.050)	(0.055)

Note: Provincial Dummies were included in the model. standard errors in parenthesis; ***, **, * Significant at 1%, 5%, and 10% respectively

Secondary education also portrayed a negative relationship to the likelihood of adoption of ADP, ripping and the hectares under ripping, but only significant in the first stage at 5%. Tertiary education was significant only for the first stage at 10% and portrayed a negative relationship in the first and third stage but not in the second stage. These education results mean that highly educated farmers do not usually adopt these technologies. Hectares cultivated was significant at 1% for all the stages but portrayed a negative relationship to the likelihood of adoption of ripping. The Tropical Livestock Units had a negative and significant effect on the likelihood of adoption of ripping. The ownership of a ripper was significant at 1% for all the three stages but had a positive effect on the likelihood of adoption of ADP and ripping but not on the hectares under ripping.

The distance to the nearest seller of veterinary products was significant at 1% for stage one and two but not stage three. Increase in the distance to the nearest seller of veterinary products is likely to negatively affect adoption of ADP and the hectares under ripping but positively affect the likelihood of adoption of ripping. The distance to the nearest agro dealer, significant for stage two at 1% and stage three at 10%, portrayed a negative relationship to the likelihood of adoption of ADP and ripping, but not for the hectares under ripping. The distance to the nearest agriculture camp office portrayed a negative but insignificant relationship for all the three stages.

For the institutional factors, the advice on CF positively influenced the likelihood of adoption of ripping and the hectares under ripping, significant at 1% significance level, but had a negative relationship with the adoption of ADP, though not statistically significant. Price of fertilizer per kg positively influenced the likelihood of adoption of ADP and ripping though only significant for ripping at 5%. The loan access had a positive influence on the likelihood of adoption of ADP and ripping with a 10% significance level, but had a negative and insignificant relationship with hectares under ripping.

For the locational factors, the different provinces portrayed significant results for all technologies with Luapula province being the base province, apart from Lusaka province for ripping and Muchinga province for hectares under ripping, that showed insignificant results.

5.3.2 Average Partial effects for adoption of ADP, ripping and the intensity of ripping

Table 7 shows the conditional APEs for the triple hurdle model, with the factors influencing the adoption of ADP in the first column, the adoption of ripping for farmers that have ADP in the second column and the intensity of ripping for farmers that rip and with ADP in the third column. The table shows the Average Partial Effects (APEs) as the coefficients, the standard errors in the parenthesis and the significance level denoted by the asterisks. The results give an indication of the likelihood of farming households to adopt ADP, Ripping and the intensity of ripping in terms of the farm and farmer characteristics, institutional factors and locational characteristics.

The factors found to be significant in influencing the adoption ADP include male headed households, labour availability, age of the household head, the hectares cultivated, ownership of a ripper and the distance to the nearest seller of veterinary products. The factors that were significant in affecting adoption of ripping for farmers with ADP include the age of the household head, labour availability, hectares cultivated, Ownership of a ripper, TLU, distances to the nearest seller of veterinary products and agro dealer, CF advice, price of fertilizer and loan access. For the intensity of ripping, significant factors were male headed households, primary education, hectares cultivated, CF advice and distance to the nearest agriculture camp office.

5.3.2.1 Adoption of ADP

Results for the adoption of ADP in the first column of Table 7 below indicates that male-headed households were 2.3 percentage points more likely to use ADP, on average, than female-headed households and this was statistically significant at 1%. Similar results were found by Chimonyo *et al.*, (1999) indicating that use of animal draught power by female headed households was limited.

This result has an intuitive explanation in that male headed households are able to manage the requirement of using ADP such as labour and resources more than women. Results further indicated that a one unit increase in the labour availability will increase the likelihood of adoption of ADP by 0.3 percentage points on average, and this is statistically significant at 5%. This is in line with the findings from Savadongo *et al.*, (1998), who found that size of the household was positively related to adoption of animal traction technology.

