Determinants of climate smart agricultural technology adoption in the Northern Province of Zambia

By

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Submitted in partial fulfilment of the requirements for the degree of MSc Agric (Agricultural Economics)

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DECLARATION

I, **Harad Chuma Lungu**, declare that this thesis, which I hereby submit for the degree of Master of Science in Agricultural Economics at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at this or any other university.

Signature:

Date**: <u>14/02/2019</u>**

DEDICATION

To the memory of my dear parents, Foster Nachula Penza and Chuma James Lungu.

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ABSTRACT

Our world, as we know it, is changing faster than what scientific evidence has thus far predicted. Globally, we see an increased occurrence of indeterminate and unpredictable climatic events changing the daily livelihood of people across the planet. Particularly, such impacts include the frequent occurrences of droughts, the increased incidences of pests and diseases in farmer fields (such as the fall army worm in Zambia), the reduced annual rainfall and shrinking freshwater supplies, the increased number of forest wild fires, and the reduction of farmers' yields. This calls for the need to adapt and build resilience. To support the adaptation and resilience agenda, various global initiatives have been undertaken and include the Intergovernmental Panel on Climate Change (IPCC), the Kyoto Protocol, the Sustainable Development Goals (SDGs), and the Paris Agreement.

Despite these global efforts, climate change impacts are still severe for developing countries like Zambia, experienced through erratic weather conditions leading to droughts and floods. This affects rural households more severely, where 70% of the Zambian population rely on agriculture (IAPRI, 2016). Between 1960 and 2003, Zambia's average temperature rose by 1.3 degrees Celsius and rainfall decreased by 2.3 % each decade (Norimitsu, 2016). To counter these adverse effects, policies were formulated at national level to guide the national agenda on climate change, which includes the National Policy on Climate Change (NPCC) and the National Adaptation Program of Action (NAPA). These policy initiatives have explicitly identified environmentally friendly agricultural and natural resource management practices, which include: (1) improved agronomic practices, (2) tillage and residual management, (3) agroforestry, and (4) increased participation of women, youth and children in climate change programmes, among others, as the main tools for improving smallholder productivity and building resilience strategies. These measures have shown to suit the Climate Smart Agriculture (CSA) framework developed by the Food and Agricultural Organization

(FAO) of the United Nations (UN), which is governed by three clear objectives. The CSA objectives include: (i) sustainably increasing agriculture productivity and incomes; (ii) adapting to climate change; and (iii) reducing greenhouse gas emissions.

A good volume of literature exists that has assessed the determinants and intensity of the adoption of conservation agricultural technology. However, few studies have examined the uptake of single technologies within the conservation agriculture package, and the low adoption rates of the entire conservation package confirms that farmers have a tendency to selectively pick technologies in the package. As a result of the selective picking of technologies, factors influencing the adoption of individual agricultural technologies and the interrelatedness of the adopted technologies, i.e. whether adopting one particular technology influences the decision to adopt another climate smart technology within a household, has remained subtle. Further, evidence on the impact of the demographic diversity of age is elusive in the CSA framework with regard to the adoption of crop rotation and an efficient stove design as individual technologies. In addition to determining factors influencing the adoption decision of crop rotation as an adaptation strategy and the efficient stove as a mitigation strategy to climate change, we test and analyse whom between the young and old farmer is most likely to adopt the efficient stove and/or the crop rotation technologies by testing hypotheses and observing the effect of the age variable. The reason for including the age variable is not only to assess the demographic impact, but also to guide the Zambian policymakers who are promoting youth participation in technology adoption. We further investigate the role of other demographic variables, such as family size, income and gender, in assessing their roles in the adoption decision. In addition to the econometric analyses, we use independent t-tests and tests of association to examine the statistical differences that exist amongst the respondents as they pertain to the adoption of the CSA technologies, i.e. the efficient cooking stove and crop rotation technologies.

This study makes use of survey data collected by the International Fund for Agricultural Development IFAD[1] as part of their Smallholder Productivity Promotional Program (S3P). The data is cross-sectional in nature, consisting of a total of 182 smallholder farm households from the Northern Province of Zambia. They used random sampling techniques, based on a sampling frame provided by the Zambian Central Statistical Office (CSO). The first stage involved identifying the Primary Sampling Unit (PSU) and randomly selected Standard Enumeration Areas (SEAs) within the PSU in which the farm households belonged. The data was captured by administering survey questionnaires to the selected respondents. Further, Key Informant Interviews (KII) and Focused Group Discussions (FGDs) were held to enrich and verify the data collected. The model used in this study is the Recursive Bivariate Probit Model (RBPM),

1 The data was collected by IFAD during the 2015/16 farming season, and we received permission to use it for this study.

which checks for potential biases, such as non-randomness and self-selection. This was necessary, given the nature of the survey that captured data in an area where development programmes are promoted.

Overall, the study revealed that, of the CSA technologies practised in the Northern Province of Zambia, crop rotation and the efficient cooking stove design were the most adopted technologies, followed by minimum tillage and residual retention. In this study, we focused on crop rotation and the efficient stove for analyses for the reason that higher rates of adoption are an indication of technology suitability and acceptance. The findings show that a greater number (55%) of the respondents indicated that they were aware of climate change and its consequences, and have since adopted measures to mitigate and build resilience. The study also identified variables found to have significant effects on influencing adoption decisions, such as various human and social capital characteristics; the wealth status of the respondent households; group formation as part of social capital, extension and awareness variables; and location and crops grown. Remarkably, the effect of age on the two technologies under investigation, i.e. the efficient cook stove and crop rotation, was mixed. For instance, the older farmers located in Mungwi and Kasama Districts were more likely to adopt the efficient stove, compared than those in Mbala District were, whereas no significant age effects were found on the crop rotation technology. We also show that those respondents who are exposed to the technologies through demonstration trials are less likely to adopt the technologies, indicating a reluctance to switch to the CSA technologies being promoted, i.e. crop rotation and the efficient stove. In terms of gender, the results show that women-headed households have statistically lower levels of income and smaller household sizes than their male counterparts do, and this can have profound effects on accessing and adopting the CSA technologies.

The key findings in the study support the importance of the CSA framework as a comprehensive guide in adapting to climate change in the Northern Province of Zambia. Greater attention must be directed towards the capacity building of agricultural groups as mediums by which the climate change agenda is pushed. The study finds that networks and associational life are more effective in promoting the adoption of CSA technologies.

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ACRONYMS

BPM	Bivariate Probit Model
CA	Conservation Agriculture
CFU	Conservation Farming Unit
CSA	Climate Smart Agriculture
CSO	Central Statistical Office
FAO	Food and Agriculture Organization
FRA	Food Reserve Agency
GAPs	Good Agricultural Practices
GDP	Gross Domestic Product
GHGs	Green House Gases
IAPRI	Indaba for Agriculture Policy and Research Institute
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
MACO	Ministry of Agriculture and Cooperatives
MoA	Ministry of Agriculture
NAPA	National Adaptation Programme of Action
NPCC	National Policy on Climate Change
RBPM	Recursive Bivariate Probit Model
S3P	Smallholder Productivity Promotional Program
SDGs	Sustainable Development Goals
TLC	Total Land Care
UN	United Nations
WMO	World Meteorological Organization
ZNFU	Zambia National Farmers Union

CHAPTER 1: INTRODUCTION

1.1 Background

The impact of climate change is felt globally and varying efforts have been made through global initiatives, such as the formation of the Intergovernmental Panel on Climate Change (IPCC), the Kyoto[2] Protocol, and the Paris[3] Agreement of 2016. The IPCC is an international body responsible for assessing the science related to climate change. It was formed in 1988 by the World Meteorological Organization (WMO) and the United Nation Environment Programme (UNEP) (IPCC, 2001). Its main purpose is to provide policy makers with assessments on climate change related issues, especially on options for adaptation and mitigation. Despite these various global initiatives, developing countries, particularly African countries, are the most vulnerable, notwithstanding the fact that they are relatively smaller emitters of greenhouse gas emissions (GHGs). Therefore, they carry a greater burden of the impact of climate change, relative to other countries, given their low levels of developmental capacity to cope with such impacts (Serdeczny et al., 2017).

Nevertheless, initiatives such as the Sustainable Development Goals (SDGs) of the United Nations (UN) have created a platform for developing countries to identify pathways (through indicators) for tracking the impact of climate change on their economies and to establish ways of addressing them in partnership with developed countries. The adoption of Climate Smart Agriculture (CSA) technologies to mitigate and build resilience, as provided for in the SDG framework, creates avenues for developing countries to find ways of addressing the climate change problem (UN, 2016). A number of the 17 formulated SDGs have linkages with the agricultural sector, and goals 2 and 13 explicitly integrate ending hunger and building resilience strategies by highlighting the need for sustainable agricultural productive systems and initiatives to build resilience (UN, 2016).

African countries like Zambia have not been spared by climate change, and several programmes have been initiated at national level, which have had varying outcomes. These varying outcomes motivated the formation of policies to guide the national agenda on climate change, which include the National Policy on Climate Change (NPCC) (2016) and the National Adaptation Programme of Action (NAPA). These policy

2 The Kyoto protocol is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC) see [http://unfccc.int/kyoto_protocol/items/2830.php]

3 The agreement sets out a global action plan to put the world on track by limiting global warming by well below a 2 °C increase.

initiatives explicitly identify environmentally friendly agricultural and natural resource management practices, which include (1) improved agronomic practices; (2) tillage and residual management; (3) agroforestry; and (4) improving the participation of women, youth and children in climate change programmes, as the main tools for improving smallholder productivity and building resilience strategies.

Statistics show that two out of three people in sub-Saharan Africa (SSA) are under 25 years of age, and further population forecasts for SSA indicate that the youth population will increase to 350 million by 2050 (Rutta, 2012). This demographic forecast presents a unique profile which identifies Africa as the continent with the youngest population on the planet. However, Fisher et al. (2015) found that the average age of farmers in Ethiopia, Tanzania, Uganda, Malawi, Zimbabwe and Zambia to range between 40 and 53 years, signalling that agricultural production and participation was mainly undertaken by older farmers. Subakanya (2016) showed that being engaged in wage employment reduced youth participation in agriculture and that this was the main cause of rural–urban migration, as the young farmers did not see agriculture as a very rewarding venture, hence the non-commitment of the younger generation to agriculture participation. As outlined by the NPCC and NAPA, the task is to find compelling evidence through continued research that would see policy formulations that directly endeavour to attract young farmers to agriculture, thereby reducing the average age of farmers involved in agriculture. This policy gap can be closed only if we understand and assess how age demographics affect the decision to adopt the CSA technologies, i.e. whether the younger farmers are likely to adopt a particular CSA technology and whether that CSA technology has compelling results to show that it is indeed better than conventional farming methods with regard to improving farmer yields.

Although many international and local initiatives such as the NPCC and NAPA have been formulated to address the youth–climate change nexus, smallholder farmers in Zambia continue to suffer from climate change impacts in the form of erratic weather conditions – droughts (experienced in the years 1991/92, 1994/95, 1997/98 and 2001/02) and floods (floods associated with increased rainfall, especially after drought years, leading to water logging) (Mubaya et al., 2010; Mason et al., 2005; Dilley, 2000; Sichingabula, 1998; Mulwanda, 1993). Furthermore, Norimitsu (2016) notes that Zambia's average temperature rose by 1.3 degrees Celsius, and rainfall fell by 2.3 %, during each decade between 1960 and 2003. The implication of this over the years has been a shorter rainy season, marked by frequent droughts. When rains fall, they do so with greater intensity and tend to cause floods as mentioned previously. Despite numerous studies on the issue of climate change, more evidence-based findings are needed, particularly with a focus on the youth as potential drivers of the adaptation and resilience agenda for climate change.

The CSA technologies being investigated in this study comprise a bundle of environmental friendly land management practices, i.e. crop rotation, minimum tillage, crop residues retention, liming, and composite manure (organic fertiliser), and the energy-efficient cooking stove. These technologies aim to improve smallholder productivity in a sustainable manner through adaptation and resilience to climate change on one hand. On the other hand, an environmentally friendly energy-efficient cooking stove would, if widely adopted, ensure low GHG emissions and at the same time discourage deforestation, thereby mitigating the climate change problem.

CSA technologies in Zambia have been promoted for over two decades, initially as conservation agriculture technologies with the aim of improving productivity in drought-prone areas and reducing input costs for farmers (CFU, 2011; Haggblade and Tembo, 2003). The technologies promoted were primarily supported by the Zambia National Farmers Union (ZNFU) and the Ministry of Agriculture (MoA) in two agro-ecological regions[4] covering the Eastern, Central, Southern and Western parts of the country, with financial support from the Royal Norwegian government's Ministry of Foreign Affairs. The conservation agriculture technologies that were promoted involved crop residue retention (soil moisture conservation), reduced tillage (minimum soil disturbances), completion of land preparation in the dry season, digging plant basins, early ripping (thus freeing up labour because of the extended period for land preparation), organic fertilisers, etc.

These practices, in addition to the implementation of crop rotation where crops are rotated with nitrogen-fixing legumes, resulted in improved smallholder farmer yields (CFU, 2011). Conservation agriculture technologies can potentially improve land productivity, reduce production costs and reduce labour input requirements (Haggblade and Tembo, 2003). Haggblade and Tembo (2003) further reported yield increases of about 60% for farmers who utilised the basin conservation agriculture technology, as compared with those using conventional farming systems in Zambia. Even with such improved yields, the adoption rates of conservation agriculture technologies have been varying across the country, and many low adoption rates (e.g. 2% for Liming, Agroforestry, Crop Residue Retention and Minimum Tillage) have been recorded (Awotide et al., 2016; Jayne et al., 2018; Namonje and Chapoto, 2016). The Food and Agriculture Organization (FAO) launched the concept of CSA in 2009 to draw attention to the linkages between achieving food security and combating climate change, which saw the inclusion of conservation agriculture technologies as meeting the CSA approach. Conservation agriculture technologies, like crop rotation, minimum tillage and residue retention, improve farm productivity and at the same time ensure resilience

[4] See the map on agro-ecological regions in the document.

for farmers by enabling them to thrive in drought and flood years, thus providing stable yields (Lipper et al., 2013).

With several initiatives on technology adoption having already been introduced in Zambia, the current study investigates the factors that influence technology adoption in the Northern Province of Zambia. The study uses data on smallholder farmers where CSA technologies are supported by the International Fund for Agricultural Development (IFAD) under the Smallholder Productivity Promotional Program (S3P). The overall goals of the IFAD/S3P program are in line with the NPCC[5] and include policy measures to: (1) promote the adoption of appropriate CSA technologies for the different agro-ecological regions; (2) promote the scaling-up of alternative energy sources; (3) promote energy efficiency and conservation; (4) reduce forest degradation and the loss of forest ecosystems; and (5) improve the participation of youth and women in climate change programmes (NPCC, 2016; TLC, 2017).

By identifying factors that influence the adoption behaviour of farmers, we can then further ascertain if differences exist between young and old farmers in order to advise government on targeted strategies for the different age groups, or to ensure that age and other demographic factors are taken into consideration in existing strategies and policies. Such information would avoid the adoption of blanket policies that do not take into account demographic factors or overlook how these factors have impacted on the adoption of the technologies over the years. The Northern Province was selected specifically because it is only in recent years that CSA technologies have been promoted there, as compared with the Eastern, Central, Southern and Western parts of the country where extensive programmes on CSA technologies have been implemented. Furthermore, the Northern Province was the largest producer of the staple maize amongst small-scale farmers in the 2014/15 farming season, contributing 94,818 metric tons to the Food Reserve Agency (FRA). This signifies the province's importance as an agriculture hub of smallholder farmers (IAPRI, 2016).

5 The National Policy on Climate Change (NPCC) of the Ministry of National Development Planning was commissioned in April 2016 with a mandate to harmonise the various programmes that seek to mitigate climate change and facilitate adaptation to the changing environment across various sectors. In the past, such interventions have been done in a fragmented and ad-hoc manner, hence the need for the NPCC.

