DETERMINATION OF FACTORS AFFECTING ADOPTION AND IMPACT OF TILLAGE PRACTICES ON SMALLHOLDER FARMERS' MAIZE PRODUCTIVITY IN ZAMBIA

By

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DECLARATION

I, Brenda Nakamba declare that this dissertation:

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ABSTRACT

The adoption of various tillage methods has varied across the continent. This study focusses on determining the factors that influence adoption of various tillage practices and the impact of tillage methods on maize productivity in Zambia. In Zambia, prior studies have focused on making comparisons of tillage methods within the CT methods and not conventional tillage types. The previous studies on conventional tillage types have lumped all the conventional tillage types and hence the need to rigorously estimate the impact of tillage practices on maize productivity without lumping conventional tillage methods. Therefore, the conventional tillage methods that were included in this study include hand-hoeing, ploughing and ridging tillage methods.

The study uses 2012 Rural Agriculture Livelihood Survey (RALS) data collected by Indaba Agricultural Policy Research Institute (IAPRI) in collaboration with Central Statistical Office (CSO) and the Ministry of Agriculture (MOA). This data has 442 standard enumeration areas (SEAs) and administered to 8,840 smallholder farm households. The probit model was used to examine factors influencing adoption of various tillage practices. Estimation of the propensity scores and generation of balancing property was satisfied using PScore. To measure the impact of tillage methods on maize productivity, this study employed the mixed effect regression model (MRM). The MRM was necessary to account for households with multiple maize fields.

The results indicated that ploughing tillage method was the common tillage method practiced by smallholder farm households at 41.6 percent and CT was found to be the least tillage method practiced by smallholder farmer households. Results from the probit model indicate that there are various factors that influence the adoption of various tillage methods. Age and education level of household head has a strong influence on the adoption of hand-hoe. Similarly, education was found to influence the adoption of CT. The MRM indicate that smallholder farm households who practice CT would experience higher maize productivity of 8.3 percent. Ploughing tillage methods though not statistically significant was found to increase the productivity of maize by 1.9 percent while hand-hoe was found to reduce the productivity of maize by 0.2 percent.

In conclusion, smallholder farmer households with lower levels of education tend to practice more of conventional hand-hoe tillage method. On the other hand, more educated smallholder farmers adopt more of CT. Smallholder farmers in their young stage in life would adopt less of ploughing tillage method but as age progresses they began to adopt more of ploughing tillage method. Finally, the results indicate that smallholder farmer households that adopted CT realized more maize produced per hectare than they would if they had adopted any other tillage method.

Therefore, this study recommends that the promoters of CT in Zambia should continue doing so as maize produced per hectare from CT tend to be more than any other tillage method.

Key words: Conventional tillage method, conservation tillage method, maize productivity, adoption.

DEDICATION

To my dear husband, LusajoMwakalesiAmbukege,my four lovely children, Lukundo, Taizya, Suwilanji and Walusungu and my mother, Christine NanyangweSiame.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS

AER	Agro-ecological Region
ATE	Average Treatment Effect
CSO	Central Statistical Office
CA	Conservation Agriculture
CF	Conservation Farming
CFU	Conservation Farming Unit
CT	Conservation Tillage
CDF	Cumulative Distribution Function
FAO	Food Agriculture Organization
FSRP	Food Security Research Project
GART	Golden Valley Agriculture Research Trust
Ha	Hectare
IAPRI	Indaba Agricultural Policy Research Institute
KG	Kilogram
LR	Likelihood Ratio
MT	Minimum Tillage
MOA	Ministry of Agriculture
MNL	Mixed Multinomial Logit
MNL	Multinomial Logit
MRM	Mixed-effect Regression Model
OLS	Ordinary Least Squares
PPS	Probability Proportional to Size
PScores	Propensity Scores
RALS	Rural Agricultural Livelihood survey
SEA	Standard Enumeration Area
SAPs	Sustainable Agricultural Practices
VIF	Variance Inflation Factor

CHAPTER 1

INTRODUCTION

1.1 Background

The agriculture sector is an important sector of the Zambian economy with more than 62 percent of the population depending on it as their main economic activity (Central Statistical Office, 2015).The sector is heavily dominated by smallholder farm households who reside in the rural parts of the country and agriculture is their main livelihood (Barrett, 2010). In the early 1990s, Zambia experienced major changes in its agriculture sector which resulted into a lot of changes in agriculture policies. Within the same period, the country had severe droughts which threatened food security and livelihoods of the majority Zambians due to low crop production. The commonly grown crop by smallholder farmer households is *Zea mays*, commonly known as maize. This is Zambia's staple food mainly grown u1nder rainfed conditions by the smallholder farmer households. There are many factors which can affect maize productivity in Zambia but soil degradation is considered to be the main hindrance (Mbaga-Semgalawe and Folmer 2000). In view of this, the Ministry of Agriculture (MOA)and other agricultural stakeholders in Zambia, such as Golden Valley Agriculture Research Trust (GART), Conservation Farming Unit (CFU),Dunavant Zambia Limited, etc. started pioneering the use of conservation farming (CF) technologies that conserve the soil and at the same time increase crop yields.CF has the potential to increase agricultural productivity growth in Zambia (Haggblade and Tembo, 2003; Baudron*et al*., 2007; Arslan*et al.,* 2013). In Zambia, CF practices involve minimum tillage(MT) and these include (zero tillage, ripping and/or planting basins); retention of crop residue from previous harvest; and planting and input application in fixed planting stations and crop rotations (Food Agriculture Organization (FAO), 2001).There is a lot of support rendered towards CF, but regardless of all this, less than 1% of arable land in Southern Africa is used for CF agricultural practices(Kassam*et al*., 2009).Some of the benefits associated with the use of CF is increased or stabilised yields in crop production (Li *et al.,* 2011).

Tillage practices are good for reduction in weeds, expansion in root depth and increasing soil moisture. In Zambia, the determinants and impacts of various tillage methods play a major role in the fertility of the soilswhich later results into an increase in crop yields.Smallholder farm households adopt various tillage methods in order to increase productivity and improve their quality of lives (Prettyet *al.,* 2011). Tillage methods can be defined as a process which disturbs the entire crop layer of the soil (Houghton and Chapman, 1986), and it is done before planting. These methods can be classified as conventional or conservation tillage (CT) methods. Some households prefer to apply both conventional and CT on different plots (Umar *et al.,* 2011) depending on the number of fields they have and also the availability of labor and tillage equipments.

CT is derived from one component of CF (minimum soil tillage) and is defined as a land preparation practice that involves minimum disturbance of the soil except in planting lines (Lankoski*et al*., 2006). It leaves the previous year's crop residue on fields before and after planting the next crop. This tillage method is mostly recommended because it results into a reduction in soil erosion and run off (MDA, 2011). CT has been widely promoted in Zambia mostly in areas where there is erratic supply of rainfall and it is used by most of the farmers as an adaptation strategy to climate variability (Nyanga*et al*., 2011).The adoption of CT methods is gradually increasing, aiming to get a wide range of benefits such as reduced soil tillage and reduced nitrogen loading (Wu *et al.,* 2003).CT has been observed to have a lot of benefits to the farmer over conventional tillage methods because it leads to an increase in the productivity of crops (Nyanga*et al.,* 2011) more especially the use of planting basins (Haggblade*et al*., 2010; Haggblade and Tembo 2003; Umar *et al*., 2011).CT leads to increases in farmer yields, often double what is achieved when using conventional methods (Grabowski *et al*., 2014). Farmers that practice CT have observed that it tends to protect the soil from damage due to rain splash, helps to keep more of the rains in the field and it makes the best use of fertilizers and seeds (Musiwa, 1999). Therefore, CT provides the best opportunity for farmers to reduce their costs, increases water infiltration which then increases crop productivity (Thierfelder and Wall, 2012). In Zambia, it is believed that CT has been widely promoted because of its various advantages over other tillage methods practiced in the country. For this reason, CT is increasingly becoming attractive to farmers (Vita *et al.,* 2007) because of the above mentioned reasons. In this study, we refer to planting basins, zero-tillage and ripping collectively as CT. These three tillage methods require minimum disturbance of the soil.

Conventional tillage is the other type of tillage method that is practiced by smallholder farm households. This tillage method is known to increase porosity and loosen the soils, allowing for good air exchange and root growth. The disadvantage of the conventional tillage method is that the amount of residue left on the fieldleaves soils more vulnerable to wind and water erosion (Rashidi*et al.*, 2010). In this study, conventional tillage methods practiced by smallholder farm households include hand-hoe, this involves the use of a hoe to prepare the field. Ridging tillage method is another form of conventional tillage, it involves making ridges through the use of a ridger and ploughing tillage method which requires the use of a plough.The choice ofa better tillage method cannot be over emphasised because different tillage practices cause changes in soil physical properties which can later the productivity of crops.If tillage methods are properly done from the beginning, they tend to enhance crop growth which in turn increases crop productivity. Hence, attention has to be given to the type of tillage methodadopted as they are vital for the germination of seeds as well as better growth of the crop. When these methods are properly done they tend to control the growing of the weeds, making the soil capable of absorbing more rain water and also helps with the mixing up of manure and fertilizers uniformly in the soil which later leads to an improvement in crop yield.

There are many factors which may lead to the determinant of different tillage method used. Some smallholder farmers use certain agricultural practices in order to receive a reward either from the government or private organizations. For instance, some households may use CT because of the benefits of receiving subsidised inputs and material reward from the government associated with the use of CT (Haggblade and Tembo, 2003). Baudron*et al.* (2007),observed that about half of the farmers do not useconservation agriculture (CA) in cases where they do not qualify for subsidies, hence, the majority of the farmers would adopt both conventional and conservation farming on different plots (Haggblade and Tembo, 2003) in order to obtain the agriculture inputs. The adoption of each land preparation tillage method could be different depending on the crop being planted, rainfall availability as well as the farmer’s preferences. Some households practice different tillage methods in order to reduce the risk of crop failure and hence food shortages.The effectiveness of tillage methods vary across regions due to the differences in weather, rainfall, type of the soils among others. Therefore, the adoption of various tillage methods is affected by so many factors, which could be socio-demographic, climatic, access to agricultural information and other characteristics. For instance, households with more members than others tend to adopt certain tillage methods that cannot be easily adopted by households with fewer members. This is so because the amount of work involved is shared among the household members. Therefore, household sizecan affect the adoption of tillage methods (Manda *et al*., 2015). Smallholder farm households lack information or knowledge on different land preparation tillage practices from the extension officers and this serves as a barrier to adopt certain methods. In some cases, adoption of tillage methods largely depend on the health of the household head. Some tillage methods arelabor intensive and require a lot of energy from the household members, therefore, labor becomes a limiting factor in the adoption of some of these land preparation tillage methods (Baudron*et al*., 2007; Umar *et al*., 2011).Adoption of these tillage methods can result into yield increase but this can take two or more years (Brouder and Gomez-Macpherson 2014), therefore adoption of these methods requires some consistency.

In this study, four major tillage methods practiced by small and medium-scale farmers in Zambia were assessed: (i) conventional hand hoe which basically involves the use of a hand hoe to prepare the field; (ii) conservation tillage which comprises planting basins, zero tillage and ripping land preparation tillage methods; (iii) conventional ploughing which includes all traditional methods of land preparation using driven animal ploughs or mechanical draught power; (iv) Ridging, bunding or mounding which is termed as ridging tillage methods in this study.

1.2 Problem Statement

In Zambia,priorstudies have focused on making comparisons of tillage methodswithin CT method techniques. For instance, Rashidi*et al.* (2006), Arslan*et al.* (2013),Haggblade and Tembo (2003) and Manda *et al*.(2015). Arslan*et al.* (2013), assessed the adoption of two main components of minimum tillage (MT) and these are no-till and planting basins. Similarly, Rashidi*et al.*(2006), assessedtillage methods as MTand no tillage and Baradi (2009), gives an over view of exclusive no-till, rotational no-tilland other tillage systems. Therefore, in Zambia, evidence onconventional types of tillage methods is still scanty. Majority of the studies that have been conducted on tillage methods are confined mostly on CT and not conventional types of tillage methods.The previous studies have lumped all the conventional tillage methods and hence the need to rigorously estimate the impact of tillage practices on maize productivity without lumping conventional methods of tillage. This study looks at the conventional types oftillage methodsthat are being practised in the country and can be of interest to otherstakeholders. Therefore, the conventional types of tillage methods that were included in this study includehand hoeing, ploughing and ridging tillage methods. Though Manda (2015) and Ng'ombe*et al.* (2017), did a similar study on factors affecting adoption of CF and their impacts, this study encompasses conventional types of tillage methods like hand-hoe, ploughing and ridging tillage methods and see how they have impacted on maize productivity among the smallholder farmers in Zambia. There is a gap when it comes to the conventional tillage types and their impact on maize productivity, hence, the need to carry out this study.

Adoption of tillage methods is affected by so many factors, therefore, it is important to discuss the factors affecting adoption of these methods.Similar studieson adoption (Chomba, 2004.Haggblade and Tembo, 2003,Kabwe and Donovan, 2005),have specialised their studies mostly in areas of Eastern and Southern Provinces where CF is widely promoted. This study will look at Zambia as a whole.

1.3 Research Objectives

The general objective of the study was to measure the determinants and impacts of tillage practices on smallholder farmer's maize productivity in Zambia. Specific objectives include:

i) To determine the factors that influence adoption of differenttillage methods available to smallholder farmers in Zambia.

ii) To estimate the impact of various tillage practices by smallholder farm households on maize productivity in Zambia.