Table 7. Determinants of Adoption of ADP, Ripping and Intensity of Ripping

VARIABLES	ADP	Ripping	Ha under ripping
Farmer and farm characteristics			
Male headed household	0.023***	0.005	0.114*
	(0.008)	(0.013)	(0.063)
Labour	0.003**	-0.010***	0.004
	(0.002)	(0.002)	(0.012)
Age of head	-0.002*	-0.004*	0.005
	(0.001)	(0.002)	(0.010)
Age squared	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Primary education	-0.018**	-0.000	-0.137*
	(0.009)	(0.015)	(0.071)
Secondary education	-0.027**	-0.005	-0.062
	(0.010)	(0.017)	(0.080)
Tertiary education	-0.032*	0.030	-0.054
	(0.019)	(0.029)	(0.134)
Hectares cultivated	0.039***	-0.006***	0.223***
	(0.002)	(0.002)	(0.010)
Ownership of a ripper	0.132***	0.204***	-0.005
	(0.022)	(0.017)	(0.079)
Tropical Livestock Units		-0.004***	-0.048
		(0.001)	(0.079)
Institutional factors			
Distance to vet seller	-0.010***	0.019***	0.035
	(0.002)	(0.004)	(0.022)
Distance to agro dealer	-0.003	-0.014***	0.003
	(0.002)	(0.004)	(0.020)
Distance to agric camp office	-0.000	-0.007	-0.048*
	(0.003)	(0.005)	(0.028)
CF advice	-0.011	0.037***	0.226***
	(0.007)	(0.011)	(0.050)
Fertilizer price per kg	0.003	0.009**	0.014
	(0.003)	(0.004)	(0.023)
Loan access	0.014*	0.022*	0.028
	(0.008)	(0.012)	(0.054)
Joint provincial dummy	17693***	34.02***	3.99***
Log likelihood	-5401.7	-2516.1	
F- test			27.85***
Number of observations	14213	5975	1063

Probit model results for ADP and ripping adoption and Lognormal model results for Ha ripped.
Notes: APEs with standard errors in parenthesis; ***, **, * Significant at 1%, 5%, and 10% respectively

Moreover, results show that farmers with more farming experience, as proxied by age of the household head, were on average, 0.2 percentage points less likely to use ADP and this is statistically significant at the 10% level. Older farmers are less likely to use animal traction technology as their physical ability to participate actively in farming activities declines with increasing age. The three categories of education were all found to be significant in influencing adoption of ADP. Those that attained primary education were 1.8 percentage points less likely to adopt ADP on average, compared to those with no education. Those that attained secondary and tertiary education were 2.7 and 3.2 percentage points less likely to adopt ADP on average compared to those that had no education, respectively. This may be because most educated farmers do not depend solely on farming activities and do other activities to earn an income. It was observed that the likelihood of adoption reduced as the education level increased.

An increase in the hectares cultivated, which was used to measure the productiveness of the farmer, by one unit will increase the likelihood of adoption of ADP by 3.9 percentage points on average and this was statistically significant at 1%. This can be due to the fact that farmers who make maximum use of their land are more organised and willing to take up risks and new technology. The more hectares cultivated, the more the need to reduce manual labour cost through the use of ADP. Similar results concerning land were found by Makki *et al.*, (2017) indicating that ADP adoption is positively driven by the farm size.

The ownership of a ripper is likely to increase adoption of ADP by about 13.2 percentage points on average and this was statistically significant at 1% significance level. Mbata (2001) found that age of the household head was negatively related to adoption of ADP while education level, though not significant, had a negative relationship to the adoption of ADP. He further found that increase in the land use increased the adoption of ADP.

The ownership of productive assets such as a ripper also has an effect on the adoption of ADP. It was found that on average, ownership of a ripper will increase adoption of ADP by 13.2 percentage points and this was significant at 1% significance level. On average, increase in the distance to the nearest seller of veterinary products will reduce adoption of ADP by 1 percentage point and this is significant at 1% significance level. The distances to the nearest agro dealer and to the nearest seller of veterinary products had a negative relationship to the adoption of ADP but this was not statistically significant for both. Moreover, increase in the accessibility of loans by one household will increase the likelihood of adoption of ADP by 1.4 percentage points, on average. Mbata (2001), found that access to credit was positively related with the adoption of ADP. The joint test for the provincial dummies indicated that there were significant differences in the adoption of ADP in the different provinces and this was significant at 1% significance level.

