# IMPACT OF CONSERVATION AGRICULTURE ON MAIZE PRODUCTIVITY AND INCOME AMONG SMALLHOLDER FARMERS IN SELECTED PROVINCES OF ZAMBIA

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## DECLARATION

I, EUGINE MWIINGA, do hereby declare that this dissertation is my original work and that no similar work has been previously published and presented for any award of a degree at the University of Zambia or any other university. Where other sources of information have been used, they have been acknowledged accordingly.

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## APPROVAL

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ABSTRACT

Agriculture is the main source of livelihood for majority smallholder farm households in Zambia, which constitutes more than 75% of the population. However, climate change continues to pose a serious threat to agricultural productivity due to its adverse effects that cause soil infertility and reduced crop productivity. In order to address this problem, the Government of the Republic of Zambia introduced Conservation Agriculture (CA) in the 1990's as a mitigation and adaption measure.

CA has been practiced for over two decades, but its impact has not been investigated conclusively probably the evaluation studies used cross sectional surveys, small sample sizes or the data lacked detail. Furthermore, very little work has been done to evaluate the impact of CA on maize productivity and income among smallholder farmers in dominant maize growing provinces of Zambia particularly; Southern, Lusaka, Central and Eastern that are located in AER I and II. Hence, this study sought to bridge this research gap by using the Rural Agricultural Livelihood Surveys 2012 (RALS 2012) data that contains a comprehensive description of Zambia's small and medium scale farming. This objective was achieved by utilizing a probit econometric model and the Propensity Score Matching (PSM) technique. The matching process using the kernel and nearest neighbour matching algorithms was also performed. Results of the study reveal that variables such as livestock assets, adult equivalent, access to loans/credit, CA advice, ZNFU/CFU extension services, Cooperatives/Farmer group extension services and farm location (Eastern, Central and Lusaka province) were positively correlation with adoption of CA adoption. The study found that practicing CA was significantly associated with improvements in maize productivity and income and smallholder maize farmers that adopted CA increased maize productivity and income by 41.8% to 43.9% and 20.7% to 22.1% respectively.

The adoption of CA in Zambia can be enhanced much more through an effective and efficient extension service delivery system. This can be achieved by strengthening collaboration between stakeholders including public/private institutions whose strategic support and services have shown a significant drive towards the enhancement of CA adoption.

**Keywords**: *Conservation Agriculture, Impact, Crop Productivity, Propensity Score Matching, Average Treatment on the Treated, Zambia.*

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## LIST OF ACRONYMS

| | |
|---|---|
| **AER** | Agro-Ecological Region |
| **ASP** | Agricultural Support Programme |
| **CA** | Conservation Agriculture |
| **CFU** | Conservation Farming Unit |
| **CLUSA** | Co-operative League of the United States of America |
| **CSA** | Climate Smart Agriculture |
| **CSO** | Central Statistical Office |
| **DFID** | Department for International Development |
| **FAO** | Food and Agriculture Organisation of the United Nations |
| **FAD** | Food Availability Declining |
| **FED** | Food Entitlement Declining |
| **FISP** | Farmer Input Support Programme |
| **FAOSTAT** | Food and Agriculture Organisation Statistics |
| **GART** | Golden Valley Agricultural Research Trust |
| **GRZ** | Government of the Republic of Zambia |
| **IAPRI** | Indaba Agricultural Policy Research Institute |
| **ICRAF** | World Agro-Forestry Centre |
| **IFAD** | International Fund for Agricultural Development |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **MAL** | Ministry of Agriculture and Livestock |
| **MDGs** | Millenium Development Goals |
| **MT** | Minimum Tillage |
| **NAPA** | National Adaptation Programme of Action |
| **NOAA-CP** | National Oceanic and Atmospheric Administration-Climate Prediction Centre |
| **NORAD** | Norwegian International Development Agency |
| **RILS** | Rural Income and Livelihood Surveys |
| **SCAFE** | Soil Conservation and Fertility project |
| **SIDA** | Swedish International Development Agency |
| **SSA** | Sub-Saharan Africa |

| | |
|---|---|
| **SNDP** | Sixth National Development Plan |
| **UN** | United Nations |
| **UNFPA** | United Nations Population Fund Agency |
| **WFP** | World Food Programme |
| **ZMW** | Zambian Kwacha Rebased (Currency) |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Agriculture is the mainstay for most smallholder farm households in sub-Sahara Africa including Zambia. It contributes positively to development as an economic activity and source of growth for the national economy. Agriculture provides a livelihood for most rural farm households in developing countries and environmental services such as sequestration of carbon and preservation of biodiversity (World Bank, 2008). Generally, agriculture plays a very significant role in enhancing food security because of its direct contribution to food availability and economic access through income (World Bank, 2008). In Zambia, the agricultural sector contributes about 18 per cent to the gross domestic product (GDP), provides livelihoods to more than 50 per cent of the population and employs about 70 per cent of the national labour force (GRZ, 2019). The above scenario underscores the importance of the agricultural sector to the Zambian economy.

The Sub-Saharan Africa (SSA) region is experiencing increasing pressure with regard to food and agricultural systems. Smallholder farmers all over the region must strive to manage the intertwined challenges of climate change and the subsequent rise in climate variability, declining land availability and declining soil fertility. Rising and unpredictable food prices, in addition to increasing food demand resulting from population and per capita income growth also put more pressure on domestic production systems (Deininger, 2013; Laurance, Sayer & Cassman, 2013). The current smallholder productivity levels in SSA are very low, particularly in sparsely populated countries such as the Democratic Republic of Congo, Sudan, Tanzania, and Zambia which falls below 25% of their potential (Deininger, 2013). However, SSA demonstrates that great opportunities exist to counter this challenge of low farm productivity being experienced. Considering the above situation, it is appropriate to develop strategies that can significantly increase agriculture productivity and at the same time increase the resilience of rain-fed farming systems to climate variability.

The pressure on food and agricultural systems has resulted in food insecurity in developing countries particularly in SSA region were food inefficiency is an everyday occurrence to millions of people (FAO, 2011). Several factors lead to food insecurity and the IPCC (2007) report cites climate change as one of the critical factors that trigger food insecurity due to the resultant adverse weather effects that cause low crop production and productivity.

Climate change (CC) possesses high risks and adverse effects which are particularly evident in rural areas of most developing countries (Adger et al., 2003; Nhemachena & Hassan 2008; IPCC, 2007; Lobell et al., 2011). Evidence of excessive weather fluctuations ranging from droughts to floods and their high rate of recurrence has been recorded in Southern Africa (DFID, 2004). In Zambia, the areas that are most affected by drought and other sudden extreme weather conditions are eastern, central, southern and western parts which are found in agro-ecological regions (AERs) I and II.  The adverse weather effects such as floods, extreme temperatures and prolonged dry spells have caused soil infertility that poses serious challenges to agricultural production and productivity especially for most rural farm households that depend on rain-fed agriculture for their livelihoods (Mute, 2009; FAO, 2009). After the Government of the Republic of Zambia (GRZ) realized that it had limited resources to effectively respond to threats posed by CC, it took appropriate steps by responding to the initiatives of the United Nations Framework Convention on Climate Change (UNFCCC) and hastily formed the National Adaptation Programme Action (NAPA) against climate change in September, 2007. The main aim of NAPA was to promote technology advancements such as conservation agriculture that would mitigate the effects of climate change and variability in AERs I and II of Zambia. Subsequently, development and extension works on conservation agriculture technology have been extensively focused in the dry and semi dry central and southern parts of Zambia (Haggblade *et al*.,2011), and less in the northern part of Zambia (AER III) where some CA practices such as planting in basins and crop residue retention are scientifically not recommended (Kabwe and Donovan, 2005).

The adverse effects caused by climate change and variability do not only impact negatively on basic food security but also on household incomes and poverty (Thurlow *et al.,* 2009; GRZ, 2013). Jayne (2006) postulated negative economic implications due to climate change and variability. They predicted a reduction in net revenue per hectare from maize in Zambia ranging between 243 – 252 per cent because of a 20 per cent decrease in mean precipitation between January and February and a 1°C increase in mean temperature between November and December, respectively. Since then appropriate agricultural technologies designed to mitigate and adapt to climate change and variability to enhance and increase smallholder productivity have been greatly promoted. One of these agricultural technologies researchers have developed is Conservation Agriculture (CA).

Conservation Agriculture is a climate-resilient technology and management system that is increasingly being encouraged to address the problem of low crop productivity by enhancing the capacity of smallholder farmers to mitigate and adapt to the effects of climate change (Corbeels *et al*., 2014; Friedrich, Derpsch and Kassam., 2012; Verhulst *et al*., 2012; Giller *et al*., 2011; Thierfelder and Wall, 2010). CA is being practiced in other developing countries including the Indo-Gangetic plains of south Asia and the irrigated maize-wheat system of northwest Mexico (Sayre and Gupta, 2006). In South America, specifically Brazil, about 23 million hectares of commercial farm land is cultivated using the conservation agriculture system. In 2009, Paraguay another South American country had the highest no-tillage adoption percentage in the world (FAO, 2009).

The conservation agriculture technology is sometimes referred to as conservation tillage, no-tillage, and zero-tillage or direct seeding/planting (Hobbs *et al*., 2006). Conservation agriculture (CA) and conservation tillage (CT) are two concepts that are regularly used interchangeably, however, CT may include some of the principles of CA, but it is characterized by more soil disturbance that results in the failure to maintain a permanent or semi-permanent soil cover (Hobbs, 2007). Primarily, CA should not be perceived as mere less soil tillage but be comprehended as a holistic system that includes interactions among households, crops and livestock (Hobbs, 2007). It is defined as an array of agricultural practices with three associated basic principles: permanent organic soil cover, minimum mechanical soil disturbance and diversified crop rotation or intercropping including legumes (FAO, 2011c; Govaerts *et al*., 2009; Hobbs, Sayre and Gupta, 2008; Haggblade and Tembo, 2003). It is well acknowledged that CA enhances water harvesting, advances gains from increased soil organic matter, lowers the risk of crop failure, increases and stabilizes yields. It also lowers soil erosion, improves soil structure, reduces pest infestation and diseases, reduces weed germination, and increases productivity (Derpsch, Friedrich, Kassam & Hongwen, 2010; Li *et al*., 2011; Marongwe *et al*., 2011).

Smallholder agricultural productivity and improved livelihoods have remained low despite the shift towards technology orientations recommended by development partners and national research systems. This is not only because of the lack of appropriate technologies and the subsequent access to those technologies, inputs, credit and access to markets and rural infrastructure, but also as a result of gaps in information and skills that impede smallholder farm households from effective utilization and adoption of technologies (Merriam *et al*, 2011).

### 1.2 Statement of the Problem

In Zambia, many smallholder farmers have been grappling with low agricultural productivity like in many other countries of the Sub-Saharan Africa region due to the adverse effects of climate change. Reports indicate that by the year 2010 about six million Zambians which denote 44% of the national population (13.5 million) were encountering food deficiency (FAOSTAT 2011; UNPFA, 2011). This situation hastened the Government of Republic of Zambia (GRZ) in partnership with development partners, non-governmental organizations (NGOs) and national research institutions to implement mitigatory measures such as Conservation Agriculture (CA).
However, several arguments about CA have been raised among researchers in SSA and in Zambia this can be observed through previous studies that have been conducted to assess the adoption and impact of CA on farmers' livelihoods (Haggblade and Tembo, 2003; Chomba, 2004; Baudron *et al.,* 2007; Haggblade, Kabwe and Plerphoples, 2011; Umar *et al*., 2011; Nyanga, 2012; Arslan *et al.,* 2013; Grabowski & Kerr, 2013; N'gombe et al, 2014 and Ngoma *et al*., 2014). Again, the conclusions of these studies have been mixed because; some studies found that CA significantly and positively contributes to crop yield and household income increases (Kabamba and Kankolongo, 2009; Giller, Witter, Corbeels, and Tittonell., 2009; Mazvimavi and Twomlow, 2009; Giller et al., 2011; Haggblade *et al.,* 2011; Nyanga, 2012; Shitumbanuma, 2013; Brouder and Gomez-Macpherson, 2014; Corbeels et al., 2014), whereas others doubt the impact of the technology (Tarawali et al., 2002; Haggblade and Tembo, 2003; Bishop-Sambrook *et al*., 2004; Hobbs, Sayre and Gupta, 2008; Giller et al., 2009; Kassie *et al.,* 2009; Becerril and

Abdulai, 2010; Burke, 2011; McCarthy, Lipper and Branca, 2011;Umar *et al.,* 2011; Thierfelder, Mwila, and Rusinamhodzi 2013; Arslan *et al.,* 2013). Conversely, some authors argue that the empirical evidence on the productivity impact of CA among smallholder farmers in SSA remains mixed (Andersson and D'Souza 2014; Brouder and Gomez-Macpherson 2014; Giller et al. 2009). Other researchers argue that there is little empirical evidence to show the impact of CA practices on smallholder maize income (Jane, 2006; Thurlow et al., 2009; GRZ, 2010).

Considering the above, one may argue that despite CA having been practiced in the past two decades, its impact has not been investigated conclusively probably because these evaluation studies used small sample sizes, lacked detail in the data or cross sectional surveys. Furthermore, very little focus has been put to evaluate the impact of CA on maize productivity and income among smallholder farmers in dominant maize growing provinces of Zambia particularly; Southern, Lusaka, Central and Eastern that are located in AER I and II. Hence, this study sought to evaluate the impact of CA on maize productivity and income among smallholder farmers solely in provinces that predominantly produce maize in Zambia using the Rural Agricultural Livelihood Surveys 2012 (RALS 2012) data that contains a comprehensive description of Zambia’s small and medium scale farming. The study aimed to bridge this research gap.

The findings of this study are important and helpful for planning and implementation of policies and strategies that aim to enhance sustainable livelihoods among smallholder maize farmers in Zambia. Generally, the study will add towards empirical evidence concerning the impact of CA practices.

## 1.3 STUDY OBJECTIVES

### 1.3.1 General Objective

To assess the effects of conservation agriculture adoption on maize productivity and the value of maize (income) among smallholder maize farmers in four selected provinces of Zambia.

### 1.3.2 Specific Objectives

a. To evaluate factors that influence CA adoption among smallholder maize farmers in four selected provinces of Zambia.

b. To estimate the effects of CA adoption on maize productivity and income (value of maize) among smallholder farmers in four selected provinces of Zambia.

## 1.4 Research Question

To achieve the stated objectives, this study endeavours to address the understated research questions;

a. What are the key factors that influence CA adoption?
b. What is the effect of CA adoption on maize productivity?
c. Does CA adoption influence the value of maize harvested (income)?

## 1.5 Hypothesis

This study postulates that:

a. There are no factors that influence the adoption of conservation agriculture;
b. The adoption of CA has no impact on maize productivity and value of maize production (income) among smallholder farmers in Zambia.

## 1.6 Significance of the study

Evaluating the impact of CA adoption on increased maize productivity among smallholder farmers is essential as it demonstrates efficient input utilization as well as provision of hard evidence resulting from technology impact to all stakeholders (beneficiaries, Ministry of Agriculture, donors and other development partners) whose actions aim at formulation, implementation and promotion of such projects. In this regard, the stakeholders need to obtain comprehensive information that will enable them to know the influence of the technology so that experiences gained can be shared and used to improve project designs and intervention implementation. Hence, an impact evaluation study like this is particularly important for establishing of success stories and giving hard evidence that help to achieve greater impact at a larger scale. It is also worth mentioning that evidence based project planning and implementation would greatly save scarce resources from being used imprudently.

## 1.7 Scope and Limitations of the Study

This study basically aims to analyse factors that influence adoption of CA and its impact on maize productivity and income among smallholder farmers in four selected provinces of Zambia. This analysis did not consider some livelihood outcomes like nutritional and food security. However, the aforementioned livelihood outcomes including household income are equally important in assessing farmer livelihood status although they are usually considered to have an indirect link with CA; conversely crop productivity and CA are viewed to have a direct link (Nkala *et al.,* 2012).

In addition, focus group discussions (FGDs) were not conducted so as to establish the actual farmer perception as regards CA because this study used secondary cross sectional data (non-experimental study). The absence of adopters' perception is a limitation because the subjective perceptions of new technologies held by farmers were not at play in this study. Another limitation with this type of data is its challenge in controlling for unobservables principally because the analysis used the PSM method which only controls for observables. This may lead to hidden bias and to a certain extent the problem of heterogeneity in the adoption decision.

Based on the literature on factors determining adoption of CA among smallholder farmers and its impact on maize productivity and income as well as data availability, this study focused on four dominant maize producing provinces of Zambia. Therefore, some of the findings may be generalized to the entire country.

## 1.8 Organization of the Thesis

This dissertation has five chapters. The first chapter contains the introduction and background while chapter two presents literature. Chapter three outlines the research methodology which covers the scope of study, data collection and data analysis. Chapter four presents the study results which show descriptive statistics and empirical results from the probit and propensity score matching models as well as the discussion. The final chapter presents the main summary of the study findings and recommendations.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

In this chapter, we review literature concerning the adoption of CA and its impact on livelihood outcomes of importance among smallholder farmers in Zambia. We discuss factors that influence adoption of the conservation agriculture technology. Furthermore, we review literature on empirical studies that evaluate factors affecting adoption and impact of CA in developing countries including SSA countries.

## 2.2 Theoretical Perspectives

According to Feder *et al.,* (1985), literature concerning adoption of an agriculture technology is extensive and relatively difficult to abridge efficiently. Most economic analysis of agricultural technology adoption has been predominantly focused on human capital, infrastructure, imperfect information, institutional constraints, input availability, risk and uncertainty as possible reasons for adoption decisions (Feder *et al.,* 1985; Foster and Rosenzweig, 1996). For example, Rogers' innovation-diffusion theory posits that information dissemination is a major factor in influencing the decision to adopt (Rogers, 2003). It states that the adoption-decision process appears to occur in a linear sequence of five stages. The first stage is the knowledge stage in which information and knowledge about an innovation is acquired by the adopting farm household or participant. The second stage is the persuasion stage where the adopting farm household or participant makes an opinion regarding the innovation (Rogers, 2003:161-163) and the third is the decision stage where the resolve to either adopt or not adopt is made. The fourth stage is the implementation stage where there is an obvious behavioral change due to the usage of the new innovation. This stage may involve adaptation or reinvention of the innovation to conform to the local conditions. The fifth and final is the confirmation stage; here the adopting farm household or participant decides either to continue or abandon the innovation depending on the satisfaction derived from the outcomes of implementation.

The economic constraints theoretical perspective (Aikens, Havens, & Flinn, 1975; Adesina & Zinnah, 1993) suggests that technology adoption is influenced by economic factors and economic constraints due to the asymmetric allocation of resources. Participants may be constrained from adopting new innovations due to lack of land ownership and access to capital. Conversely, the adopter-perceptions theoretical perspective (Adesina & Zinnah, 1993) has a different viewpoint as it brings in perceptions of farmers in explaining adoption. Despite that, these schools of thought fail to satisfactorily address the specific function of social learning in adoption of innovations. According to Bandura (1977), social learning theoretical perspectives presume that humans learn by observing other people's behavior. Learning may not necessarily guarantee change in behavior depending on the cognitive capacity (intellectual/reasoning ability) of the learner, their retention capacity (memory/ability to remember the observed behavior), their motor capacity (ability to replicate the observed behavior) and their motivation level (ability and willingness to put into practice the observed behavior) (Bandura, 1977). Furthermore, (Bandura, 1969) states that adoption of an innovation is considered as a social process where learning of knew practices happens both formally and informally through sharing information, observation, imitation or as a normative action. The innovation adoption process as a social learning process and the associated outcomes are influenced by structures and human activity in society (Giddens, 1984), networks (Long, 1992) as well as values and norms (Rogers, 2003:24-26). The classic structure agency theoretical perspective is another innovation adoption process where social structures such as gender tend to affect human action (Giddens, 1984). This theory states that different categories of farmer groups adopt different options of innovations; in other words, the likelihood to adopt a technology is increased because many alternative options are available for different categories of farmers with varying socio-economic capabilities to practice CA.

Adoption literature states that the basic requirement for a technology to be taken up sustainably it should produce tangible benefits to farmers (Pannell et al., 1999; Cary and Wilkinson, 1997). In other words, farmers normally engage in activities they perceive will enable them to sustain life and improve their livelihoods using available resources. This brings in the aspects of sustainability and livelihoods in people's pursuit for improved well-being. According to Costanza and Patten (1995:193-194), sustainability can be defined in biology to mean: "avoiding extinction and living to survive and reproduce", and in economics to mean: "avoiding major disruptions and collapses, hedging against instabilities and discontinuities". This underscores that sustainability is concerned with the transitory and permanence as well as the need for continuous inheritance of both renewable and non-renewable resources by future generations. In this study, livelihoods refer to "capabilities, assets and activities required as means of living" and sustainable livelihoods as "those that can cope and recover from stress and shock, maintain and enhance its capabilities and assets; and provide opportunities for the next generation which contribute to the net benefit to other livelihoods" (Chambers & Conway., 1991:6).