1.2 Technologies under CSA

The CSAs under investigation have been promoted in the country since 1996 as conservation agriculture technologies (CFU, 2011; IAPRI, 2016). The core principles guiding the technologies, as investigated by Haggblade and Tembo (2003), are:

- Winter land preparation by using minimum tillage methods (either ox-drawn rip lines or hand-hoe basins laid out in a precise grid of 15,850 basins per hectare);
- Retention of crop residuals from previous season's harvest;
- Planting and input application in fixed planting stations; and
- Crop rotations with nitrogen-fixing plants (legumes);

Most of the technologies that are being promoted by various programmes in Zambia are conservation agriculture based technologies as aforementioned, which encompass the principles mentioned earlier in the previous paragraph. Considering the country's desire for adaptation and mitigation, conservation agriculture technologies are seen as comprising 'silver bullets' in that they have within their components the attributes of both mitigation and adaptation to climatic variability. The table below summarises the CSA practices being promoted and the corresponding benefits of the technology.

Table 1–1: CSA Technologies Promoted in Northern Province

CSA Technology	Adoption Rates	Benefits
Crop Rotation	63%	The practice entails rotating legumes with maize (staple). The idea of this practice is that the legumes fix nitrogen in the field, which is beneficial to the maize. This practice furthermore replenishes soil fertility and helps to control weeds, diseases and pests by breaking their life cycles through the introduction of new crops
Manure (Composite Fertiliser)	2.8%	Organic residues improve organic matter content and the soil nutrient status, and in addition provide a beneficial environment for the soil fauna.
Minimum Tillage	<5%	The idea is to disturb the soil only where the seed, fertiliser and manure (composite) are to be placed. This reduces the destruction of soil structure, causes little destruction to soil fauna, saves time as less land is tilled, and reduces soil compaction.
Crop Residuals Retention	<5%	Residual retention helps to reduce direct rain impact on soil and thus reduces the risk of soil erosion. The practice is important because it further reduces evaporation, thereby conserving soil moisture, provides a conducive environment for biological tillage, and suppresses weed pressure.
Liming	0%	Region III receives rainfall in excess of 1000 mm, and as such, soils are highly acidic. Liming is recommended to neutralise the acidity, and in addition for improving increased nutrient availability, improved soil structure, and better rates of infiltration.
Efficient Stove (Cook Stove)	33%	The cooking stoves use twigs, small branches and, at times, crop residues sourced within the village. The felling of trees from surrounding woodlands is eliminated because these cook stoves use twigs, and thus produce low volumes of GHGs and eliminate deforestation.

Source: Adapted from TLC Baseline Report (2017) and Nyasimi et al. (2017)

Table 1–1 shows an overview of the rates of adoption of the various CSA technologies being promoted, and their corresponding benefits. In terms of adoption rates for the different technologies, the highest were 63% and 33% for crop rotation and the efficient cooking stove, respectively. This shows a high preference for crop rotation technology and the efficient cooking stove among the farming households. This was a basis for selecting the two types of technology for our study. In the model strategy presented in Chapter 3, we identified and defined the variables[6] we investigated as they relate to the CSAs. The study captured adopters and non-adopters of the CSA technologies: crop rotation, residue retention, minimum tillage, liming and the efficient cooking stove, from which we seek to establish a linkage or identify the influence against other factors as defined in the model.

1.3 Problem Statement

Climatic variability in SSA has impacted on the smallholder farmers extensively, with varying climatic models for Zambia supporting the assertion that this would have a profound impact on the country's agricultural productivity in the near future (IAPRI, 2015; Hassan and Nhemachena, 2008). With the majority of farmers being smallholder farmers who depend on rain-fed production, there is no doubt of the threat that climatic variability poses to the agricultural sector. Various adaptation strategies have been undertaken at national level as means to combat climate change (NAPA, 2007; NPCC, 2016), which have included conservation agriculture, agroforestry, drought-tolerant seed production, and Good Agriculture Practices (GAPs). Despite having developed these affordable and scalable solutions in the last two decades and making them available to farmers to enable them adapt, mitigate and build resilience, literature shows that the adoption rates are as low as 1.4% for minimum tillage to as high as 60% for crop rotation technology (TLC, 2017).

A number of studies have been conducted to assess the determinants and intensity of agricultural technology adoption (Husen et al., 2017; Fisher et al., 2015; Nhemachena and Hassan, 2008; Adesina and Seidi, 1995; Awotide et al., 2016; IAPRI, 2016; IAPRI, 2015). These previous studies highlighted and identified the importance of aspects such as socio-economic variables in influencing the decisions to adopt farming technologies. However, farmers rarely adopt the entire conservation package promoted to them, as evidenced by the 2.6 % adoption rate recorded in most studies on Zambia (Ng'ombe et al., 2014; Jayne et al., 2018). The trend has been that smallholder farmers choose those technologies within the package that meet their needs and convenience at a particular time (Banda, 2017). Evidence has remained elusive with respect to identifying the factors that influence the adoption of individual technologies within the conservation package, and that indicate how the adoption of this technology is related with the adoption of another climate-smart agriculture technology within the household. For instance, will the factors that influence the adoption of the efficient stove be identical to those influencing the adoption of the crop rotation technology? We use hypotheses to check if a household's decisions to adopt the two technologies

[6] See Table 3-1 in Chapter 3 of the paper.

are interrelated and further check the differences in adoption between young farmers and old farmers. Further, this study distinguishes the factors that affect the adoption behaviour of young farmers from the older farmers by observing the coefficients on age.

With the above in mind, the main objective of this study was to identify the factors that influence the decision of a farmer to adopt crop rotation as an adaptation and resilience measure to climate change, and the efficient stove as a mitigation measure to climate change impacts. By filling this literature gap (both in terms of demographic considerations as well as methodological approach), the study will generate important knowledge for identifying intervention strategies that take into account both demographic and socio-economic factors in designing CSA programmes promoting individual technologies that are suitable for a given location at a particular time.

1.4 Research Questions

To better understand and focus our study, we are motivated to pose some research questions that form the foundation upon which the study objectives and hypotheses are developed.

- **i.** Do statistical differences exist in the adoption behaviour of the CSAs (crop rotation and efficient cook stove)?
- **ii.** What are the underlying factors that influence the adoption of the efficient cook stove as a mitigation measure to climate change among smallholder farmers?
- **iii.** What are the underlying factors that influence the adoption of crop rotation as an adaption and resilience measure to climate change among smallholder farmers?
- **iv.** Do significant differences exist between young and old farmers in the use/adoption of CSAs?

1.5 Objectives of the study

The overall objective of the study was to identify factors that influence the adoption of CSA technologies as climate change coping measures among smallholder farmers in the Northern Province of Zambia. The more specific objectives of the study are presented below:

- **i.** To examine the statistical differences that exist in adoption decisions of the CSAs (crop rotation and efficient cook stove).

ii. To identify factors that influence the adoption of the efficient cook stove as a mitigation measure towards climate change among smallholder farmers.

iii. To identify factors that influence the adoption of crop rotation as an adaptation and resilience measure to climate change among smallholder farmers.

iv. To draw lessons for policy implications

1.6 Hypotheses

The study will test the following two hypotheses:

i. Crop rotation and the efficient stove are independently adopted as CSA technologies.
ii. A statistical difference does not exist between young and old farmers in the adoption of CSA technologies.

1.7 Research report outline

This dissertation report has five chapters. The first chapter has discussed the overall study background, the country demographics, a brief literature review of CSA technologies, the problem statement, and the study objectives. Chapter 2 discusses the literature review in detail, starting with definitions of terms, followed by a review of studies on the adoption and the identification of factors that influence adoption. The third chapter presents the data and methods section in detail and further describes the model that was employed in the econometric analysis. The fourth chapter of this dissertation discusses the results of the descriptive analysis and the econometric outputs of the model strategy. In the last chapter, we provide study recommendations and a conclusion is drawn accordingly.

CHAPTER 2: REVIEW OF LITERATURE

2.1 Introduction

This section covers the definitions of concepts covered in the study concerning agriculture technology adoption and climate change in general, and concludes with a more specific approach to CSA literature on the need and importance for adoption studies. Also discussed in this section of the study are the roles of social capital in adoption and how bounded rationality has limited farmers' management decisions.

2.2 Definition of Terms

2.2.1 Climate Change

The IPCC defines climate change as a "state of the climate that can be identified using statistical test, by changes in the mean and/or the variability of its properties, and that persist for an extended period, for decades or longer. The changes in climate may be because of natural internal processes or external forcing such as modulations of the solar cycle, volcanic eruption, and persistent anthropogenic changes in the composition of the atmosphere or land use (IPCC, 2014:117)."

2.2.2 Weather Variability

For purposes of understanding climate change, there is need to understand weather variability. Hoegh-Guldberg et al (2007) define weather as the current atmospheric conditions, such as rainfall, temperature, and wind speed, prevalent at a particular place and time. They further distinguish weather from climate in that weather has a tendency to change from day to day, whereas climate is the average pattern of the weather for a particular place over several decades. It must be noted that changes in climate are hard to detect without access to long-term records. In this study, we rely on farmer experiences to deduce if, indeed, weather variability has been prevalent and to understand what measure the households employ to adapt to climate change impacts.

2.2.3 Mitigation

The IPCC defines mitigation in the context of climate change as "a human intervention to reduce the sources or enhance the sinks of GHGs" (IPCC, 2014:128). In this study, the programme's mitigation measures being promoted comprise the energy efficient cooking stove that uses less fuel wood and subsequently releases fewer GHGs emissions, compared with the conventional open, three-stones cooking practices.

2.2.4 Adaptation

The key purpose of adaptation is to be able to withstand and manage the potential effects of climate change (Howden et al., 2007). The FAO (2007) defines two main types of adaptation – autonomous and planned adaptation. Autonomous adaptation refers to the reaction of a farmer to changing precipitation patterns by practising crop rotation or crop diversification, or employing different harvest or planting dates, to suit the changing climate. Planned adaptation, on the other hand, comprises well-coordinated policy options or response strategies directed towards changing the adaptive capacity of the agricultural systems (FAO, 2007). The two types of adaptation measures are in line with the study context in that we observe household behaviour on adoptions, based on how farmers are responding to intra-annual rainfall variations by adopting technologies such as crop rotation, and at the same time on how government policies on climate change promote and coordinate the adaptation efforts (IAPRI, 2016; NPCC, 2016; NAPA, 2014).

2.2.5 Climate Smart Agriculture

According to Lipper et al. (2017), they defined the CSA approach as a methodological approach for transforming and reorienting agricultural development under the new realities of climate change. From the definition of CSA, the FAO (2010) suggests that the CSA approach has three main objectives:

- **i.** Sustainably increasing agriculture productivity and incomes;
- **ii.** Adaptation and building resilience to climate change; and
- **iii.** Reducing and/or removing greenhouse gas (GHG) emissions.

With particular interest in the CSA framework, this study investigates two technologies, i.e. crop rotation practice and the energy-efficient cooking stove (as promoted by TLC in the Northern Province of Zambia since 2014) to determine the factors that influence farmer's decisions to adopt the two technologies. For example, the efficient stove, if adopted, ensures reduced indoor air pollution and subsequent reduction in the emission of GHGs through reduced consumption of fuel wood, while crop rotation is used as part of an adaptation strategy and in building resilience towards climate change, thereby meeting the CSA criteria.

2.2.6 Conservation Agriculture

The FAO (2015) of the United Nations defines conservation agriculture as an approach to managing agro-eco systems for achieving improved and sustained productivity, increased profits, and food security, while preserving and enhancing the resource base and the environment. In this study, the technologies under investigation are conservation agriculture technologies which have been promoted in Zambia from the mid-1990s. Conservation agriculture technologies are suitable because they are less labour demanding if employed effectively, and also reduce environmental degradation (FAO, 2015).

2.3 Review of agricultural technology adoption

2.3.1 Importance of adoption

Conducting an adoption study allows to assess the current progress of a technology and use that information to design environmental strategies that are more effective (CIMMYT, 1993). One of the critical benefits of such studies is that they show the potential for technology diffusion, achieved by demonstrating progress in areas where institutional coordination is good, or might be used to analyse the problems in areas where technology diffusion has been slow and thus provide guidelines for improvements. In our case, we observe a clear adoption by farmers of the crop rotation technology, at 60%, while the same farmers reluctantly adopt minimum tillage technology, at 2.6%, and some technologies are not adopted at all (TLC, 2017). This is in line with what the CIMMYT (1993) proposes, that perhaps coordination and institutional understanding of the crop rotation technology is more defined and understandable, compared with the other loosely adopted technologies.

Adoption technology studies further help to map the dynamics of the households that adopt the technologies, together with their social demographic characteristics. It has been identified that, in the light of climate change, much emphasis has been focused on the adoption of management practices, rather than on crop-specific technologies (Doss and Doss, 2006). This is supported by Jayne et al (2018), where they emphasise the need to introduce technologies that help to mitigate the impacts of climate change. By so doing, we are actually, in a way, reducing the vulnerability of the vast agricultural systems to climate change, including extreme weather incidences like the *El Nino*[7]. Gaining an understanding of the underlying farmer behaviour in adopting agriculture technologies will help in drawing up strategies and policy measures that would guide the effective extending of these technologies (i.e. crop rotation and the efficient cooking stove) to a wider population.

2.3.2 Factors influencing the decision to adopt

Literature (Ng'ombe et al., 2014; Namonje and Chapoto, 2016; Ngoma et al., 2014; Awotide et al., 2016) have shown that there are a number of factors that play a role in determining whether a farmer decides to adopt a certain farming practice or not. Vosti and Witcover (1996) classify the factors that affect the decision to adopt technologies into three groups, human, financial and natural factors, which combined they refer to as internal factors. The ***human factors*** include demographic variables such as household[8] size, age, gender, farming experience, income level, and other sources of income (Shuck et al, 2002; Vosti and Witcover, 1996). ***Financial factors*** include farmers' productive assets and access to financial capital (Vosti and Witcover, 1996). ***Natural factors*** include location of area, weather, soil quality and water resources. ***External factors*** also play a role, though not under farmers' influence, and will in turn condition farmer behaviour with regard to adopting a particular technology.

Further literature investigations (Kuntashula et al., 2014; Ngoma et al., 2014; Awotide et al., 2016) showed that most human factors like gender, farming experience and level of income generally positively influenced a farmer's decision to adopt a certain farming practice. In a similar manner, financial factors such as productive assets and indeed access to financial capital or credit positively influenced the farmer's decision. Nhemachena and Hasan (2008) found such Natural Factors as location and agro settings to positively influence a farmer's decision. However, Manda et al (2014) found such human factors as gender and age to be negative in influencing the decision to adopt. Other studies have been conducted that have identified

7 El Nino describes a climate pattern with unusual warming of surface waters in the eastern tropical Pacific Ocean. El Nino is just a "warmer phase" of a much larger phenomenon called the El Nino-Southern Oscillation [ENSO]. See [https://www.nationalgeographic.org/encyclopedia/el-nino/].

8 A household in the Zambian context is defined as a group of persons who normally live and eat together. These people may not necessarily be related by blood, but rather make common provision for food or other essentials, and have only one person whom they regard as the head of the household (CSO, 2013).

factors that influence farmers' decisions to adopt a technology, which have included both internal and external factors. Scriecui (2001), Mendelsohn and Dinar (1999), and Awotide et al. (2016) identified such external factors as government policies, institutional arrangements, input prices, commodity prices, and land tenure. Deressa et al. (2009) and Awotide et al. (2016) in their investigations identify variables such as level of education, gender, age of the household head, wealth, access to extension services and credit, agro-ecological settings, and temperature as all influencing the decision to adopt.