5.3.2.2 Adoption of Ripping

Results from the adoption of ripping in the second column of Table 7 for farmers with ADP indicated that male headed households were 0.5 percentage points more likely to adopt ripping compared to the female headed households though this was not statistically significant. The labour availability had a negative relationship to the adoption of ripping. Increase in the labour availability by one unit is less likely to increase adoption of ripping by1 percentage point on average and this was statistically significant at 1%. This may be because households that use ripping do not require much labour compared to those that do not use ripping.

Increase in the age of the household head by one year will reduce the likelihood of adoption of ripping by 0.4 percentage points on average, statistically significant at 10% significance level. This is as expected because the older the household head, the less willing they will be to try new technologies. All the education categories had a negative relationship to the adoption of ripping apart from tertiary education, though all these categories were not statistically significant. Increase in the hectares cultivated by one hectare will reduce the likelihood of adoption of ripping by 0.6 percentage points and this is statistically significant at 1%. This result was not as expected.

For every ripper owned, the likelihood of adoption of ripping, on average, will increase by 20.4 percentage points and this is significant at 1% significance level. Increase in the TLU by one unit will reduce the likelihood of adoption of ripping by 0.4 percentage points on average, statistically significant at 1% significance level. For the distances, increase in the distance to the nearest seller of veterinary products by 1km will increase the likelihood of adoption by 1.9 percentage points on average, statistically significant at 1% significance level. It is expected that the further away the seller of veterinary products is, the less likely that farmers will adopt the technology, but this is not the case. This may be because farmers still adopt ripping using ADP, irrespective of the distance to the nearest seller of veterinary products. Furthermore, increase in the distance to the nearest agro dealer will reduce the likelihood of adoption by 1.4 percentage points on average. The distance to the nearest agriculture camp office portrayed a negative relationship to the adoption of ripping though not statistically significant. Increase in the advice on CF will increase the likelihood of adoption by 3.7 percentage points on average, statistically significant at 1% significance level. This is expected as more CF advice dissemination will enable awareness of the technology and thus adoption. The price of fertilizer per kg had a positive relationship to the adoption of ripping. Increase in the price of fertilizer by 1 kwacha will increase the likelihood of adoption by 0.9 percentage points on average and this is significant at 5%. For every additional household that had access to loans, the likelihood of adoption of ripping increases by 2.2 percentage points on average, statistically significant at 10%. The provincial dummies showed that there were some significant differences in the adoption of ripping for farmers with ADP across the different provinces.

5.3.2.3 Intensity of Ripping for farmers with ADP

Results from the third column of Table 7 indicate that for every additional male headed household, the hectares under ripping increases, on average by 0.114 hectares compared to the female headed households. The labour availability and age had a positive but insignificant relationship to area under ripping. All education categories had a negative relationship to the area under ripping and only primary education was significant at 10%.

Compared to those with no education, household heads that attained primary education were less likely to increase area under ripping by 0.137 hectares. Increase in the hectares cultivated will increase the area under ripping by 0.223 hectares, on average, statistically significant at 1%. The ownership of a ripper had a negative but insignificant relationship to the hectares under ripping. The distance to the nearest seller of veterinary products had a positive but insignificant effect on the area under ripping. Moreover, increase in the distance to the nearest agriculture camp office by one Kilometre will reduce the area under ripping by 0.005 hectares on average, statistically significant at 10%. Increase in CF advice will on average increase the area under ripping by 0.226 hectares.

5.3.3 Unconditional Average Partial effects

The unconditional APE in this case, is the average partial effect of a given determinant on the expected value of hectares under ripping, not conditional on using draught power or ripping. After running the triple hurdle model in Stata 14, the Inverse Mills Ratio (IMR1) was generated to test the null hypothesis that the errors between stage one and two were conditionally uncorrelated. The IMR was not significant, with a *p*-value of 0.37 and so it was not included in the second stage. However, in testing the null hypothesis that the errors between stage two and three were conditionally uncorrelated, the second IMR2 was generated. The generated IMR2 was not significant with a *p*-value of 0.55 and so it was not included in the third stage. One exclusivity restriction was imposed on the price of fertilizer per kg which is statistically significant in stage 2 but not in stage three, if included in the model. The coefficient estimates for all the three stages in Table 7, are not partial effects because of the non-linearity of the likelihood function. The direction and statistical significance was analysed for each stage based on these results.