## 2.3 Evolution and Adoption of Conservation Agriculture in Zambia

### 2.3.1 Evolution of Conservation Agriculture in Zambia

In Zambia, modern conservation agriculture is reported to have emerged as a consequence of technology transfer by large-scale commercial farmers who adopted minimum tillage practices for their individual use. Afterwards the commercial farmers supported lower versions for smallholder farmers living in regions of low to medium rainfall (IFAD, 2014). Generally CA practices begun between the late 1980s and early 1990s when many parts of the country experienced droughts and prolonged dry spells (FAO, 2013). Other reasons cited to have ignited the promotion of the CA technology are the introduction of a liberalized economy (free market) and withdraw of subsidies on most commodities by the GRZ. These policy measures added to the economic challenges people were already experiencing especially the vulnerable smallholder farm households. The above situation prompted some national and international organizations to intensify the promotion of CA practices among smallholder farmers in Zambia (Haggblade and Tembo, 2003; N'gombe and Kalinda, 2014). For instance, the Soil Conservation and Fertility (SCAFE) project which was funded by the Swedish International Development Agency (SIDA) started the first Conservation Agriculture project in the Eastern Province and later extended it to Lusaka Province (Baudron *et al.,* 2007). The Co-operative League of the United States of America (CLUSA) is another organization that promoted CA. It compelled smallholder farmers to use CA practices as a prerequisite to access input credit (Haggbade and Tembo, 2003).

Since inception in the late 1999, conservation agriculture has been administered by the Ministry of Agriculture (formerly Ministry of Agriculture and Co-operative (MACO)) which came up with a climate change adaptation and mitigation agenda and also identified potential adaptation areas suitable for the technology. Thereafter, CA promotion was specified in the 2004-2015 Zambian National Agricultural Policy and its promotion continued by the MoA working in collaboration with various organizations such as the Agricultural Support Programme (ASP), Conservation Farming Unit (CFU), Golden Valley Agricultural Research Trust (GART) and the World Agro-Forestry Centre (ICRAF) (MAFF, 2001; GART, 2001). Massive financial support was rendered to these institutions from the World Bank, the European Union (EU), the World Food Programme (WFP), Norwegian International Development Agency (NORAD) and the Food and Agriculture Organization (FAO) (Chomba, 2004). The main aim was to increase access to extension services that integrated CA practices among the small and medium scale farmers. According to Haggblade and Tembo (2003), by the mid-1990s CA practices particularly the use of hand hoe basins was noticeable among the small and medium scale farmers. The CA technology has been considerably promoted in seven of the ten provinces of Zambia since inception in the 1980s (Arslan *et al*., 2013). The Conservation Farming Unit (CFU), an affiliate of the Zambia National Farmers Union introduced the CA technology to smallholder farmers in Zambia in 1996; in the wake of the 1995 drought. Since that time, the CFU has continued to play a pivotal role in CA promotion in Zambia especially in AER I, IIa and IIb because of the vulnerability of these regions to the effects of climate change (Kabwe and Donovan, 2005; IFAD 2014). The CFU aimed to initiate about 240,000 small-scale farmers into practicing conservation agriculture techniques by the year 2012 and by 2011 the CFU had affirmed that in seventeen districts of Zambia over 65% of the smallholder farmers were practicing CA. This was done during the Conservation Agriculture Programme (2006 to 2011) and so far this could be the largest programme to be implemented by the CFU with funding by the Government of Norway (IFAD 2014).

There are three forms of CA practiced in farming, namely; hand-hoe planting basins, animal draft power ripping and tractor draft power or mechanized operational system. Nyanga (2012) and Ngoma et al. (2014) indicate that hand-hoe planting basins and animal draft power ripping are the two most commonly practiced forms of minimum tillage in Zambia. The third type of CA (tractor draft power or mechanized operational system) is mostly used by commercial farmers due to its huge capital outlay.

The Hand-Hoe based CA relates to digging of planting basins spaced at 0.9 meters between rows and 0.7 meters along the rows using a Chaka hoe as shown at Appendix I (CFU, 2009b). The crop residues and other vegetative material are retained on the field as organic soil cover in the area between basins. The recommended dimensions of a basin are 0.3 meters in length, 0.2 meters in depth and the same width as that of the blade of the Chaka hoe. The Chaka hoe has a lengthened thick, strong blade and a longer handle compared to a traditional hand hoe. These features of a Chaka hoe account for its heaviness (4 to 5 kg) relative to a traditional hoe. The planting stations should be placed in permanent positions so that farmers can use the same stations for some years repeatedly, thus reducing the family labour requirements after the first year (Haggblade and Tembo 2003). These permanent planting stations are supposed to optimize input use (such as fertiliser or manure), improve water retention (especially in drought prone areas), and help to build up soil organic matter. It is recommended that land preparation (basin and ripping) is done soon after harvest when soils are still moist (Derpsch, Friedrich, Kassam, & Hongwen, 2010; Lee et al., 2011; Marongwe et al., 2011). The dry season land preparation facilitates early planting which improves yields (Nafziger 1994, CFU, 2011). It also allows crops to benefit from the initial nitrogen flush in the soil that comes with the onset of the rains. Again, it allows farmers to use freely available family labour during the lean season (Haggblade et al. 2011). CA crop residue retention involves leaving at least 30% of crop residues in the fields.

The animal draft power ripping uses a Magoye ripper as opposed to a conventional moldboard plough as shown at Appendix II. The typical moldboard plough used in conventional agriculture overturns the soil completely, while the magoye ripper rips the soil at least 0.15-0.20 meters in depth and spaced at 0.9 meters while retaining crop residues between the ripped lines (CFU, 2009a).

### 2.3.2 Adoption of Conservation Agriculture in Zambia

Conservation agriculture has progressively been promoted in SSA for almost three decades as an option to tackle the problems of climate variability that negatively affects crop productivity (Andersson and D'Souza 2014; Grabowski and Kerr 2013; Umar et al. 2011; FAO, 2011c). Despite its strong promotion in Zambia, adoption among smallholder farmers remains fairly low

(Haggblade and Tembo, 2003). Smallholder farmers practice both conventional farming and CA on different plots and CA adoption tends to be inconsistent and partial (Nyanga, 2011; Umar *et al.,* 2011).

Since CA was initiated a number of studies have been conducted to analyze the adoption of CA in Zambia and these include Haggblade and Tembo, 2003; Chomba, 2004; Baudron *et al.,* 2007; Haggblade, Kabwe and Plerphoples, 2011; Nyanga, 2012; Arslan *et al.,* 2013; N'gombe et al, 2014; Ngoma, 2014 and many more. A review of some studies indicates that there are basically three constraints that hinder adoption of CA among smallholder farmers in Zambia. And these are; the conflict in use of crop residues (mulch and stock-feed purposes), labour availability limitations and inadequate capacity to grow cover crops during dry season (Umar *et al.,* 2011). Most researchers suggest that out of the three constraints, labour is the main hindrance to CA adoption in Zambia (Haggblade and Tembo, 2003; Baudron *et al.,* 2007; Umar *et al.,* 2011). Baudron *et al.,* (2007) and Mazvimavi, (2011) postulate that the labour constraint appears to be a major constraint because most smallholder farmers are unable to pay daily wages that are normally high during peak periods such as during land preparation and weeding.

Other studies have shown higher adoption rates within the Conservation Agriculture Project (CAP) areas. For example, Kasanga and Daka (2013) indicate that 41% of farmers adopted minimum tillage in 16 CAP districts; Kuntashula et al. (2014) and Grabowski et al. (2014) show adoption rates of 12% and 13% respectively, in their study areas (agro-ecological zones I and IIa). Another earlier study argues that only 20 per cent of farmers in the 2002/3 season were natural CA adopters while the bigger proportion of 80 per cent practiced CA just for the purpose of eligibility to receive subsidized inputs (Haggblade and Tembo, 2003). These estimated adoption rates show a much lower achievement than the government projected target of 40% by 2016 (GRZ, 2013).

Arslan *et al.,* 2013 analyzed the adoption and non-adoption of only two elements of CF, namely minimum soil disturbance and planting basins. The study found a very significant and robust relationship between the district level changes in historical rainfall during the growing season and adaptation in addition to the intensity of adoption of the CF practices.

Nyanga *et al*., (2011) investigated farmers' perception of climate change, attitudinal and knowledge-based drivers of CF adoption involving 469 farmers in twelve (12) districts of Central, Southern, Western, and Eastern Provinces of Zambia. The study found a positive correlation between perception of increased climate change variability and the practice of CF, but no link between attitudes concerning climate change itself and CF practice.

Nyanga (2012) carried out another study using a mixed method approach (Quantitative and Qualitative methods) to evaluate factors that determine CA adoption and the acreage under CA in Zambia. The findings revealed that trainings in CA increased the likelihood of farm households to adopt the technology and had a positive influence on size of area under CA. Additionally, the qualitative analysis of the study showed that good rapport by the trainers had some positive effect in CA adoption. Again, the study revealed that past experience in CA projects using minimum tillage practices significantly increased the probability to adopt the CA technology in future activities. However, the results showed that the age of household head (denoting experience of household head) had a significant but negative effect on CA adoption.

Conversely, other studies revealed a positive correlation between age and CA adoption (Jera and Ajayi; 2008). This study further postulated that ownership of CA equipment (labour saving) such as rippers together with the repute linked with ownership of such implements increased the likelihood of adopting CA. The findings agree with studies which indicate that possession of productive assets increased the probability of adopting a particular technology (Chomba, 2004; Umar *et al.,* 2010; Mavunganidze *et al.,* 2013 and Lugandu, 2013).

Gender was another factor examined and it showed that both men and women were likely to adopt CA using ripping and CA basins respectively among several alternatives of CA under project promotion. This result reveals a classic structure agency theoretical perspective where social structures such as gender tend to affect human action (Giddens, 1984). Basically the study showed that different farmer groups adopted different options of CA. For example, farmers without livestock could not practice Animal Draught Power (ADP) ripping; instead they had another option to practice CA using hand-hoe basins. This situation is common among women farmers who in most cases lack access to productive resources (Bishop-Sambrook *et al.,* 2004).

In this study, some institutional factors such as livestock assets, access to loans/credit, access to CA advice, membership to agricultural co-operative/farmer group, distance to agro-dealers, adult equivalent and access to land were significant which suggests they are more likely to increase the adoption of CA. On the other hand, some factors such as age of household head, education level of household head, off-farm income, size of area planted, maize yield, total fertilizer, productive assets, gross value of maize (income), ownership of radio and customary title were not significant which suggests they are less likely to increase the adoption of CA which contrasts with Arslan *et al.,* (2013) and Mlenga *et al.,* (2015).

Baudron *et al.,* (2007) investigated the adoption of conservation agriculture in the Southern Province of Zambia and found that most of the cultural practices used were in conflict with the CA principles. The study states that majority of the farmers in Southern Province were engaged in mixed farming as a tradition (rear livestock and grow crops). The livestock is mostly dedicated to ploughing huge acreages of land which contradicts the CA principle of minimum soil disturbance. After harvesting, the crop residues are gathered and fed to the livestock or the livestock are left to graze freely on crop residues which also contradict the CA principle of maintaining a permanent soil cover. Another aspect of controversy is that traditionally a legume such as beans is used in intercropping because it offers an additional source of food, hence replacing beans with cover crops such as canavalia or mucuna poses a challenge especially where the main objective of the farm household is food security. Alternatively this situation caused weed control to remain a challenge among most smallholder farm households because it necessitated hoeing several times or using herbicides of which both options appeared not feasible.

Umar *et al.,* (2011) examined the agronomic practices of smallholder CA farmers in AER I and IIb of Zambia. From a target of 129 farm households assessed only one farm household used CA on all cultivated plots while most of them practiced both CA and conventional farming on different fields. It is assumed this was attributed by a number of reasons that vary from traditions and culture to socio-economic. For instance, after crop harvesting is completed, traditionally livestock is left on free range grazing and in most villages fencing off crop fields is untraditional apart from being expensive which contradicts the principle of crop residue retention. Crop rotation as a recommended practice was also found difficult to achieve because most farm households never wanted to grow legumes that did not have market value; they would rather intercrop maize with crops like beans which had market value and were edible (food security concerns).

Becerril and Abdulai (2010) posit that technology adoption involves the use of a package of innovations and not just a single component of productivity enhancing factors. This is consistent with most studies on CA adoption in the SSA region including Zambia which reveal that majority smallholder farmers scarcely adopt CA as a complete package consisting the three core principles: minimum tillage, permanent soil cover and diversified crop rotation (Mazvimavi and Twomlow, 2009; Kassie *et al.,* 2009 and Arslan *et al.,* 2013). Earlier studies also indicate that usually smallholder farmers tend to only practice some elements of CA; usually minimum tillage and use of herbicides in the early stages (Karanja *et al.,* 2003). Again, Kassie *et al.,* (2009) posits that partial adoption of the CA technology could fail the productivity enhancing factors to properly combine to achieve the desired gains. Hence, it is suitable to use the complete bundle in order to realize the full benefits of CA (FAO, 2001; Ito *et al.*, 2007).

### 2.4 Impact of CA Adoption on Smallholder Crop Productivity and Income

Existing literature on the impact of CA on smallholder crop productivity is expressed with some consensus among researchers. This consensus is based on the premise that CA-based farming systems have potential to increase crop yields compared to conventional farming systems only if certain conditions are satisfied (Kassam et al., 2009). For instance, there is less agreement in the literature about the magnitude of the yield impacts. Also, there is conflicting evidence on how many years it takes from the initial adoption of CA to the realization of benefits. Furthermore, some studies reveal significant CA yield benefits only after two or more years (Brouder and Gomez-Macpherson, 2014; Corbeels et al., 2014; Thierfelder, Mwila, and Rusinamhodzi, 2013). CA trials in the Southern and Eastern parts of Zambia; Thierfelder et al. (2013) suggest significant yield advantages only after two seasons. On the other hand, subjective evidence from CA proponents suggests that CA presents immediate yield benefits. Corbeels et al. (2014) attributes the CA yield advantages to improved water infiltration, soil moisture, soil porosity, soil organic matter, and crop management.

Researchers claim that the influence and outcome of CA practices differ across regions and among researchers as highlighted by some studies that have been carried out in Zambia to evaluate the impact of CA on livelihood outcomes such as crop productivity and income among smallholder farm households (Haggblade and Tembo, 2003; Kabamba and Kankolongo, 2009; Haggblade *et al.,* 2011).

Haggblade and Tembo (2003) assessed the development, diffusion and impact of CF in Zambia and the study observations were extraordinary. Firstly, the study shows that economic benefits realized from practicing CF using ox-drawn rippers were less than economic benefits realized from the use of hand hoe CF basins among smallholder farmers. The second observation was that farmers who used conventional hand hoe improved performance much more than those who used ADP tillage and CF basins. Nevertheless, the general results revealed that on average the profits to peak labor season are higher with CF than conventional farming.

Enhancing agricultural productivity is perceived to advance great potential towards poverty reduction in Africa (Diao *et al.*, 2007; World Bank, 2008). Diao, Headey and Johnson (2008) state that farm productivity increase tackles poverty in three different ways. Firstly it raises productivity and incomes of the poorest households in Africa who mainly subsist on agriculture. Secondly it decreases food prices which control real incomes and thirdly it promotes vital growth linkages with other sectors of the economy (Haggblade and Dorosh, 2007).

Haggblade *et al.,* (2011) carried out a study to investigate the impact of conservation agriculture on cotton productivity among farmers in Zambia. The study focused on asset-poor farm households who cultivated using hand hoes in cotton growing zones where conservation agriculture was most suitable and properly established (Kabwe and Donovan, 2005). This study shows that CF enabled the smallest and seriously cash-strapped Zambian farm households to attain yield gains of about 40% more than conventional tillage. It also suggests that area gain of 40-50 per cent supports cultivation of about 1.5 hectares which raises the feasible benefits (income) when using hand hoe CF. Furthermore, the study revealed that there are several CF packages with viable means of doubling crop income for the resource-deprived smallholder cotton producers in central Zambia. For example, without cash inputs the resource-deprived cotton producing households could raise their crop revenue by 140 per cent from $170 to $420 from cotton and low-input maize through the use of CF hand hoe packs. The other group of farmers with access to cash inputs of nearly $60 per season, could access high-input CF groundnut and maize packs in addition to the standard company-financed cotton packs, thereby increasing revenue high to $495 per season. Addition of herbicides to the standard CF hand hoe pack could encourage the smallholder farmers to enlarge their cotton fields and possibly quadruple crop income to $800 per season. It was also noticed that when herbicides where financed through cotton companies the farmer-financed input cost could reduce to $70 per season while crop income could rise to $870 per season, signifying a fourfold increase than that attained under conventional tillage. The use of herbicides offers great advantages in supporting income increases for smallholder farm households because it reduces the high labour demands during the peak weeding season associated with rain fed African agriculture.

Kabamba and Kankolongo (2009) carried out a study to determine the rate of adoption of CA and its impact on crop productivity in Kapiri-Mposhi District of Zambia. The study reveals that out of 2,108 smallholder farmers sampled in the district 2,085 adopted the technology from 2000 to 2008 which indicates a CA adoption rate of 98.5 per cent on average. After adoption of CA, the average maize yield gain among the smallholder farmers in the district was 2.0 ton/hectare during the same period. The yield increase was significant and denotes a ratio of 3:1 between CA fields and conventional fields. Furthermore, an evaluation of crop yields for four successive cropping seasons in the district equally showed a stable rise in yield of main crops as well as a rise in adoption of CA implying a positive impact on crop productivity vis-à-vis conventional tillage.

Evidence that shows the crop yield effects of MT in Zambia is mixed. For example, Haggblade et al. (2011) and Nyanga (2012) indicate that use of basins increased maize yields but Burke (2012) suggests a contrary outcome. Additionally, studies based on bivariate mean comparisons, found that experienced CF adopters had as much as two metric tons per hectare yield advantage over less experienced CF farmers (Shitumbanuma, 2013). While the above mentioned studies provide valuable information, most of the studies are based on small samples and draw their samples from within concentrated CA promotion areas. Others depend on experimental data, which have low external validity.

## 2.5 Empirical Studies

### 2.5.1 Empirical Studies on Adoption of Conservation Agriculture

A number of empirical studies have been performed to examine factors that influence adoption of technologies including CA in Africa and other parts of the world. These studies have specified a lot of factors that influence the decision to adopt or not adopt technologies. Arslan *et al.,* (2013), states that there is strong literature concerning the adoption of new agricultural technology that was mainly stimulated by the search to understand the adoption of green revolution technologies. Just and Zilberman, (1983) and Feder *et al.,* (1985), claim that early studies on adoption were primarily centred on the risks and uncertainty about new technologies that would make a farmer diversify their crop selection rather than adopt new technologies. Some studies suggest other constraints farmers encounter such as agro-ecological constraints, credit limitations, labour limitations, seed supply constraints, risk preferences or traditional values as major factors that influence farmers decision to adopt (Smale, Just and Leathers, 1994; Ajayi *et al.,* 2003; Franzel *et al.,* 2004; Phiri *et al.,* 2004; Arslan and Taylor, 2009).

Technology adoption including CA could be viewed as a risky investment because farmers are required to learn new practices and usually most of the smallholder farmers lack access to insurance (McCarthy, Lipper and Branca, 2011). According to Hobbs, Sayre and Gupta (2008) the decision to adopt CA is affected by lack of access to credit considering that the initial costs are high (e.g. purchase of cover crop seed, herbicides, sprayers etc.) and that benefits from CA do not start accruing immediately but later around the fourth to fifth year. Other studies have shown that the CA technology is labour intensive. For example, when weeding is done without the use of herbicides there will be high demand for labour. This situation brings about the labour constraint among smallholder farmers who often lack access to herbicides and enough labour.

Tarawali et al., (2002) and Bishop-Sambrook et al.,(2004) posit that maintaining permanent soil cover may be costly because farmers need access to appropriate seed which is usually expensive and not easily obtainable in rural markets. Another challenge most smallholder farmers experience is crop residue retention because traditionally crop residue has alternative uses such as livestock feed and fuel etc. (Giller et al., 2009). Again, low crop residue retention is caused by the customary land tenure system pursued by most SSA countries which authorizes livestock to graze freely on harvested fields. This creates difficulties for individual farmers desiring to integrate crop residues in their fields because they don't own land rights or title also lack financial capacity to fence off their fields (Feder et al., 1987). Additionally, the customary rules prohibit burning of fields and tenure insecurity makes it hard for farmers to keep their plots permanently covered which lessen the motivation to wholly adopt CA (Ibid).

Knowler and Bradshaw (2007) performed an assessment of 23 studies with the intention of finding universal variables that explain CA adoption and 06 of those studies where from developing countries. After carrying out evaluations by region, results showed that farm size and education tends to have a significant effect on the decision to adopt CA in Africa and North America respectively. In conclusion the study suggests that farm households who own large farm land tend to easily adopt CA in SSA because of the availability of abundant land at their disposal to invest in new technology. Also farm households where the household head had some education tended to easily adopt CA because the HH had a better comprehension of the technology and the benefits linked to it.

Nkala et al., (2011b) carried out a meta-analysis of CA with a view to establish key factors that hinder successful implementation of CA projects in Southern Africa. The study postulates that a lot of constraints that impede extensive adoption of CA do exit and include among others lack of infra-structure, non-farmer driven methods, prevailing livestock management norms, imperfect credit and input markets and land tenure system.

### 2.5.2 Empirical Studies on the Impact of Conservation Agriculture

Past research findings state that smallholder agricultural productivity and improved livelihoods have remained low despite the shift towards technology orientations recommended by development partners and national research systems. This status quo does not only arise because of the lack of appropriate technologies and the subsequent access to those technologies, inputs, credit and access to markets and rural infrastructure, but also as a result of gaps in information and skills that impede smallholder farm households from effective utilization and adoption of technologies (Mariam *et al*, 2011).