Somanje (2015) investigated conservation agriculture in the Southern Province (Region I) of Zambia, with the aim of identifying the challenges and finding ways to improve the implementation of conservation agriculture practice as a climate change adaptation strategy. The study reports that yields under conservation agriculture are generally much higher, in comparison with conventional farming. In particular, minimum tillage (fixed planting station/basin) performed far better than the ripped areas did, returning 60% higher yields than those achieved with conventional ploughing. Haggblade and Tembo (2003) further reported and identified the point that access to assets, especially cattle or labour, played a significant role in the adoption of conservation agriculture in Zambia. These factors identified by the study correspond with those highlighted by Scriecui (2001), which were referred to as ***internal*** and ***external*** factors influencing farmers' decisions to adopt. Umar and Nyanga (2011), in their study on conservation agriculture in Zambia, conclude that those farmers who adopted conservation agriculture are more resilient. This is because, adopters of conservation agriculture technologies produced higher production and productivity figures are experienced in both flood and drought years, overall.

It is important at this stage to understand that adaptation is not an externally driven concept for building resilience to climatic variability for farmers. Mendelsohn and Dinar (1999) found that farmers actually take the initiative to adapt, once they notice changes in the climate at farm level. Common methods that farmers employ include using different crop varieties, tree planting, soil conservation, early and late planting, and irrigation (Deressa et al, 2009). Understanding the underlying farmer behaviour in adapting technologies will help in developing strategies and measures that would guide the extending of these CSA technologies to a larger beneficiary target frame in the intervention areas.

2.3.3 Role of social capital

Over the years, growing numbers of scholars have been investigating the important role that social capital plays in development, veering away from the traditional factors of production, i.e. 'physical' capital, human capital, natural capital, institutional capital, and other traditional forms of capital (Puttnam, 2002; Narayan and Pritchett, 1999). In his seminal book on civic associations in Italy, Puttnam (2002) defines social capital as comprising social organisation features such as the networks of individuals or households, together with the accompanying norms and values that create externalities for the community, as a whole. Narayan and Pritchett (1999) further define social capital as the quality and quantity of associational life and the related social norms. In their work, they identified some dimensions of social capital. One such dimension was the individuals' membership to various voluntary associations or groups which enabled them to investigate the magnitude of social capital effects. To illustrate this, they assumed that if the group's membership is *"inclusive"* then that group's individual contribution to social capital is much more than membership in a group in which membership is *"exclusive"* to a particular clan or ethnic group would be. In addition to the information on associated life, Narayan and Pritchett (1999) highlight the existence and role of social and civic norms and individuals' attitudes towards others, with a particular focus on the degree of trust individuals felt towards social groups, like family, village or tribe, and toward government authorities.

This study investigates farmer behaviour in associational life, specifically how agricultural group membership influences the household in adopting a particular CSA technology as a form of social capital. In their study, Husen et al. (2017) showed that Ethiopian farmers who belonged to various groupings generally had a higher likelihood of adopting conservation agricultural technologies, such as soil water conservation practices, agroforestry, high-yielding seed varieties and productivity-enhancing technologies, than those not belonging to any group did. In this dissertation, we examine the various agricultural groups and cooperatives that exist in the study area, and we use the membership to an agriculture group variable to assess the role that social capital plays in the adoption of CSA technologies among the beneficiaries in the Northern Province of Zambia. Like Katungi (2007), we expect membership to agricultural groups to have a profound, positive influence in the adoption of both the crop rotation technology and the efficient stove.

2.3.4 Potential barriers to adaptation

As highlighted earlier, the CSA framework is guided by a set of objectives which include improving productivity and incomes, building resilience through adaptation, and climate change mitigation. Through this framework, empirical studies on conservation agriculture have validated the fact that it is possible to both attain increased productivity and protect the natural resources and environment at the same time (Ng'ombe et al., 2014). The key to achieving the set objectives of CSA lies in the conservation agriculture practices that must be adapted to the local conditions, such as local climate, agro-ecological settings, cultural and socio-economic characteristics, and soil types (Pedzisa et al., 2015; Nhemachena and Hassan, 2008).

A number of barriers, both socio-economic and cultural, exist that prevent the effective adoption of conservation agriculture practices. Many of these have centred on the informational problem, for instance, Brock and Barham (2013) identify ***bounded rationality***[9] as a key element that would affect a farmer's decision to change a management practice for the reason that the farmer lacked the requisite information to do so. They further suggest that this informational gap can be closed through social networks and associations, which are forms of social capital which farmers can draw from to access the needed information (Brock and Barham, 2013).

A further barrier is the failure by international and national policymakers to incorporate local knowledge in the climate change adaptation programmes (IPCC, 2014). This is particularly important, as we see most programmes promoting blanket policies that do not take into account the local environmental settings and population demographics, which subsequently affect the adoption of technologies. This aspect was echoed by Rutta (2012), who noted that a lack of documented cases of youth involvement in CSA, and indeed a lack of enabling policy environment and platforms for youth engagement, are all barriers that need to be addressed. In this study, we try to investigate the role of age in adoption decisions. Are technologies sensitive to age? And how does the household size composition interact with the CSA technologies we are investigating (i.e. crop rotation and the efficient cooking stove)?

2.4 Biases in adoption studies

A review of previous studies shows that potential biases exist in adoption studies. Such biases are, at times, poorly controlled and if not well addressed, they lead to an overstatement or understatement of the true population adoption rates and the subsequent impacts of the actual adoption. Simtowe (2011) investigated Tanzanian farmers to derive estimates of the actual and potential adoption rates of improved pigeon pea. In their investigation, they contend that exposure to an agriculture technology is usually non-random and that the technology is partially exposed to the population. This arises because extension staff may deliberately target individuals whom they assume would most likely adopt that technology (Simtowe, 2011). Because of these biases, which include partial exposure and selection biases, the real influences of adoption cannot

9 Simon (1955) refers to ***bounded rationality*** as relating to situations where decision-makers face choices in which they lack access to the full information about the problem in question, and/or the time and cognitive capacity to assess the advantages and disadvantages.

be consistently measured using the classical models, such as the probit, logit, and Tobit models. To effectively measure the actual and potential adoption rates, Simtowe (2011) apply the Average Treatment Effect (ATE) framework under partial population exposure (see the framework formulated by Diagne and Demont, 2007). This framework was suitable because the actual dissemination of the pigeon pea varieties was not widely disseminated (partial exposure), and subsequently the exposure of the pigeon pea variety to farmers was non-random. By applying the treatment framework as advanced by Diagne and Demont (2007), the study controlled for both non-exposure and selection biases, which helped to estimate the true population adoption rates and the determinants of adoption.

Like Simtowe (2011), we were concerned with exposure and self-selection biases, and how best to control and account for such biases. Such biases in our study could come from the role of technology promoters, as seen in the literature, or from exposure through demonstrations of the technologies given to farmers when promoting the technologies. We are motivated to understand and test the possibility that unobserved variables in the equation of interest are correlated with our binary explanatory variables, causing the problem of endogeneity, i.e. how self-selecting and exposure of smallholder farmers broadly impacts on our equation of interest in determining adoption (Monfardini and Radice, 2008). To address the potential biases, we worked within the simultaneous modelling framework process to determine the adoption resulting from the Recursive Bivariate Probit Model (RBPM) or Bivariate Probit Model (BPM) (Heckman and Robb, 1985; Maddala, 1995).

2.5 Summary of Literature Review

The review of literature has shown the importance of the CSA approach as a tool that would enable rural farm households ensure that productivity is increased, help them to adapt and produce sustainably, and further ensure that GHG emissions are reduced. The CSA approach, if well implemented at household level, is one that guarantees a sustainable livelihood for adopters. In essence, the majority of rural households are affected by climate change, either knowingly or unknowingly. The identification of key factors that would influence a farmer’s decision to adopt a CSA technology would assist policy makers and programme managers by providing them with the right tools to promote and sponsor effective and targeted technologies that will help the rural farm households to build resilience, increase productivity sustainably, and employ mitigation mechanisms to reduce GHG emissions.

CHAPTER 3: RESEARCH METHODS AND PROCEDURES

3.1 Introduction

This chapter provides a detailed description of the data that was used, the executed estimation methods, and strategies that were employed, together with a description of the variables that the study used to realise the stated objectives. In the first part of this chapter, a description of the type of data the study employed, data sources and the sampling techniques used are described. In the second part, we describe the estimation strategy and justification of its use. In the last section, we describe the variables we employed to estimate and hypothesise on the sign *"a priori"* that they would assume after the analyses, and also describe the independent t test and tests of association conducted to explore the statistical differences.

3.2 Country Profile and Study Area

3.2.1 *Demographics*

Zambia is a landlocked country in Southern Africa, bordered by eight neighbours, namely the Democratic Republic of Congo to the north, Tanzania to the north-east, Malawi to the east, Mozambique, Zimbabwe, Botswana and Namibia to the south, and Angola to the west. The country is located between latitudes 8 and 18 degrees south and longitudes 22 and 34 east, and covers a total area of 752,612 (inclusive of the water bodies) square kilometres (CSO, 2013). The vegetation in Zambia mainly comprises savannah woodlands and grasslands, and the country has a tropical climate with three different seasons, which are classified as the cool and dry, hot and dry, and hot and wet seasons. In the last census in 2010, the population was estimated at 13.7 million, which is projected to grow to 17.9 million by 2020, and is forecast to double in 25 years' time (CSO, 2013). The rural population accounts for slightly over 60% (7,919,216) of the total population, whereas the urban population accounts for slightly below 40% (5,173,450). The gender distribution reflects 50.7% women and 49.3% men, with the youth comprising about 40% of the population (CSO, 2013).

3.2.2 *Agriculture*

Zambia's total land area is about 743,390 square kilometres (excluding water bodies) and agriculture accounts for about 238,360 (32%) square kilometres, while forestry accounts for about 491,348 (65.42%)

square kilometres (FAO, 2014). The agricultural sector in Zambia is mostly composed of smallholder farmers who rely on rain-fed agriculture for their livelihoods, and who constitute the largest employer, responsible for 60% of the labour force (Famine Early Warning Systems Network (FEWS NET), 2017). However, given the subsistence nature of the sector, it only contributed 8.5% to GDP in 2015 (World Bank, 2017; CSO, 2013).

Zambian farmers are classified according to three categories, smallholder, medium- and large-scale, based on the landholding of each. The smallholder farmers are the largest of the three categories (Focus of Study) and are further classified into categories (Categories A, B, C). Category A farmers have a landholding of zero to two hectares and mostly grow the staple maize for home consumption, with occasional extra production for the market; Category B farmers have a holding of between two and five hectares; and Category C farmers hold between five and 20 hectares. The medium- and large-scale farmers mostly produce for commercial purposes and have access to premium markets (FAO, 2014; IAPRI, 2016).

The agricultural sector's contribution to the Zambian economy is illustrated in Figure 1-1, which shows GDP contribution by sector over the period 2012–2017. Furthermore, it depicts how the agricultural sector relates with the broader economy. We noticed that in 2013 and 2015, agricultural contribution to the economy was negative, between 0 % and -4 %, implying that government subsidies to small-scale farmers may not have yielded positive results. The 2015 season also coincided with the drought year as a result of the *El Nino* phenomenon, which explains how the country struggled to cope. The year 2013, on the other hand, is a reflection of when we had domestic glut (supply exceeded demand), and failure by government to open the borders for exports by a slow deregulating of the market. This resulted in low commodity prices in the domestic market.

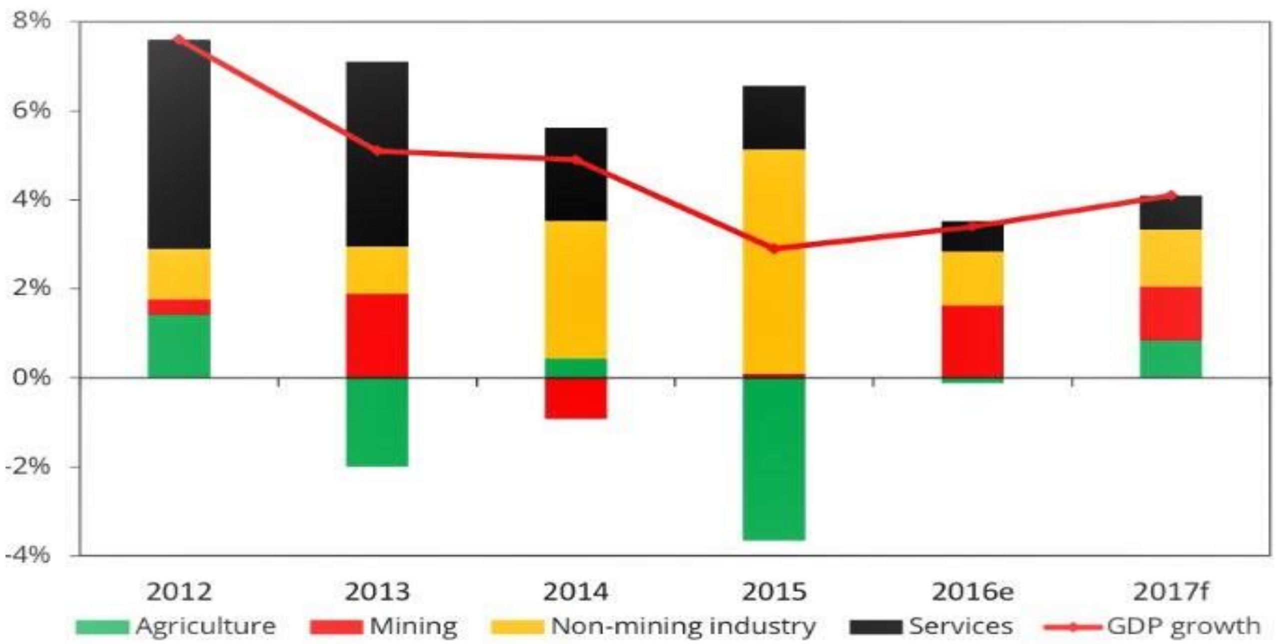

Figure 3–1: GDP Contribution by Sector

Source: CSO Zambia and Ministry of Finance (2016)

Zambia receives varying annual rainfall amounts across the country and this has been the basis upon which agro-ecological zones have been classified (Figure 1–2). Based on annual rainfall received, the country has three agro-ecological regions (I, II and III), with each having unique traits that support different cropping systems. Our study area falls under region III, and as such, farmers in that region face similar climatic conditions in terms of rainfall, temperature and the soil for their producing their crops.

Region I: This is found in the valley part of the country which includes the Southern, Eastern, and Western Provinces (Figure 1–2). The region receives rainfall amounts of less than 800 millimetres annually, and this region is humid and hot owing to its low altitude (Somanje, 2015; Agregheore, 2009; MACO, 2004). The common crops grown in this region are cotton, sorghum, millet, sesame and cashew nuts (IAPRI, 2016).

Region II**:** This region receives annual rainfall of about 800 to 1000 millimetres, which is evenly distributed over the rainy season. It is further subdivided into Region IIa and Region IIb, with Region IIb having a fairly unproductive soils that are loamy and sandy. Common crops grown are cassava, sorghum, millet, sesame, and cashew nuts (IAPRI, 2016). Region IIa[10] on the other hand, is characterised by inherently fertile

10 This region stands out as an agricultural belt owing to the fact that it has the richest soils that support a variety of crops and this is where most commercial farmers are located.

plateau soils, and supports crops such as maize, cotton, cassava, sunflower, soybeans, irrigated wheat[11], groundnuts, flowers, paprika, vegetables, cassava, millet and horticulture (MACO, 2004).