APEs were computed manually for the unconditional expected value on the area under ripping. A comparison was made between the two as shown in Table 8 includes the within and between household effects. Delta-method *p*-values are in parentheses and *** indicates the significance level at 1%.

Overall, results suggest that the magnitude of the effect is fairly small when using the pooled estimator which is essentially an aggregated estimate of the within and between-household effects. The CRE results on the other hand, disentangle between-household and within-household effects allowing for a more nuanced understanding of how determinants explain variation in the outcome. A joint test was done on the time averaged variables used to construct the Mundlak-Chamberlain device and the chi-square test statistic was $\chi^2_{(44)} = 352.77$ that was statistically significant at 1%. This means that the null hypothesis that these time averaged variables are jointly equal to zero was strongly rejected (Wooldridge, 2010). This test for the Mundlak-Chamberlain device variables implies that the unobserved heterogeneity is significantly correlated with the observed explanatory variables in the model (Burke and Jayne, 2014).

The age of the household head showed a negative and significant within household effect on the hectares ripped and for the pooled estimator only that the effect was less for the pooled results. The within effect suggests that for every increase in age by one year, the unconditional expected value of hectares ripped will reduce by 0.54 hectares.

Table 8. Average Partial Effect (APE) Estimates from the Triple-Hurdle Model on the Unconditional Expected Value of Hectares Under Ripping

	Pooled estimator	**CRE estimator**	
Variables		**Within-hh effect**	**Between-hh effect**
Age of the household head	-0.021***	-0.54***	0.70***
	(0.00)	(0.00)	(0.00)
Hectares cultivated	0.202***	2.06***	-0.91***
	(0.00)	(0.00)	(0.00)
Primary	-0.16***	0.43***	-1.06***
	(0.00)	(0.00)	(0.00)
Secondary	-0.13***	1.79***	-1.82***
	(0.00)	(0.00)	(0.00)
Tertiary	0.22***	4.85***	-2.90 ***
	(0.00)	(0.00)	(0.00)
Labour	-0.085 ***	-1.37 ***	1.19***
	(0.00)	(0.00)	(0.00)
Gender (1=male)	0.18***	3.55***	-2.33***
	(0.00)	(0.00)	(0.00)
Own a ripper	1.98***	10.61***	2.04***
	(0.00)	(0.00)	(0.00)
Tropical Livestock Units	-0.10***	-0.27***	3.86 ***
	(0.00)	(0.00)	(0.00)
Distance to nearest agro dealer	-0.13***	-0.86***	1.18***
	(0.00)	(0.00)	(0.00)
Distance to nearest vet seller	0.22***	2.25***	-3.75***
	(0.00)	(0.00)	(0.00)
Distance to nearest camp office	-0.12 ***	-0.65***	0.18***
	(0.00)	(0.00)	(0.00)
CF advice	0.61***	4.84***	-7.95***
	(0.00)	(0.00)	(0.00)
Loan access	0.25 ***	0.098***	1.97 ***
	(0.00)	(0.00)	(0.00)
Price of fertilizer per Kg	0.115***	1.99***	-2.24***
	(0.00)	(0.00)	(0.00)

Notes: Unconditional APEs with Delta-method *p*-values in parentheses; *** Significant at 1%

As the household head gets older, there is increased risk aversion and less engagement in farming activities, hence reduction in hectares ripped. Farmers find other means of making income or become dependent on the children. Young farmers are more willing to take up risk than older farmers

The between household effect for age showed a positive effect on the hectares ripped. All else constant, a household that is older will be more likely to increase the hectares ripped by 0.7 hectares, than a similar household that is younger. A household with a one year older head means that the household has more experience in farming and is likely to try new farming methods such as ripping.