Furthermore, studies reveal that there is little empirical evidence to show the impact of CA practices on smallholder maize income as highlighted by Jane (2006); Thurlow et al., 2009; GRZ (2010). Study results indicated that due to adverse effects of climate change the income from maize production would reduce significantly. On the other hand, many other studies suggest that in addition to agronomic benefits, the CA technology may also improve farm household well-being through; increased income, input cost savings and food security (Refer to Giller, Witter, Corbeels, and Tittonell (2009) and Giller (2012) for detailed appraisal of CA in general). Another study by Ngwira, Thierfelder, Eash, and Lambert (2013) found that maize produced using CA practices raised between 61% to 116% higher profits than that produced using conventional methods (US $344 per ha). Similarly, Mazvimavi and Twomlow (2009) and Guto, Pypers, Vanlauwe, de Ridder and Giller (2011) found superior profit margins for crops produced under minimum tillage practices compared to net returns obtained under conventional systems. According to Ngwira et al. (2013) farmers who are risk-averse preferred CA technology compared to conventional tillage systems, with CA risk premiums varying between 40 and 105 US dollars relative to conventional farming methods. This observation was highlighted by Jane (2006); Thurlow et al., 2009 and GRZ (2010) who postulated that due to adverse effects of climate change the income from maize production will reduce significantly. Many other studies suggest that in addition to agronomic benefits, the CA technology may also improve farm household wellbeing through increased income; input cost savings and food security (Refer to Giller, Witter, Corbeels, and Tittonell (2009) and Giller (2012) for detailed appraisal of CA in general). Another study by Ngwira, Thierfelder, Eash, and Lambert (2013) found that maize produced using CA practices raised between 61% to 116% higher profits than that produced using conventional methods (US $344 per ha). Similarly, Mazvimavi and Twomlow (2009) and Guto, Pypers, Vanlauwe, de Ridder and Giller (2011) found superior profit margins for crops produced under minimum tillage practices compared to net returns obtained under conventional systems. According to Ngwira et al. (2013) farmers who are risk-averse preferred CA technology compared to conventional tillage systems, with CA risk premiums varying between 40 and 105 US dollars relative to conventional farming methods.

### 2.5.3 Empirical Studies on Adoption of Other Technologies

This sub-section highlights many other empirical studies showing study techniques and models with results that have been conducted previously to evaluate factors that influence adoption of various technologies excluding CA. For example, Raut *et al.,* (2011) carried out a study to examine the determinants of adoption and scope of Agricultural Intensification (AI) in the central mid-hills of Nepal. The main aim of the study was to know the extent and type of correlation between dependent and independent variables concerning AI. A binary regression model was used in the study as the suitable tool to assess the extent to which each independent variable influenced the likelihood of events to occur (Long and Freese, 2006). The model was chosen based on the assumption that the dependent variable was binary or dichotomous. The indicator of intensification was measured by the number of crops adopted by farmers and was selected as the dependent variable for AI adoption. The stepwise linear regression model was also used to establish the magnitude of AI adoption. The adopters were those farmers who took up at least three crops per annum while the non-adopters were those farmers who adopted two or less crops per annum.

The study results showed that five (05) out of fourteen (14) independent variables had significantly affected AI adoption and four (04) of the five (05) significant variables that is irrigation, crop yield, land holding size and access to credit had positively influenced adoption of AI while the fifth variable; distance to chemical fertilizer store had a significantly negative effect on the farmers' behavior to adopt AI. In the adoption of AI in central mid-hills of Nepal, it was perceived that irrigation facilities were the most significant determining factor. Furthermore, the study showed that three factors, specifically the amount of chemical fertilizer, net income realized from cultivating vegetables and cereals as well as the distance to chemical fertilizer store meaningfully clarified the variances in the degree of AI. Out of the three factors, the quantity of fertilizer applied seemed the most significant determinant seconded by income raised from vegetables and cereals. In conclusion the study postulates that adoption of any agricultural innovation is persuaded by factors including characteristics of the individual farmer, characteristics of the innovation as well as the socio-economic environment.

Jariko *et al.,* (2011) conducted a study using a multinomial logistic regression model to identify the socio-economic factors that influenced adoption of sunflower varieties in Sindh. Multinomial logistic regression is the linear regression analysis conducted when the dependent variable involves nominal response variables with more than two categories and is a multi-equation model. This analysis chose a response variable with K (=4) categories that generate K-1 (=3) equations. The findings showed that the level of education and farm size had significantly influenced the probability of adopting the sunflower varieties. Conversely other variables such as tenancy status and source of income did not show any significance.

Kalineza *et al*., (1999) performed a study to investigate socio-economic factors that affect adoption of conservation practices adapted towards enhancement of agricultural productivity in Gairo, Morogoro region of Tanzania. The study particularly investigated the use of contour ridges, tree planting practices as well as the use of cow dung manure. The logistic regression model was utilized to estimate the likelihood of using soil conservation practices by farmers using the SPSS package. The analysis indicated that extension education and land tenure were the only two variables that had significant coefficients out of seven variables assumed to influence adoption of soil conservation practices. This is consistent with the innovation diffusion model initially explained by Rogers (1983). It postulates that information concerning an innovation is an important determinant of adoption. Specifically the study suggests that security of land tenure significantly affects the likelihood of farm households to adopt usage of contour ridges and use of farm yard manure. This is consistent with study results that suggest that availability of land tenure security increases the adoption of soil conservation practices (Feder and Onchan, 1987). Nonetheless, other household characteristics such as age, formal education, number of adults able to work, off-farm income, livestock ownership and land characteristic (farm size) were not significant in influencing adoption even if the coefficient of these variables were as expected.

Adebiyi and Okunlola (2013) analyzed factors that determine the adoption of Cocoa Farm Rehabilitation in Oyo state of Nigeria. The study used descriptive statistics, correlation coefficient and logistic regression and results showed that farm size and years of experience were significant factors influencing adoption of Cocoa Farm Rehabilitation methods. In addition the sources of finance and information availability were significant factors that influence the likelihood to adopt the technology.

Jera and Ajayi (2008) assessed the potential of smallholder livestock farmers in Zimbabwe to adopt tree-based fodder bank technology as a strategy of increasing livestock production and income creation. The specific objects were; to evaluate farm household resource endowment and ecological determinants of fodder bank technology adoption also to identify suitable methods of developing the technology to full potential. The study used a logit model to identify the determinants of technology adoption by examining the effect household characteristics and ecological factors exert on the technology adoption decision by farmers. The findings showed that dairy herd size, land holding size, membership to dairy association and agro-ecological potential were the main determinants influencing the adoption decision of fodder bank by the smallholder livestock farmers. However, other factors such as age, sex, household size and farmers' education level had little influence. Furthermore, both male and female farmers had equal likelihood to adopt and practice fodder bank if availed equal access to information and incentives. In conclusion the study proposed that the country strategic partnerships with Dairy Development Programme because such would offer great potential in improving the scaling up of adoption and impact of fodder bank technology.

Gregory and Sewado (2013) employed a logistic model in a study to establish factors that influence adoption of Quality Protein Maize (QPM) technology in Northern Tanzania. The regression analysis revealed that education level of household head, perception of demonstration trials by farmers, field day attendances and size of livestock herd owned had a positive significant influence on the rate of technology adoption. But access to credit and poor marketing perceived by farmers had a negative effect on the adoption process.

### 2.5.4 Empirical Studies on Technology Impact Assessment

Many empirical studies have been conducted in the past to evaluate impacts of various technologies concerning livelihoods of smallholder farmers. This sub-section highlights some important studies that have been performed on technology impact evaluation using different assessment techniques.

According to Morris *et al.,* (1999), results from impact studies confirm that financing agricultural research continues to produce attractive rates of return to research investment using the cost-benefit analysis; which is a process used to evaluate the extent of innovation diffusion that has been produced by a research program compared to the measured economic benefits accrued from its adoption (*Ibid).* Sechrest *et al*., (1998) acknowledges that cost-benefit analysis is an economic framework method but possesses its own limitations and suggests other alternative approaches such as the adoption case studies that help in understanding the impact of agriculture research because such studies create important perceptions in comprehending how rural households adopt and get influenced by these agriculture innovations.

Morris *et al*., (1999) assessed the adoption and impact of improved maize production technology in Ghana. The study revealed that adoption of Ghana Grain Development Project (GGDP)-generated maize technologies (modern varieties, fertilizer, plant configuration) had been extensively taken up by about 54% of sample farmers and had been attributed to the significant farm-level productivity increases (yield) and evidenced increase in the income earned from maize sales. The study used a simple analysis based on farmers'qualitative judgement because of the abscence of baseline data to estimate quantitative measure of project impact.

Tsegaye *et al.,* (2000) evaluated the impacts of conservation agriculture on grain yield, land and labour productivity in two districts of Ethiopia. The study used the generalized method of moments (GMM) model to determine the impact and the control functions approach was used to correct biases arising from consequences of selection and/or common problem of endogeneity and heterogeneity. The findings revealed that adoption of CA technologies improves land and labour productivity.

Shideed and Mourid (2005) conducted a study to assess the adoption and impact of improved technologies on crop and livestock production methods in West of Asia and North of Africa (WANA) region via the Mashreq (Iraq, Lebanon, Jordan and Syria)/ Maghreb (Algeria, Libya, Morocco and Tunisia) in short the (M&M) project. The initiative was conceived as an adaptive research programme meant to develop an integrated crop-livestock system. The results revealed that there was a general welfare improvement among farmers who adopted the technologies encouraged by the project.

Mendola (2007) evaluated the potential impact of adopting agricultural technology on poverty reduction strategies. The study examined the relationship between technological change and welfare of smallholder households in two rural regions of Bangladesh. Since this study was non-experimental, the variable technology adoption was not randomly assigned instead there was 'self-selection' into treatment. Generally the study attempted to solve a methodological problem by assessing the 'causal effect' of the technology on smallholder farm household welfare using a non-parametric '*p*-score' analysis. The main study objective was to evaluate whether the adoption of a modern seed technology caused income increases and reduced the predisposition of resource-poor farmers to drop below poverty line. The study results showed that adoption of these high yielding seed varieties (HYV) of rice in the two rural regions of Bangladesh had a positive significant impact on the welfare of farm households. Hence, the study confirmed a positive impact of technology adoption on resource-poor smallholder farmers with regard to income and poverty mitigation; also that the benefit gains were much higher among farmers with big land holding. Revallion and Datt (1998) equally evaluated productivity benefits arising from adoption of high yielding seed varieties among poor smallholder households in India.

Kassie *et al* (2010) assessed the ex-post impact of farmers' adoption of enhanced groundnut varieties on crop income and rural poverty in Uganda. The study evaluated the average adoption premium using the propensity score matching, poverty dominance analysis tests and linear regression model. The findings revealed that adoption of improved groundnuts varieties had a positive significant effect on crop revenue increases. The crop revenue increased from 312,095 (US$169) to 365,281 (US$198) Ugandan shillings per hectare which consequently resulted in improved livelihoods among the adopters (poverty reduction).

Ilemona *et al.,* (2011) conducted a study to assess the economic impact of enhanced agricultural technology on cassava productivity in the Kogi State of Nigeria using descriptive statistics like frequency, percentages and means. The study indicated that approximately 79.33 per cent of the respondents who adopted the use of enhanced cassava variety increased their revenue by 27,750 Nira compared to the non-adopters. The result demonstrated that the impact of enhanced agricultural technology on cassava productivity was significantly positive.

Simtowe *et al.*, (2012) assessed the welfare effect of agricultural technology adoption in Malawi. This research was a program evaluation technique aimed to determine the causal-effect of adoption of enhanced groundnut technologies on consumption expenditure and poverty measured using headcount, poverty gap and severity indices. To test the robustness of propensity score results a sensitivity analysis was done using the rbounds test and the Mean Absolute Standardized Bias (MASB) between the adopters and non-adopters. The outcome showed that adoption of enhanced groundnut varieties had a positive and significant impact on consumption expenditure and poverty reduction. Furthermore, the sensitivity analysis results revealed that the intended outcome was brought about by the technology. Similarly the Standardized Bias showed a balanced distribution of covariates between the participants and non-participants.

Awotide *et al*., (2012) investigated how adoption of improved rice varieties impacted on rice productivity and the well-being of farm households in Nigeria. The study assessed the impact using the Local Average Treatment Effect (LATE) procedure which employs the Instrumental Variable (IV). The findings showed that enhanced rice varieties had a positive and significant impact on rice productivity and total household expenditure among the adopters than the non-adopters.

Deschamps-Laporte (2013) conducted a study to investigate the impact of extension services on farming households using Propensity Score Matching (PSM) technique in Western Kenya. The specific objective of the study was to ascertain whether extension services had influence on technology adoption, crop productivity and incomes among rural farm households in Lugari district -Western Kenya. The results suggested that there were some improvements in crop productivity and household incomes among participating farmers (treatment group) that took up the government extension programmes than the non-participating farmers (non-treatment group). Asres *et al.*, (2013) similarly examined the effect of participating in agricultural extension programmes on smallholders' farm productivity in the highlands of Ethiopia. The investigation employed a combination of three analytical techniques namely, Ordinary Least Square (OLS), Heckman's Treatment Effect (HTEM) and Propensity Score Matching (PSM) to determine how participating in agricultural extension programmes influenced farm productivity. The results revealed that participation in agricultural extension programmes had a positive influence on farm productivity in the Ethiopian highlands.

# CHAPTER THREE

# RESEARCH METHODOLOGY

## 3.1 Introduction

In chapter three the data sources and techniques used in the analysis are discussed. The model selection, empirical model specification as well as the choice and definition of variables considered to have influenced the decision to adopt CA are explained. Furthermore, empirical challenges related with technology impact evaluation in observational studies as well as other techniques that are available for use to solve these challenges are expounded. We continue to present the estimation procedures of Average Treatment on the Treated using the propensity scores matching and evaluate the distribution of covariates between the adopters and non-adopters using the standardized bias (SB). Lastly, we explain how the sensitivity analysis of the evaluated impact results to unobserved covariates was assessed.

## 3.2 Data Sources and Collection Methods

This study used secondary data drawn from a national representative cross-sectional household survey known as the Rural Agricultural Livelihood Surveys (RALS-2012) that was conducted in 2012. The data were collected by the Indaba Agricultural Policy Research Institute (IAPRI) in collaboration with the Zambia Central Statistical Office (CSO) and Ministry of Agricultural and Livestock (MAL). The survey covered 8,839 smallholder households during the 2010/11 agricultural production season and 2011/12 agricultural marketing seasons where information on households' income, cropping patterns, landholdings, and other assets was collected. Also, information on crop and livestock production, as well as retrospective and current socio-demographic information on all household members were captured. The information and cartographic data from 2010 Zambia household population census formed the basis of the sampling frame for the survey. The design of the sample represented rural farm households that cultivated less than 20 hectares of land for farming purposes or reared livestock in all the ten provinces of Zambia, which are subdivided into 117 districts. The first stage of sampling was at the level of Standard Enumeration Areas (SEAs) where 442 SEAs were selected using probability proportional to size sampling scheme across the country. Each sample SEA listed all households then each household categorized and selected into a random sample of 20 households (RALS 2012).

Households were included in the sample only if they were found to cultivate crops or raise livestock. Non-agricultural households were excluded so as to improve the efficiency of the sampling frame for crop and livestock production and other agricultural characteristics. Households were classified into small and medium-scale farming households; defined as those cultivating areas less than 5 hectares and between 5 and 20 hectares, respectively. Households cultivating more than 20 hectares were classified as large-scale farmers and were not included in this survey. Initial village listings of all households were generated to prepare the sample frames. Since smaller households greatly outnumber the larger ones, the survey over-sampled the medium-scale farming households to ensure adequate inclusion of the larger households in the survey (RALS 2012). For more details about survey design and sampling procedures, the reader is referred to Megill (2004).

In this study, the population of households that were initially captured at national level was 8,839 but this reduced to 4,167 after selecting a sub-sample. The data obtained from RALS 2012 survey is suitable for this type of evaluation study because it included variables related to CA, crop productivity and smallholder farmer well-being. And findings can be generalised because majority of the smallholder maize farmers dwell in the selected four provinces of Zambia (Central, Lusaka, Eastern and Southern) that are dominant maize producers and situated in agro-ecological zones I and IIa. These zones normally receive medium to low annual rainfall and CA is practiced among smallholder farmers.

It is worth mentioning that Zambia comprises three main agro-ecological regions with different climatic, agro-ecological, productivity, socio-economic and demographic characteristics. These agro-ecological regions are I, IIa, IIb and III with geographic locations; I found in the southern end, II in the middle belt and III in the extreme north of the country. This study focused on four provinces namely- Central, Lusaka, Eastern, and Southern where agro-ecological zones I and IIa are situated. These zones normally receive medium to low annual rainfall and most smallholder households farming in these regions predominantly grow maize and practice conservation agriculture. A map of Zambia depicting the provinces is shown at Appendix III and another one depicting the districts and agro-ecological regions is shown at Appendix IV.

### 3.3 Data Analysis and Empirical Model Specification

Data analysis in this study was mainly performed using the stata version 12 software. The assessment of the descriptive statistics illustrates the characteristics of the two sub-samples and the likelihood to adopt CA including its impact on the desired outcomes. Descriptive statistics provide a clear understanding of the sample households' data and helps to efficiently perform the subsequent empirical data analysis. These statistics include *inter alia*; standard deviations, percentages, mean, frequency and inferential statistics such as chi-square test (categorical variables), *t-test* (continuous variables) and Kruscal-Wallis (binary/dichotomous variables) that enable to make proper comparisons of the participants and non-participants in relation to demographic, socio-economic, institutional and other characteristics.

The first objective of the study "To evaluate factors that influence CA adoption among smallholder maize farmers in four selected provinces of Zambia" was addressed using a probit regression model. The model is considered as the most suitable tool to quantitatively evaluate and investigate the demographic, socio-economic and institutional factors that influence the adoption of CA. Given that the adoption of CA is a dichotomous or binary dependent variable which involves the choice of either adoption or non-adoption; the probit model was employed to examine how each explanatory variable affects the likelihood of assignment into the treatment group (1998, from Bryson et al., 2002, p23; Caliendo and Hujer, 2005). For purposes of this study adopters are individuals or households who used at least one or more of the three core principles of CA thus minimum soil disturbance, permanent soil cover and diversified crop rotation (Hobbs *et al.,* 2008; Govaerts *et al.,* 2009). Each of the regression outcome variables was subjected to a binary coding, where 1 equals participation in CA and 0 otherwise. Hence, the probit model is given as:

$$\Pr(D_i = 1/x_i) = \Phi\{h(x_i)\} \quad (1)$$

Where: $D_i$ is the response variable indicating exposure to treatment (CA); $x_i$ is a vector of regressors or a set of covariates assumed to influence farmer decision to practice CA; $h(x_i)$ denotes a starting specification that includes all covariates as linear; and $\Phi$ is the normal cumulative distribution function.

### 3.4 Choice and Definition of Variables

Most economic analysis concerning agricultural technology adoption has been predominantly focused on human capital, infrastructure, imperfect information, institutional constraints, input availability, risk and uncertainty as possible reasons for adoption decisions (Feder *et al.,* 1985; Foster and Rosenzweig, 1996). Feder *et al.,* (1985) postulate that literature concerning adoption of an agriculture technology is extensive and relatively difficult to abridge efficiently. For instance, Adesina and Zinah (1993) postulate that the behaviour and determinants of technology adoption can effectively be explained using three paradigms; namely the innovation diffusion model, the adopters' perception model and the economic constraints model. The innovation diffusion model views access to information concerning an innovation as the major factor determining adoption decision. According to Makokha *et al*, (1999) the model puts emphasis on extension support, use of media and leaders' views as possible ways of influencing adoption of new technology). The adopters' perception model argues that the subjective perceptions of new technologies usually held by farmers given the prevailing socio-economic environment guide their adoption behaviour (Makokha *et al.,* 1999). The economic constraint model suggests that technology adoption decision is influenced by economic factors and economic constraints due to the asymmetric allocation of resources (Aikens *et al.,* 1975). The adoption decision of new innovations is significantly constrained due to lack of land ownership and access to capital (Yapa and Mayfield, 1978; Havens and Flinn, 1976).

For purposes of this study, only two of the above mentioned models were employed; namely, the innovation diffusion and economic constraints models because the covariates used were obtained from the RALS-2012 survey dataset which excluded variables associated with farmer perceptions. Additionally, the covariates included were based on theory, review of past studies on agricultural technology adoption, technology impact on productivity and other welfare outcomes. In this study, the livelihood outcomes are crop productivity and household income.

Crop productivity refers to the average yield per area of maize (ton/ha), household income refers to the estimated household crop income in one farming season (ZMK'000) and maize was preferred because it is both a staple food and cash crop for most farm households in Zambia. The covariates included in this study and their assumed relations with the dependent variables are shown in Table 1 below.

