DETERMINATION OF FACTORS THAT INFLUENCE THE ADOPTION OF CLIMATE CHANGE ADAPTATION STRATEGIES BY SMALLHOLDER FARMERS IN MACHINGA DISTRICT, MALAWI

MSC. (ENVIRONMENTAL SCIENCE) THESIS

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DECLARATION

I, the undersigned, hereby declare that this thesis is my own original work which has not been submitted to any other institution for similar purposes. Wherever other people's work has been used, acknowledgments have been made.

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CERTIFICATE OF APPROVAL

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DEDICATION

This research work is dedicated to my late father Mr James Lex Matupi Mkandawire (RIP), my mother (Anna Mkandawire) and my three sisters (Fanny, Omega and Jessie) for their partnership in the success of my life.

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ABSTRACT

Climate change effects have had significant impact on agricultural production thus adaptation to climate change impacts is essential; however, not all smallholder farmers are able to successfully adopt them. The study was therefore conducted in order to determine the factors that influence the adoption of these CCAS and further assess the challenges that limit the adoption of CCAS. Majority of the famers cited to have observed climate change in the area, however, it was noted that not all the farmers had adopted CCAS. The results disclosed that 66.9 percent of the smallholder farmers had adopted at least one or multiple CCAS while 33.1 percent of the assessed smallholder farmers had not adopted any of the CCAS. There was no correlation between the farmers' perception results and the computed annual rainfall trend which was done using Mann-Kendall statistics set at 95 percent confidence interval. However, there was a high positive correlation between the temperature trend and farmers' perceptions. The logit model analysis results showed that farm experience, access to information, temperature variability, education and land size were the major factors influencing adaptation uptake. It was also noted that the farmers faced challenges in successfully implementing most of the adaptation strategies due to among other things shortage of farm labor, deficiency of water sources, lack of raw materials and farm inputs, lack of information, shortage of arable land, culture and religious. Improving these factors would be important to enhance adaptive capacity for the smallholder farmers.

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ACRONYMS

A.D.D	Agricultural Development Division
AEDC	Agriculture Extension Development Coordinator
ASWAP	Agriculture Sector Wide Approach
DADO	District Agriculture Development Officer
EPA	Extension Planning Areas
ETC	ET Cetera
FAO	Food and Agriculture Organization
FEWS NET	Famine Early Warning Systems Network
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GoM	Government of Malawi
IFPRI	International Food Policy Research Institute
MOAIFS	Ministry of Agriculture, Irrigation and Food Security
NAPA	National Adaptation Programmes Action
NGO	Non-Governmental Organization
NSO	National Statistics Office
SADC	The Southern Africa Development Community
SPSS	Statistical Package for Social Scientists
TA	Traditional Authority
UNDP	United Nation Development Program
VAC	Vulnerability Assessment Committee

GLOSSARY

Adoption: The acceptance, embracement, and implementation status of the farmer on the identified technologies including the degree of use of a new technology in the long-run equilibrium when the farmer has full information about the new technology and its potential (Feder *et al*., 1985).

Climate change adaptation: Package of actions through which individuals or communities adjust themselves to the impacts or threats posed by climate change (Nyong, et. al., 2007).

Conservation Agriculture: Set of soil management practices that strive to achieve acceptable profits together with high and sustained production levels while minimizing the disruption of the soil structure, composition and natural biodiversity.

Crop diversification: This refers to the growing of more crops or new crops on farms by use of methods such as crop substitution, double cropping, multi-cropping and intercropping.

Head of household: The senior member residing in the household or homestead or returning there at frequent intervals. He/she makes the ultimate decisions concerning the expenditure of the household income and/or the agricultural activities.

Improved crop varieties: Planting of crop varieties that are genetically modified to survive various climatic conditions.

Irrigation: The artificial supply of water to land so that crops and plants can grow when there is insufficient rain water.

Smallholder Farmers: People who engage in crop farming owning small-based plots of land on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labour.

CHAPTER ONE: INTRODUCTION

1.0 Introduction

This chapter focuses on the background, problem statement and the significance of the study. It further discusses objectives, research questions and organization of the study.

1.1 Background of the Study

Globally, climate change has been recognized as one of the biggest challenges facing humanity (Kemal, 2016). The impact of climate change and variability on agriculture is also well illustrated by the damages it poses on agriculture. Climate is a primary determinant of agricultural productivity and any adverse changes are likely to have devastating effects in the agricultural sector by causing crop failures besides affecting the livelihoods of the majority of the population that hinge on rain-fed agricultural practices for their mainstay (Calzadilla *et al.*, 2009). Agronomic research indicates that annual dry spells, floods and higher temperatures associated with climatic change are harmful to the production of many crop and livestock groups, since agriculture is highly vulnerable to the effects of these natural disasters (Oloo, 2013).