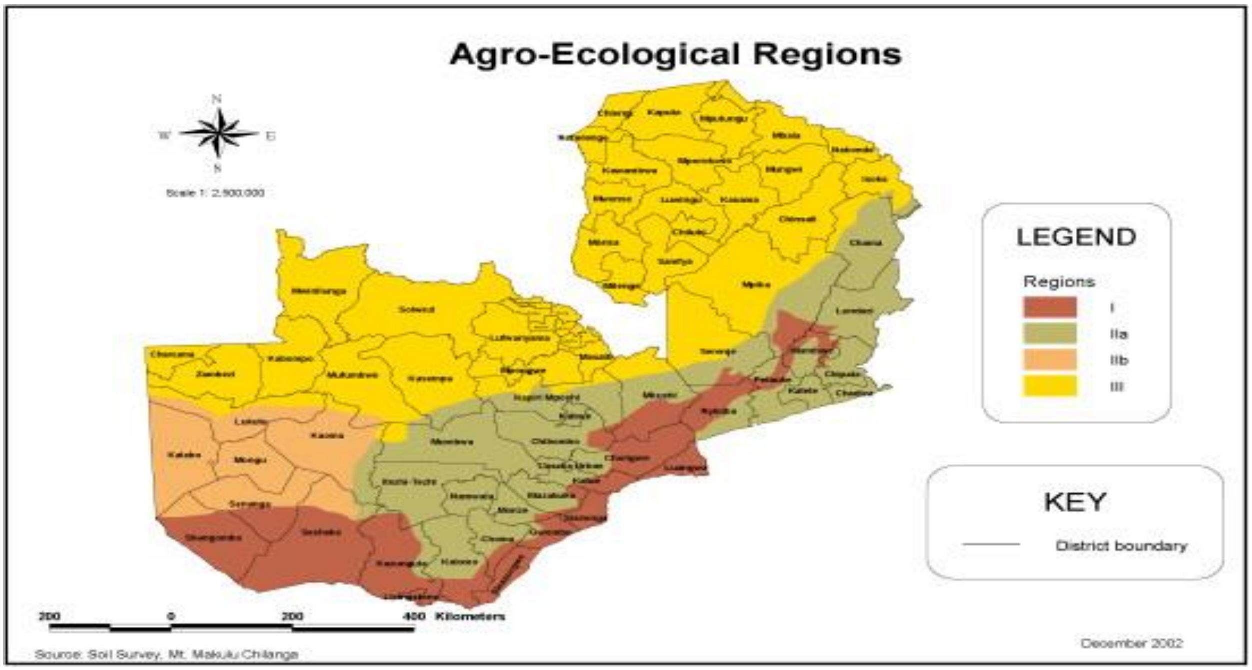

Figure 3–2: Agro Ecological Regions of Zambia

Source : Soil Survey, Mt Makulu, Chilanga 2002

Region III is located in the northern and north-western parts of the country (Figure 1–2), receiving an annual rainfall over 1000 millimetres, and covers the largest portion of the country, amounting to 46% of total land area (Somanje, 2015; Agregheore, 2009; MACO, 2004). Due to the long rains that the region receives, the soils are very deep (leached) and are sandy clay soils. It is recommended in this region that farmers plant late-maturing varieties for the crops they intend to grow. The common crops grown in the region are rice, pineapples, sugarcane, maize, coffee, tea, cassava, millet and groundnuts (IAPRI, 2016; Somanje, 2015).

3.3 Study Area

The data used in this study is secondary data and is cross-sectional in nature. The dataset comprised data collected during the 2016 farming season in the Northern Province of Zambia's Mungwi, Mbala and Kasama Districts (see Figure 3–1). The household survey was conducted by Elisil Environmental

11 Irrigated wheat is mostly grown by commercial farmers for export.

Consulting on behalf of TLC under the sponsorship of IFAD. The overall objective of the baseline was to collect, analyze and interpret data and information related to socio-economic parameters at the household level in the randomly sampled households of the target area, covering 182 households. The household survey employed a two-stage stratified sample design. In the first stage, a Primary Sampling Unit (PSU) was identified, and one agricultural camp was randomly selected from each agricultural block (consisting of two agricultural camps per district) where the project targets are working. For the second stage (at agricultural camp level), a target of 30 households (representing a Standard Enumeration Area (SEA)) per agricultural camp was randomly identified and interviewed. Of the three Districts, Mbala and Mungwi contributed 60 households each and Kasama contributed 62 households, bringing the total of households to 182. In Zambia, the Districts are divided into agricultural blocks and within those blocks we find agricultural camps which are made up of SEAs (CSO, 2013).

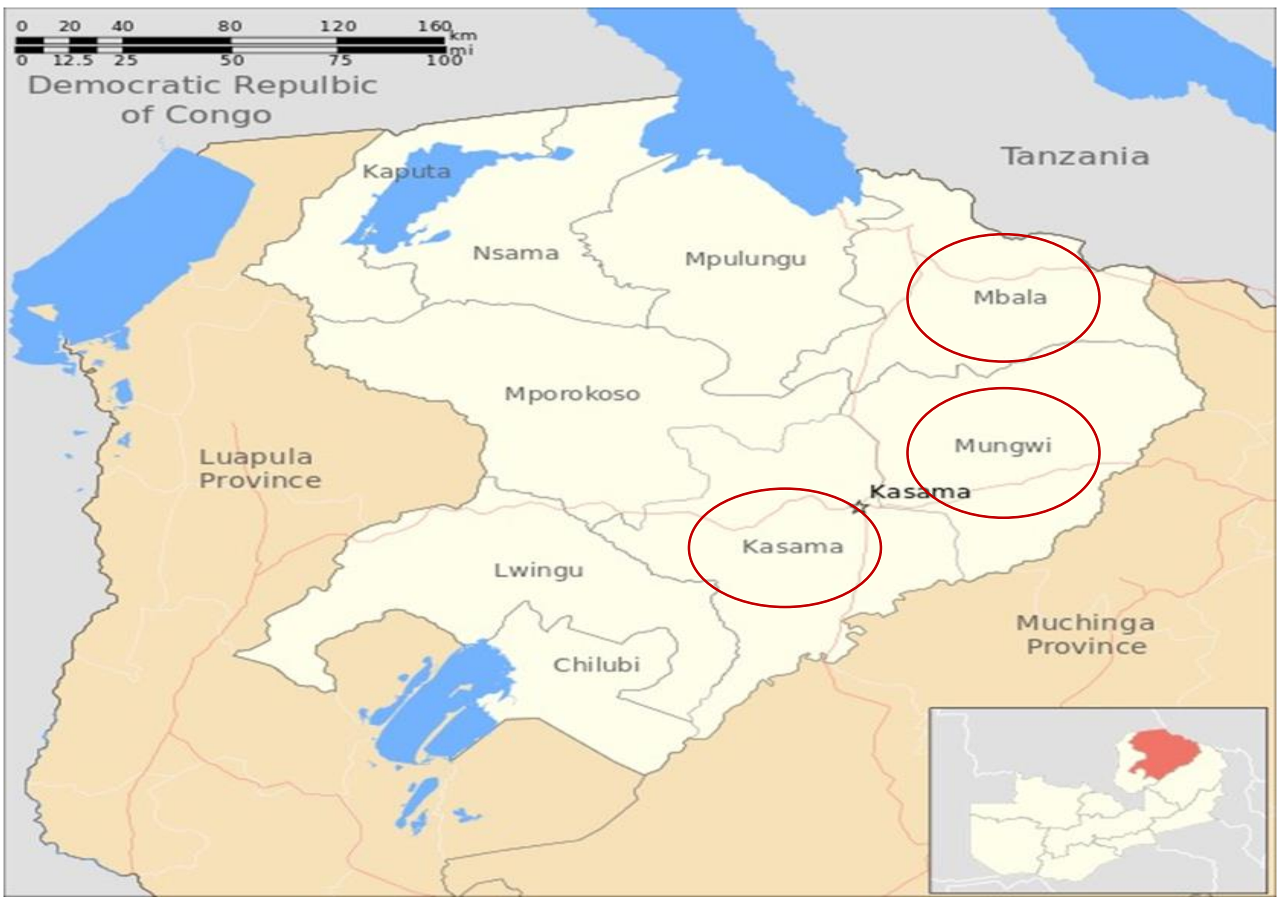

Figure 3–3: Northern Province of Zambia Districts

Source: Mellon Dor (2015)

3.4 Analytical framework

In the study model, the adoption variables are dichotomous variables which assume the values of "1" if the household is an *adopter* and the value "0" if it is a *non-adopter*. In this survey, an adopter is defined as someone who had practised crop rotation and/or had an efficient stove in the homestead during the 2015/16 farming season (TLC, 2017). In the studies of adoption, we come upon various methods which include static models, dynamic models, and a hybrid of the two models (Abera, 2008). The static model examines farmers' decisions to adopt an improved technology at a particular point in time, whereas the dynamic model assesses the adoption behaviour or intensity of adoption, over time. Further, literature specifically shows that the classical logit, probit and Tobit models are the underlying foundations upon which other models have been developed to study adoption of technologies. This has been followed by the application of other models, of which the Recursive Bivariate Probit Model (RBPM) is such a one (Namonje and Chapoto, 2016; Awotide et al., 2016; Ng'ombe et al., 2014; Ngoma et al., 2014; Jourdain et al., 2017).

This study endeavoured to capture the factors that influence the adoption of CSA technologies among rural farm households, and further examine some differences in adoption behaviour between young farmers and the older farmers. The model that best meets the needs of the study in this line of enquiry is the Recursive Bivariate Probit Model (RBPM), for the reason that it gives us the benefits of accounting for some potential biases that we may encounter under programme[12] evaluation (Jourdain et al., 2017). Firstly, possible bias arises from the design of the IFAD programme, where only project beneficiaries are included in the sample, with the implication being that these beneficiaries would have a high probability of adopting these technologies (non-random). Secondly, beneficiaries listed in the programme are most likely those who had been identified with the "inherent" abilities to adopt and perform better on projects (Self-selection). This model is further preferred as it has not been modelled before on these two particular CSA technologies in the study area, i.e. the Northern Province of Zambia.

The study employed two models to capture the analysis, based on two types of CSA technologies, namely crop rotation and the efficient cooking stove. The first model assesses the mitigation aspects using the efficient cooking stove as the dependent variable, regressed against various independent variables. The second model assesses the adaptation part of the CSA technology using crop rotation as our dependent variable, and regresses it against various independent variables. At the end of the process, we expect to identify factors that strongly influence the decision to adopt the crop rotation practice, and similarly identify factors that influence the decision to adopt the efficient stove.

12 The study focuses on IFAD/S3P sponsored smallholder farmers in the Northern Province.

To test the two hypotheses postulated, we employed the Spearman test for the first hypothesis which states that crop rotation and efficient stove are independently adopted. We run the test on our sample of respondents with the aim of drawing a conclusion as to whether differences exist between crop rotation adopters and efficient stove adopters. The objective is to investigate, at the minimum, if household's adoption decisions of CSA technologies are related and considered by them as climate smart technologies. The test's null hypothesis is that crop rotation and efficient stove are independently adopted. For the second hypotheses, testing if differences exist between young and old farmers in the adoption of the crop rotation and efficient stove technologies. We execute an independent test with unequal variances. We individually test age against the two technologies.

3.5 Modelling strategy

In a bid to identify factors that influence the adoption of CSA technologies (i.e. crop rotation and/or efficient cooking stove), the RBPM design was applied as specified by Jourdain et al. (2017). This choice of the model is motivated by Fillipini et al. (2017) who contend that a zero Bivariate Probit (BP) correlation parameter is not a mechanism that always implies independence of the binary variables under analysis. This aspect is important, as we expect a considerable possibility exists that the farmers who opt to adopt and use an efficient cooking stove and/or crop rotation technology might be influenced by their participation in a demonstration trial (Exposure). For example, Jourdain et al. (2017) found that having received prior training that would directly influence the decision to adopt a design promoted by the programme. The RBPM thus provides a tool for estimating the effect of an endogenous binary regressor on a binary outcome variable (i.e. whether a farmer adopted a cooking stove or not, or whether a farmer adopted the crop rotation practice or not) and has a separable error structure with a prescribed distributional form (Li et al., 2016).

The RBPM has been increasingly applied to study adoption models in many different economic sectors, such as agriculture, health, labour law and transport (Fillipini et al., 2017; Monfardini and Radice, 2008; Li et al., 2016). Ideally, the RBPM focuses on the endogeneity problem, where we test the correlation coefficient and an endogenous dummy coefficient in determining if biases are present. In the model estimation approach used in this study, when we execute the RBPM and get an insignificant rho parameter, this informs us that we need not correct for sample selection and further, the model collapses or is simplified to a univariate classical probit model for the outcome of interest (see Greene, 2003; Monfardini and Radice, 2008). With such a conclusion, we can be confident that our parameters are consistent and a true reflection of the population from which the sample was derived. In essence, Bivariate Probit Models (BPM) which are estimated on RBPM data can potentially deliver a zero correlation parameter, which would thus erroneously be interpreted as evidence of independence between the two outcomes, when in fact there is not. When the BPM correlation parameter is zero, testing with the RBPM gives us the opportunity to check for consistency in our results (Fillipini et al., 2017).

3.5.1 Model *O*ne – Cook*ing* stove adoption

Model One presents the recursive structure for the cooking stove, as presented in Equations (1) and (2).

$$\boldsymbol{Y_{1i}^{*} = \beta_1' X_{1i} + u_1 : Y_{1i} = 1 \ if \ Y_{1i}^{*} > 0 , Y_{1i} = 0 \ otherwise} \qquad (1)$$

$$\boldsymbol{Y_{2i}^{*} = \delta Y_{1i} + \beta_2' X_{2i} + v_{2i} : Y_{2i} = 1 \ if \ Y_{2i}^{*} > 0 \ Y_{2i} = 0 \ otherwise} \qquad (2)$$

where *i* is the *ith* observation in the sample, *Y** are the latent continuous variables for which only the binary variables ***Y*** (those who adopted and those who did not) are observable.

$\boldsymbol{Y_{1i}^{*} \ is \ the \ outcome \ variable \ for \ use \ of \ cook \ stove}$ $(\boldsymbol{1 - yes \ and \ 0 - otherwise})$

$\boldsymbol{Y_{2i}^{*} \ is \ the \ outcome \ variable \ for \ GAPdemo}$ $(\boldsymbol{1 - yes \ and \ 0 - otherwise})$

X represents the vectors of independent variable whose effect we try to investigate on the two outcome variables, viz. **Demonstration trial** and **Use of cook stove**. The vectors of the error terms for each of the Equations (1) and (2) are represented by *u* and *v*, respectively.

3.5.2 Model *T*wo – Adoption of crop rotation

Model Two presents the recursive structure for CR, as follows:

$$\boldsymbol{Y_{1i}^{*} = \beta_1' X_{1i} + u_1 : Y_{1i} = 1 \ if \ Y_{1i}^{*} > 0 , Y_{1i} = 0 \ otherwise} \qquad (3)$$

$$\boldsymbol{Y_{2i}^{*} = \delta Y_{1i} + \beta_2' X_{2i} + v_{2i} : Y_{2i} = 1 \ if \ Y_{2i}^{*} > 0 \ Y_{2i} = 0 \ otherwise} \qquad (4)$$

where *i* is the *ith* observation in the sample, *Y** are the latent continuous variables for which only the binary variables ***Y (***those who adopted and those who did not) are observable.

$$Y_{1i}^{*}\ is\ the\ outcome\ variable\ for\ practicing\ CR\ (\mathbf{1}-yes\ and\ \mathbf{0}-otherwise)$$

$$Y_{2i}^{*}\ is\ the\ outcome\ variable\ for\ GAPdemo\ (\mathbf{1}-yes\ and\ \mathbf{0}-otherwise)$$

$\boldsymbol{X}$ represents the vectors of independent variable whose effect we try to investigate on the two outcome variables, viz. **Demonstration trial** and **Practicing Crop Rotation.** The vectors of the error terms for each of the Equations (3) and (4) are represented by *u* and *v*, respectively.