**Table 1: Definition of Variables used in the Probit Model**

| Variable name | Variable Description | Expected effect on CA adoption |
|---|---|---|
| *Dependent Variables* | | |
| CA adoption | Dummy (=1if household adopted CA, 0 otherwise) | |
| Maize productivity | Maize quantity harvested per area planted | |
| Area planted | Area planted with maize (kgs) | |
| Household income | Projected household maize income per season (ZMW ,000) | |
| *Explanatory variables* | | |
| Demographic Characteristics | | |
| Age of household head | Age of household head (years) | +/- |
| Education of household head | | +/- |
| Primary education dummy | Primary education (attended =1, 0 otherwise) | +/- |
| Secondary education dummy | Secondary education (attended =1, 0 otherwise) | +/- |
| Gender | Sex of household head (=1 if Female, 0 otherwise) | +/- |
| Adult equivalent | Labour quantity and quality (= number of adults 15-59 years) | + |
| Socio-Economic Characteristics | | |
| Own livestock dummy | Household owns livestock ( 1=yes, 0 otherwise) | +/- |
| Own radio dummy | Household owns a radio ( 1=yes, 0 otherwise) | + |
| Own cellular dummy | Household owns a mobile phone ( 1=yes, 0 otherwise) | + |
| Off-farm income | Log of off-farm household income | +/- |
| In-kind income | Log of in-kind income | +/- |
| Institutional characteristics | | |
| Access to land | Availability of land (=1 if available, 0 otherwise) | +/- |
| State land title | Land title (=1 if State approved title ) | +/- |
| Customary land title | Land title (=1 if customary approved title ) | +/- |
| CA advice dummy | Access to advice in CA (=1 if yes, 0 otherwise) | + |
| MAL extension services | Received extension from MAL (=1 if yes, 0 otherwise) | +/- |
| ZNFU/CFU extension services | Received extension from ZNFU/CFU(=1 if yes, 0 otherwise) | +/- |
| ASP extension services | Received extension through ASP (=1 if yes, 0 otherwise) | +/- |
| Fellow farmers | Received extension through fellows (=1 if yes, 0 otherwise) | +/- |
| Loans/Credit dummy | Access to credit or loans (=1 if yes, 0 otherwise) | + |
| Farmer gp/cooperative dummy | Membership to farmer gp/cooperative (=1 if yes, 0 otherwise) | +/- |
| Distance to agro-dealer | Distance to dealer in agricultural commodities (km) | +/- |
| Farm Location | | |
| Central Province | Farm Household location (=1 if Central, 0 otherwise) | + |
| Eastern Province | Farm Household location (=1 if Eastern, 0 otherwise) | + |
| Lusaka Province | Farm Household location (=1 if Lusaka, 0 otherwise) | + |
| Southern Province | Farm Household location(= Base Province) | Base |

Some literature review indicates that careful consideration should be taken with regard to inclusion or exclusion of covariates in the propensity score model. For example, Heckman *et al*., (1997) showed that omission of relevant variables can greatly increase the bias in resulting estimates. Principally only variables that have simultaneous effect on both the adoption decision and the outcome variable ought to be included; in other words, clearly only those variables that are unaffected by treatment (not even anticipation of it) ought to be included in the model. And ensuring this requires that the variables are fixed over time or measured prior to treatment. Bryson *et al*., (2002) also argues against adding too many parameters in the models because including irrelevant variables in the adoption model tends to reduce the probability of finding a common support. Rosenbaum and Rubin (1983), Dehejia and Wahba (2002) and Diprete and Gangl (2004) put emphasis on the importance of ensuring that the balancing condition gets satisfied because it lessens the influence of confounding variables. Hence, the researcher can seek guidance from economic theory and empirical studies to know which explanatory variables (observables) influence both treatment (participation) and the desired outcomes (Bryson *et al.,* 2002). Additionally, the selection of an explanatory variable that is assumed to influence adoption depends on the frequency that variable is referred to in the literature. For instance, many previous studies have citations on factors that influence farmers' decision to adopt various conservation technologies (Gebermedhin & Swinton, 2001; Kuntanshula *et al*., 2002; Gladwin *et al.,* 2002; Ajayi *et al.,* 2003; Tembo & Haggblade, 2003; Chomba, 2004; Kabwe & Donovan, 2005; Keil *et al*., 2005; Rocstrom *et al.,* 2006; Jera & Ajayi, 2008; Chiputwa *et al,* 2011; Nkegbe *et al.,* 2011; Nyanga *et* al., 2011; Kassie *et al.,* 2012; Nyanga, 2012). A description of variables and their presumed association with the dependent variable are outlined below.

**Demographic Factors**

Most literature on agriculture technology adoption considers that the adoption decision of technologies including CA is influenced by the characteristics of the farm household head and the household in general (Gebermedhin & Swinton, 2001; Haggblade & Tembo, 2003; Chomba, 2004; Kabwe & Donovan, 2005; Rockström *et al.,* 2009; Chiputwa *et al.,* 2011; Nkegbe *et al.,* 2011; Nyanga *et al.,* 2011; Kassie *et al.,* 2012; Nyanga, 2012). By and large the household head is the ultimate decision maker as such he/she presides over serious family matters including those concerning resource distribution; which suggests that age could enhance new technology adoption (Jera and Ajayi, 2008). This study uses age of the household head as a proxy for farming experience although some literature suggests that the influence of age on CA adoption seems to be inconsistent. Some studies indicate that age has no influence on farmer's decision to adopt CA (Gbetibouo, 2009), while other studies found age to be significantly and negatively linked to farmer's decision to adopt CA (Adesina and Baidu-Forson, 1995; Asiedu-Darko, 2014). Young people are perceived to have great potential to become prolific farmers due to their enthusiasm to take up new farming practices (Kalinda *et al.,* 2014). They are also presumed to have a long planning horizon hence the ability to adopt long term conservation measures (*Ibid*). Equally the older people possess some experience due to several years of farming, but in most cases are less enthusiastic or not eager to adopt new farming techniques which do not give immediate benefits (Jera and Ajayi, 2008). The age of a farmer can either build or destroy confidence; in other words, the older a farmer becomes the more risk-averse to new technology and vice versa (Gregory and Sewando, 2013). With the aforementioned, age in this study is assumed to affect the CA adoption decision by farmers either negatively or positively.

The proxy for farmer's ability to acquire and efficiently use information is the education level of the household head. This determines the human capital development that enables individual farmers to access information that helps to make informed and effective decisions about resource management (Asafu-Adjaye, 2008; Asiedu-Darko, 2014). Education level has been reported as an important variable that influences farmers' adoption decision (Ngoma, 2012). It tends to increase the ability of farmers to acquire then process and utilize information which is essential to technology adoption (Gregory and Sewando, 2013). However, there is a possibility that some educated farm households may be conservative to adopt CA while others might be eager to adopt the technology (N'gombe, 2013). Considering the above, the education level of household head can be an ambiguous factor. However, in this study education level of household head is assumed to have either a positive or negative influence on the CA adoption.

Another variable of importance concerning farmer's decision to adopt CA is gender of the household head. Earlier studies have revealed that predominance of males in new technology programs is associated with firm traditional and cultural systems that differentiate gender roles in agriculture usually biased to men (Nkala, 2012). Female headed households tend to be less enthusiastic to adopt new technologies than men due to cultural factors and differences in ownership of productive resources/wealth that are unfavorable to women (Jera & Ajayi, 2008; Kassie *et al.*, 2012). Mazvimavi *et al.,* (2010) indicated that gender directly affected CA adoption in a study conducted in Zimbabwe; male headed households adopted the CA technology extensively than female headed households. However, there are some female heads that also have enough eagerness to engage and practice new technologies such as CA (Jera & Ajayi, 2008). Hence, gender of the household is expected to have either a negative or positive relationship with the adoption of CA.

The proxy used for household labour quantity and quality is the adult equivalent. Basically it is the number of adults in a household aged between 15 and 59 years. It is an important factor with regard to CA adoption because the technology is assumed to be labour intensive which implies that large sized households tend to be better-off in terms of labour availability (Haggblade & Tembo, 2003; Marenya & Barett, 2007; Kassie *et al.*, 2012). This agrees with suggestions that most smallholder farm households rely on family labour for their daily agriculture activities (Nchemachena and Hassan, 2008); households comprising many members readily available to perform farm work have the advantage to provide the extra labour required by the new technology (Tadesse and Belay, 2004; Gregory and Sewando, 2013).

**Socio-Economic Factors**

Land and livestock ownership are the major proxies for wealth status of the household head in this study. The other measure of wealth that was considered is ownership of radio set because it enables households to easily access agricultural programmes and information. Normally wealth tends to enhance the risk taking capabilities; hence it may increase the likelihood of a farmer to invest funds in new technology (Jera and Ajayi, 2008). Smallholder farmers who own a lot of livestock may easily sale some animals to raise finances required to invest in new technologies; and also expected to afford animal draught power (ADP) required for CA activities. Additionally, smallholder farm households who own big acreages of land are more likely to reserve extra land to engage in new technology (Mavunganidze et al., 2013); they may also offer the extra land as collateral for credit acquisition (Gregory and Sewando, 2013). Assets are considered to enhance the capacity of a farmer to adopt CA (Nchemachena and Hassan, 2008). It is hypothesized that the size of land holding and size of herd have a positive relationship with CA adoption just like the other measures of wealth mentioned above.

Off-farm and in-kind income are other factors that may influence farmers' decision to adopt CA. Past studies reveal that such forms of income are vital elements in shaping the behavior of farmers with respect to adopting conservation oriented farming (Tadesse & Belay, 2004; Marenya & Barett, 2007). According to Knowler and Bradshaw (2007), adoption of agriculture technology requires adequate finances, therefore off-farm/in-kind income and the decision to adopt CA is expected to have a positive correlation. However, other studies found a negative relationship between off-farm income and the decision to adopt CA (Gebetibouo, (2009); Ng'ombe et al., 2014). On one hand, smallholder farm households may be expected to utilize off-farm/in-kind income to purchase appropriate implements required for CA and on another it is expected that the income may not be utilized to procure CA implements but instead used to purchase basic items due to different priorities of smallholder households. Therefore, this study hypothesizes that off-farm/in-kind income could be inconsistent (either be negative or positive) in influencing the farmers' decision to adopt CA.

**Institutional Factors**

Land tenure security is a fundamental factor that affects smallholder farm households' ability to adopt agricultural technologies because it provides them encouragement and flexibility to invest in new agricultural technologies which enhance land productivity. Some studies suggest that smallholder farmers who are land secure (own land) may use the land in any manner they wish, apply various management strategies and take up best practices earlier than their land insecure counterparts (Schertz & Wunderlich, 1981; Norwak & Kersching, 1983; Tadesse & Belay, 2004 and Marenya & Barett, 2007). Smallholder farm households that are land secure are expected to have a high likelihood to adopt CA than those renting land (Arellanes & Lee, 2003; Gebremedhin & Swinton, 2003; Haggblade & Tembo, 2003; Kassie *et al.,* 2012). Hence, this study hypothesizes that land tenure security will positively influence CA.

Agricultural cooperative societies or farmer groups have defined membership, specific purposes of assembly and organizational structures. They are voluntary farmer organizations established to support members in pursuing their individual and collective farming business interests. They are also considered to enhance access to productive resources like farming information, training as well as seed (Jera & Ajayi, 2008; Kassie et al.2009; Wollni et al. 2010). A smallholder farm household head with membership to a farmer group/cooperative is believed to improve their social capital development, hence more likely to adopt CA. Therefore, this study assumes that membership to a farmer group/cooperative positively affects farmers' decision to adopt CA.

Access to advice plays an important role of providing valuable information about crop and animal production. Basically smallholder farm households require access to advice concerning new agricultural technologies before they can opt to adopt (Jera & Ajayi, 2008). Advice or information of such value (including information dealing with input and output prices) can better be acquired through different forms of extension services like public, private and NGOs among other means. Several studies reveal that extension education is an important factor that encourages the use of specific soil and water conservation practices (Bekele and Drake, 2003). Access to extension advice has been reported to be positively correlated to farmers' technology adoption decisions that mitigate climate change effects (Deressa, 2009 and Hisali *et al.,* 2011). Other studies argue that access to extension education may not be that important but infer that the message contained in the extension package is rather important (Bryon *et al.,* 2009 and Kassie *et al.,* 2012). This study assumes that generally extension advice on CA positively affects the decision to adopt the technology. However, if CA advice/information is provided by different sources that have various CA packages, then the effect can either be positive or negative.

Distance to input-output market is also an important factor that can influence the decision to adopt the CA technology. It is perceived that a readily available input-output market can influence the adoption of a technology (Mutuma et al, 2013). Conversely, smallholder households who dwell in remote rural areas may be less likely to adopt CA because of difficulties to access inputs or appropriate equipment such as rippers from agro-dealers. Due to the above, this study assumes that there is both a negative and positive relationship between the famers' decision to adopt CA and distance to input-output market.

Credit is widely considered as an essential instrument for enhancing the economic welfare for smallholder farm households both in the short and long term. Access to credit may increase the ability of a farmer to bear risk in the event of financial failure also may inspire them to invest in high yielding activities like CA. Therefore, it is perceived that access to credit/loans by farmer households has influence on adoption decision of new technologies. Many studies indicate that access to credit/loans is a critical factor which can enhance farmers capability to better their management practices in response to climate change (N'gombe et al., 2014; Deressa *et al.,* 2009 and Bryon *et al.,*2011) and adoption of different types of technologies (Nyanga, 2011). On the other hand, it is expected that smallholder farm households with limited or no access to credit/loans do not have adequate capital to purchase appropriate farm implements needed for adoption and practice of CA. Hence, this study assumes that access to credit/loans is positively correlated to farmers' decision to adopt CA.

Conservation agriculture has been reported to affect farmers' incomes. For example, Ng'ombe (2013) posits that smallholder farmers that adopted CA realized more crop income per hectare than non-adopters. Haggblade and Tembo (2003) investigated the development, diffusion and impact of CA in Zambia. Their overall results showed that on average income returns to peak season labor are higher under CA than under conventional farming. According to Diao, Headey and Johnson (2008) an increase in farm productivity attacks poverty in three different ways: increases productivity and incomes of majority of Africa's poor that mainly subsist on agriculture; reduces food prices, which govern real incomes.

### 3.5 Impact Evaluation Framework

This section addresses the second objective by examining the effect of CA on maize productivity and income among the smallholder farmers. It uses non-experimental data that is identified with problems of overt and hidden biases as well as endogeneity of the treatment variable which brings about inconsistent estimation. Various methods exist in the statistics and econometric literature that try to address (remove or minimize) the effects of these biases (Ravallion, 2001; Bryson and Dorsett, 2002; Imbens and Wooldridge, 2008). Generally these methods are divided into two categories; those that only remove overt biases and those that correct for unobservable biases as well. In this impact evaluation study two techniques were applied; one of them being propensity score matching and the other regression analysis.

### 3.5.1 Impact Evaluation Problem

When evaluating the impact of CA adoption on maize productivity and income, it is necessary to create what the situation would have been of the treatment group (adopting farmers) had they not participated in the intervention. In empirical literature this is known as the Roy-Rubin model, or the potential outcome model (Caliendo & Kopeinig, 2008 citing Roy, 1951; Rubin, 1974). The model is given as follows:

$$T_i = Y_{i1} - Y_{i0} \qquad (2)$$

Where: $T_i$ denotes the treatment effect for individual *i*; $Y_{i1}$ denotes the potential outcome for individual *i* when treated (the actual outcome) and $Y_{i0}$ is the potential outcome for individual *i* when they would not have participated (the counterfactual). Undoubtedly, there exists a problem of missing data because for each individual just one of the potential outcomes can be observed. This problem of missing data can well be solved by formulating a realistic counterfactual thus the potential outcome if this individual would not have participated.

In order to construct a realistic counterfactual in technology impact evaluation, a researcher requires to take two considerations into account; firstly, the decision to participate in the technology and secondly the processes and factors that influence the socio-economic outcome indicators (Bryson and Dorsett, 2002). Given that participation in the technology is voluntary, it is incorrect to simply compare participants with non-participants because there are expected differences with respect to several observable and unobservable characteristics that can influence the outcome indicators regardless of program participation. Hence, to achieve a valid estimate of impact evaluation using observational studies, it is necessary to solve existing empirical challenges so as to establish a realistic counterfactual that will account for the effects of self-selection (based on both observed and unobserved characteristics). The self-selection problem occurs when households decide by themselves whether or not to adopt the CA practices, due to wealth differentials as well as endogeneity due to intervention assignment; where CA program administers or development agents choose farm households that have specific characteristics (Shiferaw *et al.,* 2013; Asres *et al.,* 2013).

Assessment of welfare effects from technology adoption based on quasi-experimental studies is difficult despite several theoretical claims that improved agricultural technologies can improve farm household welfare (Kassie *et al*., 2010). The reason is the inability to observe the counterfactual (unobserved outcome) which is what would crop productivity and income situation be like given that the technology had not been adopted (Rosenbaum and Rubin, 1983; Shiferaw *et al.,* 2013). Random assignment of sample participants to either treatment or non-treatment groups ensures that any differences in conditions of the two groups subsequent to the intervention can be entirely attributed to the intervention. However, this study uses non-experimental data where the groups are not randomly assigned as such the decision to adopt the technology is more likely to be affected by both unobserved (managerial skills and motivation) and observed heterogeneity that might be correlated with the desired outcomes (Caliendo and Hujer, 2005). The basic problem in impact evaluation relates to the inference of causal link between the treatment and the outcome (Simtowe *et al.,* 2012).

There are a number of econometric techniques available to address the selection bias problem such as the Propensity Score Matching, Reflex Comparison, Double Difference and Instrumental Variable (IV) methods among others (Khandker *et al.,* 2010; Awotide *et al.,* 2012; Shiferaw *et al*., 2013). These techniques vary in terms of assumptions and data requirements to solve selection bias during calculating treatment effects (Khandker *et al.,* 2010). Details of these techniques have already been explained under impact evaluation techniques in chapter two. Considering the aforementioned problem associated with impact evaluation in non-experimental studies, this study applies the PSM semi-parametric technique to estimate the ATT because it is an appropriate alternative in the absence of either baseline data or randomization (Jalan & Ravallion, 2003 and Caliendo and Kopeinig, 2008). As earlier indicated PSM has its own limitations; the requirement for large samples, need for a considerable group overlap and hidden bias may remain since matching only controls for observed variables (Guo *et al*., 2006; Diaz and Handa, 2006). Therefore, when implementing the PSM it also requires selecting a suitable matching algorithm, checking the common support condition as well as testing the matching quality. In this study, variations in crop productivity and income levels were used to measure the impact of CA on smallholder maize farmers' livelihoods. The econometric analysis of the PSM technique is described below.

### 3.5.2 Specification of PSM Technique

The propensity score matching (PSM) is a semi-parametric technique that involves two phases to estimate the average treatment on the treated (ATT). In the first phase a probit regression is performed to estimate the propensity scores which determine the farm household's probability of participating in the CA technology, viz, *p(x)*, and in the second phase it utilizes the propensity scores (*p-score*) found in the first phase to match the CA and non-CA farm households with similar propensity score values. The aim for using matching was to obtain a group of treated persons (adopters) similar to the control (non-adopters) in all relevant pre-intervention characteristics, but only differ because one group participated in the CA technology while the other group did not participate (Rosenbaum & Rubin, 1983; Heckman et al., 1998; Smith & Todd, 2005; Nkala., 2011). The PSM technique compares the outcome of technology participants against matched non-participants; where matches are selected based on similarities in observed characteristics (propensity to participate). Let Ti = 1 to signify a dummy variable equal to 1 if household *i* adopt CA and 0 otherwise; the propensity score is defined by:

$$P\ (X) = Prob\ (Ti = 1/X) = E\ (Ti\ /X)\ (0 < P\ (X) < 1) \qquad (3)$$

Where; X is a vector of covariates hypothesized to influence adoption of CA (Rosenbaum & Rubin, 1983) and *E* (.) is the expectations operator.

These pre-treatment control variables are those based on knowledge of the technology being evaluated and on the social, economic as well as institutional assumptions that may affect CA technology adoption. It is further indicated that if outcomes without the treatment are independent of participation given X, then they are also independent of participation given P(X). This tends to reduce the matching problem from a multidimensional to a single dimensional problem (Ravallion, 2003).

### 3.5.3 Evaluation of Technology Impact

In this study, technology impact evaluation is dealt with through the Rubin's potential outcome framework (Rubin, 1974). And as stated by matching theory the propensity score will be generated using the probit model, which will include predictor variables that affect the selection process or participation in the CA technology and the desired outcome (Rosenbaum and Robin, 1983; Bryson *et al*., 2002; Jalan and Ravallion, 2003). The aim of CA technology impact evaluation is to establish how the intervention or applied treatment influences an outcome of interest, thus assessing the treatment effect against a counterfactual. Participation of farm household *i* in the CA technology is denoted as a "treatment" given by $T_i = 1$ and $T_i = 0$ if the household has not been exposed to treatment. The observed outcome for farm household *i* is specified as:

$$Y_i = T_i y_{1i} + (1 + T_i) y_{0i} \quad (4)$$

Where: $y_{1i}$ is the outcome if a farm household participates and $y_{0i}$ if they do not participate. The treatment effect of the CA technology intervention is:

$$\tau_i = \Delta y_i = y_{i1} - y_{i0} \quad (5)$$

However, one may easily notice that $T_i y_{1i} = 1$ and $T_i y_{0i} = 0$ cannot be observed for the same farm household at the same time; subject to the locus of the individual farmer in the treatment, either $T_i y_{1i} = 1$ or $T_i y_{0i} = 0$. Considering the fact above, it is not possible to estimate individual treatment effect ( $\tau_i$ ); therefore one should instead shift to estimate the average treatment effects of the population. The commonly used estimation of average treatment effects (ATE) is the average treatment effect on the treated (ATT) which refers to the mean difference in the values of desired outcomes between the matched treated and non-treated sub-samples given the pre-intervention characteristics. In other words, it is the expected value of the outcome for those who participated in the CA technology, conditional on the individual characteristics that determine CA technology participation.