1.4 Research Hypothesis

The study hypothesizes that,

i) Socio-demographiccharacteristics of smallholder farm householdspositivelyaffect the adoption of tillage methods.

ii) CT methods have a positive impact while conventional tillage methods have a negative impact on smallholder farm maize productivity.

1.5 Justification of the Study

Tillage methodsplay a vital role in determining the effects on the crop yields and can either impact negatively or positively on the productivity of crops. Furthermore, since farmers select a tillage type from a number of methods that are available in their region, identification of factors which influence their choice is important to inform policy makers on how to promote various tillage methods in the country. It is cardinal to understand differenttillage methods so that policy makers can know what incentives to come up with in order to enhance adoption and support these methods by coming up with appropriate policy. This can also help the adoption of the method/s which can result in higher crop productivity and enhanced food security in the country.

Finally, a focus on Zambia as a whole is justified as adoption rates differ by province or district.Hence, for the results to be generalised at country level, it is better that Zambia is considered as a whole.Adoption of tillage methods differ by district and province due to differences in historical rainfall patterns during the growing season in each agro-ecological region (AER)and different agricultural practices in each province. Therefore, the adoption rate for eachtillage method may be different depending on the regions. Looking at Zambia as a whole would allow policy makers to make informed decisions at national and local level.

This study is timely and relevant to our local situation as it helps policy makers to know what tillage methods some households have adoptedin order to curb the negative effect of climate change. This research will also add value to the existing literature ontillage methods in Zambia by identifying the factors that affect the decision to adopt individual practices of conventional hand hoe, CT, ploughingand ridging and their impacts on the productivity of maize.

1.6 Scope of the Study

Farmers prepare their fields with a wide array of crops, including crops like sorghum, sunflower, soyabeans but this studylooked atthe tillage methods that are practised on maize fields only. Data from Indaba AgriculturalPolicy Research Institute (IAPRI) was used and it measures various tillagemethods used by smallholder farmers on different crops. It has the coverage of the whole country. Adoption in this study is defined as having an area under maize with one or moretillage method.The tillage methods looked at in this study are those commonly practiced by smallholder farm households in the country. In this study, we focus on four different types of tillage methods that relate to major tillage practices in Zambia. These are; conventional hand-hoe, this strictly involves the use of the hoe.CT, which has a combination of planting basins,zero tillage and ripping tillage methods.Ploughing whichinvolves the use of the ploughand the fourth tillage method was the ridging tillage method. In this study, ridging involves the combination of the ridges, bunding and moulding tillage methods.

1.7 Organization of the Report

This paper is structured in five chapters. The next chapter (chapter 2) provides a review of literature, highlightingthe various research studies on tillage methods, factors affecting adoption of tillage methods and impact of tillage methods on maize productivitythat has been conducted in Zambia and the world at large. Chapter 3 presents the research methodology that was used in the study.Chapter 4 presents the results and discussion while chapter 5 presents the conclusion and recommendations based on the findings of this study.

CHAPTER2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews some literature on various tillage methods that are being practised in Zambia and other parts of the world. It begins with the definitions of the major concepts that were used in the study. Then goes on to highlight a number of studies that have been conducted on varioustillage methods, the factors that affect adoption of severalof thesetillage methods and finally it looks at the impact of tillage methods on maize productivity.

2.2 Definition of Concepts

The following are definitions of some common terminologies that have been used in this study;

- **TillageMethod**- These are processes that are involved in land preparation just before planting is done. These processes involve mechanical manipulation of the soil with tools and implements for obtaining conditions ideal for seed germination, seedling establishment and growth of crops(CSO, 2015).
- **Conventional Tillage**- This is the mechanical soil manipulation, the method buries most of the crop residue into the soil (FAO 2001).It is the type of cultivation that involves the use of ploughs, horrows or mechanical implements to prepare the field for crop production The following are the tillage methods that fall under conventional tillage methods;
    - i) **Conventional Hand-Hoe**- This is the form of tillage method where a hand hoe is used to till or prepare the entire field (CSO, 2015).Figure 1 depicts the instrument used for hand-hoe tillage method.

Figure 1: Conventional Hand-Hoe

Source: The Prepper Project.com, 2014

ii) **Ploughing**- This is a tillage method that involves the opening of compact soil with the use of a plough(CSO, 2015). A plough could be a country plough, mould board plough and or a bose plough.

Figure 2: Ploughing tillage method through the use of draught power

Source: TNAU Agritech Portal, 2016

Figure 3: Ploughing tillage method through the use of a tractor

Source: TNAU Agritech Portal, 2016

iii) **Ridging**- A form of tillage method that involves making ridges with a ridger or hand hoe(CSO, 2015). In this study ridging is combined with bunding and mounding tillage methods.

- **Conservation tillage (CT)** - Conservation tillage is any method of soil cultivation that leaves the previous year's crop residue (such as corn stalks or wheat stubble) on fields before and after planting the next crop to reduce soil erosion and runoff, as well as other benefits such as carbon sequestration (MDA, 2011). Under CT, we have the following tillage methods:

i) **Planting Basins**- This is a land preparation method where planting holes or basins are formed. It is in this same holes where the plant is planted(CSO, 2015).

ii) **Zero Tillage**- This is the tillage method where the land is left undisturbed, with the exception of only planting stations (CSO, 2015).

iii) **Ripping**- This is a tillage method were land is left undisturbed with the exception of the planting lines, which are ripped with a ripper(CSO, 2015).

- **Maize Productivity**- This is the amount of maize produced in kilograms divided by the amount of area planted in hectares. In this case productivity is measured in kg/ha. This is also referred to as yield(CSO, 2015).

2.3 Empirical Literature on Tillage Methods

The primary operation of tillage is basically to reduce the compression of the soil and increasing root growth. In Zambia, there are many tillage methods that are practised by smallholder farm households and these can be categorised into two, conventional tillage and CT.CT is of importance for smallholder agricultural households to achieve the objectives of food security and the mitigation of climate change. It is mostly favoured more especially in areas which are arid and semi-arid regions because it is regarded as `an improved soil water management practice (Haggblade*et al*., 2010;Arslan*et al*., 2013).Haggblade and Tembo, 2003 also observed that ripping and hand-hoe basins are best practiced in areas of low or scattered rainfall. CT is well known for conserving soil and water resources, reduced farm energy usage and increased production of crops (Bescansa*et al*., 2006).

There are many forms of CT, for instance, no-till tillage is a form of CT, this method involves the planting of the crop into the soils without any disturbance to the soil surface. The only disturbance done to the soil is when seed openers are created otherwise planting of the seed is done at a slot created by coulters, row cleaners, disk openers, in-row chisels or roto tillers (CFU, 2007). This tillage method is widely increasing in some parts of North and South America and Australia (Lal, 2000). In the USA and Canada, no-till tillage method covers 37 percent of the total area under cultivation and 48 percent in South America (Holland, 2004).A study conducted by Baradi, (2009), indicated that 15.6 percent of the farmers believed that no-till tillage method was less profitable compared to any other tillage method whilst the rest of the farmers observed it was more profitable compared to any other method.

CT method requires less energy when operated at shallower depths than conventional tillage method. The other advantage of this tillage method is that it facilitates faster land preparation allowing a large piece of land to be sown within a short stipulated time (Cannell, 1985). Though conventional land preparation tillage methods have been found to produce higher yields compared to other methods, it is time consuming and involves costly operations. Therefore, reduced yields under this tillage system is seen to be a major problem to the uptake of such land preparation systems in Europe (Jones *et al*., 2006) regardless of it being less costly.

Kabwe and Donovan (2005),looked at tillage method as a sub component of CF practices, and these were planting basins and ripping tillage methods. Arslan*et al*.(2013),looked at the two components of CT methods, minimum tillage and planting basins. This was analysed in two dimensions, CF1 and CF2. CF1 comprises the use of a hand hoe, planting basins or zero tillage in any of the fields whilst CF2 looked at the use of planting basins or zero tillage in any of the fields. It was observed that the number of households that practised CF2 had decreased in almost all the provinces of the country between 2004 and 2008 except for Eastern Province.

The above studiespaid attention tothe components of CT methods and as a result there is scanty knowledge on the conventional types of tillage methods. This study willexamineconventional tillage methods practiced in the country and these arehand-hoe, ploughing and ridging methods. Thesetillage methods are cardinal because there are smallholder farm households who still practice these methods and policy makers would want to know the extent of these conventional tillage methods on maize productivity in the country.

According to CSO (2015),about 32.8 percent of the smallholder farmers countrywide practice conventional hand hoeing as the main tillage method.This was mostly used in Eastern followed by Northern and Central Provinces. Ploughing and ridging were practised by 31.3 percent and 25.1 percent of the farmers respectively(CSO, 2015). These results are consistent with Sessiz*et al*. (2010), who carried out a study in the south eastern Anatolian region of Turkey and observed that conventional tillage were the main tillage methods used by most of the farmers in this region. Regardless of its popularity, most stakeholders prefer to encourage CT than conventional tillage because conventional tillage is believed toresult into physical degradation of the soil and increased soil erosion. The other disadvantage of conventional tillagemethods is that it requires a lot of labor, time, energy and production cost (Sessiz*et al*., 2010). Ripping and hand basins are other forms of tillage, theseare best suited to areas with low or scattered rainfall and clay or loamy soils (Haggblade and Tembo, 2003). The study bySessiz*et al*. (2010), lumped all the conventional tillage methods as one. This study looks at the conventional tillage methods separately.

In other studies it is noted that conventional tillage practiced together with the planting of one crop results into soil degradation which later results into soil failing to support crops (Musiwa, 1999). According to Haggblade and Tembo (2003), planting basins seem to be common in AER II compared to the other regions. Hand-hoe tillage method was found to be more effective in maize production in parts of Central and Southern provinces of Zambia compared to conventional ox-plow tillage method. Farmers that use hand-hoe had their maize yields roughly double compared to ox-plow farmers (Haggblade and Tembo, 2003). Unlike hand-hoe, the use of rippers resulted into slight yield gains for maize in some years but no major difference in some other years (Haggblade and Tembo, 2003).

Kabwe and Donovan (2005), used data from a panel study that was conducted in the agricultural season of 2000/2001 and then in 2002/2003. They described new adopters of CF as those households that used the practice in 2002/03 agricultural season but not in 2000/2001 agricultural season. They noted that new adopters of CT had higher income compared to those that did not adopt.This was consistent with the results obtained by Haggblade and Tembo (2003). Therefore, adoption of CT results into higher yields compared to non-adopters.This study will fill in the gap by looking at the factors that affect adoption of tillage methods and analyse itsimpact on the productivity of maize.

2.4. Factors Affecting Adoption of Tillage Methods

There are several factors that may affect the adoption of tillage methods. Climatic factors, rainfall patterns and temperatures being experienced can affect the type of tillage method a farmer can use or not to use (Feder*et al.*, 1985). In Zambia and across the world, tillage methods are viewed in different dimensions depending on the AER one is located. Adoption of tillage method is sometimes viewed with good soil fertility (Manda *et al.,* 2015).Economic theory postulates that a consumer will opt to purchase a commodity that optimises his/her utility subject to the budget constraint. Similarly, smallholder farm households will adopt based on the variables that will maximise the household welfare subject to their constraint. Therefore, adoption of tillage methods can be affected by human capital variables and or household socio-demographic characteristics like household size, age, education level of household head, sex and also marital status of the household head.

Adoption of tillage or land preparation methods is subject to some traditional constraints found in most literature. Several studies have been carried out to look at the factors that affect adoption and determinants of different tillage practices in Zambia and other developing countries (for example, Chomba,2004; Chiputwa*et al.*, 2011;Feder*et al.*, 1985;Gebermedhin& Swinton, 2001; Haggblade&Tembo, 2003, Nyanga*et al.*, 2011; Kassie *et al.*, 2012;).Kassie *et al.* (2012), observed that both socio-economic and plot characteristics are significant in the adoption of CF tillage practices. Arslan*et al.* (2013), classified tillage methods in terms of CF, CF1 was equal to one if the farmer used hand hoe, planting basins or zero tillage methods on at least one of the fields and CF2 was equal to two if the farmer used planting basins or zero tillage on at least one field. It was observed that extension services and rainfall variability were the strongest determinant of adoption of both (Arslan*et al.*, 2013).Haggblade&Tembo, 2003, assessed tillage methods in terms of MT, hand-hoe basins and ripping tillage methods, and the results also illustrates that access to extension support influences adoption of the two tillage methods.For instance, if the distributer of cotton uses ripping tillage method, this increases the chances of it being used by other group members.Extension support plays a vital role in influencing farmer decisions. When a farmer uses CF basins, then the prevalence of using basins among his group members increases (Haggblade and Tembo, 2003) in the sense that information is shared among the groups. Farmers with access to information on different cropping systems tend to have high adoption rate of CT (Francis *et al*., 2006). This is so because the more programs a farmer participates into, the higher the chances of adopting what is taught at those programs because they become familiar with those particular practices. Farmers who have received extension support through workshops, field days are more likely to adopt CT (Francis *et al.,* 2006) because they know that the more they practice this method, the more inputs they receive from the government. Baradi, (2009), also observed that a farmer who participates in conservation programs has higher chances of adopting CT, this is also due to the knowledge obtained from the same programs. Therefore, once information is obtained and shared, the higher the chances of more farmers adopting the technique. Arslan*et al.* (2013), also had similar observations, it was noted that extension services play a vital role in the adoption of tillage methods as the proportion of households that received information on certain land preparation techniques i.e. minimum tillage had a higher adoption rate.