The smallholder farmers and communities who depend on agriculture for their livelihoods and food security are highly vulnerable to climate change impacts (Nyengere, 2015; Zulu, 2017). Malawi is one of the countries that is vulnerable to today's climate change impacts with an economy that is highly dependent on agriculture (Schulze *et al.*, 2011). The country was ranked by the World Bank to be among the 12 most vulnerable countries in the world in two of the six major global climate change threats (Mearns and Norton, 2009). Malawi has been experiencing effects of climate change and variability on agriculture for decades with most of the districts facing more erratic and scarce rainfall and higher temperatures which have led to food production facing a high level of uncertainty. The real annual fluctuations in agricultural, non-agricultural and total GDP for 1980 to 2001 show that losses during droughts which occurred in the mid-1990s, were more severe than disaster losses during the floods in 2001 (Benson and Clay, 2004). A report by UNICEF (2013) indicates that flood conditions, especially in the southern part of Malawi result in food insecurity with significant impacts on the livelihoods of poor people in rural areas.

In the quest of promoting agricultural productivity and sustainable management of land resources and reducing the problems of food insecurity, new strategies are being formulated to maintain and increase crop production among smallholder farmers worldwide in this era of unpredictable weather patterns. According to FAO (2008) the strategies include but not limited to formulation of new policies and programmes to help farmers build resilience to climate change impacts. Basically, the objective of the climate change adaptation measures in agriculture is to support and sustain agricultural production and to bring to minimum the impacts of climate change by reducing the vulnerability of agricultural crops (Alexandrov, 2008).

In reaction to national reporting obligations under the United Nations (UN) Framework Convention on Climate Change, the Government of Malawi has designed policies in response to climate change which are usually driven externally by donors(Zulu, 2017). In response to the threats that climate change poses, the Malawi Government through the Ministry of Agriculture and Food Security (MoAFS) and non-Governmental organisations has formulated a policy both to adapt to and mitigate the adverse impacts of climate change(Zulu, 2017). Some of the policies and programmes include: The Agriculture Sector Wide Approach (ASWAP), the National Adaptation Plans of Action (NAPA) and the Malawi Growth and Development Strategy II (MGDS). The identified adaptation programmes for agriculture enhance people's capacity to cope with and adapt to the natural calamities that arise due to climate change and variability in vulnerable areas (GoM, 2006). For instance, some of the interventions provided in the NAPA for coping with the climate change and variability impacts include the promotion of the following:

1. Rain-water harvesting, water conservation and small-scale irrigation.
2. Crops and livestock diversification to improve nutrition and food security.
3. Use of improved crop and livestock varieties that are drought tolerant.
4. Use of agro forestry practices.
5. Food preservation technologies for reduction in post-harvest losses.
6. Conservation agriculture which includes mixed manure application system, increased use of water and soil conservation techniques.
7. Improved community storage systems for seed and food reserves.
8. Sustainable utilization of dambos, wetlands and river valleys under sustainable *dimba* cultivation.
9. Creation of buffers along the rivers to reduce siltation.

10. Developing improved crop varieties and providing adequate seed.

11. Improving early warning and climate observational systems and improve extension delivery systems to the farming communities.

The foregoing adaptation strategies are among the numerous strategies that are considered to be an important component of the policy options in response to climate change impacts (Fankhauser and Tol, 1997; Smith and Lenhart 1996; Smit *et al.*, 1999). It is worth noting that adaptation strategies have been helpful in reducing exposure and for improving resilience to actual or expected changes and related extreme events (Adger *et al.*, 2007). These strategies increase sustainable productivity, strengthen farmers' resilience, reduce agriculture`s greenhouse gas emissions and increase carbon sequestration and further strengthen food security and deliver environmental benefits (Nyengere, 2015).

1.2 Problem Statement

Agriculture is a principal source of employment and income, it is the backbone of Malawi's economy, contributing 30 percent of total GDP and 76 percent of total national exports with 78 percent employed in the sector as of 2013(Giertz *et al.*, 2015). The Increase of food security is one of the main objectives of Malawi's 2010 Agricultural Sector Wide Approach. However, production-related shocks continue to result in high losses to the sector from extreme weather events, pests, disease and land degradation etc (GoM, 2010). Malawi has and continues to be affected by major Changes in climate whose effects have had significant impacts on agricultural production. As evident from Malawi State and Environment Outlook Report (2010), extreme weather-related events have shown an upward trend since the 1970's.

Machinga district is among the many districts in Malawi experiencing the increase in magnitude, frequency and impact of disasters, in light of climate change, population growth and environmental degradation (GoM,2014). The impact of climate change on rural communities is devastating and hinders development. The lack of adopting coping mechanisms has left smallholder farmers vulnerable to the impacts of climate change has led to food insecurity and loss of livelihoods hence trapping the majority in the poverty cycle.

Despite the high magnitude of the problem in Malawi, the adoption of climate change adaptation strategies has not been investigated dynamically as compared to other African countries which have comprehensive literature in regards to such studies(Sato, 2016). Among the few studies that have been conducted to examine the adoption of climate change adaptation strategies, a study by Sato (2016) had results that reflected low adoption status of climate change adaptation strategies in Malawi. Similarly, a study by FAO has also reported similar results reflecting low adoption status of agricultural technologies for Malawi as compared to other countries in sub Saharan African(FAO, 2011).Conversely, there remains a dearth of information on factors that influence the adoption or non-adoption of climate change adaptation strategies(Zulu, 2017).