3.6 Description of variables

Table 3–1 summarises the variables that the study employed to investigate the factors that influence farmer decisions in the adoption of CSA technologies. The table further postulates on the expected sign based on priori expectations on the outcome variables. In most adoption studies, results have indicated that market information (Market Info), climate change awareness (CC Aware) and farmer groups (Agric Group) would all positively influence the decision to adopt a technology (Haggblade and Tembo, 2003; Ng'ombe et al., 2014; Awotide et al., 2016; Ngoma et al., 2014; Kuntashula et al., 2014). The variables household size (Household size) and age of the house hold head (HHage) would influence the decision to adopt in a negative manner, depending on how the technology is perceived by the decision-maker to affect their livelihood (Nyasimi et al., 2017). The table below reflects the potential impacts of the independent variables on the outcomes of the two CSAs (i.e. Crop rotation and efficient stove) under investigation.

Table 3–1: Description of variables in the study models

Variable Code	Description	Efficient stove	Crop rotation
GAP	Whether the household practises and/or hosts Good Agriculture Practices demonstration trials: 1 if farmer is hosting/participating in GAP demo trial, and 0 otherwise.	-	-
Age	Age of the household head measured in years.	+/-	+/-
Square Age	The square of the household head age	-	-
Household size	Size of the household (number of occupants living in house).	-	-
Gender	Captures data of the gender of the household head; 1 – if the household head is male, and 0 otherwise.	+	+
Market Info	Captures data if household receives regular information about the market, especially pricing data. Measured as a binary variable: 1 – if they do receive and 0 – otherwise	+	+
CC Awareness	Whether farmer is aware about the impact of Climate Change and its consequences. The variable is measured as a binary: 1 – if the farmer is aware and 0 – otherwise.	+	+
Agric Group	Whether farmer belongs to a farmer group. The variable is measured as a binary: 1 – if the farmer is aware and 0 – otherwise	+	+
Legumes	Whether household grew groundnuts in the 2015/16 farming season; 1 – yes and 0 – otherwise	.	+
Total income	Total household income in natural logarithm form	+	+
Dist1	Kasama District dummy, 1 – if Kasama District and 0 – otherwise	+	+
Dist2	Mungwi District dummy, 1– if Mungwi District and 0 – otherwise	+	+
Dist3	Mbala District dummy, 1 – if Mbala District and 0 – otherwise	+/-	+/-

Source: Adapted from Jourdain et al., 2017 and Nyasimi et al., 2017

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results of the analyses are presented and a detailed discussion is presented. The following section presents the descriptive statistics of the surveyed households. The third section discusses the results of the first objective, were we performed various statistical tests to identify existing differences in the adoption decisions of the surveyed households. The fourth section of the chapter presents results of the Recursive Bivariate Probit Model (RBPM) employed to identify factors that influence the adoption of crop rotation technology as an adaptation measure, and the efficient cooking stove as a mitigating measure to climate change. And finally, in the last section, we analyse the study hypotheses which explored the associational tests of crop rotation and efficient cooking stove adoption.

4.2 Descriptive statistics

Table 4 – 1 presents the sample descriptive statistics. It shows that the average age of the household head among the respondents is slightly above 46 years. Just over 21% of the households are youth headed and the gender distribution is almost equally distributed, with 49% of these households being female-headed households. The average household size in the study area was found to be six persons, with the distribution ranging from one to 13 persons, and this average was similar across the districts[13] in the province, viz. Kasama, Mungwi and Mbala. Other studies have found similar household average sizes (Agriculture Support Programme, 2004). In many literature sources, household size has been used as an indication for available labour, especially for agricultural-oriented rural households (FAO, 2004).

The mean household income of the survey respondents, converted[14] to the dollar from kwacha, was approximately USD 378.00 and ranged from USD 7.00 to USD 2,616.00.

13 See Table 3–1 in Chapter 3
14 Using the Exchange Rate, USD 1 – ZMW 9.80 (2016 exchange rate)

Table 4–1: Descriptive statistics of beneficiary households

Variables	Number of Observations	Mean	Standard deviation	Minimum	Maximum
Technology Adopted					
Crop rotation	182	0.64	-	-	-
Efficient stove	182	0.35	-	-	-
Independent variables					
Age	182	46.16	14.00	21	93
Household size	182	6.36	2.44	1	13
Gender	182	0.50	-	-	-
Total income (ZMK) logged	182	6.65	2.80	0	10.71
CC Awareness	182	0.55	-	-	-
Legumes	182	0.65	-	-	-
GAPs	182	0.45	-	-	-
Market Info	182	0.69	-	-	-
Dist1	182	0.34	-	-	-
Dist2	182	0.33	-	-	-
Dist3	182	0.33	-	-	-

Source: Authors' own computation from TLC baseline data

Regarding formal education (Figure 4–1), 92% of the respondents indicated having attended some form of formal schooling and more specifically, 52 % of those who indicated having been to some school had received primary education. Furthermore, 40% of those mentioned having received some level of secondary education, and just slightly over 1% indicated that they had received tertiary education.

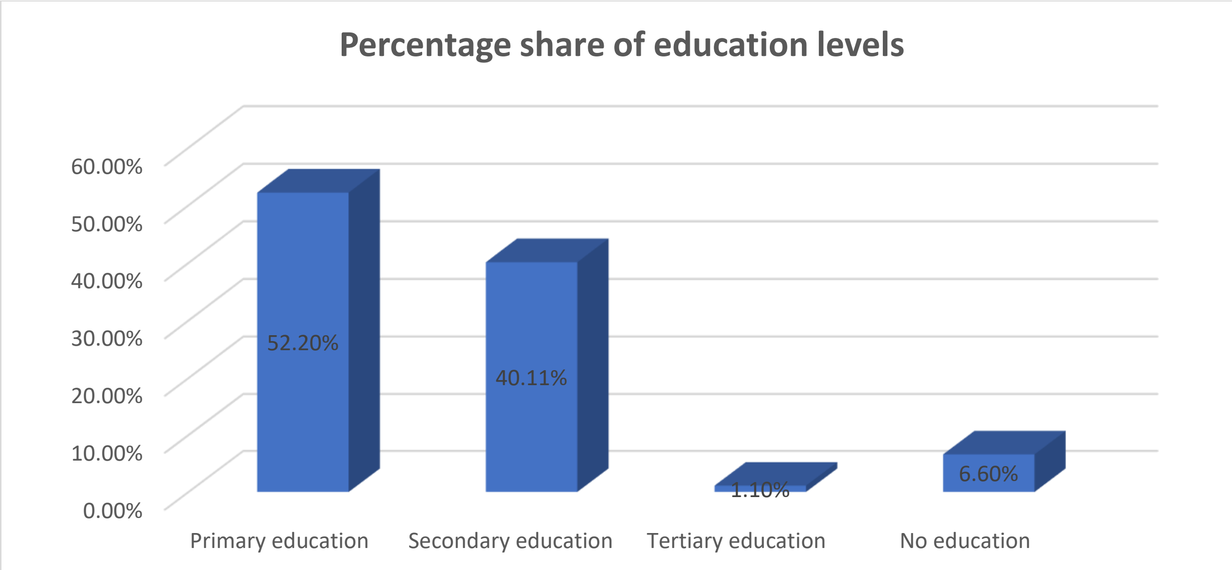

Figure 4–1: Education distribution amongst the respondents

Source: Author's own construct from TLC baseline data

Table 4–1 further reflects that 55% of the respondents indicated that they are affected by and aware about climate change, and are employing various remedial measures to deal with climate change. Some of the measures employed by the smallholder farmers include crop rotation and/or intercropping with legumes[15], residual retention , early planting, using improved hybrid seed, and adopting new farming practices, as similarly reported by Manda et al. (2016).

The analysis also reveals that 75% of the surveyed households declared that they belonged to some agricultural group that served many purposes in fostering agricultural development. The group purposes included dealing with general agriculture issues, farming, and access to credit and loans. Figure 4–2 summarises the percentages of farmers who had joined an agriculture group for different purposes. The results suggest that the major purpose for joining a group was for farming purposes (61%), followed by general agriculture issues (26%), and credit and loans (11%). From the FGDs conducted in the study area, we noticed that a considerable number of agriculture groups had been formed that aided in the dissemination of technologies to various respondents in the project catchment areas.

15 For crop rotation and intercropping to be effective as adaptation measures, smallholder farmers need to rotate and/or intercrop with legumes. The nitrogen-fixating legumes provide nutrients for the cereals simultaneously in an intercrop scenario or improve the soil structure and fertility for the cereal in a rotation. See Table 1–1.

The descriptive statistics further revealed that 65% of the surveyed households grew groundnuts as a leguminous crop. The sample composition further showed that each of the districts, Kasama, Mungwi and Mbala, provided approximately one-third of the sampled households.

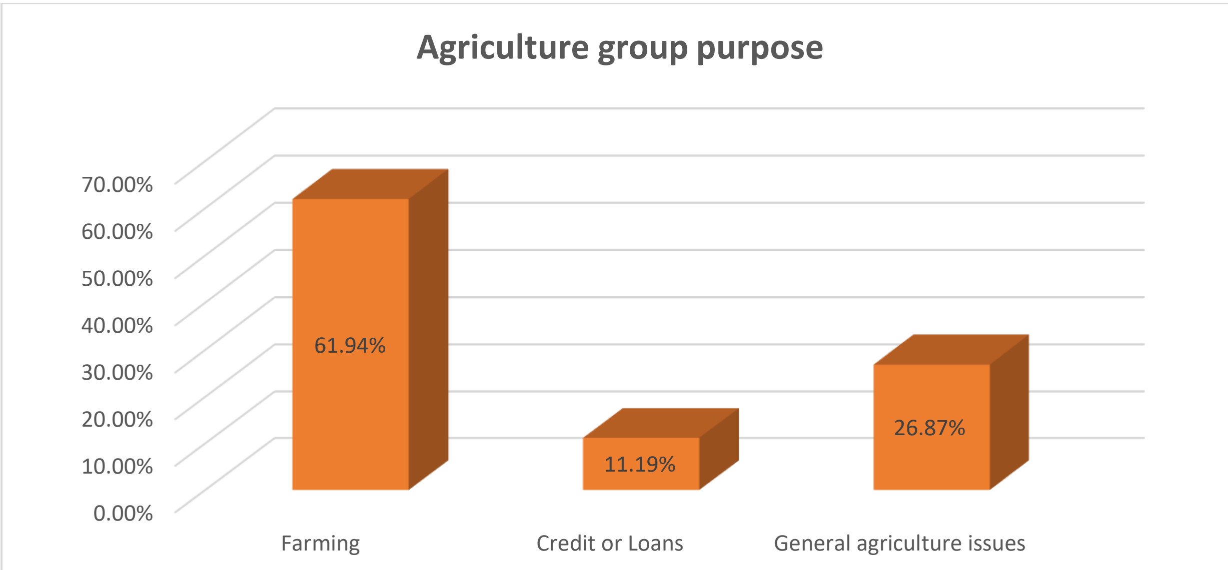

Figure 4–2: Agriculture group composition

Source: Author's own construct from TLC baseline data

4.2.1 Overview of adoption rates

Regarding the adoption of the CSA technologies, the table indicates that about 64% and 35% of the surveyed households had adopted crop rotation and the efficient cook stove, respectively, at the time of the baseline survey. Results from the data show that very few (only 2.6%) of the respondents had adopted the entire conservation agriculture package[16] summary statistics, and this has been the general trend across the country, as similarly reported by Arslan et al. (2015). An indication of this development is that farmers seem to be selecting technologies that suit their needs at that given point in time, and leaving out other technologies that are available in the package.

From the household survey results, we found that Kasama, Mbala and Mungwi Districts reflected crop rotation adoption rates of 70%, 57% and 67%, respectively. For the efficient cooking stove, the rates were 55% for Kasama, 20% for Mbala, and 30% for Mungwi. With Kasama being the provincial capital, the

16 See Figure 4–3 regarding adoption rates of CSA technologies that are promoted in the Northern Province of Zambia

promotion of the technology might be more vigorously undertaken, as compared with the Mungwi and Mbala Districts that are further away from the provincial capital. Hence, this might explain the observed higher rates of adoption. Figure 4–3 summarises the rates of adoption of the various CSA technologies being promoted in Northern Province: crop rotation, composite fertiliser, minimum tillage, residual retention, liming, and efficient cooking stove use, and also records the rate of the conservation agriculture package adoption. Looking at the figure, we clearly notice that crop rotation and the efficient stove stand out as the technologies being utilised by the farmers.

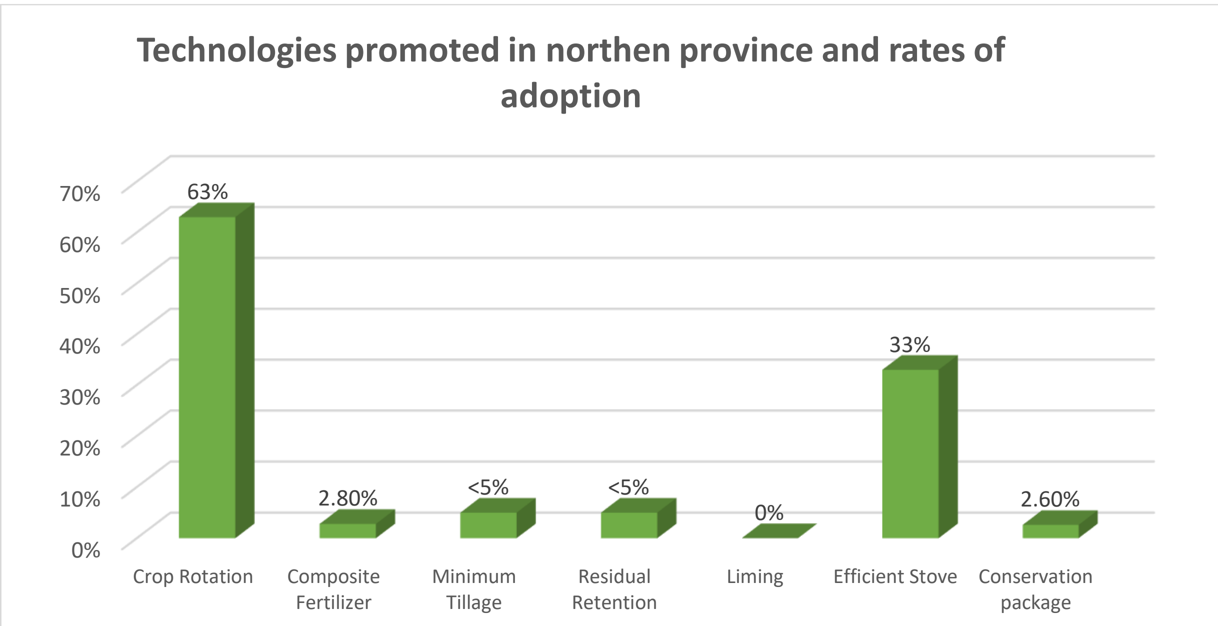

Figure 4–3: Adoption rates of CSA land management practices promoted in Northern Province

Source: Author's own construct from TLC baseline survey report 2017

Some 68% of the respondents had access to market information, which had helped them trade the occasional surplus (usually the staple maize) on the market. From the KII and FGDs interviews, it was noted that the major buyer of the staple maize is the Food Reserve Agency (FRA), a government parastatal tasked with purchasing maize to maintain a secure store of the staple as a food security measure for the nation. However, it was also revealed from the discussions that private buyers ('briefcase buyers') are also prevalent in the Northern Province, and are known for buying at low prices that are unreflective of the prevailing market prices that are usually set by the government each year.

A further marketing challenge faced by smallholder farmers is one involving market linkages, poor road infrastructure, and lack of proper off-road vehicles, all of which prevent timely access to markets, and those transporters who operate in these areas charge exorbitant transportation fees to move farmer produce. From the KII, access to market information is considered ineffective, to some extent, because the challenges prevailing may supersede the anticipated gains, even when market prices are good.