Information on various farming techniques can be obtained in various ways, for example, through cellphones. A farmer who has a cellphone or radio can have access to information on prices and markets as well as extension services related to tillage method activities, unlike the farmer who doesn't have a cellphone. The use of mobile phones would ease communication between the farmer and the extension workers. A farmer can easily obtain new technologies through the use of a mobile phone. This is consistent with most of the soil conservation adoption studies that have found that information exposure to be significant indicator of the likelihood of adoption (Rahm and Huffman, 1984, Wang *et al.,* 2000). The other way information can be obtained is through kinship ties to the chief in a local area (Ng'ombe*et al*., 2014). Chiefs normally have first-hand information in a locality so there relation to local farmers enable adoption of certain farming technologies.

Nyanga*et al.*(2011), looked at MT as an indicator of CA and observed that previous experience in MT membership in farmer organization, the number of rippers owned and the use of herbicides increased the adoption of MT adoption. It was further observed that location in drought prone areas would affect the adoption of MT negatively. Gender was also found to affect the adoption of tillage methods.Women were found to be more involved in CA basins than men instead men were found to be more involved in ripping tillage method. These results are consistent with the results obtained by Grabowski*et al.* (2014) andNgoma, Mulenga and Jayne (2014) that female headed households are more likely to use basins than ripping tillage methods.

Climatic factors as well as geographical location of households are found to be significant in the adoption of varioustillage methods (Chomba 2004; Tembo and Haggblade 2003). For instance, smallholder farm households found in AER l are likely to adopt animal draught ripping and planting basins (Haggblade and Tembo, 2003). Tillage methods like ripping and planting basins are highly adopted in AER I because the basins are designed to hold water in drought persistent areas, therefore, there are more likely to be adopted in AER I and II. AER I and II are known to have less rainfall and are prone to drought compared to AER III. These results are consistent with the other studies on CF adoption in Zambia (for example, Clay *et al*., 2002, Gebremedhin and Swinton 2003). Some studies have observed that CT is labor demanding in times of weeding when implemented without the use of herbicides (Giller*et al*., 2009). Household size is another factor that affect adoption of tillage methods. Large sized households are more likely to adopt tillage practices of all types compared to small sized households. It is observed that as the household size continue to increase, the higher the chances of adopting different tillage practices (Manda *et al*., 2015). In other studies, Chomba, (2004), observed that household size and land size had a positive influence on adoption rates on CF plots. This was consistent with results obtained by Kassie *et al*. (2012), who found that size of the household is significant in the adoption of CF.

Smallholder farm households look at different factors associated with the adoption of a particular land preparation or tillage method, i.e. the benefits of adopting a certain method, the feasibility of practicing the method, availability of labor, the crop being planted and other farm characteristics among others. The other studies have revealed that households with more oxen are statistically significantly more likely to adopt ploughing tillage method(Haggblade and Tembo, 2003)because this tillage method requires the use of draught power. Nyanga*et al.* (2011),observed that age, education and ownership of draft power were likely to reduce adoption of CA significantly. But other factors like farm size, ownership of rippers, use of herbicides, membership to a farmer organisation and trainings in CA had a positive relationship with area under CA.Baradi, (2009), observed that the larger a piece of land a farmer has, then the higher the chances of the farmer adopting no till and the lesser the chances of adopting more conventional tillage systems. As much as some studies have discovered that farm size is positive statistically significant in the adoption of some tillage methods, on the contrary, Francis *et al.* (2006), observed that farm size had no significant influence on the probability of tillage method adoption but land tenure does. Farmers who own a piece of land will have a higher probability of adopting tillage methods in long term (Kassie *et al*., 2012).Households with secure land tenure are more likely to adopt because they will be able to use the land in the way that they want. They can apply any new technology than those with land tenure which is insecure.

Ng'ombe*et al*. (2014), observed that factors that greatly affect adoption of MT are marital status of the household head and distance to access transport.Manda *et al*. (2015),observed that education, gender of household head, size of land a farmer has, contacts with government extension agents, off farm income and distance to markets were significant factors in the adoption of agricultural farming activities. Manda *et al.*(2015), assessed the determinants of three sustainable agricultural practices (SAPs), maize-legume rotation, improved maize varieties and residue retention. Residue retention involves the accumulation of organic matter and minimum soil disturbance (CT). The factors that were found to affect the adoption of minimum soil disturbance included, education, gender of household head, size of land, contacts with government extension agents. These had a positive impact on the rate of adoption while off farm income and distance to markets negatively affected the rate of adoption (Manda *et al*., 2015).Manda *et al*. (2015), in the study used a multinomial endogenous treatment effects model which is composed of the mixed multinomial logit (MNL) model as the first stage then the average treatment effects (ATE).In this study,the probit method is employed to examine the factors that affect the choice of land preparation methods being practised and later a mixed effect regression model (MRM) is used to measure the impact of these tillage methods on maize productivity. The above studies focussed on CT but this study will highlight also on the conventional tillage methods that are practised by smallholder farmer households.

Chomba (2004),observed that factors that affect adoption of various tillage methods include agricultural support programs, quantity of labor, area cultivated, ownership of farm equipment and access to agricultural support programs.Baradi (2009),in his study observed that farm size, profit comparison between no-till and other tillage systems, familiarity with conservation programs and participation in conservation programs were statistically significant in the adoption of land preparation or tillage methods. For instance, the increase in farm size by 1000 acres would increase the chances of the respondent adopting exclusive no-till and rotational no-till but would decrease the chances of the respondent adopting MTand conventional tillage methods (Baradi, 2009). Farmers who agreed that profits from no-till were equal to other tillage systems had higher chances of adopting no-till as well as rotational no-till, but decreased the probability of the respondent adopting MT as well as other conventional systems. It was also observed that the more familiar the respondent was with conservation programs, then the higher the chances of adopting exclusive no-till but the lesser the chances of adopting rotational no-till, MT and other systems (Baradi, 2009). Therefore, farmers who participated in more conservation programs had higher chances of adopting exclusive no-till but decreased the probability of adopting rotational no-till, MT as well as other tillage systems. This tells us that extension support plays a vital role when it comes to adoption of land preparation tillage methods.

The amount of rainfall received annually also has a positive influence on the probability of adoption of various tillage practices. Francis *et al*.(2006), observed that annual rainfall in the long runindicates that a year with below average rainfall increases the likelihood of adoption in the following year. This is consistent with the results from Caswell *et al.*(2001), who observed that higher average monthly rainfall significantly increased the probability of adopting CT.

This study will improve on previous literature on factors affecting adoption of tillage methods in Zambia and will go on to determine its impact on maize productivity. This study will also address the other tillage types that are practised in the country such as the hand-hoe, ploughing and ridging tillage methods. Most studies that have looked at tillage methods have paid particular attention to CT (Haggblade&Tembo, 2003, Nyanga*et al*., 2011).

2.5. Impacts of Tillage Methods on Maize Productivity

Tillage methods have a greater impact on the productivity of the crops that are planted by the farmers. Depending on the type of tillage method that the farmer adopts, they can either result into high or low yields (Karuma*et al*., 2016).For a crop to grow and produce better yields a number of factors have to be taken into consideration. For instance, fertilizer application, type of seed planted, i.e.was it improved or local, access to credit and so on and so forth. Low maize yield is as a result of low and poorly distributed rainfall, high evapotranspiration rates, low and declining soil fertility, mismatching of varieties and crop management practices (Mburu*et al.*, 2011; Kutu, 2012). Various tillage methods activities are vital on the impact of crop yields, for example, the type of tillage method the smallholder farm household uses, will determine how much yield a farmer can be able to have based on a particular crop planted. Apart from the tillage method used, there are also other factors which can affect the productivity of the farmer. These could be household, farm, climatic or crop management characteristics. Manda *et al.*(2015),observed that depending on the type of tillage method the farmer uses, it can either cause an increase or decrease in the productivity of the crop, this is contrary to the results obtained by Aykas and Onal, (2004), who observed that type of tillage method useddoes not show any significant difference on the seed cotton and leaf quality of the crop. Studies have revealed that adopters of various CF practices tend to have higher crop yields compared to non-adopters (Manda *et al.,* 2015; Ng'ombe*et al.,* 2017).The other studies conducted demonstrate that the disc harrowing tillage method produces the highest maize yields compared to no-till (Aikins, 2012). Conventional tillage method was found to produce higher sorghum emergence and productivity as compared to CT (Chisamanga, 1995).Grabowski*et al.* (2014), observed that farmers who practice planting basins have higher cotton productivity. The study by Raoufat and Matbooei, (2007), looked at two methods of tillage operations, disc and chisel tillage operations. It was indicated that these two methods of tillage operations were able to reduce maize productivity. This was consistent with the study that was done by Mupangwa*et al.*(2007), which showed that MT had no significant effect on maize productivity. A study done by Mafongoya*et al.* (2015), revealed that zero tillage practice resulted in lower maize grains compared to conventional tillage method. The other factor that can affect the productivity of maize is the amount of fertilizer applied. Chapoto and Ragasa (2013), found out that applying 1Kg of nitrogen fertilizer per hectare would yield an additional 22-26 Kg of maize per hectare in Ghana, 8 Kg/ha in Malawi and 23 Kg/ha in Uganda. Maize seed variety planted also tend to affect the yields for maize. Smallholder farmer households that plant certified maize seed tend to experience higher yields compared to those that plant local/ recycled maize seed (Ragasa*et al.,* 2014).

As much as the above studies have looked at the impact on maize productivity, they failed to capture the conventional tillage methods such as ploughing and ridging tillage methods and their impact on maize productivity. This study will add to existing literature by making an additional of the other components of tillage methods that are practised by smallholder farm households in Zambia and their impact on the productivity of maize.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter begins with the description of the study area and then discusses the methods that were used to determine the factors that affect adoption of tillage methods on smallholder farm householdsin Zambia.Lastly, the chapter looks at the regression model which was used to measure the impact of the tillage methods on maize productivity in Zambia.

3.2 Study Area

Zambia is a country located in southern Africa. The country is located approximately between 22° to 34° east of Greenwich and 8° to 18° south of the equator with an area of 752,618km^2. Zambia is divided into three AER zones with rainfall as the dominant distinguishing climatic factor.

AER I lies in the western and southern part of the country and accounts for about 15 percent of the land area. These areas include the Luangwa-Zambezi rift valley and western semi-arid plains, including drought and flood prone valleys of Gwembe and Lunsemfwa. This region receives less than 800mm of rainfall annually. The amount of rainfall received in this region has reduced over time according to the meteorological data. These constraints make this region a primary target for promotion of CT practices such as planting basinsor ripping as these enhance water retention critical for plant development (Haggblade and Tembo, 2003).

AER II which is divided into two (IIa and IIb) covers the central part of the country, extending from the east through to the west. This is now considered to be the food basket of the country with over 4 million inhabitants. It has relatively fertile soils and receives about 800-1000mm of rainfall annually, which is evenly distributed. The common land preparation tillage methods used in this region are ripping and zero tillage (Haggblade and Tembo, 2003).

AER III covers the northern part of the country and has the population of over 3.5 million people, it receives over 1000mm of rainfall annually. This area is suitable for late maturing varieties and due to high rainfall in this area it has caused the soils to become leached. It covers Copperbelt, Luapula, Northern and North-Western provinces. Figure 4 shows the map of Zambia by agro-ecological regions.

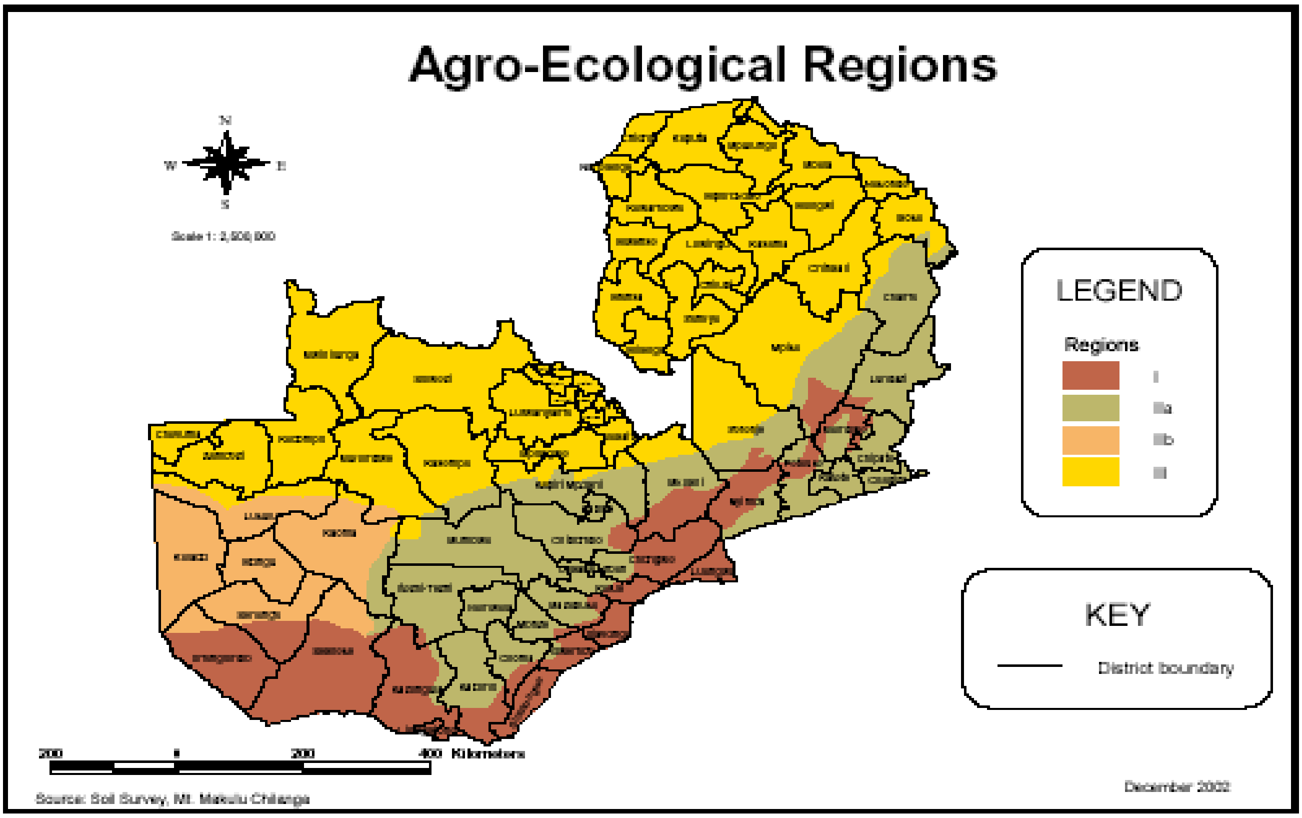


Figure 4: Agro-ecological Regions of Zambia

Source:Soil Survey, Mt. Makulu,Chilanga,2002.