Information on factors affecting the adoption of climate change adaptation strategies by the smallholder farmers is not readily available in spite of it being one of the nations' policy recommendation in response to climate change impacts. Similarly, no study of this nature has ever been conducted in Machinga district hence the study intends bridge the information gap. The study is set out to determine some of the factors that influence the decision of smallholder farmers to adopt climate change adaptation strategies and also assess the challenges that hinder and limit them from adopting the strategies in Machinga.

1.3 Significance of the study

Climate change adaptation strategies are designed to transform the lives of farmers who are impacted by climate change conditions by helping them build resilience to the harsh climatic conditions that are as a result of climate change. Changes in climate severely erode the resilience and adaptive capacity of individuals and communities especially for the smallholder farmers who depend directly on agriculture for their livelihoods (Chikwezga, 2016). Thus, effective adaptation of agriculturists to climate change is crucial in addressing numerous types of risks associated with it. Therefore, the study intends to make a contribution to knowledge on adaptation to climate change, by firstly, identifying factors that shed more light on what influences smallholder farmers to adopt climate change adaptation strategies. The study will further highlight the farmers' perception of climate change and the constraints to the full adoption of climate change adaptation strategies by smallholder farmers in the rural areas. The study is important since many studies agree that clear understanding of factors in farmer decision-making regarding adoption of climate change adaptation strategies is crucial in crop productivity, preventing crop losses and improving food security for sustainable livelihoods among smallholder farmers. The knowledge generated from the study on the factors that influence adoption of climate change adaptation strategies could help towards efforts of expanding the adoption rate of climate change adaptation strategies in Malawi, particularly in rural areas where the adoption of climate change adaptation programmes specifically in subsistence farming is hindered by a number of challenges and unknown factors.

1.4 Objectives

The overall objective of this study was to explore the factors that influence the adoption of climate change adaptation strategies by smallholder farmers in Machinga. Specifically, the research study intended to:

(a) Examine the selected socio-economic and demographic characteristics of the adopters and non-adopters of climate change adaptation strategies.

(b) Assess farmers' perception of a changing climate of the area against empirical evidence.

(c) Evaluate the on-farm challenges that affect the adoption of climate change adaptation strategies.

(d) Evaluate the factors that influence the adoption of climate change adaptation strategies.

1.5 Research Questions

The research was specifically set out to answer the following questions:

(a) What are the socio-economic and demographic characteristic differences between the adopters and non-adopters?

(b) What are the smallholder farmers' perceptions of climate change for the study area?

(c) What are the on-farm challenges limiting the adoption of climate change adaptation strategies?

(d) What are the factors influencing the adoption of climate change adaptation strategies?

1.6 Organisation of the Study

This work has been presented in five chapters. Chapter one contains the background, problem statement, significance of the study, objectives and research questions. Chapter two reviews related theoretical and empirical literature and discusses the conceptual framework. Chapter three encompasses research design and methodology which specifically describes the study site, sample size, research methods, sources of data, sampling techniques, data collection, data analysis techniques and it concludes with ethical considerations and limitations of the study. Chapter four presents the results of the research findings. It discusses the characteristics of the smallholder farmers, the challenges limiting the adoption of climate change adaptation strategies, the smallholder farmers' perceptions on climate change and variability indicators against the empirical evidence. The chapter concludes by providing the outcome of the binary Logit regression model on factors that influence adoption of climate change adaptation strategies. Chapter five is the last chapter. The chapter presents a summary of the key findings and conclusion of the study and provides suggested areas for future research.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter presents a comprehensive review of related literature on the emerging issue of climate change and climate change adaptation strategies in Africa including Malawi. The chapter also presents the key issues that have been noted in other similar studies. Towards the end of the chapter the conceptual framework that has been used in the study is discussed. The chapter concludes by discussing some key determinants of smallholder farmers' choice of adaptation to climate change.

2.1 Theoretical Literature Review

2.1.1 Overview of climate change impacts on agronomic productivity in Malawi

Agriculture is an important sector worldwide (World Bank, 2008). It is a source of livelihoods for an estimated 86 percent of rural people (more than 3 billion people, half of the world's population that live in rural areas). Roughly, 2.5 billion of these rural people derive their livelihoods from agriculture (FAO *et al*., 2013). For many economies, especially those of developing countries, agriculture is an important engine of economic growth (Moyo, 2014).

Agriculture provides an important haven against global economic and financial turmoil, often more effectively than other sectors (Asfaw *et al.,* 2014). However, this sector is one of the most vulnerable and sensitive to change and variability of the climate. Climate change poses a great threat to global food stocks as farmers can no longer grow enough food, having experienced decline of crop yields every year due to rainfall variability, harsh climatic conditions and natural disasters (Osman-Elasha and El-Amin, 2008). Fluctuations in agricultural production stem from various factors including climate change, weather variability, and pests and disease. These have devastating effects on food security and agricultural growth. As such, agricultural risk needs to be reduced in respect of climate change impacts particularly if the food security and nutrition needs of the country are to be met consistently.