4.3 Examining the statistical differences

This section presents the statistical results that reveal certain disparities between adopters and non-adopters of the CSA technologies under investigation, i.e. crop rotation and the efficient cooking stove. Further gaps explored are those ascertained in a gendered analysis as it pertains to incomes, and how household size varies between the CSA technologies (used as a proxy for labour availability).

4.3.1 Independent t-tests

An independent t-test was run on a sample of 182 respondents to determine if there were differences in total household incomes based on the gender of the household head, i.e. female-headed versus male-headed households. Both groups consisted of 91 randomly assigned participants. The results showed that female respondents had statistically significantly lower incomes (6.102+/- 0.320) at the time the data was captured, as compared with their male counterparts (7.190+/- 0.253), $t(180) = -2.673$, $p = 0.0082$. These results show the income disparities that exist between the male- and female-headed households, and the figure below graphically shows the differences in a box plot.

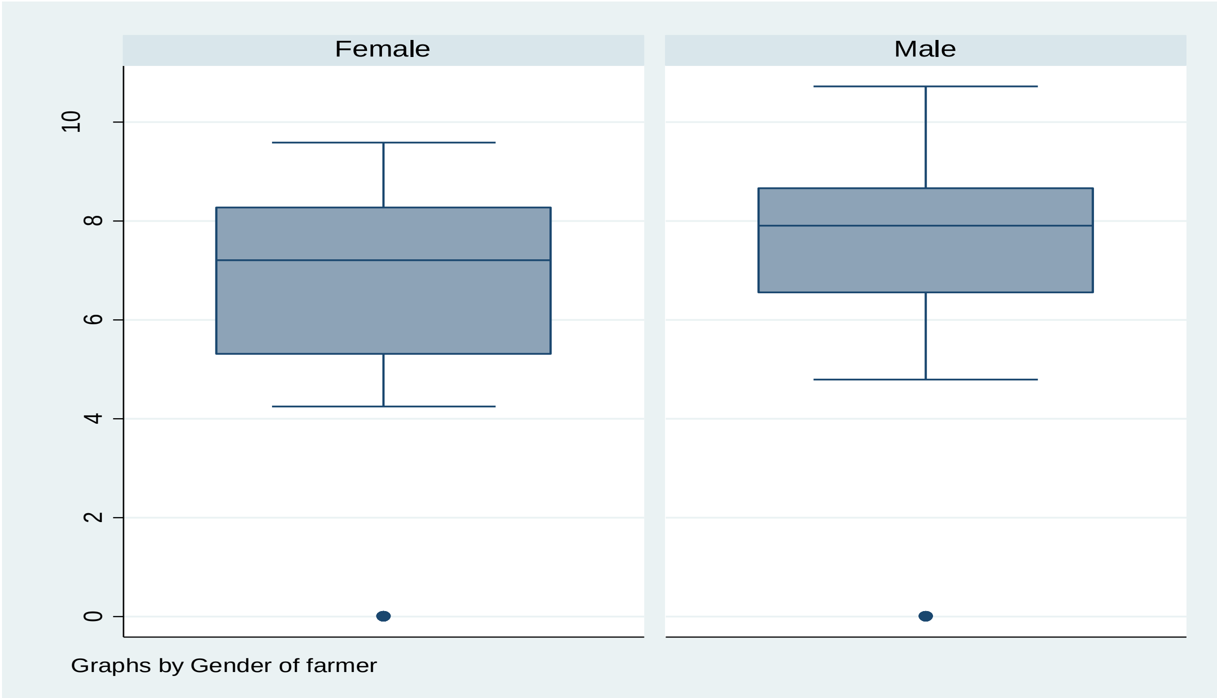

Figure 4–4: Income disparities by gender

Source: Author's own computational analysis from TLC baseline data

Another t-test with unequal[17] variances was run on a sample of 181 respondents to determine and ascertain if there were differences in yield output of maize, based on adopters and non-adopters of crop rotation. In the adopters' group, we had 117 participants, whereas the non-adopters had 64 participants. The results showed that adopters of crop rotation had a statistically significant higher maize output (7.168+/- 0.093) at the time the data was collected, as compared with the non-adopters of crop rotation (6.700+/- 0.141), *t (92.819)* = -2.763, *p* = 0.007. The results show the significant productivity-improving value of practising crop rotation, as similarly reported by (Ng'ombe et al., 2017). Figure 4–5 summarises the box plot results, showing the error bars and the average maize yield in each group. The potential outliers are also shown and excluded as displayed.

17 Levene's test for equal variances failed, which is a key assumption for an independent t test; hence, to control for it, we employed the unequal variances t test.

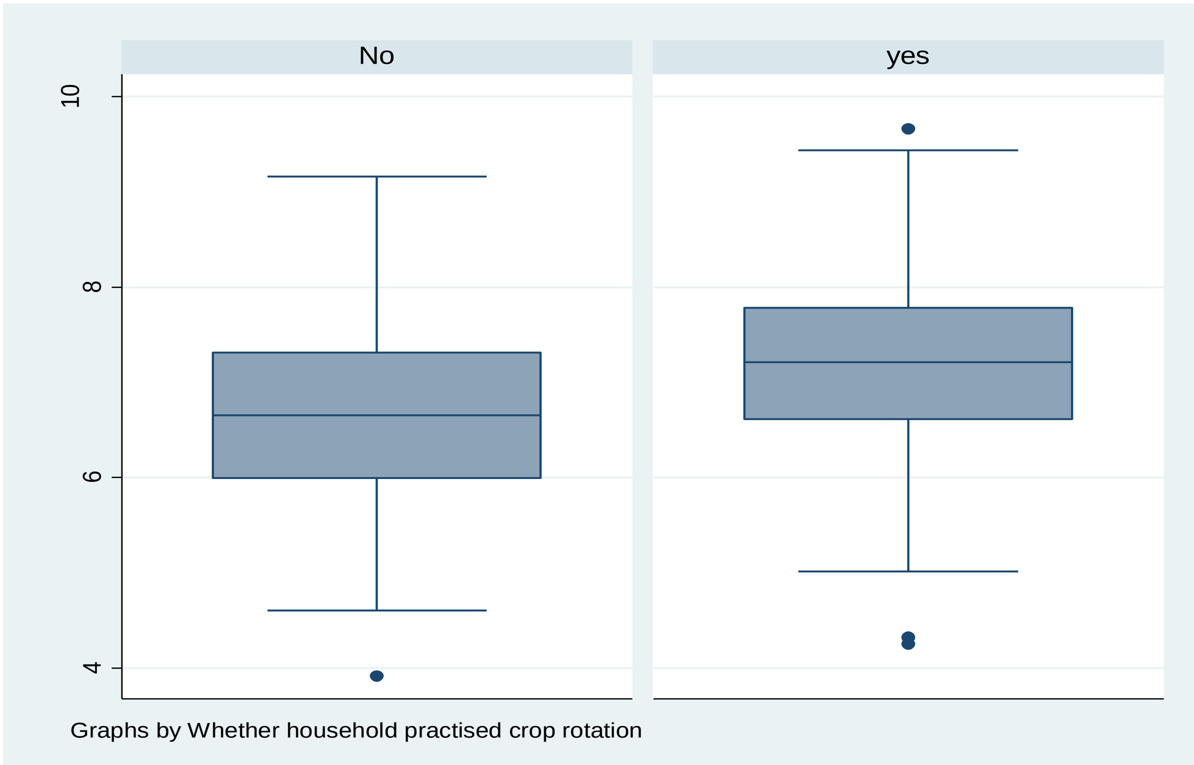

Figure 4–5: Maize yield by practicing crop rotation

Source: Authors own computational analysis from TLC baseline data

A further unequal variances t test was conducted to ascertain whether differences existed in household size between the two age groups, i.e. youth and seasoned farmer-headed households. The youth-headed group consisted of 38 randomly selected participants and the seasoned-farmer households comprised 140 randomly selected participants. The results showed that youth-headed homes had statistically lower household sizes (5.184+/- 0.250) at the time of the survey data capture, as compared with the seasoned-farmer headed households (6.714+/- 0.214), *t (98.88) = 4.766, p = 0.000.* These findings show the labour disparities among respondents' households that exist with respect to household labour availability, where household size is used as a proxy for labour availability (see FAO, 2004). The implication of this well-known aspect is that labour-intensive technologies will be appealing mostly to respondents with larger households, as compared with those with lower household family sizes.

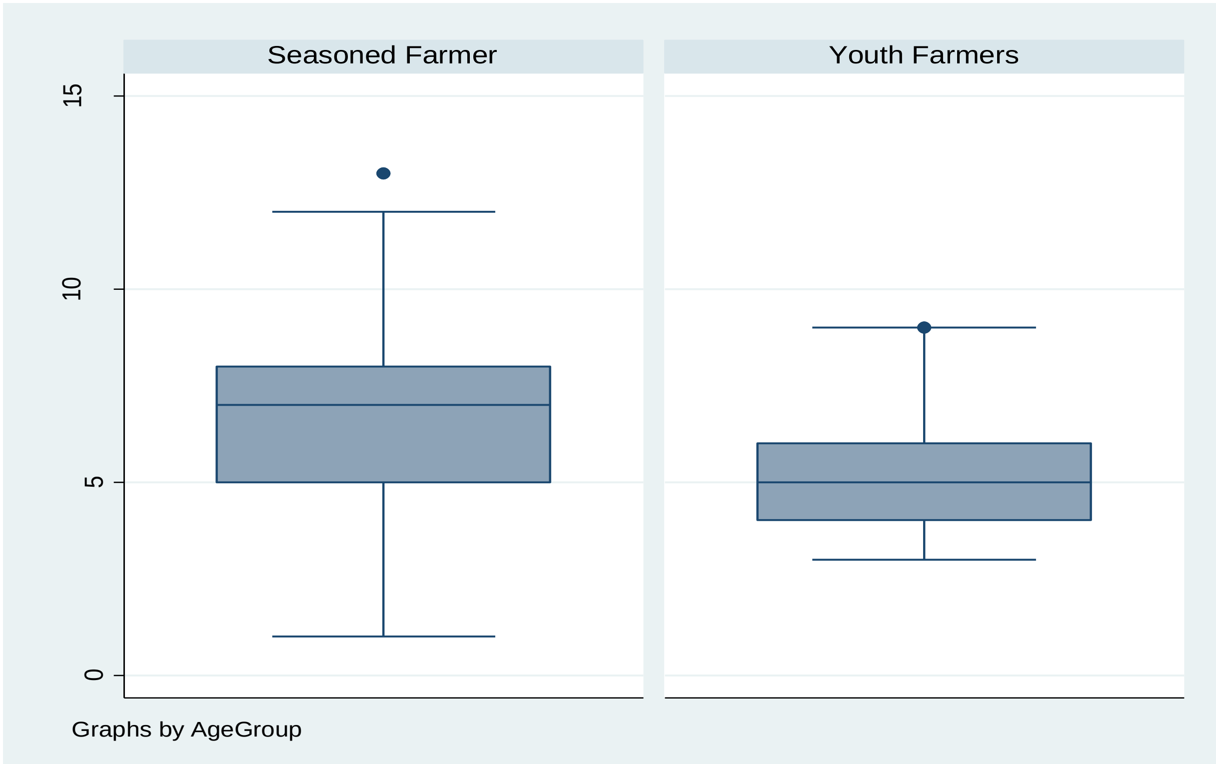

Figure 4–6: Household size by age group of farmer

Source: Author's own computational analysis from TLC baseline data

4.3.2 Tests of associations

First, we tested the association between practising crop rotation and belonging to an agricultural group. The null hypothesis in this test is that there is no significant difference between adopters and non-adopters of crop rotation in their choices for being members of an agricultural group. The test results are presented in Table 4–2. The Fisher's exact statistic is significant at 1%, which requires us to reject the null and instead hypothesise that differences do indeed exist. This suggests that that farmers who practised crop rotation are more likely to be members of an agricultural group.

Table 4–2: Test of association between crop rotation and agricultural groups

Whether household practiced crop rotation	**Whether household belongs to an agricultural group**		
	No	*Yes*	*Total*
No	27	38	65
Yes	18	99	117
Total	45	137	182
Pearson chi2(1) =	15.35	Pr =	0.00
Likelihood-ratio chi2(1) =	14.88	Pr =	0.00
Fisher's exact =			0.00
1 – sided fisher's exact =			0.00

Source: Author's own computational analysis from TLC baseline data

Another test of association between climate change awareness and its consequences and crop rotation adoption. the null hypothesis that climate change awareness has no impact on the decision to adopt crop rotation. The implication here is that farmers, in a way, farmers' decision to adopt a crop rotation is in not related to knowledge about climate change and its consequences. The results are significant at 1% level, and thus we reject. See Table 4–3 for the summary results of the test of association between climate change awareness and crop rotation adoption.

Table 4–3: Test of association between climate change awareness and crop rotation

Whether household is aware of climate change and its consequences	Whether household practiced crop rotation		
	No	*Yes*	*Total*
No	41	40	81
Yes	24	77	101
Total	65	117	182
Pearson chi2(1) =	14.12	Pr =	~0.00
Likelihood – ratio chi2(1) =	14.20	Pr =	~0.00
Fisher's exact =			~0.00
1 – sided Fisher's exact =			~0.00

Source: Author's own computational analysis from TLC baseline data

4.4 Factors related to adoption

This section presents and discusses the econometric results of the analysis performed to determine the factors that are related to the adoption of the efficient cooking stove and crop rotation practice. We employed a Recursive Bivariate Probit model (RBPM) for both technologies.

4.4.1 Factors influencing the adoption of the efficient stove

In the model equation, we could not reject the null hypothesis of no correlation. This suggests that there was no endogeneity bias. Table 4–4 presents the maximum likelihood estimates derived from a RBPM of the factors that are related with the adoption of the efficient cooking stove. The model chi square, which measures the goodness of fit of the model, was significant at 1% level, implying that the variables are related to the adoption. The correlation rho parameter is non-significant, indicating little to no correlation between unobserved factors affecting a decision to adopt the efficient cooking stove and the farmers' decision to participate/host a demonstration trial (Fillipini et al., 2017; Greene, 2003).

Results from Table 4–4 show that GAPs farmer participation is negatively and statistically significantly related to the adoption behaviour regarding the efficient cooking stove. This is an indication that some of the respondents are unwilling to adopt the efficient stove, showing that they are drawing much-preferred utility from the current cooking mechanism than would be provided by the alternative.

The household-head age coefficient is strongly positive and significant, showing that older or seasoned farmers are more likely to adopt the efficient stoves than the younger ones are, holding other factors constant. Islam et al. (2012) found similar age effects, where older farmers, and hence experienced farmers, readily adopted new technologies. This is quite contrary to our earlier a priori expectation, where we contended that younger farmers (youths) are more likely to adopt new technology, based on the findings of Danso-Abbeam et al. (2017) that older and experienced farmers were reluctant to adopt new innovations, and rather preferred their old practices.

Table 4–4: Recursive Bivariate Probit Model estimates for the adoption of the efficient stove

VARIABLES	Efficient Cook Stove	Selection Equation
GAPs Demos, 1 – Yes	-1.59***	-
	(0.17)	-
Age	0.10**	-
	(0.05)	-
Square Age	-0.0012**	-
	(0.00052)	-
Agric Group, 1 – Yes	0.66**	0.98***
	(0.26)	(0.28)
Gender, 1 – Male	0.012	-
	(0.18)	-
Household size	0.095**	0.12**
	(0.046)	(0.05)
CC Awareness, 1 – Yes	0.54**	0.14
	(0.24)	(0.24)
Total income logged	0.018	0.0011
	(0.043)	(0.04)
	(0.046)	(0.05)
Dist1 dummy, 1 – Kasama	0.72***	-
	(0.19)	-
Dist2 dummy, 1 – Mungwi	0.44***	-
	(0.17)	-
Constant	-3.43***	-1.57***
	(1.06)	(0.48)
/athrho	11.26	-
	(45.57)	-
Rho	1	-
	(~0.000)	-
Observations	*156*	*156*
Wald chi2(14)	120.42***	-
Log Pseudo - likelihood	-172.56	-
Wald test Rho = 0 : chi2(1) = 0.061		*Pro > chi2 = 0.805*

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's own computational analysis from TLC baseline data

Interestingly, the results from the square of the household age was negative and significant, indicating that, at a certain age, older farmers will not be keen to adopt the efficient stove, possibly signalling the later stages of normal life where respondents are no longer economically active, or a decline in active participation in development programmes owing to old age. This negative quadratic relationship has been reported in many studies on agriculture productivity (See Okoye et al., 2016; Koirala et al., 2015; Ogunyi et al., 2013). This outcome is attributed to many compounding factors, which have included resource constraints such as hired labour and available inputs. Younger farmers tend to be less financially endowed, which limits their purchase power and thus affects their agriculture productivity. On the other hand, the older farmers are usually risk intolerant regarding the adoption of new and progressive technologies (Kloss and Petrick, 2014).