3.3 Data Sources

The study primarily used secondary data collected in the 2012 Rural Agricultural Livelihood Survey (RALS)done by IAPRI, formerly called Food Security Research Project (FSRP) in collaboration with Central Statistical Office(CSO) and MOA. This data was nationally representative with 442 standard enumeration areas (SEAs) and administered to 8,840 smallholder farmhouseholds. A two stage cluster sampling scheme was used. In the first stage, a pre-determined number of 442 SEAs was drawn using probability proportional to size(PPS) sampling scheme using the 2010 Census of Population and Housing sampling framework. At the second stage of sampling, all the households in selected SEAs were listed and agricultural households were identified and stratified into three categories of A, B and C on the basis of the total area under crop, presence of some specified crops, number of cattle, goats and chickens raised. Then a random sample of 20 households were selected from each SEA, bringing the total national sample size to 8,840 smallholder farm households. A large sample was preferred to increase the statistical power.In this study, the analysis was done at plot level in order to account for households with more than one maize field. There were 10,158 maize fields, 1,217 maize fields had missing observations on the type of tillage method practised, hence, the total number of maize fields came to 8,941 fields.

3.4 Descriptive Statistics

The choice of the explanatory variables was based on the literature available. Most literature on agricultural technology adoption consider farm household characteristics, climatic factors, assets, crop management practices and information access to be among the factors affecting adoption. Table 1 presents some descriptions of the explanatory variables used for attaining objectives number 1 and 2. Variable explanations and hypothesised relationships to the dependent variable follow immediately after the table.

Table 1: Definition of Variables used in the Probit and Regression model

Variable Name	**Variable definition**
Farm Household Characteristics	
Age of head in years	Age of household head (years)
Age squared of head	Age of household head Squared (years squared)
Sex of head(=1 if male)	Dummy=1 if household head is male, 0 otherwise
Household size	Number of people living in the household
None education	none education dummy (none=1, 0 otherwise)
Primary education	Primary education dummy (attended=1, 0 otherwise)
Basic education	Basic education dummy (attended=1, 0 otherwise)
Secondary education	Secondary education dummy (attended=1, 0 otherwise)
Tertiary education	Tertiary education dummy (attended=1, 0 otherwise)
Never married	Never married dummy(yes=1, 0 otherwise)
Monogamously head	Monogamously married dummy (yes=1, 0 otherwise)
Polygamous head	Polygamous married dummy (yes=1, 0 otherwise)
Divorced head	Divorced (yes=1, 0 otherwise)
Widowed head	Widowed dummy (yes=1, 0 otherwise)
Cohabiting head	Cohabiting dummy (yes=1, 0 otherwise)
Climatic factors	
AER I	Agro-ecological region I(yes=1, 0 otherwise)
AER II	Agro-ecological region II(yes=1, 0 otherwise)

Variable Name	Variable definition
AER III	Agro-ecological region III(yes=1, 0 otherwise)
Assets	
Own a radio	Own radio (yes=1, 0 otherwise)
Own a mobile phone	Own mobile phone (yes=1, 0 otherwise)
Own Cattle	Own cattle (yes=1, 0 otherwise)
Information access	
Extension service	Access to extension service (yes=1, 0 otherwise)
Cooperative	Member of a cooperative (yes=1, 0 otherwise)
Women group	Member of a women group (yes=1, 0 otherwise)
Access to credit	Access to credit (yes=1, 0 otherwise)
Crop Management Practices	
Basal dressing fertilizer	The amount of basal dressing fertilizer used per hectare
Top dressing fertilizer	The amount of top dressing fertilizer used per hectare
Maize seed Variety	Planted local/recycled maize seed (yes=1, 0 otherwise)
Land size	Size of maize field in hectares
Tillage in rains	Tillage done in the rains (yes=1, 0 otherwise)

Gender-Gender is an important factor affecting adoption decisions at farm level. In this study it was hypothesised that male headed households have a higher chance of adopting varioustillage practices as most of the methods are labour intensive, hence very few women can handle them. The greater demand on female labor, child bearing and household chores limit female heads from practising labor intensive tillage methods.

Age- This is an important determinant of the choice of land preparation tillage methodbecause as one grows older you expect them to have gained a lot of experience about various tillage methods, hence, the adoption rate tends to become higher. Older farmers are also expected to have a lot of experiences on the benefits of new technologies as well as the most efficient ways to improve their production. This study hypothesises that age of the household head increases the chances of adoption of more advanced tillage methods because old age is associated with more experience and expect older farmers to adopt various tillage methods. Younger ages are expected not to adopt new tillage practices (Chomba, 2004) as they have little or no experience on different tillage methods.

Age Squared- This is the square of age. This variable shows the effect of age, which may have a non-linear relationship with the independent variable. Age squared allows us to model the effect a differing ages, rather than assuming the effect is linear. For instance, the effect of age could be positive up to a certain age, and then negative thereafter.If one has a positive effect of age and a negative effect on age squared, it means that as people get older the effect of age is lessened. A positive effect of age and a positive effect of age squared means that as people get older the effect is even stronger.

Household Size- Chomba, (2004), observed that household size influences the rate of adoption. It is expected that the larger the family, the more labour is available for agricultural production, hence, more labor intensive tillage practices are employed.

Education- The higher the level of education, the better the capability to understand information on various technologies (Feder*et al.,* 1985). Therefore, farmers with higher education levels were hypothesised to be more likely to adopt tillage methods as there are more aware of the benefits of the new technologies associated with the adoption.

AER- Soils and climate are likely to affect the rate of adoption, and these differ by region.According to literature, ripping and planting hoe basins are best practiced in areas that have low or scattered rainfall and clay or loamy soils (Haggblade and Tembo, 2003). Therefore, farmers located in AER I and II are expected to be practising more of ripping and planting hoe basins. This was proved by Haggblade and Tembo (2003), where it was observed that none of the Dunavant cotton farmers practiced CF basins in AER III.

Extension support- Access to extension services plays a vital role among the smallholder farmer households.It influences the decision the smallholder farmers make towards adoption of certain types of tillage method especially if the support is more frequent (Adegbola and Gardebroek, 2007). Extension support was found to be an important factor motivating increased use of specific soils and water conservation practices (Bekele and Drake, 2003). It is proved that cotton farmers are among the largest group of CT adopters because there are able to share the information obtained from out-grower schemes (Haggblade and Tembo, 2003). Extension services provide a platform for interaction, hence, there is exchange of quality knowledge among farmers. Due to some cultural factors, most of the extension services are attended by male headed households, therefore, they have more access to information on new farming techniques (Jera&Ajayi, 2008). This study hypothesised that smallholder farmer households that had access to extension services had higher chances of adopting various tillage methods.

Member of a Cooperative- Membership to a cooperative has an influence on the choice made to adopt to tillage methods. Farmers who belong to a cooperative are exposed to better and suitable methods of tillage methods. This study hypothesised that membership to a cooperative would increase the chances of adopting various tillage methods.

Access to Credit- Initial investments of some tillage methods are high, therefore access to credit may influence the choice of adoption of methods which are capital intensive. With enough capital at their disposal, farmers are able to make informed decisions in response to changing climatic and other conditions. This study hypothesizes that access to credit enhance the adoption of tillage methods that involves the use of machinery(Tembo*et al*., 2004).

Cattle ownership- Ownership of some assets influences decisions to adopt tillage methods. Farmers that have assets such as cattle, to be specific, oxen are most likely to adopt the use of a ripper and conventional ploughing unlike the use of the basins and hand-hoe which are likely to be adopted by households who do not own cattle and normally farm with borrowed or rented oxen.

Time of Tillage- The time that tillage is done also influences the type of tillage method that a farmer adopt. Some farmers till their land before the first effective rains whilst others wait for the rains to commence. This study hypothesised that smallholder farmer households that are usingCT as a tillage method till their land even before the onset of the rains but those farmers using conventional methods such as ploughing have to till after the first effective rains when the soils have softened enough.

Land Size- Households with smaller pieces of land tend to have higher adoption rates due to the labor involved during tillage (Arslan*et al*., 2013). Smallholder farm households with bigger pieces of land tend to adopt various tillage method practices compared to those with smaller pieces of land.

Maize seed variety- This study hypothesize that smallholder farmer households that plant local maize seed variety have lower maize yields compared to those that plant improved maize varieties.

3.5. Theoretical Framework

3.5.1.Choice of Tillage Methods

An interpretation of data on household choices of whether to adopt different land preparationtillage methods can be provided by the random utility model. Suppose we have U^a and U^b which denotes, for instance, the utility of using conventional hand-hoe and ploughing tillage methods respectively. The choice between the two reveals which one has a greater utility than the other but does not reveal the unobservable utilities. Hence, the observed indicator equals 1(adopting conventional hand-hoe over ploughing) if $U^a > U^b$ and 0 if $U^a \leq U^b$. The linear random utility model is given by

$U^a = x'\beta_a + \varepsilon_a$ and $U^b = x'\beta_b + \varepsilon_b$. (Green, 2003)

If we say $Y = 1$ the consumer's choice of alternatives a, adopted from Green (2003), we have

$$prob[Y = 1 | x] = prob[U^a > U^b$$

$$= prob[x'\beta_a + \varepsilon_a - x'\beta_b - \varepsilon_b > 0 | x]$$

$$= prob[x'(\beta_a - \beta_b) + \varepsilon_a - \varepsilon_b > 0 | x]$$

$$= prob[x'\beta + \varepsilon > 0 | x]$$

For example, the decision of a household to adopt a particular tillage method or not depend on an unobservable utility index I_i also known as the latent variable or normal equivalent deviate (n.e.d) in the language of probit analysis. This is determined by one or more explanatory variables, for instance, source of advice X_i, it is observed that the larger the value of I_i, the greater the probability of a household adopting the particular tillage method. We can express this as;

$$I_i = \beta_1 + \beta_2 X_i$$

Where X_i is the source of advice of the i th household.A dummy variable is created let say $Y=1$ if the household adopt and $Y=0$ if the household does not adopt. If we assume that there is a critical or threshold level of the index, we call it I_i^*, this tells us that if I_i exceeds I_i^*, a household will adopt and if not it will not adopt. It is noted that I_i^*, like I_i is not observable but an assumption of normality can help us because it assumes same mean and same variance. Therefore, the probability that I_i^* is less than or equal to I_i can be computed from the standardized normal cumulative distribution function (CDF) as follows,

$$P_i = P(Y=1|X) = P(I_i^* \le I_i) = P(Z_i \le \beta_1 + \beta_2 X_i) = F(\beta_1 + \beta_2 X_i)$$

Where

$P(Y=1|X)$ Is the probability of adopting a particular tillage method. The vector for tillage related variables are separate dummy variables equal to one if the plot was tilled using conventional hand-hoe, CT, ploughing and ridging tillage methods, given the values of the explanatory variables (X_i). Z_i is the standard normal variable and F is the standard normal cumulative distribution function (CDF). To get information on the utility index, I_i, as well as on β_1 and β_2, we take the inverse of the equation 2 and obtain

$$I_i = F^{-1}(I_i) = F^{-1}(P_i)$$

$$= \beta_1 + \beta_2 X_i$$

Where F^{-1} is the inverse of the normal CDF.

3.6Empirical framework

3.6.1.Creating Comparison Samples using the Propensity Score

The treatment or participation relation was modelled through the probit framework with the aim to estimate the conditional probabilities of participation (given the observed characteristics), also known as the PScores.Estimation of the propensity scores and generation of balancing tests were achieved by using Pscore(Becker &Ichino, 2002).

To determine which variables to include in the PScore, a pair wise correlation was done between the independent variables on the treatment and control group and the results are shown in appendix 1. In the pairwise correlation, maize productivity was the outcome variable and dummy variable CT and dummy conventional tillage were the treatment group. These dummy variables were created by combining conventional tillage methods (hand hoe, ploughing and ridging) together. The specification of x took cognizant of the variables' relative effects on the variance and bias of the estimate. All the variables that are unrelated to the treatment but are related to the outcome variable were included as their inclusion will decrease the variance of an estimated treatment effect without increasing bias (Brookhart *et al*., 2006). It was important to note that including variables that are related to treatment but not to the outcome variable would increase the variance of the estimated treatment effect without decreasing bias. Therefore, following Brookhart *et al*. (2006), we include in x all covariates that are significantly correlated with the outcome variable, whether or not they are correlated with the treatment variable. However, all covariates that are themselves affected by the treatment but not the outcome variable were excluded (Maertens and Swinnen 2009; Brookhart *et al.,* 2006).