The performance of Malawi's economy is closely associated with the performance of the agriculture sector which is essentially rain-fed (GoM, 2010). Thus, successful agricultural development is a precondition for successful development. The sector remains the mainstay of Malawi's economy, contributing significantly to employment, economic growth, export earnings, poverty reduction, food security, and nutrition (GoM, 2016) (GoM, 2016). The sector accounted for about 30.2 percent of the gross national income in 2011 and 80 percent of total export value (GoM, 2011). The smallholder sub-sector dominates Malawi's agricultural sector, constituting 78percent of cultivated land and 75percent of agricultural production (Asfaw *et al.*, 2014). Nevertheless, more than 72percent of farmers cultivate less than a hectare of land, which is insufficient to meet their subsistence food needs(Zulu, 2017). Even though agriculture is critically important to the livelihoods of most Malawians, its overall productivity performance raises serious concerns about its long-term viability. Maize, which is Malawi's staple food, dominates all crops and covers 70percent of arable land. However, although maize is the main crop amongst smallholder farmers in Malawi, over the past years, maize production has been erratic (Asfaw *et al*., 2014). The factors that are commonly cited as underlying low crop productivity include weather variability, declining soil fertility, limited use of improved agricultural technologies and unsustainable land management practices, poor agricultural extension services and market failure (Mearns and Norton, 2009). The most significant problem facing crop yield in Malawi apart from the prolonged dry spells and the rainfall variability is the inability of farmers to cope with the extreme weather events (Sato, 2016)

The year 2015 was an *El Niño* year for southern African countries, which refers to the warm phase of the cycle, in which above-average sea surface temperatures develop across the east central tropic pacific(Davis, 2011). The weather is associated with decreased annual rainfall, with heavy rains in some areas and with droughts in most areas (FEWS NET, 2016). For most smallholder farmers in Malawi, crop production in the year 2015 proved to be a big challenge due to the extreme weather events influenced by the *Niño*. According to FEWS NET (2015) and Malawi Vulnerability Assessment Committee (MVAC), it was estimated that 2.83 million people in Malawi had experienced acute food insecurity during the 2015 lean season. However, agricultural producers in Zambia, which lies in the same climatic region as Malawi, managed to meet the country's national maize production average with more credit given to the smallholder farmers who plant 51 percent of the total cultivated land in the country (Kaimenyi, 2016). Kaimenyi (2016) further found that high adoption of improved crop varieties and unlimited farmer's knowledge on appropriate agricultural technologies are some of the factors which have contributed to high food production in Zambia, making the country food secure even when the rest of the countries in southern Africa were not able to harvest enough.

World Bank funded study on agricultural risk management for growth and food security in Malawi found that production losses over the past 30 years add up to US$150 million per year due to systematic risks to Malawi agricultural sector (Giertz *et al.*, 2015). To remove these losses, the study recommended concentrating on risk mitigation measures which included the increased use of climate change adaptation strategies. Therefore, climate change adaptation strategies are regarded as matter of urgency for smallholder farmers in Malawi given that increased risk of crop failure, associated with increased frequency of extreme events, poses a major threat to food security and poverty reduction (Sato, 2016). The Government of Malawi believes that adoption of climate change adaptation strategies can increase farm output, improve food security and eventually result in rising household incomes through increased tradable surplus (GoM, 2011). Adaptation strategies in the context of climate change are all those practices that are used by smallholder farmers to either get used to or minimise the effects of climate change and variability (START, 2012).

Many potential climate change agricultural adaptation strategies have been suggested, representing measures or practices that might be adopted to alleviate expected adverse impacts. For instance, crop diversification has been identified as a strategy to strengthen the agriculture sector in many countries (Yahya and Tunku, 2003). The strategies help to support food security, greater employment opportunities, increased farm incomes, income stability, adaptation to climate change, increasing demand for non-staple crops, and high profitability per unit area (Obcemea, 1996). According to

GoM (2010) and Chinsinga *et al.,* (2012), promotion of conservation agriculture is given high priority due to its expected productivity benefits as well as to mitigate the effects of climate change and weather variability. Apart from conservation agriculture, other adaptation strategies such as irrigation, agroforestry, proper timing of agricultural operations by adjusting planting times, planting drought resistant varieties, early maturing and high yielding varieties, use of organic and inorganic fertilizers, use of small-scale irrigation, crop and livestock diversification, agroforestry and increased use of soil and water conservation techniques are also important strategies and the most commonly cited in literature (Bradshaw *et al.,*2004; Kurukulasuriya and Mendelsohn, 2008 ;Kurukulasuriya and Mendelsohn 2006 ;Maddison, 2007 ;Nhemachena and Hassan, 2007; Thole, 2011;Zulu, 2017; Lema and Majule, 2009). The above cited climate change adaptation strategies have had many positive attributes to crop production and additionally they reduce many risks in smallholder agriculture. Despite data limitations, studies in Southern Africa have revealed results, that reflect low adoption status of these climate change adaptation strategies for Malawi as compared to other countries in the SADC region (World Bank, 2008).

The Government of Malawi through the Ministry of Agriculture and Food Security has further attempted to operationalize the NAPA priorities through the Agriculture Sector Wide Approach (ASWAP). Between 2007 and 2009, the Government of Malawi formulated the ASWAP to harmonise investments in agriculture and support programmes on the basis of their assessed potential to contribute to food security and agricultural growth in Malawi. The ASWAP identifies several strategies which are meant to increase the resilience of communities in rural areas to the adverse effects of climate change.