Matching subjects with a multidimensional vector of characteristics (involving large samples) is basically unfeasible. Hence, this method intends to synopsize pre-treatment characteristics of each subject into a single dimensional variable (propensity score) that makes matching feasible. Since the desired evaluation aspect is the mean impact of treatment on an individual farm household, the estimation is given as:

$$\tau_i = E(y_{1i} - y_{0i} / T_i = 1) = E(y_{1i} / T_i = 1) - E(y_{0i} / T_i = 0) \quad (6)$$

where; $\tau_i$ denotes the outcome for farm household $i$ for participating in CA; $y_{1i}$ stands for the expected value of outcome for farm household $i$ if they adopted CA; $y_{0i}$ stands for the expected value of outcome for farm household $i$ if they did not adopt CA and $T_i$ is the conditional probability of participating in CA for farm household *i.* The magnitude of benefit a CA practicing farm household gains as compared to what they would have attained without practicing CA is signified by $\tau_i$ . Real data about $E(y_{1i} / T_i = 1)$ are obtainable from the CA practicing household but finding $E(y_{0i} / T_i = 1)$ is problematic because data on a non-CA practitioner only permits identification of $E(y_{0i} / T_i = 0)$ . Clearly the difference between $E(y_{1i} / T_i = 1)$ and $E(y_{0i} / T_i = 1)$ cannot be observed for the same farm household. The problem presented above can be tackled using the solution developed by Rubin (1977) that matches the two groups to estimate the average treatment effect on the treated (ATT) instead of estimating individual treatment effect $\tau_i$ . Given that the counterfactual mean for those being treated, $E(y_{0i} / T_i = 1)$ cannot be observed, it then becomes necessary to select a suitable substitute for it that will allow estimation of ATT. The simplest way is to use the mean outcome of the untreated individual farm household, $E(y_{0i} / T_i = 0)$ instead of the unobservable counterfactual mean for those being treated, $E(y_{0i} / T_i = 1)$ . However, it is argued that this approach is inappropriate in non-experimental studies because components that determine the treatment decision are also likely to determine the desired outcome variables. Since this is a non-experimental study, variables that determine farm households' decision to participate in CA may also affect maize productivity and household income levels. Hence outcomes for individual households from the treatment and comparison groups would vary even without treatment leading to self-selection bias. This implies that the expected difference between the CA and non-CA groups may not be the same prior to the introduction of the technology. In order to deal with this problem, the expected outcome of non-CA adopters had they participated in the technology is added and subtracted from equation (5) to find:

$$\tau_{ATT} = E(y_{1i} / T_i = 1) - E(y_{0i} / T_i = 0) + E(y_{0i} / T_i = 1) - E(y_{0i} / T_i = 1) \qquad (7)$$

We re-write the equation and get:

$$\tau_{ATT} = ATT + E(y_{0i} / T_i = 1) - E(y_{0i} / T_i = 1) \qquad (8)$$

$$\tau_{ATT} = ATT + \varepsilon \qquad (9)$$

Therefore, ATT is the average gain in income and maize productivity of the CA practicing farm households in contrast to the non-CA practicing households; as if non-CA farm households also practiced the technology. This creates a condition that is similar to where a farm household randomly selected from the population is assigned as a CA participant. As such, both the CA and non-CA adopting households have an equal chance of participating in the CA technology. The selection bias is shown by the error term Ɛ which gives the mean differences between the counterfactual CA participation and the outcome of non-participation. Consequently, we may only identify the real parameter of ATT if the outcomes of treatment and control in the absence of the technology are similar:

$$E(y_{0i} / T_i = 1) = E(y_{0i} / T_i = 0) = 0 \qquad (10)$$

The above circumstance is only made certain in social experiments where assignment of treatments to units is random. But in non-experimental studies, one needs to create some identifying assumptions to solve the selection problem and two strong assumptions are shown below;

**A. Conditional Independence Assumption (CIA)**

The CIA postulates that conditional on $X$ (observables), the outcomes are independent of the treatment (T). This is prescribed as:

$$y_0 y_1 \perp T / X \quad (11)$$

Where: $\perp$ denotes independence; *X* is a set of observable characteristics; $Y_0$ stands for non-CA participants, and $Y_1$ stands for CA participants.

The conditional independence assumption asserts that any correlation between the unobserved factors and farm household's decision to participate in CA does not influence the explored effect on the desired outcomes. Given a set of observable covariates ( $X$ ) which are unaffected by treatment (in this case CA participation), potential outcomes (maize productivity and household income) are independent of treatment assignment (independent of how the CA participation decision is made by the household). This assumption implies that participating in the treatment or CA is not dependent on the outcome (maize productivity and household income) after controlling for outcome variations brought about by differences in $X$ (unconfoundedness). In other words, the selection into the treatment group is solely based on observable characteristics (selection on observables) (Bryson *et al.,* 2002; Caliendo and Kopeinig, 2008).This reveals that the mean potential outcome for $D = 1$ is the same as for $D = 0$ after adjusting for observable differences.

$$E(y_{0i} / T = 1, X) = E(y_{0i} / T = 0, X) \quad (12)$$

This allows the use of matched non-CA farmers to calculate how the CA participating group has performed if they had not participated. Rosenbaum and Rubin (1983) postulate that instead of conditioning on $X$, the researcher should condition on the propensity score (propensity score matching). Propensity score refers to the probability of participation for household *i* given a set *X* which is the household' characteristics and is presented as:

$$p(x) = \Pr(T = 1 / X) \quad (13)$$

Propensity scores are originated from discrete choice models and thereafter used to construct the comparison groups. As such, matching the probability of participation given covariates solves the problem of selection bias by using PSM (Liebenehm *et al.,* 2009). Both CA and non-CA farmers have the same distribution of observables $X$ , given that the PS is a balancing score (*Ibid*). If the outcomes devoid of intervention are independent of participation given $X$ , then they are similarly independent of participation given $p(x)$ . This tends to lessen a multidimensional matching problem to a single dimension problem. Owing to this, the differences between the CA and non-CA groups are reduced to only the attribute of treatment assignment and then unbiased impact estimate can be generated (Rosenbaum and Rubin, 1983).

**B. Common Support**

Implementing the common support (overlap) condition ascertains that any combination of characteristics observed in the treatment group can also be observed among the control group (Bryson *et al*., 2002). It is the area where the balancing score has positive density and contains the minimum and maximum propensity scores for both treatment and control group households respectively (Caliendo and Kopeinig, 2005). This assumption rules out ideal predictability of *D* given *X.* And it is written as:

$$0 < pr[T = 1/X] < 1 \tag{14}$$

The assumption perfects the quality of the matches as it omits the tails of the distribution of $p(X)$, although this action mostly leads to a great reduction in the sample. Nonetheless, nonparametric matching techniques can only be significantly applied over regions of overlapping support. In the absence of overlap between the treatment and comparison groups, no matches can be formed to estimate the average treatment effect on the treated (ATT) parameter. Basically this assumption ensures that individuals with the same X values have a positive likelihood of being both participants and non-participants.

Considering the CIA and CS (overlap) assumptions above, the ATT may be identified as:

$$ATT = E(y_{1i} / T_i = 1) - E(y_{0i} / T_i = 0) \tag{15}$$

The ATT was estimated precisely by utilizing the propensity scores *p(x)* gotten from the probit regression. It was calculated by the model:

$$ATT = E\left[y_{1i} / T_i = 1, p(x)\right] - E\left[y_{0i} / T_i = 0, p(x)\right] \tag{16}$$

Where: $ATT$ is the average treatment on the treated; $E(y_{1i} / T_i = 1)$ signify the observed changes in the outcomes of interest in the CA group; $E(y_{0i} / T_i = 0)$ signify the observed changes in the outcomes of interest in non-CA group and *p(x)* denotes the propensity score or conditional probability of being in the CA group given *x*.

### 3.5.4 Matching Algorithms

Subsequent to estimating the propensity scores (PS), it is essential to select an appropriate matching estimator. It is worth noting that merely calculating the propensity score is inadequate to estimate the ATT of interest; because propensity score is a continuous variable as such the likelihood of observing two units with precisely the same propensity score is theoretically zero. There are several matching estimators that may be utilized but they differ from each other with regard to the weights they attribute to the selected controls during estimation of the counterfactual outcome of the treated as well as the manner in which control units that are matched to the treated are selected. Generally all matching estimators provide consistent estimates of ATT under the CIA and CS (overlap) assumptions (Caliendo and Kopeinig, 2008). Examples of matching algorithms include among others; the Nearest Neighbor, Kernel, Caliper (radius), Local linear, Spline and Mahalanobis matching methods. The major task for these methods is to find one or more comparable untreated individual to each treated individual. The most commonly used matching estimators are the Kernel, Nearest Neighbor and the Caliper (radius) matching methods.

Kernel matching is a nonparametric matching estimator that compares the outcome of each treated individual (treated unit) to a weighted average of the outcomes of all the untreated individuals (control units); by way of placing the highest weight on those with scores closest to the treated individual to construct a counterfactual. In other words, weights are received by control units based on the closeness between their propensity score and that of the treated unit to which they are being matched (Heckman *et al*., 1997; Smith and Todd, 2005). The advantage of this approach is that it achieves lower variance, due to the use of more information. Its disadvantage is that some of the observations used may be poor matches. Therefore, the proper imposition of the common-support condition is vitally relevant for this method. And when the researcher is applying kernel matching, he/she has to choose the kernel function and the bandwidth parameter.

Nearest Neighbor (NN) matching: This is a straightforward matching estimator. It involves choosing an individual from a comparison group as a matching partner for a treated individual that is closest with respect to propensity score (Guo *et al*., 2006; Caliendo and Kopeinig, 2008, Nkala *et al.,* 2011). The nearest neighbor matching may be done with or without replacement options. When performed with replacement, a comparison individual may be matched to more than one treatment individuals, which improves the quality of matches but reduces the precision of estimates. Conversely, when matching without replacement, a comparison individual may only be used once, this increases bias but may improve the precision of estimates. In the event the treatment and comparison units are extremely different, finding a suitable match by matching without replacement can be very difficult (Dehejia and Wahba, 2002). This means that by matching without replacement, if comparison units identical to the treated units are few, a researcher may be forced to match treated units to comparison units that are quite different with respect to the estimated propensity score.

Caliper (radius) matching: The description of NN matching above reveals that it faces the risk of bad matches if the closest neighbor is far off. In order to solve this problem researchers use an alternative matching algorism called caliper matching; which means that a subject from the comparison group is chosen as a matching partner for a treated subject that lies within a specified caliper (propensity score range) and is closest with respect to the propensity score (Caliendo and Kopeinig, 2008). In case the dimension of the neighborhood is established to be very small, then there is a possibility that some treated units are not matched because the neighborhood does not contain a control unit. The problem with caliper matching is the difficult to know *a priori* what limits of deviation are satisfactory (Smith and Todd, 2005). Stratification or interval matching divides the common support into different strata and measures the intervention's impact at each interval (Khandker *et al.*, 2010).

Caliendo and Kopeinig, 2008 indicate that a proper matching estimator does not eliminate too many of the original observations from the final analysis but it should at the same time yield statistically equal covariate means for the treatment and comparison groups. Again, there is no single answer to the question of what estimator is best when using PSM (Bryson *et al*., 2002). However, selection of a particular estimator depends on the nature of the available dataset and especially on the degree of overlap between the treatment and control group with respect to propensity scores (Dehejia and Wahba, 2002). This study used the nearest neighbor and kernel matching estimators because they are cited in literature as being more efficient and give quality matches. The NN estimator only selects control units that are closest in terms of propensity scores to the treated units hence does not eliminate too many of the original observations than the other matching methods (Caliendo and Hujar, 2005).

### 3.5.5 Assessing the Quality of the Matching

Balancing test is a fundamental element that should be properly managed when using PSM. The quality of the matching depends on the ability of the matching method to balance the relevant covariates. These covariates are expected to have some differences before matching; but these should be avoided after matching. PSM basically aims to serve as a balancing method for covariates between the two groups. Therefore, the notion behind balancing tests is to examine whether the propensity score is balanced enough. That is to say, a balancing test seeks to analyze if at every single value of the propensity score, a given characteristic has the same distribution for the treatment and comparison groups. The general idea of all techniques is to compare the situation prior and subsequent to matching as well as to check if there are any differences remaining after conditioning on the propensity score (Caliendo and Kopeinig, 2008). The p-scores only serve as procedure to balance the observed distribution of covariates between the adopting (treated) and non-adopting (comparison) groups. Hence, the success of propensity score estimation is measured by the resultant balance instead of the fit of the models used to generate the estimated propensity scores (Lee, 2006).

There are various techniques used in covariate balancing (thus the equality of the means on the scores and all the covariates) between the treated and untreated farm households. The most commonly used are the standardized bias (SB), *t*-test, Kruscal-Wallis test, likelihood ratio test and pseudo-$R^2$ approaches.

The *t-test* uses a two sample *t*-test to check any differences in covariate means for both groups (Rosenbaum and Rubin, 1983). Usually this approach is applied if the concern is to determine the statistical significance of the results. The disadvantage of this approach is that the bias reduction before and after the matching is not clearly visible (*Ibid*). The Kruscal-Wallis H test determines whether there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable.

The other covariate balancing indicators are the pseudo-$R^2$ and the likelihood ratio test. The Pseudo-$R^2$ shows how well the explanatory variables explain the probability of participation. Sianesi, 2004 indicates re-calculating the propensity score on the matched sample (only CA participants and matched non-CA participants) and thereafter comparing the pseudo-$R^2$ before and after matching. In addition, systematic differences should not exist in the distribution of covariates between the CA and non-CA sub groups after matching and the pseudo-$R^2$ should be relatively low.

A researcher may also perform a likelihood ratio test on the joint significance of all covariates in the probit model. The likelihood ratio (LR) test is used in non-linear regression models because it is more stable in full parametric models and also preferred by statisticians and econometricians (Cameron and Trivedi, 2009; Long and Freese, 2006). It derives a Chi square distribution with degrees of freedom equal to the difference in the number of degrees of freedom between the restricted and full models and is given by $LR = -2(InL\hat{\theta}_{\tau} - InL\hat{\theta}_{u}) \approx \chi^2$, where $\chi^2$ is a Chi-square distribution. The test should not be rejected before matching but after matching the decision can be made. For the purpose of testing the matching quality of matching estimators, this study applied a combination of the above procedures.

The quality of covariate balancing (equality of means on the p-scores and equality of means on all covariates) between CA adopters and non-CA adopters is tested using the standardized bias (SB). It (the SB) refers to the difference between the sample means in the CA and the matched non-CA sub samples expressed as a percentage of the square root of the average of the sample variance in both groups (Rosenbaum & Rubin, 1985; Rubin, 1991 and Nkala, 2012). For each variable and propensity score the standardized bias is computed before and after the matching as follows:

$$SB(X) = 100 \frac{\overline{X_T} - \overline{X_C}}{\sqrt{V_T(X) + V_C(X) / 2}} \tag{17}$$

Where: $\overline{X_T}$ and $\overline{X}_C$ are the sample means for the treatment and control groups, $V_T(X)$ and $V_C(X)$ are the corresponding variances (Caliendo and Kopeinig, 2008). The reduction in bias can be computed as:

$$BR = 100\left[1 - \frac{SB(X)_{post}}{SB(X)_{pre}}\right] \tag{18}$$

The SB approach has one potential problem in that it does not have a clear indication for the success of the matching procedure.

### 3.6 Sensitivity Analysis

Sensitivity analysis is usually undertaken on the estimated ATT so as to establish whether the effect of the technology on the desired outcomes has not been influenced by unobserved factors (Rosenbaum, 2002). Other authors agree that in the recent past, checking the sensitivity of estimated results has increasingly grown to be an important subject matter in applied evaluation literature (Caliendo and Kopeinig, 2008). Given that the estimation of treatment effects with matching estimators is based on the unconfoundedness or selection on observables assumption, there could be unobserved variables which may affect assignment into treatment and the outcome variable simultaneously thereby increasing potential for 'hidden bias' to arise (Rosenbaum, 2002). If this occurs, CIA fails and the estimation of ATT is biased. The measure of the bias depends on the correlation between the unobserved factors on one end, and treatment and outcomes on the other. It should be understood precisely that matching estimators are not robust against this hidden bias. A lot of researchers have increasingly become responsive to the importance of testing the robustness of results to deviations from the identifying assumption.

Since, measuring the size of the selection bias with non-experimental data is not possible; this problem can only be solved by sensitivity analysis.

### 3.6.1 Rosenbaum Bounds

In order to check whether the examined effect of the treatment on the desired outcomes is sensitive to the unobserved covariates and the degree of sensitivity estimated, the use of Rosenbaum bounds sensitivity analysis has been recommended in evaluation literature (Rosenbaum, 2002 and DiPrete & Gangl, 2004). This analysis establishes how strongly an unobserved variable must influence the selection process for it to undermine the implications of the matching analysis (*ibid*). In other words, failure to account for the hidden biases can alter the inference about the effect of CA on maize productivity and household income (outcomes of interest). If an unobserved covariate affects assignment to treatment but does not affect the outcome beyond the covariates already controlled for, then it does not challenge the robustness of the estimations. However, if there is a particular unobserved variable of concern that affects the selection process then the probability of treatment is given by:

$$P(X) = \Pr(T = 1 \mid X, u) = F(\beta X + \lambda u) \qquad (19)$$

Where X is a vector of all observed covariates and *u* stands for the unobserved variable affecting assignment to treatment; $\lambda$ is the effect of *u* on the treatment probability. When the estimator is free of hidden bias then, $\lambda$ is equal to zero and the probability of participation is solely determined by X. But, if hidden bias exists, then two persons with the same observed covariates, X, have different chances of adopting the CA technology. Suppose a matched pair of persons *i* and *j*, and logistic distribution *F*. The odds that a person receives treatment is given by, P/(1 − P). This means that for a matched pair of persons *i* and *j*, the odds ratio is,

$$\frac{P_i \mid (1-P_i)}{P_j \mid (1-P_j)} = \frac{\exp(\beta X_i + \lambda u_i)}{\exp(\beta X_j + \lambda u_j)} \qquad (20)$$

Given that *Xi* = *Xj*, the odds ratio reduces to $\exp\left[\lambda(u_i - u_j)\right]$. The bounds on the odds ratio that either of the two persons gets the treatment are therefore given by:

$$\frac{1}{\Gamma} \leq \frac{p_i(x)(1-p_i(x))}{p_j(x)(1-p_j(x))} \leq \Gamma \qquad (21)$$

Where $P_i$ and $P_j$ are the CA participation probabilities by household *i and j* respectively, and $i \neq j$. The odds for selection into the CA group is given by $\Gamma = \exp\lfloor \lambda(u_{i-}u_j) \rfloor$ for matched households *i* and *j*. The influence of the unobserved factor on the participation decision is measured by $\lambda$. If $\lambda = 1$, households with the same unobserved characteristics have the same probabilities and odds of assignment to participate in CA, also there will be no hidden bias as either $\lambda = 1$ or $u_i = u_j$. When the bounds on the odds ratio begin to vary, it means the value of $\Gamma$ gets greater the one and the unobserved factors increase thereby influencing assignment into CA. Sensitivity analysis assesses how much the effect of CA is changed by the altered value of $\Gamma$, thus scrutinizing the bounds on $\frac{1}{\Gamma}$ and $\Gamma$. The drawback of the Rosenbaum bound approach is the inability to indicate the existence of an unobserved variable but rather identifies whether the hidden bias is large enough to render the estimated treatment effect robust or not. Since the desired outcomes (maize productivity and household income) in this study were treated as binary, the Hodges and Lehmann (HL) test statistic method was applied in the analysis.

### 3.7 Estimation of standard error

Computing of standard errors and analyzing of the statistical significance of treatment effects is a complex undertaking. The difficult is that the estimated variance of the treatment effect should also include the variance attributable to the propensity score estimation, the imputation of the common support and perhaps how orderly treated individuals are matched. The above estimation steps enlarge the difference past the normal sampling variation (Heckman *et al.,* 1998). For instance, treating the matched observations as indicated understate the standard errors in the case of matching with one nearest neighbor (NN matching).

Bootstrapping: Standard errors in psmatch2 are invalid because they do not take into consideration the estimation uncertainty involved in the propensity score (probit regressions). According to Lechner (2002), the use of bootstrapping is one way of dealing with the above problem. It is a popular impact estimation method that has been widely applied to estimate standard errors where analytical estimates are biased or unavailable in the recent past and is documented in most of economic literature. Each bootstrap draw involves re-evaluation of the results, including the first steps of the estimation (propensity score, common support, etc). Thus, bootstrap standard errors seek to integrate all sources of error that may influence the estimates. Bootstrapping estimate of standard errors is invalid for nearest neighbor matching selection (Abadie and Imbens, 2004). Therefore, computing analytical standard error is appropriate in this case. Bootstrapping standard errors for kernel matching estimators is not liable to this criticism because the number of observations used in the match increases with the sample size. The distribution of these means approximate the sampling distribution and thus the standard error of the population mean. The practical drawback of using bootstrapping is that it’s very time-consuming and expensive to compute which renders it unfeasible in some cases (Caliendo and Kopeinig, 2008).

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 Introduction

In chapter four the results on the descriptive statistics and econometric models are presented and discussed. Descriptive statistics show the farm household characteristics in the year of study (2012). The probit estimations of factors determining the adoption of CA are presented thereafter. Both the descriptive statistics and the probit econometric estimates are outlined with respect to the demographic, socio-economic and institutional characteristics. Finally, the impact of CA on maize productivity and household income using propensity score matching (in ATTs form) is presented. Testing of data quality and the sensitivity of the assessment results to unobserved covariates are also evaluated using covariate balancing test and bounding method respectively.

## 4.2 Adoption of Conservation Agriculture

The proportion of farm households that practiced CA is very low compared to those that did not practice CA in the 2012 farming season. The results in Table 2 below show that out of a total sample of 4,167 farm households, only 133 practiced the technology and 4,034 did not practice CA accounting for 3.2% and 96.8% respectively. There are various factors that could have attributed to the low participation in CA and some are discussed in the subsequent sections.