The CRE results suggest that households with more land under cultivation are expected to rip less hectares on average compared to similar households with less land under cultivation. However, as small farms grow, we find the expected quantity of ripped hectarage increases. The within effect for the hectares cultivated showed that an increase in the hectares cultivated by one hectare will increase the hectares ripped by 2.1 hectares for a household, all else constant. This means that as the farm for the household grows overtime, more land is likely to be allocated to ripping.

For the between household effect, a household that had a one unit more in hectares cultivated is less likely to increase the hectares ripped compared to a similar household with one unit less in hectares cultivated, with the unconditional expected value of hectares ripped being 0.9 hectares. This implies that households that increase the hectares cultivated are less likely to allocate it to ripping compared to a similar household that has one unit less in hectares cultivated. The reason for this may be because farmers that increase the hectarage may be less willing to try out new technologies such as ripping and still stick to the other farming methods which can show benefits within a short time.

The between effect for the three education variables portrayed a negative relationship to the hectares ripped, suggesting that an increase in the level of primary, secondary and tertiary education by one unit, all else constant, for a given household is less likely to increase the hectares ripped compared to a similar household with one unit less in primary, secondary and tertiary education. This means that households with more education are less likely to increase the hectares ripped compared to similar households with a one unit less in education. This suggests that educated households probably venture into other income generating activities such as businesses or work other than ripping. The unconditional expected values of hectares ripped for primary, secondary and tertiary education for the between effects were 1.1, 1.8 and 2.9 respectively. The within household effect on the other hand, was analysed for the three education variables because it was assumed that there was significant change in these variables within the panel period. The within effect showed a positive effect on the hectares ripped. This means that as the education level of the household increases, the household is likely to increase the hectares ripped overtime, all else constant. This implies that as households become more educated overtime, they understand and realise the importance of ripping and increase the hectares ripped. The unconditional expected values of hectares ripped for primary, secondary and tertiary education for the within effects were 0.43, 1.79 and 4.85 respectively.

The Labour availability showed a negative relationship to the hectares ripped for both the pooled and within effects. The within effect indicated that an increase in the labour availability by one unit is more likely to reduce the hectares ripped by 1.4 hectares for a given household. The adult equivalent, use as a proxy for labour availability, suggests that as the labour availability in the household increases, there is less land put under ripping. This makes sense in that there is enough labour available to work on the farm and farmers will not use oxen to rip more land, but instead use the available labour to work on the farm. Moreover, an increase in the labour availability for a household by one unit is likely to increase the hectares ripped compared to a similar household with one unit less in labour. This was the relationship portrayed by the between household effect. This shows that households with more labour, are more likely to increase the hectares under ripping, compared to similar households with less labour. In a given period, a household that increases the labour availability will need more food for the household and thus will increase the use of land that will provide this food. This means that the household will increase the hectares ripped.

The within household effect of male headed households indicated that being a male headed household will increase the hectares under ripping by 3.5. Males are considered as the overall decision makers in the house and are the providers of the household, therefore, they work hard to provide food for the household by farming more, hence increasing the hectares ripped. The between household effect showed that a household, being male headed will reduce the likelihood of increasing the hectares under ripping by 2.3 hectares, compared to a similar female headed household. Females are considered to be more active in farming activities than males (FAO, 1998) and are thus more likely to increase the hectares ripped.

For every increase in the ownership of a ripper by one unit, the unconditional expected value of hectares ripped will increase by 2 hectares for the pooled results and 10.1 hectares for the within household effect. A household that had a unit more of a ripper was found to likely increase the hectares under ripping by 2 hectares, compared to a similar household that had a unit less of a ripper. This shows that ownership of a ripper encourages an increase in the hectares ripped for households. Most farmers are poor and require incentives for them to up production of crop produce.

The TLU estimates for the pooled and within household effects were all negative. Increase in TLU in a household by one unit is likely to reduce the hectares under ripping by 0.10 and 0.27 hectares for the pooled and within estimates respectively. A household owning one unit more of livestock is more likely to increase the hectares ripped by 3.86 hectares compared to a similar household that had a one unit less of livestock. This shows that farmers with more livestock are probably more involved in ripping as they can divide their livestock across many farming activities.