2.2 The conceptual framework for adoption of climate change adaptation strategies

According to Thangata and Alavalapati (2003), various models have been suggested and used to explain the decision to adopt new agricultural technologies by farmers. Thangata and Alavalapati (1999), Navicha (2010) and Roger (1995) have argued that there is no single theory that embraces all aspects of adoption in regards to the traditional attitude of smallholder farmers. A number of complementary theories have therefore been advocated to explain the adoption process; these include the extension theory, bounded rationality, theory of reasoned action, consumer behaviour theory, diffusion theory and field theory (adoption behaviour model). The most commonly conceptualised model for adoption studies is the modification of the field theory commonly known as adoption behaviour model or the modification of diffusion of innovations theory.

Diffusion of Innovation Theory which was developed by Rogers in 1962, is one of the oldest social science theories which explains how over time, an idea or product gains momentum and spreads through a specific population or social system (Rogers, 1995).The adoption diffusion model identifies five aspects that influence adoption: perceived attributes of the innovation; type of innovation decision; communication channel; nature of the social system; and the extent of change agent promotion efforts (Rogers, 2003). Some of Rogers' generalizations as significant variables that affect adoption, which will also be used in this study include: educational level, farm size and income. Despite Rogers' theory being among the widely used theoretical framework in the area of technology diffusion and adoption, studies by other scholars have cautioned the validity of using Rogers' theory by pointing out its weaknesses. Röling (1988), notes that in spite of the diffusion of innovations theory having the dynamism in extension and the social consequences of extension that could be understood in term of the diffusion processes, most of the research using this theory do not permit conclusions to be drawn about causality, leaving most of the interpretations to the imagination of the researcher (Frempong and Düvel, 2009). The model also presents the adoption process as a linear but then again, a study by Frempong and Düvel (2009) notes that farmers, like all other entrepreneurs, do not adopt innovation simultaneously as they appear on the market. Additionally, Kabwe *et al., (*2007) notes that Rogers' categorisation of adopters into five categories namely: innovators, early adopters, early majority, late majority and laggards is another problem associated with using the theory specifically in the situation where adoption has not reached 100 percent use since it does not include those that cannot be grouped within the five groups, i.e. discontinuance and non-adopters (Rogers, 2003).

Due to the nature of the study and the limitations that Diffusion of Innovation Theory poses, this research opted for adoption behaviour model to aid the conceptual framework for the study. The adoption behaviour model is a modification of the field theory, which was deemed useful and more appropriate for this research. The model is commonly used as a framework in understanding how farmers' choices are determined for different adaptation options (Tesfay, 2014). Past studies by

Masangano (1996), Dierderen *et al.,* (2003), Thangata and Alavalapati., (2003) and Thole (2011) are among the many other publications which have established the validity of using the behavior adoption model in farmers' decision making. The model assumes that there is a chain of causality where the independent variables (characteristics of the farmer and farm), which are more personal and environmental in nature, have an effect on the intervening variables, which in turn affects the dependent variable (adoption of climate change adaptation strategies). The model explains that the adoption behaviour is governed by a set of intervening variables, specifically individual needs, knowledge and individual perceptions about the technology. However, these intervening variables are shown to depend on a set of socioeconomic, demographic, institutional and environmental variables which are regarded as independent variables.

2.3 Empirical Literature Review

2.3.1 Determinants of smallholder farmers' choice of adaptation to climate change

The study reviewed considerable amount of literature on adoption of agri-technologies/innovations, as much as most scholars have not made it clear on defining an adopter but few have, and it is with such background that has assisted the study to categorized adopters by distinguishing adopters for mere users. According to Mosher (1978) a farmer is said to have adopted an innovation after at least two repeated uses. However, Kabwe *et al*. (2007) notes that farmers who have adopted a particular innovation may decide to discontinue or dis-adopt. A study by Cary *et al.,* (1994) in a similar study in Australia found a dis-adoption rate of 1 in 3 among farmers that had successfully adopted conservation tillage practices. The above statements point out the complexity of adoption among farmer, the term adoption may vary. It can be noted that adoption is a complex nonlinear process, influenced by multiple factors. The process of adoption involves a comprehensive framework which takes into account the interaction of various factors in decision making. This section presents the compiled information on determinants of factors that influence the adoption of climate change adaptation strategies. However, from the many factors that have been reviewed, it should be noted that the adoption behaviour of an individual is a function of socio-economic and biophysical factors and the adoption process is endogenous to the sum of the interacting forces of the farmers' situation and this may vary from one community to another.