**Table 2: Adoption of Conservation Agriculture**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Non-adopters | 4034 | 96.8 | 96.8 | 96.8 |
| | Adopters | 133 | 3.2 | 3.2 | 100.0 |
| | Total | 4167 | 100.0 | 100.0 | |

The number of farm households that grew maize in general against those that practiced CA in the four provinces (Central, Eastern, Lusaka and Southern) is shown in Figure 1 below. The results reveal that Eastern province was highest with 1,979 households that grew maize while Southern was second with 1,022; Central was third with 821 and fourth was Lusaka province 345 households. However, results of households that practiced CA did not follow the maize producing regional dominance pattern. Lusaka province had the highest proportion of adopters of CA, followed by Central, then Eastern and lastly Southern province.

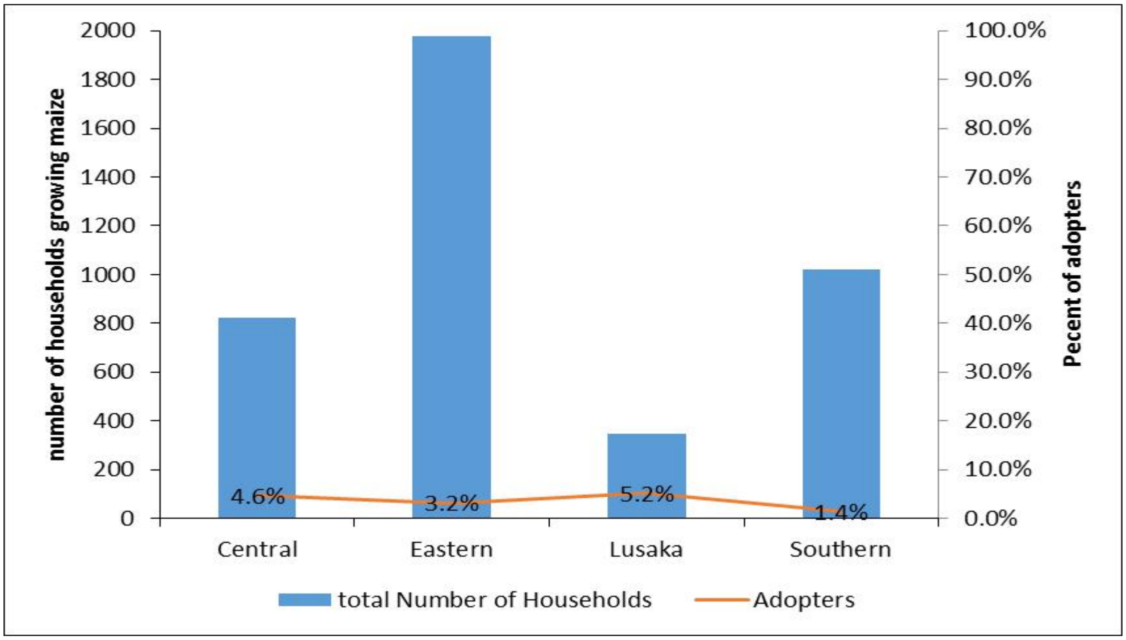



**Figure 1: Distribution of CA adopters in Maize by Province.**

### 4.3 Source of Conservation Agriculture Information

The main sources where smallholder farm households obtained information about conservation agriculture are shown in Figure 2. It particularly shows the number of households that obtained CA information from a particular source and the proportion of CA adopters within that source. The highest source of CA information was the Ministry of Agriculture and Livestock-MAL, by then Ministry of Agriculture which had 935 smallholder farmers. The second highest source of CA information was fellow farmers with 530 smallholder farmers and the third highest source of CA information was Zambia National Farmers Union/Conservation Farming Unit with 315 smallholder farmers. The fourth highest source of CA information was the agricultural support program with 269 smallholder farmers and the fifth highest source of CA information was the cooperatives/farmer groups with 209 smallholder farmers. Despite MAL and fellow farmers being the most common channels through which farmers received CA information, the proportion of farm households who practiced CA from these sources was less and this might have been due to inputs incentives. Smallholder farmers who received CA information through the ZNFU/CFU had the highest adoption rate of 10.2%. The second highest adoption rate was for farmers who received CA information through the Cooperatives/farmer groups (5.3%). The third highest CA adoption rate was for recipients that got from MAL (3.5%), the fourth highest CA adoption rate for farmers who received CA information through fellow farmers (1.1%) and the fifth were recipients that received through the agricultural support programme (0.7%). These results show the importance of the ZNFU/CFU and the Cooperatives/farmer groups in the promotion of CA. It is worth mentioning that information that describes any innovation including agricultural related innovations need to be clear and unambiguous because such information is vital in the adoption process.

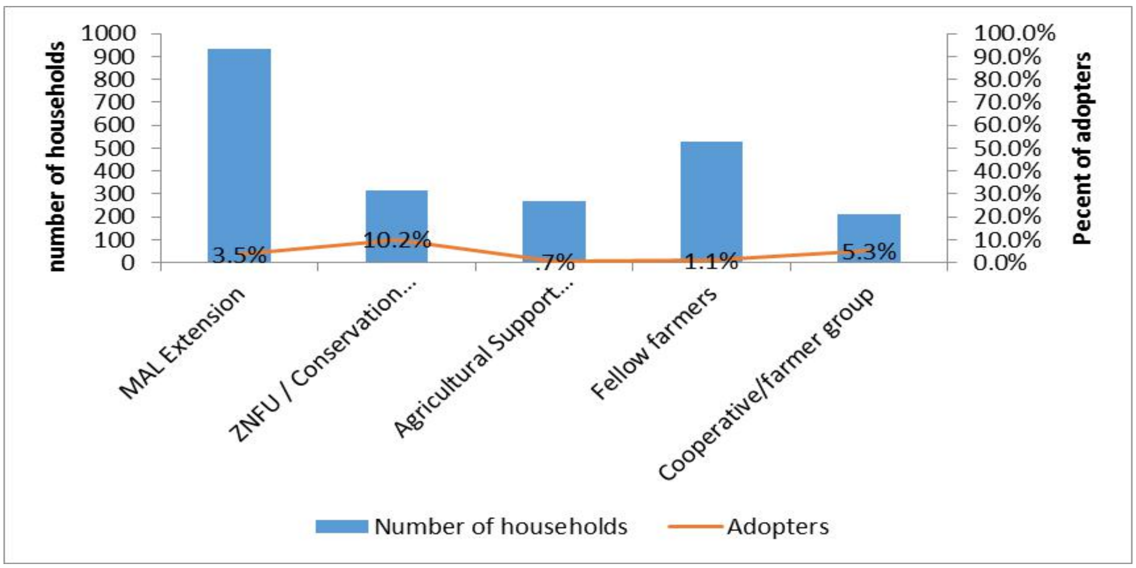



**Figure 2: Distribution of adopters by source of CA information**

The mode through which smallholder farmers accessed CA information was also checked to ascertain whether it could have some implications on the adoption process. The association between the different modes of receiving CA information and the adoption of the technology was examined. The results indicate that most smallholder farm households accessed CA information through meetings and informal conversations. However, most of those who adopted CA received information through training programmes, demonstration plots and workshops as shown in Figure 3 below. For more details see Appendix V.

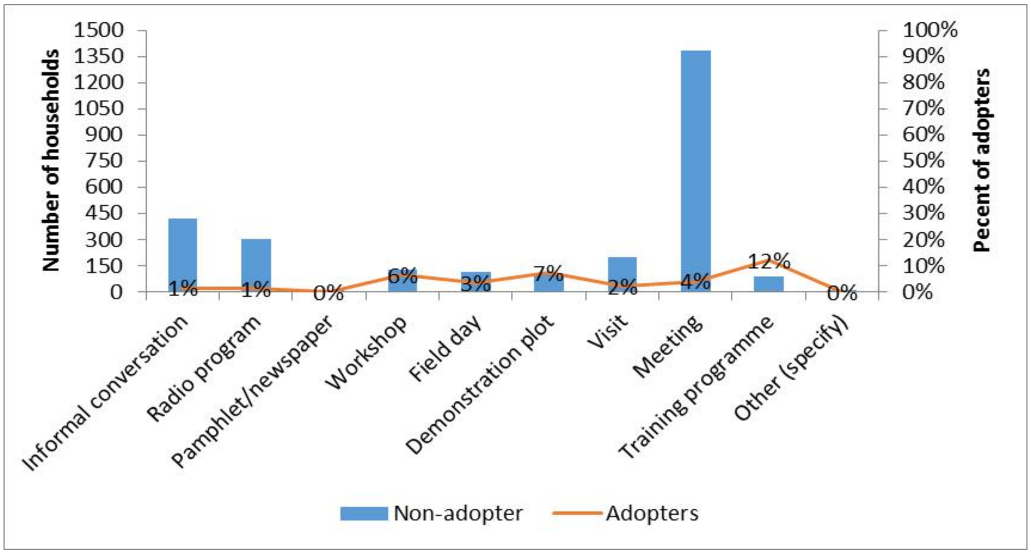



**Figure 3: Mode of receiving CA information by households.**

### 4.4 Descriptive Statistics of Household and Farm Characteristics

In this section, the descriptive statistics of selected households and farm characteristics are discussed. The mean differences from carefully chosen variables between the adopters and their counterpart non-adopters are presented.

#### 4.4.1. Demographic Factors

The results in Table 3 show that 19% of the total sample size of 4,167 farm households was headed by females which imply that most of the farm households were headed by males (81%). Results reveal that majority of the farm households are male headed. Probably this could be because we live in predominantly patriarchal society were household headship is by males. Again, this may be due to strong traditional and cultural practices that distinguish the gender roles in agriculture which are mostly biased towards men (Nkala, 2012). There is no significant difference between the adopters and non-adopters for adoption of CA. The variable female headed household has a positive correlation with adoption of CA.

**Table 3: Descriptive Statistics of Sample Households**

| Variable name | Total Sample Mean | Std. Dev | CA Adopters Mean | Std. Dev | Non-CA Adopters Mean | Std. Dev | t-test |
|---|---|---|---|---|---|---|---|
| *Dependent Variable* | | | | | | | |
| CA Adoption (=1 if yes) | 0.015 | 0.122 | | | | | |
| *Explanatory Variables* | | | | | | | |
| **Demographic Factors** | | | | | | | |
| Age of household head (years) | 45.532 | 15.034 | 46.451 | 13.770 | 45.500 | 15.075 | -0.717 |
| Education Household head (years) | 5.945 | 3.792 | 6.459 | 3.856 | 5.930 | 3.790 | -1.588 |
| Female household head (=1 if yes) | 0.192 | 0.394 | 0.180 | 0.386 | 0.193 | 0.394 | 0.350 |
| Adult equivalent (# adults 15-59 years) | 4.835 | 2.346 | 5.404 | 2.479 | 4.816 | 2.339 | -2.846 |
| **Socio-Economic Factors** | | | | | | | |
| Owns livestock assets (=1 if yes) | 0.884 | 0.380 | 0.684 | 0.467 | 0.827 | 0.379 | 4.291*** |
| Owns radio set (=1 if yes) | 0.661 | 0.473 | 0.737 | 0.442 | 0.658 | 0.490 | -1.886 |
| Distance to Agro-dealer (km) | 28.28 | 26.89 | 22.66 | 21.39 | 28.47 | 27.03 | 2.338** |
| Productive assets (ZMW '000) | 30.50 | 26.50 | 29.20 | 97.2 | 30.58 | 26.90 | 0.060 |
| Off-farm income (ZMW '000) | 0.686 | 0.464 | 0.729 | 0.446 | 0.685 | 0.465 | -1.086 |
| Maize area planted (Ha) | 2.783 | 2.587 | 3.161 | 2.434 | 2.770 | 2.591 | -1.715 |
| Total fertilizer (kgs) | 507.3 | 756.9 | 507.7 | 436.7 | 507.3 | 765.8 | -0.005 |
| Maize yield (ton/ha) | 2.180 | 1.711 | 2.319 | 1.891 | 2.175 | 1.705 | -0.953 |
| Gross value maize harvested (ZMW'000) | 6,625 | 9,361 | 7,324 | 9,826 | 6,602 | 9,345 | -0.875 |
| **Institutional Factors** | | | | | | | |
| Access to land (=1 if yes) | 0.0475 | 0.265 | 0.038 | 0.221 | 0.055 | 0.295 | 0.936 |
| State title | 0.094 | 1.181 | 0.169 | 0.682 | 0.093 | 1.187 | -0.739 |
| Customary title | 0.073 | 0.794 | 0.070 | 0.687 | 0.073 | 0.796 | 0.043 |
| Received CA advice (=1 if yes) | 0.658 | 0.474 | 0.752 | 0.434 | 0.655 | 0.475 | -2.314* |
| Access to loans/credit (=1 if yes) | 0.162 | 0.368 | 0.481 | 0.502 | 0.157 | 0.364 | -10.143*** |
| Coop/farmer group extension (=1 if yes) | 0.024 | 0.152 | 0.083 | 0.277 | 0.023 | 0.149 | -4.522*** |
| MAL extension services | 0.106 | 0.308 | 0.248 | 0.434 | 0.104 | 0.305 | -5.386*** |
| ZNFU / CFU extension services | 0.036 | 0.185 | 0.241 | 0.429 | 0.033 | 0.177 | -12.968*** |
| ASP | 0.030 | 0.172 | 0.015 | 0.122 | 0.060 | 0.238 | 1.041 |
| Fellow farmers extension services | 0.060 | 0.237 | 0.045 | 0.208 | 0.060 | 0.238 | 0.727 |
| **Farm Location** | | | | | | | |
| Central | 0.093 | 0.290 | 0.286 | 0.454 | 0.090 | 0.286 | -7.745*** |
| Eastern | 0.224 | 0.417 | 0.474 | 0.501 | 0.220 | 0.414 | -6.982*** |
| Lusaka | 0.039 | 0.194 | 0.135 | 0.343 | 0.038 | 0.190 | -5.789*** |
| Southern | 0.245 | 0.430 | 0.105 | 0.308 | 0.250 | 0.433 | 3.820*** |

*Source: Own computation from RALS 2012 data.*

The average age of the farm household head for adopters was 46.5 years and for the non-adopters was 45.5 years. This suggests that households for both the adopters and non-adopters were headed by middle aged persons and the probable effect of age on the decision to adopt CA was on account of human capital accumulation because of years of experience and skill (Langyintuo and Mekuria, 2005). The proxy for farm household labour quantity and quality was about five (05) adult members aged between 15-59 years expressed as adult equivalent. The average education level attained by the smallholder household head was 6.5 years and 5.9 years for adopters and non-adopters respectively. Results show that generally the education level for both categories were low. Nonetheless, adopters had slightly more years of education than non-adopters. Minimal education may have some negative influence in the adoption of CA because technology adoption requires some intellectual capability to comprehend in addition to eventual effective and efficient utilization. This is consistent with Matata *et al.,* (2008) who posits that if most farmers could read and write ultimately they could easily follow technical recommendations of any given innovation. Also Mupangwa *et al.,* (2012) posits that proper formal education offers an appropriate opportunity for effective extension campaigns and programmes that aim to disseminate and promote adoption of any agricultural technology.

Results show that the age and the education level of the household head have no significant differences between the adopters and non-adopters for adoption of CA. The correlation for adoption of CA is positive for both variables. Results also show that the adult equivalent has a significant difference between the adopters and non-adopters for adoption of CA. The correlation for adoption of CA is positive for adult equivalent.

### 4.4.2 Socio-Economic Factors

The characteristics associated with maize production by the sampled farm households are presented in Table 3. The average cultivated land by smallholder maize farmers was about 2.4 ha and 2.6 ha for the adopters and non-adopters respectively. A comparison of the two groups shows that non-adopters had a slightly larger area of cropped land than the adopters. This is inconsistent with Mavunganidze *et al.,* (2013) who observed that adopters normally possesed more land and could take up new agriculture innovations like CA without fear that adoption of the technology may risk household food security. Results show that the area planted with maize has no significant difference for adoption of CA between the adopters and non-adopter. And the correlation for adoption of CA is positive for area planted with maize.

Results in Table 3 show that the average total fertilizer (basal and top) applied by adopters was 705.7 kilograms and non-adopters 705.3 kilograms respectively. The average maize yield for adopters is about 2.3 tons/ha and for non-CA adopters is about 2.2 tons/ha. This maize quantity is much lower than the potential yielding of about 5-8 ton/ha. The gross value of maize harvested (income) was about ZMW 7,324, 454=00 for an adopter and ZMW 6,602,301 for a non-adopter. The results indicate that there are no significant differences between the adopters and non-adopters for adoption of CA in the variables total fertilizer and gross value of maize harvested. And the correlation for adoption of CA is negative for total fertilizer and positive for gross value of maize harvested. Ownership of a radio set is expected to enhance access of radio programmes by farm households. Amelia *et al.,* 2014 argues that access to CA radio programmes is expected to positively affect the adoption decision because farm households easily have access to information concerning the technology through radio broadcast. The proportion of CA adopters and non-adopters who owned a radio set was 74% and 66% respectively. This shows that more CA adopters owned radio sets than non-adopters. There is no significant difference for adoption of CA between the adopters and non-adopter and radio set has a negative correlation with adoption of CA. This is inconsistent with previous studies that found that mass media plays an effective role in creating awareness about innovations and ultimately their adoption (Toborn and Harvesting, 2011).

Assets are important for the livelihood of most smallholder farm households. Some assets can be directly linked to CA and these may include rippers, cultivators, ploughs and some livestock (cattle or donkeys). In this study assets are categorized in two forms, namely productive assets and livestock assets. The average value of productive assets owned is about ZMW 29,200 for adopters and ZMW 30,580 for non-adopters as shown in Table 3. This shows that CA adopters had less value of productive assets than non-adopters. There is no significant difference for adoption of CA between the adopters and non-adopter. And productive assets have a negative correlation with adoption of CA. This result is inconsistent with study findings by Umar *et al.,* (2010); Mavunganidze *et al.,* (2013) and Lugandu (2013) which indicate that ownership of productive assets increases the probability to adopt a given technology.

The proportion of smallholder farm households that owned livestock assets was 68% for adopters and 83% for non-adopters. The results imply that CA adopters owned less value of livestock assets than non-adopters. There is a significant difference for adoption of CA between the adopters and non-adopter. And livestock assets have a positive correlation with adoption of CA. This is consistent with most of the adoption studies that found ownership of livestock assets to increase the likelihood of adopting CA practices (Kassie *et al.,* 2012, Mlenga *et al.,* 2015). The farm households also possessed some off-farm income that was realised from other activities not related to agriculture. The proportion of smallholder farm households that owned off-farm income for adopters and non-adopters was 73% and 69% respectively. This result shows that CA adopters had more off-farm income than non-adopters. There is no significant difference for adoption of CA between the adopters and non-adopter. The correlation for adoption of CA is positive for off-farm income.

Distance to agro-dealers (input-output markets) plays an important role in adoption decision of a new technologies including CA practices. Mutuma, 2013 hypothized that a readily available input and output market can influence the uptake of a technology. Long distances to input-output markets are a disincentive for smallhlder farmers to engage in new farming practices due to high transaction costs. The distance to the nearest agro-dealer was approximately 22.7 kilometres and 28.5 kilometres for adopters and non-adopters respectively. This result shows that CA adopters covered less distances to agro-dealers than non-adopters. There is significant difference for adoption of CA between the adopters and non-adopter. The correlation for adoption of CA is negative for distance to agro-dealers. This is consistent with Hassan and Nhemachena (2008) and Ngoma (2012) who found a negative relationship between technology adoption and distance to input markets.

### 4.4.3 Institutional Factors

Results in Table 3 show that some institutional characteristics had significant mean differences with adoption of CA. The variables are access to CA advice, access to land, State title, access to loans/credit, receiving extension services through cooperatives/farmer groups; Ministry of

Agriculture and Livestock (MAL) and Zambia National Farmers Union/Conservation Farming Union (ZNFU/CFU).

Access to CA advice is an important factor that can influence the adoption decision because it's a source of information on agricultural practices. Many studies indicate that extension education is an important factor in motivating increased use of specific soil and water conservation practices (Bekele and Drake, 2003). Studies by Deressa (2009) and Hisali *et al.,* (2011) found that access to extension education was positively correlated to farmers' decision to adopt technologies that mitigate effect of climate change. The results in Table 3 show that the proportion of adopters and non-adopters that received CA advice was 75% and 66% respectively. This shows that on average more adopters received CA advice compared to non-adopters. This is consistent with studies carried out by Igodan *et al.,* (1988) and Arslan *et al.,* (2013). The results reveal that there is a significant difference for adoption of CA between the adopters and non-adopters. And the correlation for adoption of CA is positive for access to CA.

In addition, the CA information received by the smallholder farm households was provided by different sources, namely MAL, ZNFU/CFU, Cooperatives/Farmer groups, ASP and Fellow famers as shown in Table 3. The proportion of adopters and non-adopters who received CA information through MAL extension services was 25% and 10% respectively; through ZNFU/CFU were 24% adopters and 3% non-adopters; through Cooperatives/Farmer groups were 8% adopters and 2% non-adopters; through ASP were 1.5% adopters and 6% non-adopters and through Fellow famers were 4.5% adopters and 6% non-adopters. However, the proportion of households that adopted CA within each source of information was different, instead the highest CA adopters were those that received information from ZNFU/CFU (10.2%); second highest were from Cooperatives/Farmer groups (5.3%); third highest were from MAL (3.5%); fourth highest were from Fellow farmers (1.1%) and fifth were from ASP (0.7%) as shown in Figure 3. With regard to the source of CA information, there are significant differences for adoption of CA between the adopters and non-adopter that got CA information through MAL, ZNFU/CFU and Cooperatives/Farmer groups. And the correlation for adoption of CA is positive for ZNFU/CFU and Cooperatives/Farmer groups but negative for MAL. This is consistent with the innovation-diffusion theory that posits that access to information is essential in the adoption process of innovations (Rogers, 2003). According to Bandura, (1977), Cooperatives/farmer groups are important institutions with regard to adoption of CA because of their involvement in meetings, trainings and dissemination of information. This is consistent with the social learning theory that posits that people learn through observation and influence of key individuals in their societies either formally or informally. The results indicate that CA adopters had a higher membership to a farmer group or cooperative than the non-adopters. This is consistent with the suggestion that those institutional factors such as number of extension contacts and membership to farmers' cooperatives tend to be positively correlated to adoption decision (Chiputwa *et al.,* 2011; Wachenheim and Lesch, 2014).