The distances to the nearest agro dealer and agriculture camp office had negative effects on the hectares ripped for both the pooled and within effects, with the unconditional APEs taking on the values of 0.1. The between effect showed that Increase in the distance to the nearest agro dealer and agriculture camp office by one kilo meter by a household is likely to increase the hectares ripped by 1.2 and 0.2 hectares respectively, compared to a similar household that was a km less away from the nearest agro dealer and agriculture camp office. This case is expected as no matter the distances to the nearest agro dealer and camp office, the farmer will be forced to go to the agro dealer for inputs and to the agriculture camp office for information.

The distance to the nearest seller of veterinary products showed a positive pooled and within effect with values of 0.2 and 2.2, respectively. A household further away from the distance to the nearest seller of veterinary products by a kilometre will reduce the hectares ripped by 3.7 compared to a similar household with a kilometre less away. Farmers get veterinary drugs for the animals used in ripping. Therefore, the further the veterinary products seller, the less accessible the drugs needed for the animals used in ripping.

For every increase in conservation farming advice by one unit for a given household, the unconditional expected value of hectares ripped is expected to increase. Overtime as the conservation farming advice increases, a given household is expected to follow this advice and thus increase the hectares ripped. Conservation farming advice showed that its increase is likely to increase the hectares ripped by 0.6 and 4.8 for the pooled and within estimators respectively. The between effect showed that a household that received one more unit of CF advice is less likely to increase the hectares ripped compared to a similar household that received a unit less of CF advice. Households may be hostile to change and no matter the advice given, they might not practice it. This is when cultural issues come into play.

All the estimates of loan access had a positive relationship to hectares ripped. Increase in the loan access is likely to increase the hectares ripped by 0.2 and 0.1 for the pooled and within estimator, respectively. A household that had one unit more of access to loans was highly likely to increase the hectares ripped by 1.97 compared to a similar household that had one unit less in loan access. This makes sense as loans create incentives for the farmers to take up risks and invest in new technology. Increase in the price of fertilizer per kg by one unit is likely to increase the hectares ripped by 0.1 and 2 for the pooled and within effects, respectively.

The between effect indicated that increase in price of fertilizer had a negative effect on the hectares ripped, taking on the value of 2.2 hectares. This means that a household that had a one more unit increase in price of fertilizer is likely to reduce hectares ripped by 2.2 compared to a similar household that has a one unit less in price of fertilizer. Increase in Input prices affect the decision of how many hectares should be ripped for households. As these prices increase, farming becomes more costly and the farmer reacts by reducing the hectares ripped, all else constant. The within household effect suggested that increase in the price of fertilizer per kg by one unit will increase the hectares ripped for a given household. This means that overtime, the farmer will be forced to buy fertilizer and increase the hectares ripped, irrespective of the price.

These results show different effects for the between and within effects which are important for policy formulation.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter begins with the conclusions of the study where its objectives and key findings are summarized. It later presents the policy recommendations proposed based on the key findings. The chapter closes by tackling the limitations of the study and further proposes areas where future research could be conducted.

6.2 Conclusions

The overall objective of this paper was to understand the factors associated with farmer decisions to adopt ADP, ripping and the extent of ripping. The other objectives were to identify factors that affect the adoption of ADP and ripping and the intensity of ripping conditional on adoption decision of ADP by smallholder farmers in Zambia and also to determine the factors that influence the change in the mean level of adoption (hectares ripped) for the whole sample, irrespective of whether the farmer adopted ADP or ripping.

In order to achieve these objectives, this study used panel data from RALS 2012 and 2015 with a sample size of 14,213 households, with 7,130 and 7,083 households from RALS 2012 and 2015 respectively. This data was randomly collected across the country by IAPRI in collaboration with the Central Statistics Office (CSO) and the Ministry of Agriculture (MoA). Moreover, to determine the factors influencing the adoption of ADP, ripping and intensity of ripping conditional on adoption of ADP, the triple hurdle model was used with inferences made from the conditional average partial effects from each hurdle. To determine the factors influencing mean level of adoption of ripping for the entire sample of adopters and non-adopters, the Correlated Random Effects triple hurdle model was used which produced within and between household effects. Inferences were made from the Average partial effects on the unconditional expected value of hectares under ripping.