Education ranging from adult literacy classes to tertiary education provides flexibility of society towards change. Assessment of Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya by Barret *et al.,* (2004) found education status had a positive significant factor in influencing adoption. The study argued that educated primary decision makers are more likely to influence adoption for agricultural water management technologies than those who are not educated. An educated household head is more likely to be more informed about the benefits of modern technologies and may have a greater ability of understanding about it. Not only the benefits of adopting, but also the danger of not adopting is expected to be recognized easily by educated farm heads (Endalew, 2015). Deressa *et al.,* (2011) study on the perception of adaptation to climate change by farmers in the Nile basin of Ethiopia also found education of the household head coupled with variables such as gender of the head of the household, size of the household, livestock ownership, availability of credit and environmental temperature to significantly influence the presence of farmers' adaptation to climate change. However, a study to evaluate the factors Influencing the Choice of Climate Change Adaptation Strategies by Households: A Case of Mpolonjeni area development programme in Swaziland by Shongwe *etal.*, (2014) had contrary results. The study found education level of the household head insignificant in influencing household choice when adapting to climate change. Similarly, Thangata and Alavalapati (2003) also noted that educational attainment had no impact on adoption of agroforestry on Domasi valley farming system in Zomba district of Malawi.

In terms of age, Lwesya (2004) documented that the age of the farmer can influence the type of technology to adopt. A study by Gbegeh and Akubuilo (2013) on socioeconomic determinants of adoption of yam minisett by farmers in Rivers state, Nigeria correspondingly cited that age of a farmer may positively or negatively influence the decision to adopt new technologies. For example, the youth may be willing to use innovations that demand more energy, they are more flexible and more willing to take risks than older farmers who are known to be more risk-averse. Thus, younger farmers have a more likelihood of adopting new technologies (Adesina and Orson, 1995). Previous studies by Mattee (2009); Byron and MacKay (2005) have also found analogous results. The studies revealed that young and energetic people are more venturesome, active and ready to try innovations. Thangata and Alvalapati (2003) examined the differences between adopters and non-adopters of the fertilizer tree *Gliricidiasepium* in Malawi. The study results suggested that age of the farmers was one of important factors in the adoption process. In a subsequent study by Kaguongo *et al.*, (2012) age was found age of the household head among the factors that did not influence the adoption of agricultural technologies. The study also established that older household heads were less likely to adopt the new technologies because they were said to be less receptive to new ideas and were less willing to take risks. However, on the other hand, farm households with higher ages are expected to have more experience in farm production and adaptation measures (Di Falco *et al.,* 2011). The older farmers tend to have a more historical understanding of the state of climate in the local area. However, a study by Oloo (2013), an evaluation of climate change adaptation strategies and their effect on food production among smallholder farmers in Bungoma County, Kenya found age to be insignificant in influencing adoption of the strategies.

The impact of gender of the household head on adoption decisions is location-specific (Gbetibouo, 2009). Different societies have different roles for men and women (Lwesya, 2004). Many studies have shown that gender of the household head is an important variable affecting perception and adaptation decision at the farm level. Studies by Asfaw (2014), Temesgen *et al*. (2008). Tenge and Hella (2004), pointed out that male households have a higher probability to take up adaptation measures than female households. However, Tenge and Hella (2004) observed that women had restricted access to information, land, and other resources due to traditional social barriers and this resulted in low probability of females in adopting adaptation strategies. Deressa *et al.,* (2010) and Hassan and Nhemachena (2008) have concluded that a male headed household is more likely to adopt an adaptation strategy because males have more access and control of resources.Place *et al.,* (2011) reported that in most matrilineal societies in Malawi where land tenure is under the women, the decision-making power of women regarding tree planting is not guaranteed; women are barely involved in decision making due to the socio-cultural barriers. Some studies have results contrary to the above findings. Nhemachena and Hassan (2007) reported that female headed households are more likely to take up adaptation options to climate change and variability since much of the agricultural work is done by women. According to McCarthy (2010), women are more able to express understanding of climate change and variability than their male counterparts even though they tend to underestimate their knowledge as compared to men. In most cultures, women have always been actively involved in agriculture (Msuya *et al.*, 2014).

Furthermore, the marital status of individuals seems to affect the way people make decisions in life, including adoption of new innovations. Studies have pointed out that married-women households have a higher probability to take adaptation measures than single-female households. Married couples are regarded as more responsible than their counterparts. A study conducted by Endalew (2015) in the Nile basin of Ethiopia showed that the proportion of married respondents was a little higher for the group of adopters compared with the group of non-adopters of climate change adaptation.

In addition, expanding smallholder farmers' access to off-farm sources of income increases the likelihood for the farmers to invest in farming activities (Gbetibouo, 2009). A study on adoption of soil fertility improvement technologies among smallholder farmers in southern Malawi by Chinangwa (2006) conducted in Machinga and Zomba districts, noted that majority of farmers with high level of education had access to off-farm jobs and could therefore, afford to buy inorganic fertilizer as an option for improving soil fertility. The study results also revealed that an increase in multiple income sources increased adoption of inorganic fertilizers, although this had a negative impact on adoption of other technologies. The study observed that it had reduced the adoption of agroforestry (fertilizer tree species) because farmers with high off-farm income sources were able to afford the inorganic fertilizers since they had access to multiple income sources (off-farm jobs and credits). A study by Deressa *et al.*, (2009) also found non-farm income to have had a negative relationship with the adaptation of soil conservation practices and the use of different crop varieties.