The results in Table 3 show that farm households had access to loans/credit. Many studies have found that access to loan/credit is one of the important factors that enhance the adoption of various technologies (Nyanga, 2011); it also enhances farmers' capability to improve their management practices in response to changing climate (Deressa *et al.,* 2009; Bryon *et al.,* 2011). The proportion of CA adopters and non-adopters that accessed loans/credit was 48% and 16 % respectively. This shows that CA adopters had more access to loans/credit than non-adopters. There is a significant difference for adoption of CA between the adopters and non-adopter. Access to loans/credit has a positive correlation with adoption of CA. This is consistent with findings by Arslan *et al.,* (2013) and Mlenga *et al.,* (2015) who observed that access to loan/credit had a positive correlation with adoption of an innovation.

Land is a vital resource in agriculture and one may argue that it plays a role in adoption of CA. Studies in the past indicate that lack of access to land has been demonstrated to be a significant constraint to adoption decision (Yapa and Mayfield, 1978; Havens and Flinn, 1976). The proportion of CA adopters and non-adopters who accessed land was 3.8% and 5.5% respectively. This shows that CA adopters had less access to land than non-adopters. There is a significant difference for adoption of CA between the adopters and non-adopter. And access to land has a negative correlation with adoption of CA. Security of land tenure is another important factor in adoption of CA. According to Soule *et al.,* (2000), Gebremedhin and Swinton (2003) and Chomba (2004) secure land tenure tends to increase the probability of practicing CA. Nkala *et al.,* (2011) observed that lack of land tenure, imperfect input and credit markets are some of the major constraints that limit extensive adoption of CA in Southern Africa. This study investigated State title and Customary title. The proportion of CA adopters and non-adopters who had state title was 16.9% and 9.3% respectively. This shows that CA adopters had more State title than non-adopters. There is a significant difference for adoption of CA between the adopters and non-adopters. And State title has a negative correlation with adoption of CA. Customary title was not significant to adoption of CA.

### 4.5 Factors Influencing Adoption of Conservation Agriculture

A probit regression was performed in order to address the first objective that seeks to determine factors that influence smallholder farmers' choice to practice the CA technology in Southern, Lusaka, Central and Eastern provinces of Zambia. The results of the probit regression model were obtained with respect to the demographic, socio-economic and institutional factors to provide an indication of the likelihood that a smallholder farm household will adopt CA. Farm households that practiced at least one or more of the three main principles of CA were defined as adopters in this study. This is consistent with Arslan *et al.,* 2013 who acknowledged that most adoption is partial or incremental, adoption of CA in most literature is usually defined as having any area under one or more CF practices due to lack of detailed data. The adoption decision of a new technology by farmers at any given time is most often influenced by an interaction of factors such as the demographic, socio-economic and institutional factors; including some bio-physical factors that are related to their objectives and constraints (Tadesse and Belay, 2004).

Table 4 shows the estimated coefficients, standard errors, z-values and p-values of the probit regression model. The table shows that thirteen (13) covariates were statistically significant in the regression model. These variables include; adult equivalent, State title, access to land, access to CA advice, ownership of livestock assets, access to loans/credit, distance to agro-dealers, access to CA extension services from MAL, ZNFU/CFU, Cooperatives/Farmer groups and three farm location dummies (Lusaka, Central and Eastern).

The probit results show that the adult equivalent which denotes the number of adults in a farm household has a positive correlation with the adoption of CA. The results show a 0.0345 increase in probability to adopt CA at 10 per cent level of significance if a smallholder household had many adult members that were readily available to provide agricultural labour. It is expected that households comprising many adult members will have adequate labour to engage in the CA practice, hence more likely to adopt the technology. This is consistent with past studies that emphasise the need for high labour requirements for weeding and other crop management skills in CA (Andersson and Giller, 2012; Giller *et al*., 2009) and that the size of a household positively affects the probability of adopting a technology (Deressa *et al.,* 2009).

Results in Table 4 show that the access to land has negative correlation with the adoption of CA. The results show a 0.0023 reduction in probability to adopt CA at 1 per cent level of significance if a farm household accessed land to cultivate maize. State title has a negative correlation with the adoption of CA. The probit results indicate a 0.0249 reduction in probability to adopt CA at 5 per cent level of significance if a farm household possessed a State title to land they cultivate maize. This is inconsistent with findings by Gebremedhin & Swinton (2003); Kassie *et al.,* (2009); Nyangena (2011), Jansen *et al*., (2014) that land tenure security significantly influences adoption of soil conservation technologies. Title to land is expected to provide some motivation and encouragement for large financing to enhance land productivity. Nowak and Korsching (1983) suggested that smallholder farmers who possess land use a wide-range of management strategies and adopt best practices earlier than those who rent. They argue that smallholder farmers who rent land have no guarantee to reap benefits of long term soil conservation; hence tenant farmers are expected to use management strategies that maximize short term production even though such action threaten to decrease future soil fertility.

The probit results show that livestock assets have a positive correlation with the adoption of CA. The results show a 0.091 increase in probability to adopt CA at 1 per cent level of significance if the smallholder household owned livestock assets. This consistent with findings from past studies whose results found a positive relationship between wealth and decision to adopt new technology (Nyanga (2012), Nkala *et al*., (2012) and Ngoma (2012)); that rich farmers have the willingness and effectiveness to invest in new technologies and that wealthier farmers with higher asset portfolio are more likely to adopt and practice conservation agriculture than their poor counterparts (Giller et al., (2009).

**Table 4: Probit Estimates for Adoption of Conservation Agriculture**

| Variable | Coefficients | Robust Std. Err | Z | P>\|z\| |
|---|---|---|---|---|
| **Demographic Factors** | | | | |
| Age of household head (years) | 0.0023 | 0.0040 | 0.71 | 0.477 |
| Education level of Household head | 0.0170 | 0.0159 | 1.07 | 0.285 |
| Female household head (=1 if yes) | 0.1149 | 0.1622 | 0.71 | 0.479 |
| Adult equivalent (15-59 years) | 0.0345* | 0.0196 | 1.76 | 0.079 |
| **Socio-Economic Factors** | | | | |
| Owns livestock assets (=1 if yes) | 0.0910*** | 0.1336 | 0.68 | 0.001 |
| Owns productive assets (=1 if yes) | -0.00002 | 0.00003 | -0.51 | 0.610 |
| Owns radio (=1 if yes) | 0.1059 | 0.1349 | 0.79 | 0.432 |
| Distance to Agro-dealer (km) | 0.0023** | 0.0023 | -1.97 | 0.043 |
| Off-farm activities (=1 if yes) | 0.0741 | 0.1226 | 0.60 | 0.546 |
| Maize area planted (Ha) | 0.0438 | 0.0320 | 1.37 | 0.171 |
| Total fertilizer applied (kgs) | -0.00016 | 0.00012 | -1.41 | 0.160 |
| Maize yield (kgs) | | | | |
| Gross value of maize/income (kgs) | 2.76e-10 | 1.05e-8 | 0.03 | 0.979 |
| **Institutional Factors** | | | | |
| Access Land (=1 if yes) | -0.00233*** | 0.01512 | -0.15 | 0.008 |
| State title (=1 if yes) | -0.0249** | 0.01868 | -1.33 | 0.048 |
| Customary title (=1 if yes) | -0.0663 | 0.0580 | -1.14 | 0.966 |
| CA advice (=1 if yes) | 0.3688** | 0.1825 | 2.02 | 0.043 |
| MAL extension services (=1 if yes) | -0.1947*** | 0.1749 | -1.11 | 0.001 |
| ZNFU/CFU extension (=1 if yes) | 0.3848*** | 0.1834 | 2.10 | 0.001 |
| ASP extension services (=1 if yes) | -0.7522 | 0.3876 | -1.94 | 0.3059 |
| Fellow farmers extension (=1 if yes) | -0.9391 | 0.3815 | -2.46 | 0.467 |
| Coop/farmer group extension (=1 if yes) | 0.0824*** | 0.2072 | 0.40 | 0.001 |
| Access loan/credit (=1 if yes) | 0.3870*** | 0.1170 | 3.31 | 0.001 |
| **Farm Locations** – Provincial dummies | | | | |
| Southern | Base Province | - | - | - |
| Central | 0.4640*** | 0.1842 | 2.52 | 0.001 |
| Eastern | 0.0919*** | 0.1852 | 0.50 | 0.001 |
| Lusaka | 0.7879*** | 0.2154 | 3.66 | 0.001 |
| Constant | -3.157*** | 0.571 | -5.53 | 0.000 |
| Observations | 2,290 | | | |

*Notes*: *** Significant at 1 per cent; ** Significant at 5 per cent; * Significant at 10 per cent.

Source: Own computed probit model

The probit model also shows that the Wald $chi^2$ (27) = 91.45, prob > $chi^2$ = 0.0000, Pseudo $R^2$ = 0.1328 and the log pseudo likelihood = -306.591.

Access to loans/credit has a direct influence on adoption decision among smallholder farmers. Many studies in the past have indicated that access to loans/credit is an important factor that enhances the adoption of various technologies (Nyanga, 2011). According to Deressa *et al.,*2009; Bryon *et al.,*2011, access to loans/credit enhances farmers' capability to improve their management practices in response to changing climate. Access to loans/credit has a positive correlation with the adoption of CA. The results show a 0.387 increase in probability to adopt CA at 1 per cent level of significance if a smallholder farm household had access to a loan/credit. This is consistent with findings by Kassie *et al*., (2012) that access to loans/credit positively and significant influence the adoption of CA.

Distance to agro-dealers can be assumed to have influence on the smallholder farmers' decision to adopt the CA technology. According to Chomba (2004), Alene *et al.,* (2009) and Teklewold *et al.,* (2011) shorter distances to input-output markets have a positive influence on the decision to adopt CA. They argue that long distances to input-output markets become more expensive to the smallholder farmers and result in reduced profits. Distance to agro-dealers has a negative correlation with the adoption of CA. The probit results show a 0.0046 reduction in probability to adopt CA at 5 per cent level of significance if smallholder households had to travel long distances to acquire agro-dealer services. This is consistent with Hassan and Nhemachena (2008) and Ngoma (2012) who found a negative relationship between technology adoption and distance to input markets.

Access to advice is an important in the adoption decision of a technology such as CA because it provides smallholder farmers with valuable information about the new agricultural technology before they can opt to adopt (Jera & Ajayi, 2008). Gould *et al.,* (1989) posit that awareness of problems associated with farm operators is a clear pre-requisite to technology adoption. Access to CA advice has a positive correlation with the adoption of CA. Results show a 0.369 increase in probability to adopt CA at 5 per cent level of significance if a smallholder household had access to CA advice. This is consistent with Deressa (2009) and Hisali *et al.,* (2011) who found access to extension education to be positively correlated to farmers' decision to adopt technologies that mitigate effects of climate change.

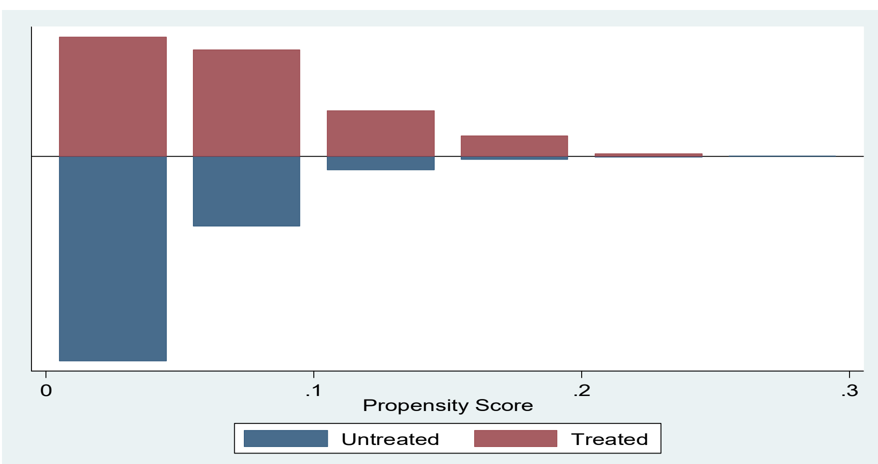
In this study CA advice/information was obtained from different sources. The sources that were significant to adoption of CA were MAL, ZNFU/CFU and Cooperatives/Farmer groups. Access to CA advice/information through MAL has a negative correlation with the adoption of CA. Results show a 0.195 reduction in probability to adopt CA at 1 per cent level of significance if a smallholder household received CA advice through MAL. Access to CA advice/information through ZNFU/CFU has a positive correlation with the adoption of CA. Results show a 0.385 increase in probability to adopt CA at 1 per cent level of significance if a smallholder household received CA advice through ZNFU/CFU. Access to CA advice/information through Cooperatives/Farmer groups has a positive correlation with the adoption of CA. Results show a 0.082 increase in probability to adopt CA at 1 per cent level of significance if a smallholder household received CA advice through Cooperatives/Farmer groups. This is consistent with the suggestion that extension services farm households receive makes them knowledgeable about the technology and the gains associated with it; also reduce the uncertainty associated with adopting complex technologies such as CA (Tsegaye *et al.,* 2000; Knowler and Bradshaw, 2007; Pannell *et al.,* 2014).

Furthermore, the probit results show that all the three (03) provinces where farm households were located had a positive correlation with adoption of CA. The provincial location dummies used in this study were Central, Eastern and Lusaka. Southern province was used as the base unit, hence was omitted in the analysis. The results show that Central province had a 0.464 increase in probability to adopt CA at 1% significance level relative to Southern province. The results show a 0.0919 increase in probability to adopt CA at 1 % significance level relative to Southern province. The probit results also show a 0.788 increase in probability to adopt CA at 1% significance level relative to Southern province. This suggests that being located in a particular province has influence on a smallholder farmer's decision to adopt CA.

### 4.6 Estimating the Impact of CA on Gross Value of Production

For the purpose of addressing the second objective of the study, ATTs were estimated to evaluate the impact of CA on maize productivity and value of maize (income). The analysis was based on the propensity score matching (PSM) technique. Basically the ATT provide the mean difference between the observed maize productivity and incomes among the adopters and non-adopters.

The PSM technique enables to examine how CA influenced the changes reported in the gross value of maize (income) and maize productivity. To estimate this impact, the estimated propensity scores were used to generate samples of the matched CA and non-CA adopters using the kernel and nearest neighbor matching methods. The kernel and nearest neighbour estimators were utilized because we wanted to compare the two in terms of robustness. The kernel estimator constructs a match for each treated individual using a weighted average over multiple persons in the comparison group. It is more efficient and also generates valid standard errors of the estimates through bootstrapping (Imbens and Abadie, 2004). On the other hand, nearest neighbour matching (NNM) estimator matches each smallholder farmer from the treated group with another smallholder farmer from the untreated group having the closest propensity score. Matching may be performed with or without replacement of observations.The common support condition was imposed in the estimation by matching in the region of common support and only observations within the common support were used. The standard errors for the average treatment effect on the treated were calculated by bootstrapping with replications.




The region of common support is [0.0086377, 0.20921227]

**Figure 4: Propensity scores distribution and common support condition**

The distribution of propensity scores and the region of common support are shown in Figure 4. The bottom half shows the distribution of propensity scores for the untreated group (non-adopters) and the upper half shows the distribution of the treated group (adopters). The densities of the scores are on the y-axis. The common support requirement for the PSM estimation was satisfied as there is an overlap in the distribution of the propensity scores of both the adopters and non-adopters. This condition is satisfied within (0.0086, 0.209) i.e. ( $0 \le PS \le 1$ ).This means that farm households within estimated Propensity Scores less than 0.008 and greater than 0.21 fell outside the common support range, hence discarded and excluded in the matching process. The number of discarded farm households in this case was 356 and all from non-CA adopting sub-sample.

**Table 5: Average Treatment Effect on the Treated from Propensity Score Matching**

| | Maize productivity (log) | | Maize income (log) | |
|---|---|---|---|---|
| | Kernel | Nearest neighbour | Kernel | Nearest neighbour |
| Adopters | 14.635 | 14.635 | 15.253 | 15.253 |
| Non-adopters | 14.196 | 14.217 | 15.032 | 15.046 |
| Difference, ATT | 0.439 | 0.418 | 0.221 | 0.207 |
| *T value* | *3.771* | *1.321* | *2.295* | *1.226* |
| Boostraped std. Error | (0.110) | (0.283) | (0.096) | (0.169) |
| Total number of observations | | | | |
| Adopters | 133 | 133 | 133 | 133 |
| Non-adopters | 4,034 | 4,034 | 4,034 | 4,034 |
| Number of observations within common support | | | | |
| Adopters | 133 | 133 | 133 | 133 |
| Non-adopters | 3,678 | 128 | 3,678 | 128 |

The results in Table 5 show that the kernel and nearest neighbor matching techniques produced very close estimates which suggests that they are robust. Results indicate a positive increase in maize productivity and net maize income gain due to uptake of CA. Based on the two PSM algorithms; the results reveal that adoption of CA leads to an increase in maize productivity of approximately 41.8% to 43.9% and a net gain of about 20.7% to 22.1% in gross income of maize. In other words, the smallholder farm household's maize productivity and gross income would have been reduced by 41.8% to 43.9% and 20.7% to 22.1% respectively had they not adopted CA. Therefore, adoption of CA contributes positively to household's maize productivity and income. Generally the results underscore the role CA plays in improving the livelihoods of smallholder maize farmers through increased maize productivity and income in Zambia.

The results of this study are consistent with findings from other studies carried out in the recent past. For instance, Nkala *et al*., (2012) carried out a study on the impact of CA on farmers' livelihood in central Mozambique and found a positive relationship between CA and crop productivity and income. Similarly, Awotide *et al.,* (2012) found that adoption of improved technology had a positive impact on sustainable productivity and farmers' welfare in Nigeria. Adebayo and Olagunju (2015) equally postulate that agricultural innovations like CA have positive impact on farmers' livelihood in Nigeria. Baudron *et al.,* (2007) cite that individual CA components (minimum tillage, permanent soil cover and diversified rotation) have specific effects in enhancing soil fertility and hence productivity in their study in Southern province of Zambia. Umar *et al.,* (2010) argues that CA can produce positive gains in terms of productivity in Zambia if properly implemented unlike conventional farming. Arslan *et al.,* (2013) also observes that adoption of CA has a tendency to decrease yield variability in Zambia. On the other hand, there are findings that show decreased or no yield gains from adoption of agricultural innovations. For example, yield effects were cited as variable in the short term (positive, neutral or negative yield responses) in a technical report by the African Conservation Tillage Network (2008).

## 5.0 Evaluating the Quality of the Matching Process

Given that the PSM method conditions only on the unobserved covariates, we evaluate the quality of the matching process by executing balancing tests that analyze the standardized bias for all covariates used in the matching process. Basically this examines whether the matching procedure has the ability to balance the distribution of the covariates in both the CA adopter and non-CA adopter groups. As stated earlier, significant differences are expected in some variables prior to the matching process but, if the matching process is successful no differences should exist.

Furthermore two-sample *t*-tests were done to ascertain the significance of the post-matching differences in the covariate means for the two groups. This was only done for reported increases in maize income where the CA effect was found to be significant. The balancing property was satisfied as shown by the balancing tests for the covariates used in the model presented in Table 5. The PS balancing test results confirm the existence of strong bias for most of the covariates. Thirteen out of the sixteen covariates used in the estimation of the propensity scores were highly significant before the matching was done which indicates the existence of strong bias but became insignificant after matching and restricting to a common support; this confirms the PS is balanced. These covariates include: the female headed households; education level of household head; age of household head; adult equivalent; maize area planted; basal fertilizer; top fertilizer; received CA advice; extension services from MAL, extension services from ZNFU/CFU, CA advice from fellow farmers; cooperative/farmer group extension services and farm households in southern province.

There is considerable reduction in the standardized bias after matching and the test of the null hypothesis of no significant differences after matching cannot be rejected at 10% significance level for all the variables.