The likelihood of adopting the efficient stove, among the beneficiaries, increased where one was a member of an agricultural group, when compared with non-members, which group served various purposes as presented in the previous section on descriptive statistics (See Figure 4–2). This signified the important role that social capital plays as an extension tool in the adoption decision process. Similarly, Katungi (2007) noted in a similar fashion that participation in associations and private social networks indeed enhances the likelihood of technology adoption, as these associations and networks function as a form of social capital. In a similar approach, Isham (2000) concluded that tribally based social affiliations are a form of social capital in the adoption decision process, and are thus economically justified as a means of promoting technologies during the design of extension programmes.

Results from the RBPM on the efficient cooking stove further show that gender played no significant role in the adoption decision of the household. This is quite a contrast from many other gender studies that have consistently found that men generally have greater control over household resources than women do, and as such, adoption gaps exist between men and women (See Namonje and Chapoto, 2016). Various authors have highlighted the point that this disparity has had implications on observed productivity differences between men and women (Peterman et al., 2014; Doss and Morris, 2001; Kumar, 1994). The non-significant effects can be attributed to the correlation of gender to the household decision maker, and without such a variable, we were unable to conclusively infer findings on this variable.

Remarkably, the household size effects showed a significant and positive effect in explaining the adoption of the efficient cooking stove. The estimates show that larger households were most likely to adopt the efficient cooking stove, holding other factors constant, than smaller-sized households were. Danso-Abbeam et al. (2017) found similar household size effects.

The likelihood of adopting the efficient cook stove increased with awareness of climate change and its consequences, holding other factors constant. This is important because we noticed that respondents did understand the impacts of climate change, hence internalising the efficient cooking stove technology being promoted as a mitigation measure. However, evidence exists in literature where the extent to which farmers perceived conservation agriculture as a climate change strategy has been low (Nyanga et al., 2011). The implication of this is that they may be other reasons for adopting an environmental friendly technology, other than as a climate change coping measure. The reasons can be wide ranging, from cultural aspects to social capital (because others in the community are doing it), or the reason may be that it is an incentive-driven decision to gain access to inputs, as pointed out by Haggblade and Tembo (2003). The results show that those beneficiaries who are aware of climate change and its consequences are more likely to adopt the efficient stove than those who are not aware, ceteris paribus.

The role of household income endowments in technology adoption cannot be ignored, despite this study finding a non-significant effect on the adoption of the efficient energy stove. According to Marenya et al (2007), the likelihood of the adoption of an agriculture technology greatly increased with household off-farm income levels, holding other factors constant. In the previous section, we explored a statistical significant gap that exists between female- and male-headed households as it pertains to household incomes.

Figure 4–7: (a) The efficient stove promoted in the Northern Province, in use

Figure 4–8: (b) Efficient stove during construction

Source: TLC file photos from monitoring visits (2017)

Figure 4–7 (a) displays the complete efficient stove being used in an outdoor rural kitchen, and Figure 4–8 (b) displays the efficient stove being constructed from local materials (clay plaster and bricks). The fuel material used comprises mostly shrubs and maize stover, which makes the use of this stove ideal as it discourages the felling of forest trees, as fuel material can be sourced from around the homestead. The design of the housing of the stove ensures that most of the fire is converted to usable heat energy, contributing a high heat output that is funnelled to the pot through an aluminium casing around the pot. This aspect is important as it reduces the exposure of women and children to the carbon monoxide being produced, as is the case with the traditional three-stones, open fire setup.

Regarding the districts, the respondents' farm households located in the Kasama and Mungwi districts are statistically more likely to adopt the energy efficient cooking stove than those in Mbala district are. It is important to note here that Mbala is the remotest district of the three, and that logistical challenges in terms of extension and information dissemination to farmers can affect the Mbala District's ability to adopt. Beneficiaries are noted to be responding positively to the technology in all catchment districts, and what needs to be carefully assessed further is how the technology is perceived by the beneficiaries as a climate change mitigating initiative.

In summary, this section has discussed the estimated results generated from the RBPM regarding the efficient energy cooking stove, and reported that farmer participation in GAPs, household-head age, agriculture group membership, awareness of climate change and its consequences, and the location of districts (Kasama and Mungwi) are factors that strongly influence the beneficiaries in adopting the efficient energy cooking stove.

4.4.2 Factors influencing the adoption of the crop rotation technology

In the model equation, we could not reject the null hypothesis of no correlation. This suggests that there was no endogeneity bias. Table 4–5 presents the maximum likelihood estimates from an RBPM of the factors that influence the adoption of crop rotation as a productivity improving and adaptive measure for climate change. The model's chi square is similarly significant, at 1%, implying that the variables are related to the adoption. The correlational rho parameter is non-significant, indicating little to no correlation between unobserved factors affecting decisions to adopt crop rotation technology and farmers' decisions to participate/host a GAP demonstration trial (Fillipini et al., 2017; Greene, 2003).

Table 4–5 shows that farmer participation in GAPs is negative and non-significant in explaining the adoption of crop rotation technology. The non-significant effects are no surprise, as the respondents indicated having received farming inputs from many other sources, for example, one such source is the Farmer Input Support Program (FISP) which allows farmers to acquire additional farming inputs from that programme, thus allowing them to cultivate a greater portion of land.

Table 4–5: Recursive Bivariate Probit Model estimates for the adoption of crop rotation

VARIABLES	Crop Rotation	Selection Equation
GAPs Demos, 1 – Yes	-0.83	-
	(0.66)	-
Age.	0.04	-0.014
	(0.038)	(0.031)
Square Age	-0.00039	0.00003
	(0.00037)	(0.0003)
Agric Group, 1 – Yes	0.72**	0.91***
	(0.28)	(0.28)
Gender, 1 – Male	0.22	-
	(0.21)	-
Household size	0.0045	0.094**
	(0.05)	(0.04)
CC Awareness, 1 – Yes	0.54**	0.25
	(0.22)	(0.25)
legumes, 1 – Yes	0.34*	-
	(0.19)	-
Total income logged	0.091**	-
	(0.038)	-
Dist1 dummy, 1 – Kasama	0.25	-
	(0.27)	-
Dist2 dummy, 1 – Mungwi	0.62**	0.33
	(0.27)	(0.24)
Market Info, 1 – Yes	-	0.54**
	-	(0.23)
Dist3 dummy, 1 – [18]Mbala	-	0.14
	-	(0.25)
Constant	-2.27**	-1.56**
	(1.03)	(0.79)
/athrho	0.78	-
	(0.66)	-
rho	0.65	-
	(0.378)	-
		-
Observations	*179*	*179*
Wald chi2(19)	64.26***	-
Log Pseudo - likelihood	-199.35	-
Wald test Rho = 0 : chi2(1) = 1.404		*Prob > chi2 = 0.24*

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's computational analysis from TLC baseline data

18 A dummy variable trap is avoided here because the dummy for Mbala only appears in the selection equation and not in the outcome equation.

Household age is non-significant in explaining the adoption of crop rotation, signalling that perhaps the institutional arrangements for this particular technology and the acceptance of this technology are well established as a way of life and are incorporated in the cultural practices among the beneficiaries, i.e. crop rotation is an accepted way of life (CIMMYT, 1993). The square of the household age is negative and insignificant, confirming that after a certain age, though, active participation in agricultural activities declines owing to old age.

The likelihood of practising crop rotation, as with using the efficient stove, increased significantly if one was a member of an agricultural group. The role of social capital in adoption is important, and Husen et al. (2017) showed that membership of a group greatly increased the likelihood of member farmers adopting an agricultural technology, as compared with those who were not members of any group. They further strongly concluded that social capital must indeed be considered as alternative policy in technology adoption. Farmer groups, at whatever level, are important in that they may reduce transaction costs and reduce the informational asymmetry gaps that exist in agricultural-related supply chains through the effective associations, dissemination of information and networking in the groups (See Mittal and Tripathi, 2009).

While it is a well-recorded and investigated fact that the gender of the household head has significant influence on adoption decisions related to agricultural technology, this study found no significant gender effects for the adoption of crop rotation. The non-significance of the gender variable can be attributed to the correlation of gender to another variable, thereby causing its effects to be recessive. However, Arslan et al. (2017) also found similar non-significant gender effects for most conservation agriculture practices.

Furthermore, this study used household size as an indicator for the labour availability of a household, as applied in numerous literature sources (see FAO, 2004). The analytic results show that the likelihood of adopting a crop rotation practice is non-significant with regard to household size. These findings have been ambiguous in most studies found in the literature, for instance Teklewold et al. (2013) and Arslan et al. (2017) found, similar to this study, no significant effect of household size. However, Manda et al. (2016) found a significant but negative sign on the effects of household size.

Regarding whether a household was aware of climate change and its consequences, this study found a significant and positive effect on the adoption of crop rotation. D'Souza et al. (2016) showed that climate change awareness creates "an awareness effect", upon which policies for promoting sustainable agriculture adoption can be formulated. Furthermore, they concluded that awareness creates a derived demand for sustainable agriculture, going forward.

This study showed that the households of respondents who had grown groundnuts (legumes) in the previous farming season were more likely to plant maize in their fields that had the groundnuts than those who did not plant groundnuts would be, holding other factors constant. Figure 4–9 shows a typical crop rotation layout of maize and groundnuts. For crop rotation to be effective and serve the intended nitrogen fixating aspect, it is important that the farmer cycles between cereals (maize being most commonly grown) and a leguminous crop (groundnuts or beans being most commonly grown), and this has been the conservation agriculture aspect that has guided the practice (See FAO, 2007).

Figure 4–9: A field in Northern Province under crop rotation (groundnuts and maize)

Source: TLC field monitoring pictures (2017)

Figure 4–9 shows a typical layout of a maize–groundnut crop rotation field, where the area that now has groundnuts planted had previously had maize planted, and vice versa. This is important because the leguminous plant fixes nitrogen, which is beneficial to the cereal in the next season, and when effectively practised, disease life cycles are broken, thereby ensuring a healthy and highly productive yield.

To examine the impact of wealth on crop rotation adoption, total income at household level was used as an indicator for wealth in this analysis. As expected, the study findings showed a significant and positive effect of total household income on the adoption of crop rotation. Marenya et al. (2007) reported similar income effects on the adoption of technologies among rural farm households. These study findings on crop rotation thus align with many studies which indicate, holding other factors constant, that households with higher incomes are the most likely to adopt conservation agriculture technologies.

The results for district dummies showed varying effects on crop rotation adoption. Specifically, Mungwi District was statistically significant and positive in explaining the adoption of crop rotation, as compared with Kasama District which had a positive but non-significant effect. The KII revealed that this could be attributed to certain extensive conservation agricultural programmes that had previously been promoted in the district, suggesting that some carry over effects in the new TLC programme are being seen now.

Overall, the factors that have been identified as having an influence on the adoption of the crop rotation comprise the fact whether a farmer belongs to an agriculture group, whether a farmer is aware of climate change, whether farmer grew groundnuts, the household income, and being located in Mungwi District.

4.5 Testing the study hypotheses

The study tested two hypotheses to endeavour to answer the postulated research question. The first hypothesis is one that assumed that crop rotation and efficient stove adoption are being independently adopted as CSA technologies by the household. A Spearman Test was run on a sample of 182 respondents to determine if there were any differences between those adopting crop rotation and those adopting the efficient stove, to test the null hypothesis H0: crop rotation and efficient stove are independently adopted. The results showed that crop rotation and the efficient stove are not independently adopted, but rather that those households who practised crop rotation are most likely to adopt the efficient stove as well. The results were significant at 1% $pro > | t | = 0.0054$, which requires that we reject the null hypothesis in favour of the alternative hypothesis.

The second hypothesis tested was one that postulated that a statistical difference between young and seasoned farmers in the adoption of CSA technologies does exist. The test results for both crop rotation and utilising the efficient stove were non-significant at all alpha levels, and thus we failed to reject the null hypothesis and conclude that the two age groups, i.e. young and seasoned farmers, independently adopt the two CSA technologies.

4.6 Summary of results section

In conclusion, this chapter has presented the results in response to the study objectives, which were (1) to explore the gaps that exist among the beneficiaries in adoption of CSA technologies; (2) to identify the factors that influence the adoption of the efficient stove as a mitigation measure to climate change; and (3) to identify factors that influence the adoption of crop rotation as an adaptive and productivity improving measure to climate change. This chapter has further responded to the two study hypotheses and has drawn conclusions accordingly.

CHAPTER 5: RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

This section presents the key findings of the study. The recommendations and conclusions are drawn from the study results that were derived while investigating the three main objectives as set out in Chapter 1, viz. (1) To explore the statistical differences in adoption decisions; (2) To identify factors that influence the adoption of the efficient stove as a mitigation measure to climate change; and lastly (3) To identify factors influencing the adoption of crop rotation as an adaptation measure to climate change. This section also presents certain policy recommendations as an overall study outcome, and lastly, we explore certain opportunities for further studies.

5.2 Summary of key findings

Cognisance has been taken of the vulnerability of the vast agricultural system in Zambia and the subsequent impacts of climate change on the smallholder farmers. It is important to identify the factors that influence the decisions of farmers to adopt technologies that would enable them to adapt and build resilience within the CSA framework. A number of studies have shown that most agricultural technologies are location- and time-specific, hence the need to find specific, tailored policies that are targeted to different groups, based on the locations and current needs of the targeted households. Overall, the study has found that demonstration trials, the age of the household head, membership of agricultural group, awareness of climate change and its consequences, family size, household income levels, district location, and crops grown are the factors that significantly influence farmers' decisions to adopt a particular CSA technology, i.e. the efficient cooking stove and crop rotation. Of particular interest, we see the sensitivity of demographic variables, such as age and family size, in affecting the decision to adopt the efficient stove, while having no significant effects on the crop rotation technology. The implication regarding age is that middle-aged farmers (40 to 65years) are more likely to adopt the efficient stove than the younger ones are. Interestingly, we noticed from the statistical tests analysis that those respondents who practised crop rotation were most likely to be members of agricultural groups, and the effects of group membership in both models were strongly significant.

The most common of the technologies practised and adopted in the Northern Province was found to be crop rotation, with an adoption rate of about 64%, followed by the efficient stove, at 33%. The other CSA technologies, such as agroforestry, liming, minimum tillage, residual retention and use of the entire conservation agriculture technology package, had been adopted by less than 5% of the survey respondents. About 75% of the respondents indicated that they belonged to agricultural groups that served many purposes pertaining to agriculture. Interestingly, over 50% of the respondents indicated that they were aware of climate change and its consequences, and that they had adopted certain remedial measures to counter the impacts of climate change.

The econometric analyses of both technologies, the efficient cooking stove and crop rotation, were significant at 1%, implying that the selected independent variables were related to the dependent variables in the respective models. The rho parameter in both models was statistically non-significant, implying that farmers' decisions to adopt an efficient cooking stove and/or practice crop rotation were not influenced by their involvement or participation in demonstration trials, leading us to accept the independence of the two binary regressors in the RBPM. The factors that affect the decisions to adopt the efficient cooking stove or crop rotation can be categorised as human and social capital, wealth, climate change awareness, types of crops grown, demographic factors, and location.