Household size and farm labour availability can speed up or impede adoption of some farming technologies because some of the climate change adaptation strategies reduce the need for labour, whereas others increase it. Feder and Umali (1993) noted that when smallholder farmers were faced with labour shortages, they were less likely to adopt labour increasing agri-technologies. Household size as a proxy to labour availability may positively influence the adoption of a new technology as its availability reduces the labour constraints (Marenya and Barret, 2007). A study by Thangata and Alavalapati (2003) observed that an additional working member in a household increases the probability for agroforestry adoption on Domasi valley farming systems in Zomba, is diverted Malawi. However, it is not all the time that large household sizes have enough farm labour; at times part of the labour force is diverted to off-farm income generating activities in an attempt to earn income to ease the consumption burden imposed by a large family size (Gbetibouo, 2009). Similarly, Deressa *et al.*, (2009) observed that larger household size did not significantly increase the probability of adaptation.

Likewise, smallholder farmers' income level and credit access can influence decision for adoption of farming technologies. Different studies have shown that access to credit increases the likelihood of smallholder farmers adaptation to climate change (O'Brien *et al*., 2000; Nyengere (2015); Temesgen *et al*., 2008; Gbetibouo, 2009; Temesgen *et al*., 2008; Deressa *et al*., 2009). A study in Tanzania by O'Brien *et al*., (2000) observed that lack of income to purchase the necessary inputs and other associated equipment (e.g., purchasing seeds, acquiring transportation, hiring temporary workers) was one of the significant factors constraining farmers to adapt. Equally, a study by Deressa *et al.*, (2009) concluded that farmers' financial constraints was one of the factors hindering the farmers' uptake of other adaptation methods. Similarly, Gbetibouo (2009) also found inadequate access to credit as one of the major factors restraining farmers' adaptation to climate change. Gbetibouo's study (2009) found, among other things, farmers' income, the size of the household, farmers' experience and engaging in non-farm activities as the main factors that promote adaptive capacity of farmers. In 2006, a study by Total Transformation Ltd observed that most smallholder farmers in Malawi could not afford materials for adoption of beekeeping technologies hence the need for provision of soft loans and subsidies.

By the same token, the households' participation with off-farm income activities can influence decision making for adoption of farming technologies. A study by Chinangwa (2006) noted that there was high adoption of inorganic fertilizer for soil fertility improvement among high income farmers because they were able to afford the fertilizers. However, it is expected that the more farmers work off farm, the more likely they are to adopt time saving technologies and less likely to adopt time-intensive technologies (Caswel *et al.,* 2001). The pursuit of off-farm income by most farmers may weaken their adoption of modern technology by reducing the amount of household labour allocated to farming activities (Goodwin and Mishra, 2002).

In a study carried out by Thangata *et al.,* (2002) in Kasungu district, Malawi, on evaluating the potential for small scale farmers to adopt improved fallows, the adoption pattern for improved fallows was driven by the amount of land hence the technology was adopted by the majority who has sufficient land. This has also been reported in areas where there is high population density like the Southern part of Malawi such that the best technology becomes the technologies that do not demand too much land. Technologies that require larger piece of land such as tree-crop fallows would be a barrier to adoption by small holder farmers with land of less than 1 hectare. Thangata *et al.,* (2007) further reported that farmers in southern Malawi who had small land holding retorted to adoption of maize tree intercrops. In the same way, past studies by Nhemachena and Hassan (2007), Ajayi *et al.,* (2007) and Msuya *et al*., (2014) have also identified farm size as one of the farmers' characteristics that influences adoption rate of climate change adaptation strategies. Correspondingly, Nhemachena and Hassan (2007) reported that farmers having larger farm sizes adopts the use of multiple cropping and integration of a livestock component, especially under dry-land conditions.

In addition, land certificate is also crucial in adopting agricultural technologies by smallholder farmers. Studies have shown that more farmers are willing to invest on land whose security is guaranteed. Feder and Umali (1993) noted that most land renters are less likely to adopt conservation practices than land owners. Farmers feel that if they do not own the land then they cannot own any future benefits that may result from their hard work (Kabwe, 2010). Therefore, on a rented land, farmers only prefer to use technologies that can yield immediate results such as crop diversification and the use of improved varieties unlike setting up an irrigation scheme or adoption of agroforestry.

Food adequacy also affects adoption of agricultural technologies. A study by Navicha (2010) cites that the number of months the household experiences food shortage affects adoption of farming technologies. This happens because food shortage tends to reduce the amount of time households spend in their own farms(Sato, 2016). However, this food shortage could also be an influence for adoption, where farmers will have the need to adopt to increase production and ensure food security in future. Polson and Spencer (1997) found that migrant farmers in Nigeria were more likely to adopt improved cassava varieties than the resident farmers. This was because migrant farmers were less privileged in terms of access to land and other farming resources hence most of them were facing food shortages. Consequently, the study found that the food insecure farmers were more aggressive in their adoption of improved varieties unlike the food secure farmers.

Another important factor affecting adoption of farming technologies is the households' farm experience. Experience in farming increases the likelihood of farmers adopting adaptation measures to climate change (Maddison, 2007; Nhemachena and Hassan, 2008; Gbetibouo, 2009; Deressa *et al.,* 2009). A study by Nhemachena and Hassan (2007), found farming experience to be among the factors that increased the probability of farmers adopting irrigation, crop diversification and different crops as adaptation measures to climate change.