**Table 6: Balancing tests for all Matching Covariates**

| Variable | Unmatched | Mean | | Standardized bias | | t-test | |
|---|---|---|---|---|---|---|---|
| | Matched | Treated | Control | %bias | %bias.red | T | p>t |
| Female headed HH | U | 0.180 | 0.193 | -3.1 | | -0.35 | 0.726 |
| | M | 0.180 | 0.188 | -1.9 | 38.2 | -0.16 | 0.875 |
| Education HH head (years) | U | 6.459 | 5.928 | 13.9 | | 1.59 | 0.112 |
| | M | 6.459 | 6.541 | -2.2 | 84.4 | -0.18 | 0.860 |
| Age household head (years) | U | 46.451 | 45.501 | 6.6 | | 0.72 | 0.473 |
| | M | 46.451 | 46.496 | -0.3 | 95.3 | -0.03 | 0.980 |
| Percent of chronic ill adults | U | 0.018 | 0.017 | 0.6 | | 0.06 | 0.953 |
| | M | 0.018 | 0.004 | 18.6 | -3025.9 | 2.37 | 0.018 |
| Adult equivalent | U | 5.404 | 4.816 | 24.4 | | 2.85 | 0.004 |
| | M | 5.404 | 5.393 | 0.5 | 98.1 | 0.03 | 0.973 |
| Maize planted (Ha) | U | 1.726 | 1.763 | -2 | | -0.21 | 0.835 |
| | M | 1.726 | 1.728 | -0.1 | 94.5 | -0.01 | 0.992 |
| Basal fertilizer (kg/ha) | U | 98.964 | 82.531 | 15 | | 1.92 | 0.055 |
| | M | 98.964 | 83.475 | 14.1 | 5.7 | 1.20 | 0.233 |
| Top fertilizer (kg/ha) | U | 99.441 | 83.736 | 15.1 | | 1.87 | 0.062 |
| | M | 99.441 | 86.038 | 12.9 | 14.7 | 1.10 | 0.272 |
| Off farm activities (=1, 0 | U | 0.729 | 0.685 | 9.7 | | 1.09 | 0.278 |
| otherwise) | M | 0.729 | 0.774 | -9.9 | -1.6 | -0.85 | 0.396 |
| CA advice | U | 0.752 | 0.655 | 21.3 | | 2.31 | 0.021 |
| (=1, 0 otherwise) | M | 0.752 | 0.707 | 9.9 | 53.3 | 0.83 | 0.410 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MAL extension services | U | 0.248 | 0.224 | 5.8 | | 0.67 | 0.505 |
| (=1, 0 otherwise) | M | 0.248 | 0.248 | 0 | 100.0 | 0.00 | 1.000 |
| ZNFU / CFU extension | U | 0.241 | 0.070 | 48.3 | | 7.36 | 0.000 |
| services (=1, 0 otherwise) | M | 0.241 | 0.203 | 10.6 | 77.9 | 0.74 | 0.462 |
| Fellow farmers extension | U | 0.045 | 0.130 | -30.3 | | -2.89 | 0.004 |
| (=1, 0 otherwise) | M | 0.045 | 0.030 | 5.4 | 82.3 | 0.64 | 0.521 |
| Coop/farmer group | U | 0.083 | 0.049 | 13.6 | | 1.75 | 0.080 |
| extension (=1, 0 otherwise) | M | 0.083 | 0.098 | -6.1 | 55.3 | -0.43 | 0.670 |
| Farm HH in Eastern | U | 0.474 | 0.475 | -0.3 | | -0.03 | 0.977 |
| province (=1, 0 otherwise) | M | 0.474 | 0.496 | -4.5 | -1664.1 | -0.37 | 0.714 |
| Farm HH in Southern | U | 0.105 | 0.250 | -38.5 | | -3.82 | 0.000 |
| province (=1, 0 otherwise) | M | 0.105 | 0.090 | 4 | 89.6 | 0.41 | 0.681 |

**Table 7: Quality of Matching**

| Sample | Ps $R^2$ | LR $chi^2$ | p>$chi^2$ | Mean Bias | Median Bias |
|---|---|---|---|---|---|
| Unmatched | 0.065 | 76.9 | 0.000 | 14.6 | 13.6 |
| Matched | 0.033 | 12.11 | 0.793 | 6.7 | 5.4 |

The results of the likelihood ratio joint test are shown in Table 7. They indicate that all covariates were significant at 76.9% before matching was done but reduced to a highly insignificant level of 12% after matching. The results imply that the PSM was successful in eliminating the hidden bias caused by unobserved effects through balancing. Following the successful specification and application of the propensity scores, then estimation of the impact of participating in CA based on propensity score matching was done.

## 6.0 Sensitivity Analysis

This study performed a sensitivity analysis to address the problem of estimating the magnitude of hidden bias associated with non-experimental data using the bounding approach proposed by Rosenbaum (2002), the rbound. The Becker and Galiendo's (2007) procedure for bounding treatment was utilized since the outcomes of interest (maize productivity and income) were treated as binary in the analysis. The Hodges-Lehmann test statistic method was employed to calculate the ATT by setting the level of hidden bias at a certain value, Γ and thereafter testing the null hypothesis of "no CA effect on maize productivity and income".

The Hodges-Lehmann point estimate of a stabilizer treatment effect is a robust estimate derived from the randomization distribution of a rank test. It helps to carry out a sensitivity analysis for such an estimate in a non-experimental study where treatments are not randomly assigned focusing on two cases of the matched and unmatched groups. This method uses a model for the distribution of treatment assignments when the hidden bias is expected to be present (PR Rosenbaum, 1993 and PM Michalis, 2008). The lower bound shows the case when the CA effect has been underestimated while the upper bound indicates the case when the CA effect has been overestimated. The results of the sensitivity analysis are presented in Table 7.

Under the assumption of no hidden bias (Γ = 1), the significant test-statistic gives the same result, indicating a significant treatment effect. In this case, the statistic is 0.244 indicating a positive significant impact of CA on maize income.The two bounds in the output table can be interpreted in the following way; the sig+ statistic adjusts the rbounds statistic downward for the case of positive (unobserved) selection. The case of positive selection bias occurs when those most likely to adopt CA tend to have higher maize income even in the absence of adoption; given that they have the same attributes as the individuals in the control group. This leads to an upward bias in the estimated treatment effects. In this study, the positive CA effect on maize income is least affected by the hidden bias. There is no critical level of Γ at which some doubt or question could be raised about the conclusion of positive effect or overestimation of the effect. However, the results show that somehow there could have been an underestimation of the effect between Γ =1 and 2. Nonetheless, it can safely be concluded that adoption of CA has a great impact on maize productivity and value of maize (income).

For a survey of different methods and detailed estimation of sensitivity analysis for continuous outcome variables, see Caliendo, M. and Kopeinig, S. (2008); Becker, S. O & Caliendo, M. (2007) and DiPrete, T. A., & Gangl, M. (2004).

**Table 8: Sensitivity Analysis**

| Gamma (Γ) | sig+ | sig- | t-hat+ | t-hat- | CI+ | CI- |
|---|---|---|---|---|---|---|
| Maize income | | | | | | |
| 1 | 0.244 | 0.244 | 0.110 | 0.110 | -0.203 | 0.416 |
| 2 | 0.997 | 0.000 | -0.422 | 0.654 | -0.753 | 1.022 |
| 3 | 1.000 | 0.000 | -0.723 | 0.978 | -1.097 | 1.408 |

Gamma log odds of differential assignment due to unobserved factors

sig+ upper bound significance level

sig- lower bound significance level

t-hat+ upper bound Hodges-Lehmann point estimate

t-hat- lower bound Hodges-Lehmann point estimate

CI+ upper bound confidence interval (a= 0.95)

CI- lower bound confidence interval (a= 0.95)

# CHAPTER FIVE

# CONCLUSIONS AND RECOMMENDATIONS

## 7.1 Introduction

In this chapter some conclusions derived from the findings of study are presented based on the set objectives. Further on the chapter suggests some policy recommendations and areas that may require future research.

## 7.2 Conclusion

The primary objective of the study was to evaluate factors that determine adoption of conservation agriculture (CA) and its impact on smallholder farmers' maize productivity and income using the propensity score matching technique. The study sample was drawn from the cross sectional Rural Agricultural Livelihoods Survey (RALS) data of 2012 in Zambia.

The study findings suggest that CA has productivity and income enhancing benefits. The study reveals that thirteen (13) covariates were statistically significant for adoption of CA and nine (09) were positively correlated with adoption of CA while four (04) were negatively correlated with adoption of CA. The nine significant and positively correlated covariates include:
Adult equivalent (AE) which is a proxy for household labour quantity and quality, namely: the number of adult household members aged between 15 and 59 years. AE was found significant at 10% for adoption of CA and had probability to increase adoption of CA. The plausible explanation is that smallholder maize farmers had big numbers of household members and had the ability to provide the labour required by the CA technology.

Ownership of livestock assets was found significant at 1% for adoption of CA and had probability to increase adoption of CA. The possible explanation is that smallholder maize farmers that possessed livestock assets were able to convert their assets into cash in order to acquire the requirements for CA farming.

Access to loans/credit was found significant at 1% for adoption of CA and had probability to increase adoption of CA. The probable reason is that smallholder maize farmers received financial assistance in form of loans/credit to purchase the requirements for CA practice such as equipment/implements and inputs (herbicides, seeds,lime and fertilizers).

Access to CA advice was found significant at 5% for adoption of CA and had probability to increase adoption of CA. Probably this is because smallholder farm households who received advice on CA became knowledgeable and confident about the CA technology.

ZNFU/CFU and Cooperatives/Farmer groups' extension services were both found significant at 1% for adoption of CA and both had probability to increase adoption of CA. The plausible explanation is that perhaps ZNFU/CFU used effective and efficient methods and probably provided smallholder maize with inputs/grants as incentives in their extension services delivery.

The three provincial location dummies (Lusaka, Central and Eastern) were all found significant at 1% for adoption of CA and had probability to increase adoption of CA. The possible explanation is that the climatic or weather conditions in Lusaka, Central, Eastern and Southern province were favourable to cultivate maize using the CA practices.

The significant and negatively correlated covariates include;
Distance to agro-dealers that was found significant at 5% for adoption of CA and had probability to reduce adoption of CA. The plausible explanation is that the distances smallholder farmers travelled to access the input-output markets either encouraged or discouraged them. It is expected that short distances to agro-dealers reduce transaction costs and consequently increase profits.

State title to land was found significant at 5% for adoption of CA and had probability to reduce adoption of CA. Probably this is because smallholder maize farmers possessed State titles to land; hence they were secure and free to take up the CA technology. On the other hand, the process to obtain State title can be tedious as such may become a discouragement.

Access to land was found significant at 1% for adoption of CA and had probability to reduce adoption of CA. The possible explanation is that smallholder farm households were able to access land and practiced the CA technology. Conversely, smallholder farm households could have not practiced CA despite accessing land.

Access to CA extension services through MAL was found significant at 1% for adoption of CA and had probability to reduce adoption of CA. The plausible explanation is that perhaps MAL used ineffective methods of providing extension services and probably the input/grant package provided to the smallholder maize farmers was demotivating.

Covariates such as Education level and age of the household head, area planted with maize, ownership of a radio set and value of off-farm income were not significant but positively correlated to adoption of CA. On the other hand, some Covariates such as total fertilizers applied, customary title to land and value of productive assets were not significant and negatively correlated to adoption of CA.

The findings of this study reveal that adoption of conservation agriculture had a positive influence on maize productivity and income of smallholder farm households located in Southern, Lusaka, Central and Eastern provinces of Zambia. Smallholder maize farmers that adopted CA recorded higher maize productivity and income than non-adopters. In other words, smallholder maize farmers that adopted CA had their maize productivity and gross income from maize production increased by 41.8% to 43.9% and 20.7% to 22.1% respectively.

The sensitivity analysis of the assessed results show that the increases in maize productivity and value of maize (income) are solely attributed to adoption of the CA practices. This underscores the role CA plays in improving smallholder maize farmers' livelihoods through increased maize yields. And signifies the potential CA adoption has to enhance the livelihoods of smallholder maize farmers in Zambia.

### 7.3 Recommendations

Improvements of smallholder farmers' livelihoods through the practice of conservation agriculture in vulnerable low rainfall maize production regions of Zambia cannot be overemphasized. The findings of this study may benefit development stakeholders that seek to identify and promote sustainable and efficient methods of crop farming particularly designed to improve livelihoods for the majority poor smallholder farmers. Certainly, knowledge about the factors that affect the adoption of CA will enable development stakeholders including government agencies (extension, research, policy and planning), NGOs and financiers to enactment policies, strategies and plans aimed to increase adoption and sustainable practice of CA. Subject to the findings of this study, the following recommendations are forwarded;

1. Provision of conservation agriculture advice and extension services should be enhanced by strengthening cooperation between development stakeholders; the Ministry of Agriculture (MoA), technology financiers and other public/private institutions such as the ZNFU/CFU. Building robust synergies among partners has the potential to help development of effective and efficient tools and methods (e-extension) that would ensure proper CA implementation and increased adoption rates.

2. Title to land guarantees smallholder farmers some security. It motivates and encourages them to easily take up new farming technologies and invest finances to enhance land productivity. Smallholder farmers who own land use a wide-range of management strategies and adopt best practices earlier because they are guaranteed to reap benefits of long term investment but in the absence of title farmers become risk averse and uncertainty of what would happen if new technology failed. Hence, MoA and other relevant ministries should provide easy land acquisition and ownership to smallholder farmers in order to increase CA adoption and crop productivity in general.

3. Easy access to loans/credit enables smallholder maize farmers to get funds to purchase inputs early and begin farm operations in time. It is expected that timely farm operations will result in improved yields. Therefore, the government through MoA and its co-operating partners should find an effective way of assisting the smallholder farmers with operational capital. This can be

done through formation of an agriculture bank or offering incentives to financial lenders who give credit to smallholder farmers. These institutions should also be given the supervisory powers of the smallholder farmers' farm operations to ensure business success.

4. Smallholder farmers should be motivated to engage into livestock farming because it increases their livestock assets. The value of livestock assets is considered as wealth and tends to enhance the risk taking capabilities; may easily be converted into cash required to invest into the CA technology and pay for the farmers' amenities. The livestock can also be used as animal draught power (ADP) ripping in CA practices.

### 7.4 Future Research Areas

There is need to conduct focus group discussions (FGDs) when capturing survey information because FGDs help to establish the actual farmer perceptions about CA. In the absence of adopters' perception the subjective aspects of a new technology held by farmers/adopters is not at play in a research.

Most studies designed to investigate, among other things, the factors that influence the adoption of CA and its impact among smallholder farmers fail to effectively capture the multiple determinants that influence farmers' decision to adopt the technology. Basically this is because most of these studies are subject to inadequate detail in data, small sample sizes or cross sectional surveys. Therefore, there is need for researchers to consider including more livelihood outcomes such as nutritional and food security in turn increasing sample size and detail in the data.

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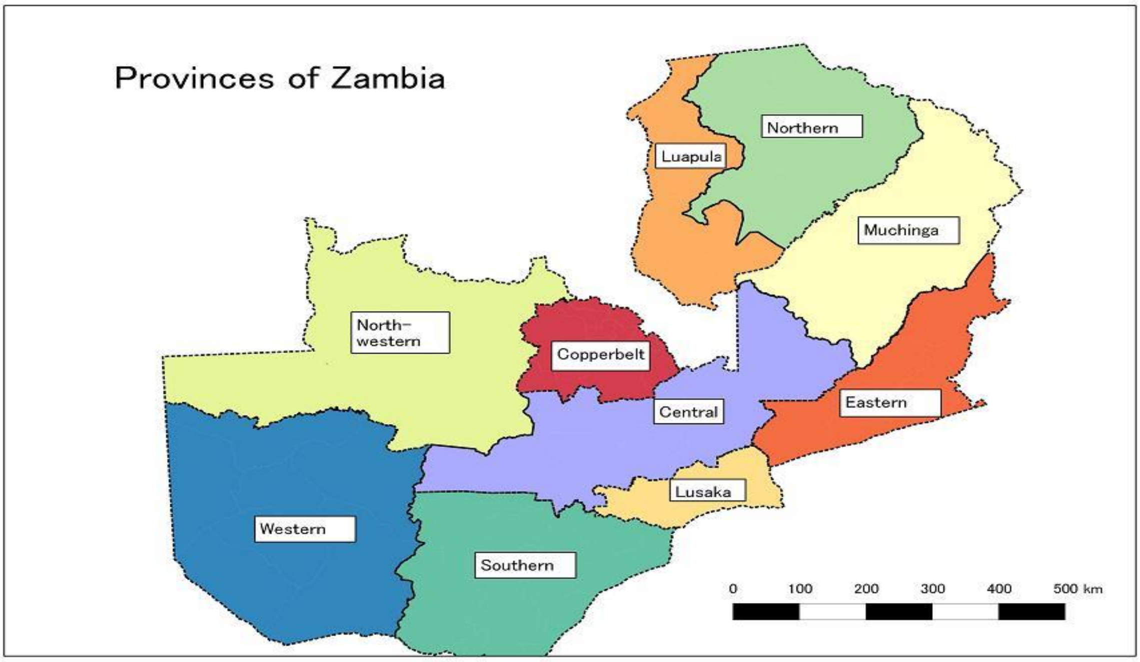
APPENDICES

Appendix I: Hand – Hoe Planting Basins


Appendix II: Animal Draft Power Ripping

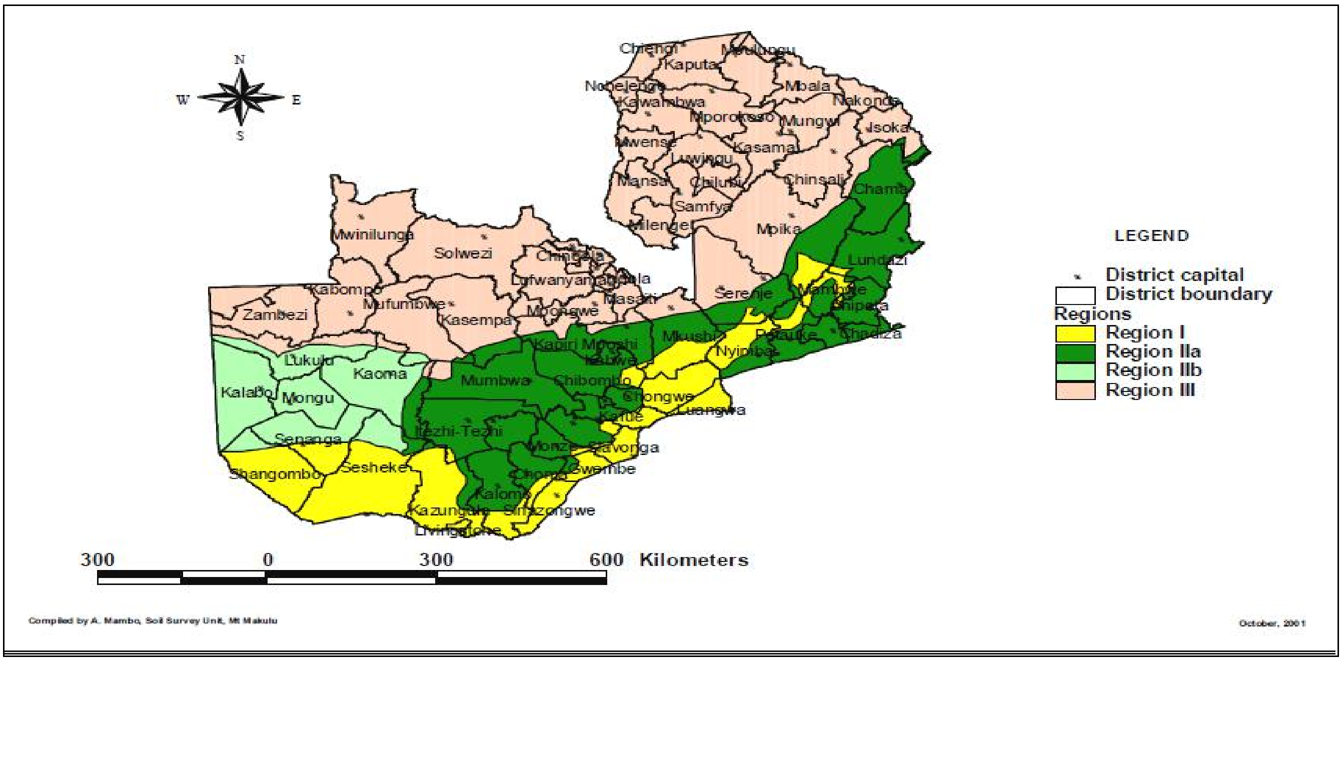
A household practices CF during the dry season by ripping furrows using magoye ripper
Source: Conservation Farming Unit.

Appendix III: Map of Zambia showing the Provinces




Source: Wikipedia

Appendix IV: Map of Zambia showing District Boundaries and Agro-Ecological Regions




**Appendix V: Distribution of adopters by source of CA information**

| | Info.conv | Radio prog | Pamph/newspaper | Workshop | F.day | Demo plot | Visit | Meet | Training | Other (specify) |
|---|---|---|---|---|---|---|---|---|---|---|
| Non-adopt | 420 | 303 | 9 | 124 | 115 | 98 | 196 | 1384 | 90 | 2 |
| Adopt | 1% | 1% | 0% | 6% | 3% | 7% | 2% | 4% | 12% | 0% |

**Appendix VI: Mode of receiving CA information by households**

| | | tillconser | | | | | |
|---|---|---|---|---|---|---|---|
| | | .00 | | 1.00 | | Total | |
| | | Row N % | Count | Row N % | Count | Row N % | Count |
| How did the household receive this advice? | Informal conversation | 98.6% | 414 | 1.4% | 6 | 100.0% | 420 |
| | Radio program | 98.7% | 299 | 1.3% | 4 | 100.0% | 303 |
| | Pamphlet/newspaper | 100.0% | 9 | 0.0% | 0 | 100.0% | 9 |
| | Workshop | 93.5% | 116 | 6.5% | 8 | 100.0% | 124 |
| | Field day | 96.5% | 111 | 3.5% | 4 | 100.0% | 115 |
| | Demonstration plot | 92.9% | 91 | 7.1% | 7 | 100.0% | 98 |
| | Visit | 98.0% | 192 | 2.0% | 4 | 100.0% | 196 |
| | Meeting | 96.0% | 1328 | 4.0% | 56 | 100.0% | 1384 |
| | Training programme | 87.8% | 79 | 12.2% | 11 | 100.0% | 90 |
| | Other (specify) | 100.0% | 2 | 0.0% | 0 | 100.0% | 2 |