3.6.2 Balancing Tests and Common Support

The propensity score is only as good as the quality of the matching, and any propensity-score-based estimator would be unbiased only under certain identifying assumptions. The balancing effects of the propensity score were tested using a number of procedures. Two-sample*t*tests are used to investigate the significance of the post-matching differences in the covariate means for the two groups (participants and non-participants)(Rosenbaum and Rubin 1985) and ability to drive the overall probit relationship to insignificance as measured by a joint likelihood ratio (LR) test and pseudo $R2$ (Caliendo &Kopeinig, 2008).

A well-balanced propensity score is necessary for artificially constructing an experimental environment from a quasi-experimental situation. The idea is that there should be no association between treatment status and each covariate once the observations have been restricted to the region of common support.

The results show that the balancing properties were satisfied. A key identifying assumption is that there should be no unobserved factors that influence both participation and the outcome variable. The standard procedure of using interaction terms and higher order polynomials in the specification of the propensity score (as explained above) helps to deal with the former. The latter, on the other hand, is non-testable but is not an issue if we assume that the unobserved factors are equally distributed between the two groups. The estimated propensity scores also satisfied the common support requirement. Households for which no match was found were dropped because there was no basis for comparison. Tables for the balancing tests are provided in appendix 4 and 5.The region of common support from the propensity score model was captured and those that did not satisfy the common support condition were dropped in order to have a comparable sample.The variables that were selected in the Pscore were those that were statistically significant to the outcome variable. This was in order to minimise biase in the selection of variables to include in the propensity score (Brookhart *et al.,* 2006).

3.6.3. Probit Model

In objective number 1, we were trying to determine the factors that influence adoption of different tillage methods available to smallholder farm households in Zambia. This is a binary categorical variable taking one if a farmer uses any of the tillage methods and 0, otherwise. The relationship of the farmer making a decision between to adopt and not to adopt a particular technology with the observed factors requires the use of qualitative response models. The analytical framework that was used in this study was the probit model.The probit model was specified as:

$$\Pr ob(w = 1 \mid x) = \varphi(\alpha + \delta^{/} x + \varepsilon),$$

Where w is a dichotomous variable equal to one if the household was able to adopt tillage method and zero otherwise. φis the standard normal CDF: $\mathscr{E}$ is the error term; α and ꝺ are parameter and vector of parameters to be estimated; and x is a vector of household and farm covariates used in the adoption selection process.A dummy variable was created for each tillage type i.e conventional hand hoe, CT, ploughing, and ridging tillage methods.

3.6.2.Regression Analysis

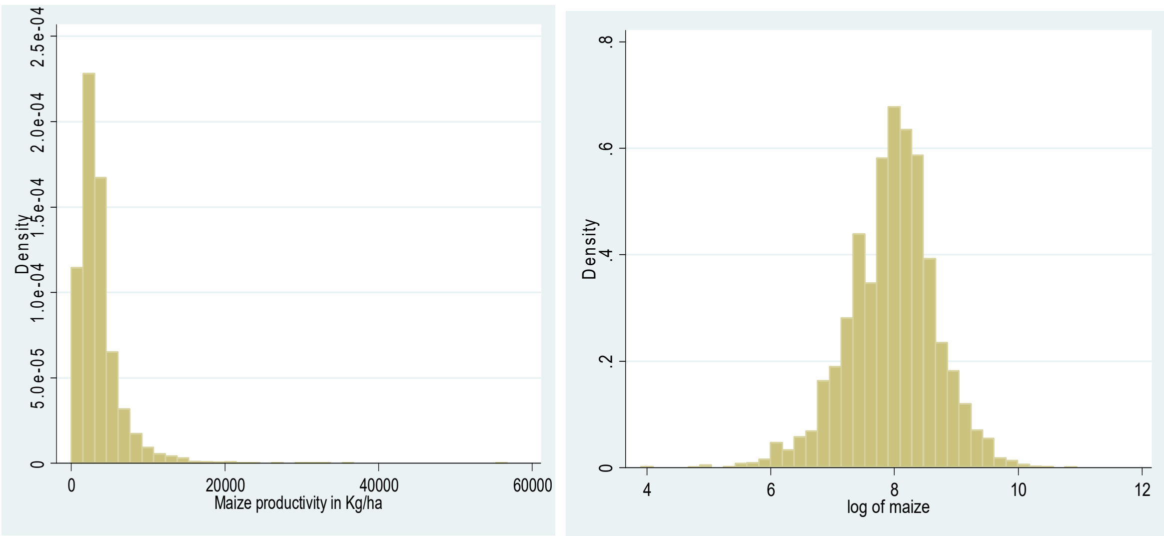
In objective number 2, we estimated the impact of tillage methods by smallholder farmer households on maize productivity. There are various methods that are used to measure the impact under quasi-experimental conditions. The impact was estimated using the MRM on the matched subsample. This thesis employed the ordinary least squares (OLS) and MRM on the matched subsample to estimate the impact of tillage methods on maize productivity using the matched observations obtained from the Pscore matching. A regression model indicates the relationship between the dependent variable and the independent variable and it also indicates the strength of impact of multiple independent variables on a dependent variable. Each slope estimate measures the partial effect of the corresponding independent variable on the dependent variable, holding all other independent variables fixed. The multiple linear regression model is given as:

$$Y_i = \beta_0 + \beta_1 X_i + B_2 X_2 + B_3 X_3 + \cdots + B_k X_k + u,$$

Where Y is the dependent variable, B_0 is the intercept,X_i are the independent variables, B_1 is the slope of the coefficient associated with $x_{1,}B_2$ is the slope of the coefficient associated with $x_{2,}$ and so on. $u$is the error term for observations. The dependent variable was maize productivity, using a scatter plot, maize productivity was found to be skewed to the left. Log of maize productivity was used as an outcome variable. The productivity of maize also termed as yield is measured by the total maize produced in Kgs divided by the area planted in hectares. This is given by;

$$Yield\ (\frac{Kg}{ha}) = \frac{Production(Kg)}{Area(Ha)}$$

Therefore, the regression analysis employed the log of maize productivity variable to enable a normal distribution. The histogramof maize productivity verses log of maize productivityis presented in Figure 5.



a) Maize productivity b) log of maize productivity

Figure 5: Maize Productivity Verse Log Maize Productivity

Source: Authors'calculations, Data from RALS 2012, July, 2018

The regression analysis was done based on the log of maize productivity and the explanatory variables. The types of tillage methods practised were included in order to measure their impact on maize productivity.

The model that gives a constant percentage effect is what we are estimating and this can be presented as,

$$\log(Mz_{prod}) = B_0 + B_1 tillage + B_2 hage + B_3 edu \ldots + u.$$

Where log (.) denotes the natural logarithm. The dependent variable in this study was log of maize productivity and the independent variables were the tillage methods and other household and farm characteristics. The OLS model was fitted and the model was tested for multicollinearity using the variance inflation factor (VIF) and it was found to be less than 10 which indicate that multicollinearity is not a serious problem in this model.

In this study MRM was employed to account for households which have multiple maize fields. Multilevel modelling is more appropriate to take into account the hierarchical structure of the data, clustering at different levels coupled with simultaneous analysis of household and field level factors (Gajda, 2008). In this study you may have one household having more than one maize field, hence, the MRM comes into play. Multiple observations for each level of a random effect are necessary for mixed-effects analysis. This model corresponds to a hierarchy of levels with the repeated, correlated measurement occurring among all the lower level units for each particular upper level unit. As the name implies, the MRM generally contains some fixed effects in the model in addition to the random effects. Mixed effects regression analysis allow to use random intercepts and random slopes to make the regression formula as precise as possible for every individual observation in our random effects.

3.7 Diagnostic Tests

In this study, we corrected for heteroscedasticity by running robust standard errors. Robust standard errors are important as they are asymptotically valid in the presence of many forms of heteroscedasticity (Green, 2012). Multicollinearity was checked using theVIF. The mean VIF was found to be less than 10 which shows that multicollinearity was not a factor. See table in appendix 3. Basal and top dressing fertilizers were found to have a higher VIF, this could be because the two are always applied in same quantities. When a joint test was done, the two were found to be statistically significant in determining the productivity of maize.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter begins by highlighting the four differenttypes of tillage methods practised by smallholder farm households. It continues with the description of the variables for the smallholder farm households included in this study. It goes on to look at the determinants of adoption of varioustillage practices using the probit model.Finally it looks at the impact of these tillage methods on maize productivity in Zambia using the OLS regressionand the MRM on the matched sample.

4.2 Tillage Methods Practised

In this study, the tillage methods that were looked at were four namely: (i) conventional hand-hoe which basically involves the use of a hand-hoe to prepare the field; (ii) conservation tillage which comprises of planting basins, zero tillage and rippingtillage methods; (iii) conventional ploughing which includes all traditional methods of land preparation using ploughs driven animal or mechanical draught power and finally; (iv) ridging which comprises of bunding and mounding tillage methods. CT methods were lumped together following similarities in function i.e. zero tillage, planting basins and ripping tillage methods. The analysis was done at plot level by asking the households the main tillage method that was used on a plot or field. Table 2 and Figure 6, illustrates the four major tillage methods that were examined in this study.

Table 2:Number and Percentage of Tillage Methods Practiced

Tillage Methods	Number	Percent
Conventional hand hoe	2,609	29.18
Conservation tillage	211	2.36
Ploughing	3,718	41.58
Ridging	2,403	26.88
Total	8,941	100

Source: Author’s calculations, Data from RALS 2012

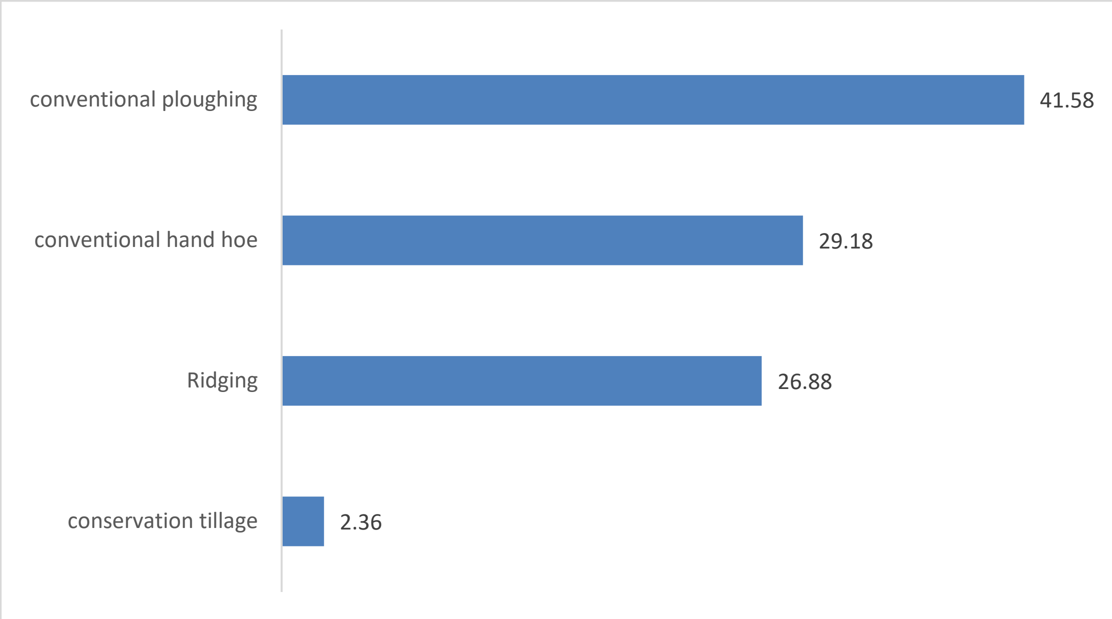


Figure 6: Percentage of Tillage Methods Practiced

Source: Author's calculations, Data from RALS 2012

Table 2 and Figure 6 illustrates the different tillage methods analysed in this study. The results show that conventional ploughing is the most practised tillage method at 41.6 percent. The figure also indicates that CT is the least practiced tillage method at 2.4 percent of the total smallholder farm households that practiced tillage methods. CT has theleast adoption rate regardless of it being highly promoted.

4.3Descriptive Statistics

Descriptive statistics concerning smallholder farm households involved in various tillage methods are presented in Table 3. From the table, there are six major columns showing the variable name, total sample, hand-hoe, CT, ploughing, and ridging tillage methods.