5.3 Policy Recommendations

The key findings in the study support the importance of the CSA framework as constituting a comprehensive mechanism in combating climate change in the Northern Province of Zambia. The various tests conducted on the data showed that those farmers who had practised crop rotation mostly experienced a significant yield improvement, as compared with the non-adopters of crop rotation. The study has further shown that the factors that influence the adoption of either the efficient stove or crop rotation vary, implying that intervention strategies that promote either of the two of them must be tailored specifically for a targeted group. For instance, we see the important role that social capital (agriculture group membership) plays in the adoption decisions of the two technologies, and this must be promoted at national level in driving the promotion of the technologies. The existing farmer groups and cooperatives must be strengthened through capacity building and with a clear purpose for promoting CSAs.

Furthermore, emphasis must be placed on creating more numbers of farmer groups that are attractive to the youth in order to spur their involvement in the adoption and promotion of the efficient stove technology, bearing in mind that no age impacts were found regarding the adoption of crop rotation technology. The role of extension services must also not be overlooked; we clearly see that awareness of climate change affects the farmers' decisions to adopt the technology. Accordingly, policies should be put in place to ensure that extension agents are supplied with updated and specific climate-related information for the locations that they work in. For the CSA approach to be effective in addressing climate change impacts, there is need for considerable efforts to be made to invest in extension, training and knowledge sharing to ensure that an increased adoption of the entire conservation agriculture package is realised amongst farmers (Kaczan et al., 2013).

5.4 Limitations and opportunities for further research

The dataset employed in this study had some key variables missing, which made it difficult to conclusively make inferences on some findings. For instance, certain variables such as the enumeration of the household decision-makers were not captured by the survey, thus making it impossible to measure the real effects on technologies such as the efficient stove and crop rotation adoption. Another important variable that was not captured was the distance of the household to the nearest forest and common sources of household energy. Having such variables would have allowed us to show causality of the impact on the adoption of the efficient cook stove. We also would have preferred to have had a variable that directly records farmers' perceptions of the technologies as climate change adaptation and mitigation measures.

The above limitations offer a broader scope for further research, especially in endeavouring to ascertain whether the farmers adopting these technologies really do consider them as being climate smart technologies. It would be important to measure the impacts of these technologies on the welfare of households, preferably through a panel data analysis where the same households are visited again at later stages when further variables would be solicited from them, for instance identifying technology dis-adopters and identifying what had influenced their decisions to stop further use of the CSA technology in question.

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APPENDICES

Questionnaire

Total LandCare (TLC) S3P Baseline Survey Household Questionnaire

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Enumerator Name: …………………………………………………………………………..

Date: ………………………………………………………………………………………

Start time:………………………………………….

Please indicate your voluntary consent by participating in this TLC S3P baseline survey and note everything you say will be held as confidential. If have questions about this survey, you may contact EliSil Environmental Consulting, Plot 1259 Chendauka Road, Chelstone, Lusaka elisilconsulting@yahoo.com, 097 7 748335

Note: *For the data like* ***length/distance, area, weight, price, etc.*** *please take answers in local units then convert them into international units as, hectares, and kg.*

Household Identification Details	Coding
1. What is your status in the household?	*1=head of household, 2= spouse, 3=child, 4= worker,5= mother,5= father, 6=other relative*
2. Name of Household Head/Respondent	
3. Sex of household head	*1= Female 2=Male*
4. District	*1=Kasama 2 =Mungwi 3 =Luwingu 4 =Mbala 5 =Kawambwa 6 =Mansa 7 =Samfya*
5. Agricultural Block	
6. Camp	
7. Village	

Basic Household Information	Coding
8. Educational Level of Head of HH	*1. Never been to School* *2. Primary* *3. Secondary* *4. Tertiary*
9. Age of the head of Household (years)	………………. Years
10. Marital Status of Household head	*1. Married* *2. Widow* *3. Widower* *4. Bachelor* *5. Spinster* *6. Divorced*

Household Composition								
	Under 5		Children (6-17)		Adults (18-59)		Elderly (60+)	
	M	F	M	F	M	F	M	F
11. No. of people living in homestead:								
12. No. of chronically ill								

"living" is defined as someone who stays there at least for three months in a year)
chronically ill is defined as, *sick and unable to work for a total of 3 months over the last 12 months*

13. Are you aware of Smallholder Productivity Promotion Programme (S3P)?

14. Are you a beneficiary of the S3P project? 1) Yes 2) No

Adoption of good agricultural practices for the production of priority crops among smallholder farmers in the targeted district sites.

15. Fill in the following Tables on crops grown during the 2014/15 and 2015/16 seasons

Crops grown (2014/15)	Varieties name	Area (ha)	Crops grown (2015/16)	Varieties name	Area (ha)
Cassava	1.		Cassava	1.	
	2.			2.	
	3.			3.	
Beans	1.		Beans	1.	
	2.			2.	
	3.			3.	
Groundnuts	1.		Groundnuts	1.	
	2.			2.	
	3.			3.	
Rice	1.		Rice	1.	
	2.			2.	
	3.			3.	
Maize	1.			1.	
	2.		Maize	2.	
	3.			3.	
Other (specify)	1.		Other (specify)	1.	
	2.			2.	
	3.			3.	
Other (specify)	1.		Other (specify)	1.	
	2.			2.	
	3.			3.	

16. Which of the below listed sustainable soil management practices did you use and area of use?

Practice	Used in 2014/15	Area	Used in 2015/16	Area
	1 = Yes 2=No	Ha	1 = Yes 2=No	Ha
Crop rotation				
Agroforestry				
Manure				
Liming				
other (specify)				

17. Do you have a Good Agricultural Practices (GAP) demo plot?1) Yes 2) No

18. If yes, which month and year was it established? ___________________________________

19. Has any member of the household been trained in any seed multiplication technique?

    1) Yes 2) No

20. If yes, for which crop(s) and when was the training done?

    ....

    ....

21. Is your household involved in seed multiplication? 1) Yes 2) No
22. If yes, when did the household get involved in seed multiplication (month and year)? ………….
23. Which crop(s) are you specifically multiplying the seed

    1) Cassava (2) Beans (3) Groundnuts (4) Rice (5) Maize (6) Other (specify)…………………
24. Do you use a treadle pump for seed multiplication? 1) Yes 2) No
25. Give reason for your answer above? …………………………………………………………..

    …………………………………………………………………………………………………

    ……………………………………………………………………………………………… .
26. Did you have access to extension services in 2014/15 season? 1) Yes 2) No
27. If yes, what was the source of extension services? 1) GRZ 2) Private 3) NGOs 4) Other (specify)

    …………………………………………….
28. Where you satisfied with the extensions services provided? 1) Yes 2) No
29. Did you have access to extension services in 2015/16 season? 1) Yes 2) No
30. If yes, what was the source of extension services? 1) GRZ 2) Private 3) NGOs 4) Other (specify)

    …………………………………………….
31. Where you satisfied with the extensions services provided? 1) Yes 2) No

Improved access and linkages to markets

32. Do you belong to an agricultural group? 1) Yes 2) No
33. If yes, what is the main purpose of the group? …………………………………………………

…………………………………………………………………………………………………….

34. When did you join the group? ....

35. Have you ever been trained in running farming as a business? 1) Yes 2) No
36. If yes, has this training made you start running farming as a business? 1) Yes 2) No
37. If yes, in what ways? …………………………………………………………………………...
…………………………………………………………………………………………………….
38. Do have access to market information? 1) Yes 2) No
39. If yes, since when (month and year) ……………………………………………………….

40. What mode do you use to access the information? *1) Radio (2) TV (3) Newsletters (4) Extension staff (5) Mobile phones (6) Seed dealers (private seed company, agro-dealers…) (7) Fellow farmer (8) Project/ Institution (name…………………………) (9) Other (specify)………………………..*

41. What challenges do you have in selling your agricultural produce?
………
………………………………………………………………………………
42. Where do you often sell your agricultural produce?
…….
43. Are you able to sell whatever quantity of products you want at this market? 1) Yes 2) No

44. Fill in the following Table about your 2014/15 marketing of agricultural produce

Crop/products	Quantity produced (Kg)	Quantity sold per Kg	Place sold/Name of buyer	Price per Kg	Were you happy with price?
Groundnuts					
Beans					
Rice					
Maize					
Other (specify)					
Other (specify)					

***Conversion data

45. Was food retained (not sold) in 2014/15 season last the whole year? a) Yes b) No
46. If no, how many months on average did you stay without the retained food? ....
.
47. Fill in the following Table about your 2015/16 marketing of agricultural produce

Crop/products	Quantity produced (Kg)	Quantity sold per Kg	Place sold/Name of buyer	Price per Kg	Were you happy with price?
Groundnuts					
Beans					
Rice					
Maize					
Other (specify)					
Other (specify)					

***Conversion data

48. Did food retained (not sold) in 2015/16 last the whole year? 1) Yes 2) No
49. If no, how many months on average did you stay without this retained food? ....

50. Fill the below Tables on cassava and its products during the 2014/15 season

Cassava products	Quantity produced (Kg)	Quantity sold per Kg	Place sold/Name of buyer	Price per Kg	Were you happy with price?
Flour					
Chips					
Whole Dried Roots					
Leaves					
Fresh Roots					

***Conversion data

51. Fill the below Tables on cassava and its products 2015/16

Cassava products	Quantity produced (Kg)	Quantity sold per Kg	Place sold/Name of buyer	Price per Kg	Were you happy with price?
Flour					
Chips					
Whole Dried Roots					
Leaves					
Fresh Roots					

***Conversion data

52. Did you access your inputs through the agro dealers in 2014/15? 1) Yes 2) No

53. If yes, which inputs and from which agro-dealer? ………………………………………..
…..……………………………………………………………………………………

54. Did you access your inputs through the agro dealers in 2015/16? 1) Yes 2) No

55. If yes, which inputs and from which agro-dealer? ....
……………………………………………………………………………………………..

56. Do you have access to financial services for your agricultural activities? 1) Yes 2) No

57. If yes, from which financial institution? ....

58. Who linked you to this financial institution? ....

Resilience of smallholder farmers to the impact of climatic variations/shocks

59. Kindly answer the following climate change related questions

Are you aware of climate change issues and their consequences? ***1= Yes*** ***2= No***	When did you become aware?	Who shared climate change information with you?	What MAIN effect has CC had on your crop/livestock activities? ***Use codes below***	What have you done to deal with the negative consequences of CC?	When did you start using the practice mentioned in 13? *Enter* ***Year***	Who influenced you to take up the practice? *1= Relative* *2=NGO/Church* *3= Extension worker* *4= Others (specify)*	Is the measure working for you? *1= Yes* *2= No*
60.	61.	62.	63.	64.	65.	66.	67.

Codes(22) 1= Decline in yields2= Decline in livestock production3= Difficult to time seasons
4= Increased weeds 5= Increased diseases 6= Decrease in soil quality 7= decrease in water availability 8= Scarcity of pastures 9= Increase in yields 10= Others(Specify)

68. Which of the below conservation agriculture activities are you practicing?

Practice	Area in ha (2014/15)	Area in ha (2015/16)
Minimum tillage, crop rotation & residual retention		
Minimum tillage & crop rotation		

Minimum tillage & residual retention		
Crop rotation & residual retention		
Minimum tillage		
Crop rotation		
Residual retention		

Adoption of processing, preparation, cooking and consumption of nutritious foods

69. Where you trained (before October 2015) in the following activities related to the different crops in the table below? Indicate **Yes** or **No**

Food product	**Improved processing**	**Improved preparation**	**Improved cooking**	**Consumption of product**
1, Cassava				
2. Beans				
3. Groundnuts				
5. Rice				
6. Maize				
7. Other (specify) ……………………				
8. Other (specify) ……………………				

70. Did you practice (before October 2015) what you were trained in the following activities related to the different crops in the table below? Indicate **Yes** or **No**

Food product	**Improved processing**	**Improved preparation**	**Improved cooking**	**Consumption of product**
1, Cassava				
2. Beans				
3. Groundnuts				
4. Rice				
5. Maize				
6. Other (specify) ……………………..				
7. Other (specify) ……………………				

71. Where you trained (in 2015/16) in the following activities related to the different crops in the table below? Indicate **Yes** or **No**

Food product	**Improved processing**	**Improved preparation**	**Improved cooking**	**Consumption of product**
1, Cassava				
2. Beans				
3. Groundnuts				
4. Rice				
5. Maize				
6. Other (specify)				

………………….				
7. Other (specify) …………………				

72. Did you practice (in 2015/16) what you were trained in the following activities related to the different crops in the table below? Indicate Yes or No

Food product	**Improved processing**	**Improved preparation**	**Improved cooking**	**Consumption of product**
1, Cassava				
2. Beans				
3. Groundnuts				
4. Rice				
5. Maize				
6. Other (specify) ………………….				
7. Other (specify) ………………….				

73. Household consumption of various food stuff Table

Food item names	**(a)In a typical week between October 2014 and October 2015, how often did the household members consume the following foods?**	**On average how much did the household consume per week?**	**(b)In a typical week between October 2015 and October 2016, how often have the household members consumed the following foods?**	**On average how much did the household consume per week?**
1. Cassava				
2. Beans				
3. Groundnuts				
4. Rice				
5. Maize				
6. Orange maize				
7. Orange fleshed potato				
8. Soy beans				
9. Vegetables				

10.Other (specify) …………………..				
11. Other (specify) …………………..				

74. What cooking structures do you use for preparing your meals? 1) Three stones (2) Blazier (3) Others (specify)…………………

75. Are you aware about the TLC rocket stove? 1) Yes 2) No

76. If yes in 56, does the household own and use a TLC rocket stove? 1) Yes 2) No

77. If yes, what are the advantages of the rocket stove? 1) Use less fuel wood (2) Produces less smoke (3) Saves on time (4) Other (specify) ……………………………………………………..

78. Tick the following assets owned by the household and indicate the number owned now and before October 2015 in the Table below.

Does household possess any of the following physical assets? (tick all that apply)	**Quantity Owned (Now) 2016**	**Quantity Owned last year (before October 2015)**
1. ☐ Local Cattle		
2. ☐Improved Cattle		
3. ☐ Local Oxen		
4. ☐Improved Oxen		
5. ☐ Local Goats		
6. ☐Improved goats		
7. ☐ Local Chicken		
8. ☐Improved Chicken		
9. ☐ Local Pigs		
10. ☐Improved Pigs		
11. ☐Donkeys		
12. ☐Ox carts		
13. ☐Ox drawn ploughs		
14. ☐Ox drawn harrows		
15. ☐Cultivators		
16. ☐Ridging plough		
17. ☐Knapsack sprayers		
18. ☐Bicycles		
19. ☐Radios		
20. ☐TV set		
21. ☐Iron roofed house		
22. ☐Grass thatched house		
23. ☐Open water source		
24. ☐Water well		

25. ☐Borehole		
26. ☐Ordinary		
27. ☐VIP		

79. Fill the household source of income for the two seasons as indicated in the Table

Does household receive income from the following livelihood strategies? (tick all that apply)	**Approximate how much per year (ZK)** Oct 2014 – Sept 2015	**Approximate how much per year (ZK)** Oct 2015 – Sept 2016
1. ☐ Petty trading (Specify)		
2. ☐ Gardening activities/Off season farming		
3. ☐Chicken rearing		
4. ☐ Goat rearing		
5. ☐ Cattle rearing		
6. ☐ Remittances		
7. ☐ Sale of rain fed food crops (specify crops)		
8. ☐ Sale of rain fed cash crops (specify crops)		
9. ☐ Piece work		
10. ☐ Sale of charcoal		
11. ☐ Other (Specify)		

Thank you so much for your participation!

End Time: ……………………………….