The main conclusions that can be drawn from this research are that firstly, there are a number of factors that influence the adoption of ADP. Household with more labour and non-educated heads were more likely to adopt ADP compared to educated farmers.

Male headed household are more likely to adopt ADP than female headed households. Hectares cultivated, ownership of a ripper and loan access had positive effects on the adoption of ADP while distance to the nearest seller of veterinary products and Age of the household head had a negative effect on the adoption of ADP.

Moreover, for the adoption of ripping for farmers with ADP, male headed households were more likely to adopt ripping compared to the female headed households. Other factors that positively influenced adoption of ripping were the ownership of a ripper, distance to the nearest seller of veterinary products, CF advice, price of fertilizer per kg and loan access. For the intensity of ripping, male headed households were more likely to increase the hectares under ripping compared to their female counterparts. Increase in the hectares cultivated was more likely to increase the hectares under ripping. CF advice positively influenced the hectares under ripping. However, household heads that had primary education were less likely to increase hectares under ripping compared to those with no education.

The unconditional APEs of the pooled and CRE triple hurdle model showed all factors significant at 1% significance level. The effects for the pooled estimator, which is an aggregate of the between and within effects, was fairly small compared to the within and between effects. This showed that the CRE triple hurdle model was more robust than the pooled model. The between and within effects showed contradicting effects apart from the ownership of a ripper and loan access that showed positive signs for both effects. These results show that there are differences in factors affecting changes in a given household within a given period and between households overtime, all else constant.

6.3 Recommendations

In line with the results for the adoption of ADP, this study recommends that there should be an increase in the incentives offered to farmers such as ownership of rippers and increase in loan access to farmers for the adoption to increase. The sellers of veterinary products and veterinary services should be brought closer to the farmers. Thus, in the formulation of policies involving the adoption of ADP, these factors that drive adoption should be considered.

This study also recommends that the CF advice dissemination should be intensified so that adoption of ripping will increase for adopters of ADP. Farmers should also be encouraged to have access to loans and productive assets such as rippers through the production of necessary incentives. The agro dealers should also be brought closer to the farmers in order to up adoption. These factors should be considered when formulating programmes or policies that aim at increasing the adoption of ripping using ADP as a conservation farming technology.

Furthermore, to encourage increase in the hectares under ripping, CF advice should be given more to the farmers by stakeholders such as CFU, government extension departments and others.

Moreover, results for the CRE triple hurdle model showed that there were differences in the effects between the households and within the households on the hectares ripped. However, the variables that are relevant to policy formulation in this analysis was the loan access and ownership of a ripper. These factors were found to positively influence the hectares ripped for both within the household overtime and between the households in a given period, irrespective of the farmer adopting ripping and ADP or not. Therefore, in order to encourage increase in hectares ripped for the entire population, policies that encourage farmers to have access to loans and rippers, should be formulated. Stakeholders in the agriculture sector, lending agencies and the government can be brought on board to ensure access to loans and other incentives. These results provide useful insights for policy makers and the designers of poverty reduction strategies, as well as a useful demonstration for researchers on the nuanced differences between these two dimensions of results on the hectares ripped.

6.4 Limitations of the Study

The major limitation of this study was that it relied on secondary data that may not have been designed to specifically address the question of ADP and minimum tillage use. The farmers using these technologies, especially ripping could have been under sampled. The data that was used had some missing variables that were important for the research such as the cost of hiring ADP and ripping services.

6.5 Future Research

Since both ADP and ripping are considered as technologies that can contribute to an improvement in the livelihoods of farmers, there is need for future research. Future research should consider determining the impact of adoption of ADP and ripping on the livelihoods of farmers and since there is a shift in technology, there should also be a comparison between mechanised ripping smallholder farmers and those that use ADP ripping to compare the profitability and productivity. New research is necessary to dig deeper and unearth the hidden dimension of the adoption of conservation farming technologies in Zambia.

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