Table 3: Descriptive Statistics

	Total sample		Convention hand-hoe		Conservation tillage		Ploughing		Ridging	
Variable name	mean	Std Dev.	mean	Std Dev.	mean	Std Dev.	mean	Std Dev.	mean	Std Dev.
Dependent Variable										
Maize productivity (kg/ha)	2742.68	1948.05	2625.24	1849.71	3004.57	2061.07	2689.46	2049.29	2929.18	1864.97
Independent variables										
Farm Household characteristics										
Age of head in years	45.85	14.75	46.18	14.99	46.33	14.01	46.07	14.77	45.10	14.48
Age Squared	2319	1515	2358	1532	2341	1439	2341	1541	2244	1462
Sex of head (=1 if male)	0.83	0.38	0.78	0.41	0.83	0.37	0.85	0.36	0.84	0.36
Household size (number)	3.88	2.00	3.56	1.76	4.19	1.99	4.18	2.18	3.74	1.86
None education (=1 if yes)	0.11	0.32	0.12	0.33	0.08	0.27	0.11	0.31	0.11	0.32
Primary education (=1 if yes)	0.55	0.50	0.58	0.49	0.59	0.49	0.56	0.50	0.52	0.50
Basic education (=1 if yes)	0.17	0.38	0.15	0.36	0.11	0.32	0.17	0.38	0.19	0.40
Secondary education (=1 if yes)	0.12	0.32	0.11	0.31	0.11	0.32	0.12	0.33	0.12	0.32
Tertiary education (=1 if yes)	0.05	0.21	0.04	0.19	0.10	0.31	0.04	0.20	0.05	0.22
Never married (=1 if yes)	0.01	0.10	0.02	0.13	0.00	0.07	0.01	0.09	0.01	0.08
Monogamously head (=1 if yes)	0.71	0.46	0.71	0.45	0.73	0.45	0.67	0.47	0.75	0.44
Polygamously head (=1 if yes)	0.13	0.34	0.07	0.26	0.11	0.31	0.18	0.39	0.11	0.31
Widowed head (=1 if yes)	0.10	0.30	0.12	0.33	0.10	0.31	0.08	0.28	0.09	0.28
Climatic factors										
AER I (=1 if yes)	0.26	0.44	0.11	0.31	0.15	0.35	0.54	0.50	0.00	0.04

	Total sample		Convention hand-hoe		Conservation tillage		Ploughing		Ridging	
AER II (=1 if yes)	0.46	0.50	0.50	0.50	0.72	0.45	0.43	0.50	0.45	0.50
AER III (=1 if yes)	0.27	0.45	0.39	0.49	0.13	0.34	0.02	0.15	0.55	0.50
Assets										
own a radio (=1 if yes)	0.66	0.47	0.60	0.49	0.73	0.44	0.69	0.46	0.68	0.47
own a mobile phone(=1 if yes)	0.59	0.49	0.53	0.50	0.72	0.45	0.64	0.48	0.55	0.50
Own Cattle (=1 if yes)	0.38	0.49	0.11	0.32	0.36	0.48	0.65	0.48	0.22	0.42
information access										
Extension service (=1 if yes)	0.87	0.34	0.83	0.37	0.87	0.34	0.89	0.32	0.88	0.32
Cooperative (=1 if yes)	0.52	0.50	0.46	0.50	0.59	0.49	0.52	0.50	0.58	0.49
Women group (=1 if yes)	0.24	0.42	0.21	0.41	0.31	0.46	0.25	0.43	0.24	0.43
Access to credit (=1 if yes)	0.04	0.19	0.04	0.20	0.09	0.28	0.03	0.17	0.04	0.19
Crop Management Practices										
Basal dressing (kg/ha)	119.74	238.31	84.53	155.44	132.69	186.66	142.76	306.60	121.21	185.59
Top dressing (kg/ha)	120.94	237.49	85.41	155.14	134.68	184.65	143.89	305.38	122.81	185.16
Maize seed Variety (=1 if local variety)	0.43	0.50	0.51	0.50	0.37	0.49	0.38	0.49	0.43	0.50
Land size (hectares)	1.27	1.47	0.91	1.00	1.35	1.27	1.66	1.80	1.04	1.18
Tillage in rains (=1 if during rains)	0.83	0.37	0.73	0.44	0.75	0.43	0.92	0.27	0.81	0.39

Source: Author’s calculations, Data from RALS 2012

Within the columns we have variable means and their standard deviations. In the table the dependent variable is maize productivity whilst the independent variables include farm household characteristics, climatic factors, assets, information access and crop management practices. From Table 3, the total number of maize plots that smallholder farmers had used various tillage methods were 8,941. The mean value of maize productivity countrywide was found to be 2,742 Kg/ha. The results show that smallholder farmer's households that practised CT tillage methods had higher maize productivity of 3,004Kg/ha, this was followed by ridging tillage method at 2,929Kg/ha. Hand-hoe smallholder farmers were found to havethe least maize produced per hectare of 2,625kg.

The average age of the household head was found to be 45 years. Household heads that practiced hand-hoe, CT and ploughing tillage methods were found to have an average age of 46 years while household heads that adopted ridging tillage method had an average age of the household head as 45 years.When it comes to sex of household head, the results show that 83 percent of the smallholder farm households were headed by males. This was consistent with all the tillage methods practiced by smallholder farm households which indicated that more than half of the households were headed by males. Household size for the total sample was 3. This was consistent with conventional hand-hoe and ridging tillage methods. CT and ploughing tillage method had higher household size of 4. Education of household head was broken down into five categories, namely, none, primary, basic, secondary and tertiary levels of education. The results indicate that the majority (55 percent) of the household heads had attained primary level of education whilst only less than 10 percent of smallholder farmer household heads had attained tertiary education.

Marital status was categorized into four, this was never married, monogamously married, polygamous married and widowed household heads. The results indicate that 71 percent of the household heads that adopted various tillage methods were monogamously married. Never marriedhousehold heads were found to have less than 10 percent, this is expected because most tillage practices are labor intensive and one would expect that single headed household not to adopt to such practices.

It is observed that majority of the households were located in AER II at 46 percent followed by those in AER III with about 27 percent of the total. AER I had the least number of households at 26 percent of the total number of households. In AER I, the results indicate that ploughing tillage method is the most practised at 54 percent and ridging tillage method was the least tillage method practised at less than 1 percent. In AER II, CT tillage method was the most practised at 72 percent and the least tillage method was ploughing. The results further indicate that the majority of the households located in AER III reported to have been using ridging tillage methods at 55 percent. When it comes to asset ownership, the results show that from the total sample, 66 percent of the households reported to have owned radio and 59 owned mobile phones. The radio was found to be useful in the communication of agricultural information. Households that owned cattle were found to be at 38 percent of the total sample. Cattle are used mainly in ploughing.The results show that 65 percent of the households that owned cattleused ploughing tillage method. This is expected as ploughing involves the use of animal draught power, hence, households that own cattle are likely to adopt ploughing tillage method.

Access to information was found to be important among smallholder farmers. There are so many ways in which information can be accessed. Information can be accessed through extension officers, farmer cooperative and women group meetings. From the total sample, the results indicate that 87 percent of the smallholder farmer households had access to extension services while 52 percent belonged to a cooperative and 24 percent towomen's group. The majority of the smallholder households that had access to extension services used ploughing tillage method at 89 percent.Less than 10 percent of the total sample had access to credit. Therefore, the adoption rates for those with access to credit was low for all the tillage methods, with less than 10 percent for each tillage method. Access to credit plays a very important role as it enables smallholder farmers to venture in various farming activities especially those that require the purchase of equipment.

Finally, results on crop management practices indicate that the amount of basal and top dressing fertilizer applied was found to be almost the same in each type of tillage method per hectare. In the total sample, the results show that about 119kg of both basal and top dressing fertilisers were applied in the maize fields per hectare. The results show that most basal and top dressing fertilisers were applied in ploughing tillage methodofabout 142 and 143kg/ha, respectively. The least amount of both basal and top dressing fertiliser applied was in the conventional hand hoe plots with only about 84kg of each per hectare. On average, 43 percent of the total smallholder farmer households had planted local maize seed variety or recycled maize seed variety. These results were consistent with the other tillage methods were about half of the households had planted local maize seed variety in their fields. When it comes to land size, the results show that on average, the smallholder farmer had 1.27 ha of maize field. The results further show that households that adopted ploughing tillage method had larger maize fields of 1.66 ha while the conventional hand-hoe tillage method had the least amount of land size for maize at less than 1 ha. Planting of maize can either be done before or during the rains. From the total sample, 83 percent of the smallholder farm households indicated that they planted their maize during the rainy season. This was found to be consistent with the rest of the tillage methods where more than half of the households planted their maize during the rainy season for each tillage method type.

4.4 Determinants of Factors Affecting Adoption of Tillage Methods

The adoption of tillage methods depend on the availability of information, finance, labour and other complementary inputs available to the farmer. In this study, one of the objectives was to identify the determinants of tillage method adoption in Zambia. The probit model was employed to achieve this objective.Therefore, this section discusses results of the probit model analysis of factors affecting smallholder farm households' choices of particular land preparation tillage method.

4.4.1. Estimation of the propensity scores for Conventional hand-hoe

The balancing property was satisfied to indicate that within the region of common support, fell the conventional hand-hoe comparison and treatment smallholder farm households with similar observable characteristics. The common support region was selected and only 7,569 observations fell within and 1,372 observations did not satisfy the common support region and these were dropped in order to have robust results. The balancing test was satisfied and the results are presented in Appendix 4.

4.4.2. Estimation of the propensity scores for Conservation tillage

From the overall sample size of 8,941 smallholder farm households,7,850 observations fell within the common support region while 1,091 did not fall within the common support region. The kernel density distributions of the propensity scores was done and plotted in Figure 7 below. The densities of the scores are on the y-axis and the PScores are on the x-axis. The balancing property was satisfied to indicate that within the common support, fell the CT comparison and treatment smallholder farm households with similar observable characteristics. The table of the balancing test is presented in Appendix 5.

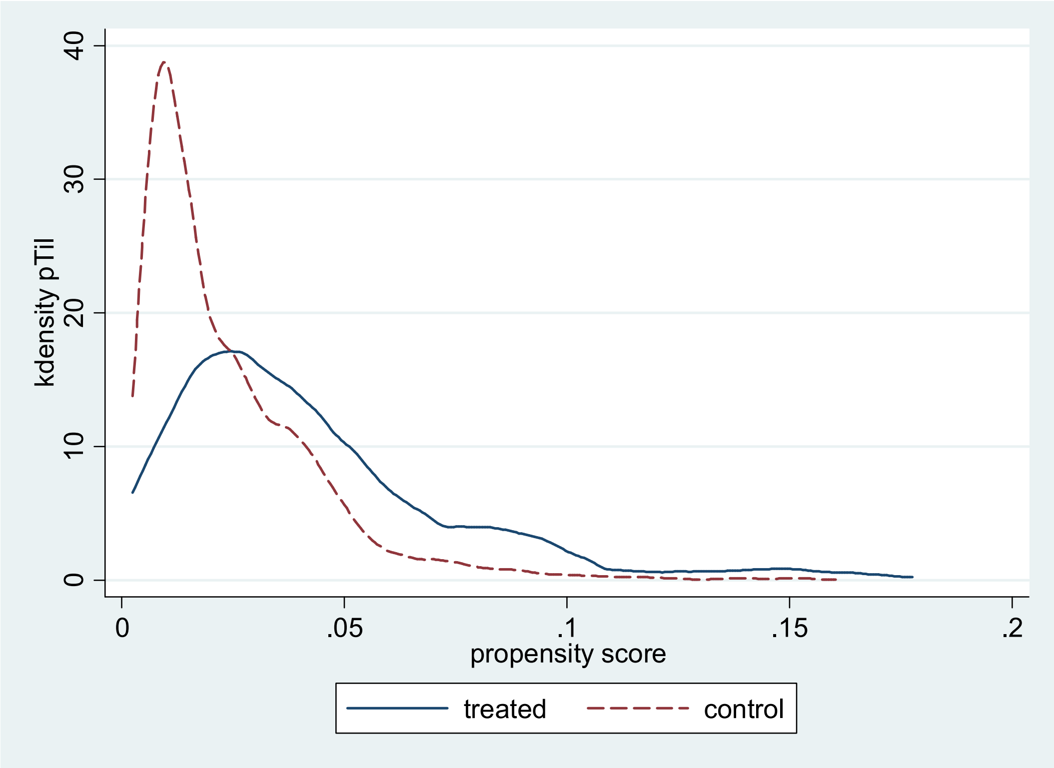


Figure 7: Propensity score kernel distributions for Conservation tillage comparison and treatment

Source: Authors'calculations, Data from RALS 2012

4.4.3. Estimation of the propensity scores for Ploughing tillage method

This section shows propensity scores for ploughing tillage method so as to cater for those smallholder farm households who may decide to use ploughing tillage method alone. The model results indicate that from a total sample size of 8,941 households, only 7,720 smallholder farm households fell within the area of the common support region and 1,221 did not.

4.4.4. Estimation of the propensity scores for Ridging tillage method

In the sample there were smallholder farmer households that practised ridging tillage method alone. A total of 8,589 observations satisfied the common support condition with 352 observations which did not fall within the common support region.

Table 4: Determinants of use of Hand-hoe, CT, Ploughing, Ripping and Ridging Tillage Methods from the Probit Model

Variable	conventional hand-hoe	conservation tillage	ploughing	ridging
Farm Household Characteristics				
Age of head in years	0.006***	0.001	-0.004**	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Age squared of head	-4.58e-05**	-9.53E-06	2.99e-05*	2.07E-05
	(0.000)	(0.000)	(0.000)	(0.000)
Sex of head(=1 if male)	-0.037	0.01	0.018	0.009
	(0.023)	(0.010)	(0.019)	(0.023)
Household size (number)	-0.003	0.001	0.001	0
	(0.003)	(0.010)	(0.002)	(0.003)
None education (=1 if yes)	0.060**	-0.036***	-0.008	-0.009
	(0.029)	(0.009)	(0.023)	(0.026)
Primary education (=1 if yes)	0.068***	-0.023***	-0.014	-0.028
	(0.025)	(0.007)	(0.020)	(0.022)
Basic education (=1 if yes)	0.033	-0.037***	-0.01	0.015
	(0.026)	(0.008)	(0.021)	(0.024)
Secondary education(=1 if yes)	0.044	-0.031***	0.013	-0.021
	(0.027)	(0.008)	(0.022)	(0.025)
Never married (=1 if yes)	0.140***	-0.014	-0.010**	-0.031
	(0.048)	(0.025)	(0.044)	(0.062)
Monogamously head (=1 if yes)	0.0222	-0.012	-0.014	0.013
	(0.028)	(0.011)	(0.023)	(0.029)
Polygamously head (=1 if yes)	-0.0452*	-0.009	0.007	0.044
	(0.027)	(0.011)	(0.023)	(0.029)
Widowed head (=1 if yes)	-0.01	-0.002	0.013	0.004
	(0.024)	(0.010)	(0.021)	(0.025)
Cohabiting head (=1 if yes)	0.383**		-0.281*	
	(0.189)		(0.150)	
Climatic factors				
AER I (=1 if yes)	-0.219***	0.004	0.610***	-0.763***
	(0.014)	(0.006)	(0.010)	(0.044)
AER II (=1 if yes)	-0.0266**	0.029***	0.287***	-0.177***
	(0.011)	(0.005)	(0.012)	(0.009)
Assets				
Own a radio (=1 if yes)	-0.0216**	0.003	-0.011	0.032***
	(0.010)	(0.004)	(0.009)	(0.010)

Variable	conventional hand-hoe	conservation tillage	ploughing	ridging
Own a mobile phone (=1 if yes)	0.00211	0.010**	0.015*	-0.026***
	(0.010)	(0.004)	(0.009)	(0.010)
Own Cattle (=1 if yes)	-0.232***	-0.002	0.170***	-0.017
	(0.011)	(0.004)	(0.008)	(0.011)
Information access				
Extension service (=1 if yes)	-0.0331**	-0.008	0.035***	0.01
	(0.014)	(0.005)	(0.012)	(0.015)
Cooperative (=1 if yes)	-0.00401	0.003	-0.030***	0.044***
	(0.011)	(0.004)	(0.009)	(0.010)
Women group (=1 if yes)	0.000521	0.004	0.019*	-0.025**
	(0.011)	(0.004)	(0.010)	(0.011)
Access to credit	0.0446*	0.013*	-0.026	-0.033
	(0.023)	(0.007)	(0.020)	(0.022)
Crop Management Practices				
Basal dressing (kg/ha)	-5.93E-06	-4.95E-06	4.81E-05	-7.66E-05
	(0.000)	(0.000)	-	-
Top dressing (kg/ha)	-1.78E-05	-6.86E-06	-9.72E-05	0
	(0.000)	(0.000)	-	-
Maize seed Variety (=1 if local variety)	0.0547***	-0.001	-0.088***	0.036***
	(0.011)	(0.004)	(0.009)	(0.010)
Land size (hectares)	-0.0160***	7.32E-05	0.0302***	-0.027***
	(0.005)	(0.001)	(0.004)	(0.005)
Tillage in rains (=1 if during rains)	-0.120***	-0.0137***	0.179***	-0.015
	(0.012)	(0.005)	(0.013)	(0.012)
Observations	7,849	7,846	7,849	7,846

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Author's calculations, Data from RALS 2012

Table 4shows results of the probit model. Age of the household head was found to be statistically significant in the adoption of conventional hand-hoe and ploughing tillage methods. The positive sign on the coefficient of age of the household head on conventional hand hoe indicate that one year increase in age of the household head would lead to a 0.006increase in the adoption of conventional hand-hoe. This implies that as the age of the household head increases, the more likely to adopt conventional hand-hoe.However, the negative sign of age on the ploughing tillage method shows that as the household head age increases, the less likely of adopting ploughing tillage method. These results could be because older household heads tend to be rigid to new technologies and want to maintain their old way of doing things and conventional hand-hoe is known from way back. Therefore, someone would want to stick to want they already know. These results contradicts with the results obtained by Kassie *et al*. (2013), where it was observed that older farmers are more experienced with different farming technologies and have more capital which can enable them to adopt to different farming practices. The negative sign of age squared on conventional hand-hoe indicate that as age of the household head progresses, it reaches a point that adoption of conventional hand-hoe begin to decrease. While the positive sign of age squared on ploughing tillage method shows that as the age of the household head increases, it reaches a point that adoption to ploughing tillage method begin to increase.

The results further indicate that sex of the household head was found not to be statistically significant in determining the adoption of any of the tillage methods. These results contradicts with the ones obtained by Manda*et al*. (2015).It was observed that most land preparation methods are labor intensive and requires high man power, therefore there are mostly adopted by male headed households and not female headed. Women also face the challenges of accessing inputs such as land, education and information on improved agricultural farming activities (Pender and Gebremedhin, 2007, Doss and Morris, 2000). This also hinders them to venture in certain tillage methods. Most of the cooperatives and farmer groups are mostly attended by males, therefore, more males are expected to adopt most of the farming technologies.

The results on the highest level of education attained by household head indicate that household heads that had not attained any level of education would adopt more of conventional hand-hoe by 0.06 but less likely to adopt CT by 0.036. The results further indicate that smallholder farm household heads with only primary level of education would adopt more of hand-hoe by 0.068 and reduce the adoption of CT method by 0.036. Household heads with basic level of education were found to adopt CT methods less by 0.03 compared to those that had attained tertiary level of education.

When it comes to marital status, divorced household heads was the reference variable, the results indicate that household heads who have never being married, the adoption of conventional hand-hoe would increase by 0.14. The results further show that household heads in polygamous marriages would adopt less of conventional hand-hoe by 0.05. Cohabiting household heads would increase the chances of adopting conventional hand-hoe and less likely to adopt ploughing tillage method.

Both AER l and ll were found to be statistically significant in the adoption of tillage methods with AER III being the reference variable. The results show that households that belonged to AER l and II had less chances of adopting conventional hand-hoe by 22 and 2.7 percents, respectively and also less likely to adopt ridging tillage methods by 76 and 18 percents, respectively compared to households in AER III. The results show that households in AER I and II had more chances of adopting ploughing tillage method at 61 and 29 percents respectively compared to the households in AER III. AER l receives less amount of rainfall of less than 800mm annually, therefore the land is usually hard and requires the use of machinery to till the ground. That could be the reason why ploughing tillage method is mostly adopted in AER I unlike conventional hand-hoe. AER ll was found to be statistically significant in all the tillage methods practiced by smallholder farmer households. AER ll receives annual amount of rainfall of between 800 to 1000mm and may also require the use of machinery to till the ground.

When it comes to asset ownership, the results show that smallholder farmer households that owned a radio had higher chances of adopting ridging tillage method by 3 percent but less chances of adopting conventional hand-hoe by 2 percent. Smallholder farmer households that owned a mobile phone were found to have more chances of adopting CT and ploughing tillage method by about 1 percent each and less chances of adopting ridging tillage method at 2.6 percent. A radio and a cellphone are means of communication used by most of the smallholder farmer households to access information on different farming technologies. The results show that smallholder farmer households that owned cattle would adopt less of conventional hand-hoe by 23 percent and adopt more of ploughing tillage method by 17 percent. This is expected as ownership of cattle by smallholder farmer households would allow the use of a plough, hence, the reason why ploughing tillage method is more adopted to households that own cattle.

The other factors that were found to affect the adoption of tillage methods wereaccess to information like extension services, belongingness to a farmer cooperative or women group and others. Access to credit and loans are also important factors in the adoption of tillage methods. These factors were included in the model for adoption of tillage methods. Access to information plays a vital role in the adoption process of tillage methods. Smallholder farmer households that had access to extension services were found to have higher chances of adopting ploughing tillage method by 4 percent but less chances of adopting conventional hand-hoe by 3 percent. This could be because ploughing tillage method requires knowledge on how to use the instrument and other things. Therefore, the more support one receives from extension officers the more likely they began to think of adopting it. Extension services rendered to smallholder farmer households is very important as it helps them obtain adequate information on what type of farming techniques to apply. Unlike most of the studies supporting extension services as a factor that influences adoption of tillage methods, Bryan *et al*. (2009), found that access to extension services was not important in farmers' decision to adopt to climate change adaptation strategies. Some instances reveal that households with no access to agricultural extension support usually practiced pot holing (Chomba, 2004), maybe because it is found to be simpler to follow without any help from extension officers unlike other tillage methods.

Household heads that reported to belong to a cooperative had less chances of adopting ploughing tillage method but were more likely to adopt ridging tillage method. Unlike being a member of a cooperative, households that belonged to a women group had high chances of adopting ploughing tillage method and less chances of adopting ridging tillage method. Access to credit was found to be statistically significant in the adoption of conventional hand-hoe and CT. Households with access to credit were found to increase the adoption of both conventional hand-hoe and CT tillage methods by 4.4 and 1.3 percent, respectively. This was not expected on conventional hand-hoe, as access to credit ought to allow smallholder farmer households to apply more complex tillage methods rather than the use of conventional hand-hoe.

Planting of local/recycled maize seed varietywas found to be statistically significant in the adoption of all tillage methods except for CT. The results indicate that smallholder farmer households that plant local/recycled maize seed variety are more likely to adopt hand-hoe and ridging tillage methods but there are less likely to use ploughing tillage method.The size of the maize field was also found to be statistically significant in the adoption of tillage methods. The results indicate that as the size of the land is increasing, the smallholder farmer household would adopt less of hand-hoe and ridging tillage methods, but would adopt more of ploughing tillage method. Ploughing involves the use of draught power, therefore, the bigger the land size, the more use of ploughing method because there is not so much involvement of manual labor compared to the use of a hand-hoe. Households with bigger sizes of land found it difficult to employ labor intensive farming technologies such as the use of hand-hoe or ridging tillage methods due to the labor that is involved. The results are consistent with results found by Teklewold*et al*. (2013a) and Manda *et al.* (2015). Households with more land are likely to adopt different tillage methods as they can allocate to a portion of area to a particular tillage method. Therefore, households with larger pieces of land are likely to adopt several of these agricultural technologies compared to those with rented pieces of land. In some studies, it is observed that households with smaller area cultivated tend to have higher adoption rates of hand-hoe to prepare their fields (Arslan*et al*., 2013).Finally, tillage done during the rains would enable the smallholder farmer household to adopt more of ploughing and less of conventional hand-hoe and CT tillage methods.

4.5Impact of Tillage Methods on Maize Productivity

Table 5 reports the impact of various variables on the log of maize productivity.The table presents estimation of the impact by OLS of the log of maize productivity function and also MRM on the log of maize productivity. OLS does not account for potential structural differences between adopters and non-adopters of tillage methods. Therefore, estimation using OLS would lead to biase and inconsistent estimates.MRM was used to account for households with different observations. We took into account households which have more than one maize field. The R- squared was found to be 22 percent. This shows how much of the variation in maize productivity is actually explained by the independent variables. This means that about 78 percent of the maize productivity for the smallholder farmer households is left unexplained because there are many other characteristics that should influence the productivity of maize. Model diagnostics were performed to check for possible model specification errors. The model was highly statistically significant at 1 percent significance levels. Tests showed that the model was free from omitted variables and multicollinearity with the VIF of less than 10 as shown in appendix three (3).

Table 5: Maize ProductivityRegression Model Estimates

Variable Name	OLS	Mixed-Effects Regression
Tillage methods		
Conventional hand-hoe (=1 if yes)	-0.008 (0.020)	-0.010 (0.020)
Conservation Tillage (=1 if yes)	0.1159**	0.0827*

Variable Name	OLS	Mixed-Effects Regression
	(0.047)	(0.047)
Ploughing (=1 if yes)	0.024	0.019
	(0.023)	(0.024)
Farm Household Characteristics		
Age of head in years	-0.0012**	-0.0014**
	(0.00)	(0.00)
Sex of household (=1 if male)	0.043	0.051
	(0.037)	(0.039)
Household Size (number)	0.004	0.004
	(0.004)	(0.005)
None Education (=1 if yes)	-0.0866**	-0.0933**
	(0.042)	(0.045)
Primary Education (=1 if yes)	-0.0761**	-0.0860**
	(0.036)	(0.038)
Basic Education (=1 if yes)	-0.029	-0.048
	(0.038)	(0.040)
Secondary Education (=1 if yes)	-0.034	-0.046
	(0.039)	(0.042)
Never married (=1 if yes)	0.093	0.074
	(0.085)	(0.087)
Monogomously head (=1 if yes)	0.054	0.056
	(0.046)	(0.047)
Polygamously head (=1 if yes)	0.055	0.074
	(0.047)	(0.049)
Widowed head dummy (=1 if yes)	0.0984**	0.1089**
	(0.042)	(0.044)
Cohabiting head (=1 if yes)	-0.116	-0.107
	(0.130)	(0.135)
Climatic factors		
AER I (=1 if yes)	-0.2329***	-0.2464***
	(0.028)	(0.030)
AER II (=1 if yes)	-0.1097***	-0.1100***
	(0.019)	(0.020)
Assets		
Access to Radio (=1 if yes)	0.0466***	0.0551***
	(0.017)	(0.018)
Own a mobile phone(=1 if yes)	0.000	0.008
	(0.017)	(0.018)
Own Cattle (=1 if yes)	0.1188***	0.1221***

Variable Name	OLS	Mixed-Effects Regression
	(0.018)	(0.020)
Information access		
Extension service (=1 if yes)	0.1193***	0.1147***
	(0.026)	(0.027)
Cooperative (=1 if yes)	0.1013***	0.1146***
	(0.017)	(0.018)
Women group (=1 if yes)	0.007	-0.008
	(0.017)	(0.018)
Access to credit (=1 if yes)	-0.031	-0.028
	(0.036)	(0.038)
Crop Management Practices		
Basal dressing (kg/ha)	0.0005**	0.0003*
	(0.000)	(0.000)
Top dressing (kg/ha)	0.0006***	0.0008***
	(0.000)	(0.000)
Maize seed Variety (=1 if local variety)	-0.2955***	-0.2833***
	(0.018)	(0.018)
Land size (hectares)	-0.1475***	-0.1449***
	(0.009)	(0.009)
Tillage in rains (=1 if during rains)	0.0781***	0.0722***
	(0.022)	(0.022)
Constant	7.6917***	7.6998***
	(0.066)	(0.069)
R-squared	0.222	6620.000
Log Pseudo		7102.375
Wald chi2		1742.72
Prob>Chi2	0.000	0.000
Number of Observations	7814	7814

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations, Data from RALS 2012

The results clearly show that the variables that are significant for both OLS and MRMare the same, the only difference was in the size of the parameters. In this study, only the MRM results were interpreted. The results indicate that among all the tillage methods used by smallholder farm households, CT was found to be statistically significant in determining the impact of maize productivity. The results indicate that smallholder farmer households that practiced CT tillage methods were found to have an increase in maize productivity of 8.3 percent compared to the ones that used ridging tillage methods. Some studies have indicated that tillage methods are not significant in determining the yield of crops (Aykas and Onal, 2004).The other tillage methods though found not to be statistically significant in measuring maize productivity were found to either positively or negatively affect the productivity of maize. Ploughing tillage method was found to be positively affecting maize productivity, the results show that smallholder farmer households that practiced ploughing tillage method would experience a 1.9 percent rise in maize productivity while smallholder farmers using conventional hand-hoe tillage method would have their maize productivity reduce by about 0.2 percent.

Age of the household head was found to negatively affect the productivity of maize. As smallholder farmer household heads get older, the less maize they produce per hectare. The other factors that had an impact on maize productivity included the education level of the household head. Household heads that have never attained any formal level of education or have attained primary level of education were found to reduce the productivity of maize by less than 10 percent compared to those that have attained tertiary education. The results further indicate that household heads that are widowed would have more maize produced per kg by 10.9 percent. When it comes to climatic factors, smallholder farmer households located in AER I and II would experience a reduction in the maize yield per hectare of 24 and about 11 percent, respectively compared to those smallholder households located in AER III. This could be because AER I and II are low rainfall areas and drought prone areas in Zambia which could affect the productivity of maize. Ownership of a radio or cattle was found to increase maize yields by 5.5 and 12 percent, respectively. This is expected as a radio will enable the household have access to information which would enable them to practice improved technologies in order to have an increase in their yields. Cattle provides labour for conventional practices such as ploughing tillage methods which would enable the farmer cultivate more land since there is no manual labor that is involved. These results are consistent with those by Kassie *et al.* (2012), in Tanzania. The results further show that smallholder farmer households that had access to extension services and or were members of a cooperative would have high maize productivity per hectare of 11 percent each. This confirms the results by Haggblade and Tembo (2003),smallholder farmer households with access to extension services were more likely to adopt certain improved agricultural technologies which would later improve on their maize production.

The results further demonstrates that smallholder farmer households that had applied basal and or top dressing fertiliser would experience high maize yields of 0.1 percent each.This is expected as maize requires the application of fertiliser for optimum growth, hence application of fertilisers improves the productivity of maize. Planting of the local or recycled maize seed and the size of the maize field, had a negative impact on the productivity of maize. Smallholder farmers that planted local or recycled maize seed would experience 28 percent less of the yields. An increase in the size of the maize field by 1 hectare would result into a reduction in maize productivity by 14 percent. Finally the regression results show that smallholder farmer households that planted during the rainy season are more likely to experience more yields of about 7 percent unlike smallholder farmers that planted before the onset of the effective rains.

CHAPTER 5

CONCLUSIONS AND RECCOMMENDATIONS

5.1 Introduction

This chapter begins with the conclusion of the study where its objectives and key findings are summarized. It later presents the policy and recommendations proposed based on the findings of the study.

5.2 Conclusions

To estimate the impact of various tillage practices by smallholder farm households on maize productivity in Zambia, the study looked at the four tillage methods that are practiced by smallholder farm households and these were conventional hand-hoe, CT, ploughing and ridging tillage methods. The study found that the majority of the smallholder farm households practice conventional ploughing at about 41 percent. Regardless of CT being highly promoted and having many potential economic and environmental advantages it was still found to be the least tillage method practiced by smallholder farm households at about 2 percent.

To determine the factors that affect adoption of various tillage methods, a probit model was employed. The results indicate that there are several factors that affect the determinants of various tillage methods. The results showed that conventional hand-hoe was positively affected by age of household head, head who has never been to school, primary education level, never married, cohabiting head, access to credit and planting of local maize seed variety. The study further observed that the determinants of hand-hoe was negatively affected by age squared of head, polygamous head, location in AER I and II, ownership of a radio, ownership of cattle, access to information services, size of land and the tillage done in the rains. Based on the research results, it can be concluded that age and education level of household head has a strong influence on the adoption of convention hand-hoe. Smallholder farmers in their young age of life would be able to adopt more convention hand-hoe but as age progresses it reaches a time that they would desist from using the hand-hoe. It can also be concluded that smallholder farmer households with lower levels of education tend to practice more of conventional hand-hoe tillage method.

CT was found to be positively affected by AER II, ownership of a mobile phone and access to credit. Ownership of a mobile phone is equally important in the adoption of CT because it enables smallholder farmers to have quick access to information. On the other hand, CT was found to be negatively affected by all levels of education except for tertiary level. This shows that more educated smallholder farmers tend to adopt more of CT methods than the less educated smallholder farmers. Similarly, tillage done during the rainy season would also reduce the adoption of CT.

The results further demonstrate that factors that would increase the adoption of ploughing tillage method, include, age squared of household head, location in AER I and II, ownership of a mobile phone, ownership of cattle, access to extension services, membership to a women group, size of the land and tillage done in the rains. Similarly factors that would reduce the adoption of ploughing tillage method are age of household head, never married, cohabiting, household being a member of a cooperative and planting of a local maize variety. Smallholder farmers in their young stage in life would adopt less of ploughing tillage method but as age progresses they began to adopt more of ploughing tillage method. Ownership of cattle would make it easier for the smallholder farmer households to adopt ploughing tillage method.

Finally, the results on ridging tillage method shows that factors such as ownership of a radio, membership to a cooperative and local maize seed variety would increase the adoption of ridging tillage method. Factors that reduce the adoption of ridging tillage method would be AER I and II, ownership of a mobile phone, membership to a women group and land size.

To assess the impact of tillage methods on maize productivity among the smallholder farm households, the MRM was employed. The results indicate that the smallholder farmer households that adopted CT realized more maize produced per hectare than they would if they had adopted any other tillage method.

5.3 Recommendations

These results are important to inform policy makers on the effective tillage methods that can be implemented by smallholder farmer households in order to improve their productivity in maize and improve their livelihoods. The study has shown that more educated smallholder farmer households (tertiary education) have the high chances of adopting CT. It is therefore recommended that more attention be paid to this target group in particular.

Results on the impact of tillage methods on maize productivity indicate that CT results into higher maize productivity. Considering the declining agricultural productivity in Zambia, there is urgent need to promote the use of CT methods. Therefore, this study recommends that the promoters of CT in Zambia should continue doing so as maize produced per hectare from CT tend to be more than any other tillage method.

General recommendations that can be made is that households should be encouraged to have access to radios and mobile phones for easily accessibility of agricultural information which can enable them apply improved agricultural technologies. Ploughing tillage method should be encouraged in livestock prone areas because it was found that smallholder farm households that owned cattle had higher chances of adopting ploughing tillage method and this resulted into high maize productivity though not statistically significant. Households should be encouraged to belong to a women group or cooperative as this increases the chances of adopting more improved tillage methods and hence results in more maize productivity.

Finally, smallholder farm households should be encouraged to be planting improved maize varieties as this was found to increase maize productivity.

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APPENDICES

Appendix 1: Pairwise correlation of the independent variable on the outcome and treatment groups

Variable name	Maize Productivity	Dummy variable CT
Farm Household Characteristics		
Age of head in years	-0.015	0.005
Age squared of head	-0.023**	0.002
Sex of head(=1 if male)	0.069***	0.003
Household size	0.085***	0.024**
None education	-0.058***	-0.018*
Primary education	-0.082***	0.012
Basic education	0.045***	-0.024*
Secondary education	0.077***	-0.001
Tertiary education	0.083***	0.044***
Never married	-0.004	-0.010
Monogamously head	0.050***	0.007
Polygamously head	0.005	-0.007
Widowed head	-0.039***	0.004
Cohabiting head	-0.015	-0.004
Climatic factors		
AER I	-0.106***	-0.040***
AER II	0.018**	0.080***
AER III	0.085***	-0.049***
Assets		
Own a radio	0.117***	0.024***
Own a mobile phone	0.131***	0.042***
Own Cattle	0.061***	-0.008
Information access		
Extension service	0.102***	-0.001
Cooperative	0.216***	0.022**
Women group	0.090***	0.028***
Access to credit	0.036***	0.041***
Crop Management Practices		
Basal dressing	0.249***	0.008
Top dressing	0.250***	0.009
Maize seed Variety	-0.291***	-0.019*
Land size	0.052***	0.010
Tillage in rains	0.013	-0.033***

Appendix 2: Results of Multicollinearity Test

Variable name	VIF	1/VIF
Top dressing fertilizer	44.740	0.022
Basal dressing fertilizer	44.380	0.023
Monogamously head	8.170	0.122
Primary education	6.880	0.145
Polygamously head	4.740	0.211
Basic education	4.430	0.226
None education	3.660	0.273
Sex of head(=1 if male)	3.570	0.280
Secondary education	3.400	0.294
AER I	2.740	0.364
Ploughing	2.660	0.376
Widowed head	2.620	0.382
Land size	2.080	0.481
AER II	1.870	0.534
Conventional hand-hoe	1.560	0.643
Own Cattle	1.540	0.650
Cooperative	1.380	0.722
Maize seed Variety(=1 if local/recylcled 0 otherwise)	1.360	0.738
Own a mobile phone	1.310	0.763
Household size	1.290	0.775
Age of head in years	1.240	0.804
Never married	1.200	0.832
Own a radio	1.180	0.848
Women group	1.150	0.869
Conservation Tillage	1.110	0.904
Tillage in rains	1.090	0.920
Extension service	1.060	0.939
Access to credit	1.050	0.957
Cohabiting head	1.010	0.989
Mean VIF	5.330	

Joint test of top dressing fertilizer and basal dressing

F= 105.63

Prob>F=0.000

Appendix 3: Balancing Tests for Hand-Hoe Covariates

Variable	Mean		%bias	*t* test
	Hand-hoe	Non-handhoe		*p* values
Age of head in years	2369.3	2332.8	2.4	0.439
Household size	3.684	3.645	2	0.489
None education	0.120	0.120	0	1
Primary education	0.593	0.569	4.9	0.113
Basic education	0.151	0.164	-3.5	0.256
Secondary education	0.105	0.113	-2.7	0.375
Tertiary education	0.032	0.035	-1.5	0.609
Monogamously head	0.730	0.711	4.2	0.171
Widowed head	0.112	0.123	-3.8	0.252
AER I	0.098	0.102	-1	0.682
own a radio	0.623	0.630	-1.4	0.657
own a mobile phone	0.542	0.554	-2.5	0.423
Own Cattle	0.112	0.100	2.8	0.212
Extension service	0.850	0.857	-2	0.544
Cooperative	0.507	0.491	3.2	0.297
Access to credit	0.047	0.046	0.5	0.884
Basal dressing	90.675	93.470	-1.5	0.552
Top dressing	91.436	94.614	-1.7	0.498
Maize seed Variety	0.492	0.480	2.3	0.461
Land size	0.972	0.979	-0.5	0.84

Source: Author"s Calculations. Data from RALS 2012

Appendix 4: Balancing Tests for CT Covariates

Variable	Mean		%bias	t test
	CT	Non-CT		*p* values
Age Squared	2345.7	2501.0	-10.8	0.304
Sex of head	0.849	0.823	7.2	0.492
Household size	4.240	4.057	9	0.343
None education	0.068	0.099	-11	0.269
Primary education	0.599	0.568	6.3	0.536
Basic education	0.109	0.099	3	0.739
Secondary education	0.109	0.125	-4.9	0.635
Monogamously head	0.729	0.667	13.9	0.183
Widowed head	0.089	0.115	-9.2	0.4
AER I	0.151	0.161	-2.6	0.779
AER II	0.714	0.719	-1.1	0.91
AER III	0.135	0.120	3.9	0.647
own a radio	0.755	0.719	8.1	0.418
own a mobile phone	0.740	0.786	-10.1	0.281
Own Cattle	0.359	0.323	7.5	0.452
Extension service	0.870	0.813	17.4	0.125
Cooperative	0.620	0.578	8.5	0.406
Women group	0.323	0.328	-1.2	0.914
Access to credit	0.078	0.042	15.7	0.133
Basal dressing	138.170	115.210	11	0.181
Top dressing	139.440	113.150	12.6	0.117
Maize seed Variety	0.359	0.380	-4.3	0.673
Land size	1.416	1.252	11.8	0.19
Tillage in rains	0.771	0.776	-1.3	0.903

Source: Author"s Calculations. Data from RALS 2012