Additionally, extension support is one of the factors that enhances the adoption of farming technologies since it is a medium in which the farmers access information on new technologies, production, weather changes and agricultural markets. This agrees with the work of Lwesya (2004) where 87percent of the treddle pump adopters in Kasungu district had acquired extension support from the Government extension workers in the area of which 13 percent were non-adopters and among the non-adopter's81percent of them had no extension support. Households with access to agricultural extension about climate change adaptation strategies are more likely to adjust their farming practices in response to climate change. The various forms of extension services help farmers to take climate change and weather patterns into account in their daily farming activities by advising them on how to tackle climatic variability and change at farm level. A study conducted by Gbetibouo (2009) cited that it is the farmers who have access to extension services who are more likely to be aware of changing climatic conditions and to have knowledge of the various management practices that they can use to adapt to changes in climatic conditions.

Another important variable affecting adoption of farming technologies is membership to farmer association. Farmer associations or clubs are aimed at creating productive farmers and improving the economy of the farmers (Navicha, 2010). Membership in a cooperative agricultural organisation promotes farmers' knowledge and understanding of particular technologies (Chinangwa, 2006). This is aligned with study results on adoption of agricultural water management by Endalew (2015) who reported that membership to farmer associations or clubs increases the likelihood of farmers taking up adaptation measures.

Cultural values of the household or the community where the farmer is coming from may also influence decision making for adoption of farming technologies. Consumption preferences, taboos and religious beliefs affect the farmers' participation in adoption of farming technologies. A study by Kapanda *et al.,* (2005) notes that seed technologies which were introduced without addressing the socio-cultural need of the community faced adoption resistance by the farmers and the technology was not be sustainable in the absence of incentives.

Mindfulness of climate change and the variabilities of climatic conditions (temperature and precipitation) is also important for adaptation decision making. Information access on climate change and variability, rainfall and temperature pattern, enhances the efficiency of decision-making regarding adoption of the strategies (Mwangi and Kariuki, 2015). According to Komba and Muchaponda (2012) environmental variables such as incidences of droughts and floods, the farmer's observation of changes in environmental conditions such as rainfall, flash floods, droughts and temperature are among the important variables that help to give important decision-making power of the smallholder farmers at the farm level. Farmers who experience increased incidents of either droughts or floods are more likely to adapt to climate change through the adoption of the climate change adaptation strategies (Deressa *et al.,* 2008). Studies by Nhemachena and Hassan (2007), Murgor and Jerotich (2016), Gbetibouo (2009), Mwangi and Kariuki (2015), Yesuf *et al.,* (2008) and Deressa *et al.,* (2010) all report a positive relationship between temperature and uptake of climate related technologies.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

This chapter presents the various methods that were used in the research study. The chapter also discusses the study area, type of data, source of data, sampling technique and sample size, data analysis techniques and the econometric model employed to analyse the data. It further discusses the pre-test process and the ethical considerations and limitations of the study.

3.1 Study Area

The study was conducted in the eastern region in Malawi, Machinga District. The district has a total land area of 3,771 square kilometres and shares common boundaries with the districts of Mangochi, Balaka and Zomba and the Republic of Mozambique. Geographically, the study site lies at 15^{o} 16’ 55. 15” S latitude and 35^{o}43’ 05. 84” E longitude. Major economic activities of the district are tourism and agriculture.

The district was purposively selected for the research due to the following reasons:

1. The area has been experiencing extreme weather events as the evidence of climate change and variability in Malawi (MNVAC, 2005).
2. The adoption status of climate change adaptation for the area is unknown, there is lack of information on reasons influencing adoption, rejection and dis-adoption of

the strategies by the smallholder farmers in the district. (No documented study of this nature in the area).

3. Proximity to the researcher's university, which made it possible to maximize use of the limited resources (time and finances).

3.1.1 Climate and Vegetation

Machinga is in the Middle Shire Zone which is highly vulnerable to climate change and variability(Sato, 2016). The zone has a relatively dry climate with mean annual precipitation ranging from 200-1000 millimetres. The zone is characterized by near-subsistence farming, with fishing on a small scale amongst those living close to the River Shire(Malawi National Vulnerability Assessment Committee, 2005).

The district faces a number of disasters, both natural and human-made which include floods, drought, strong winds, hailstorms, landslides, earthquakes, pest infestations and disease outbreaks like cholera (GoM, 2014). The magnitude, frequency and impact of these disasters have been increasing in light of climate change, population growth and environmental degradation. Approximately 75 percent of the total population in the district is at risk of flooding each year (Machinga District Disaster Contingency Plan 2013/2014).

3.2 Type of Data

To achieve the study objectives, a cross sectional study was conducted in the month of December, 2016. This was a deliberate decision by the researcher to conduct the study at the time that the farmers were in the field. This helped ensure that the data was collected at farm level, by conducting the interviews from the gardens helped the enumerators reduce the chances of reaching incorrect inferences. The information received from the respondents was then being cross checked with the practices taking place in their respective gardens. The study used both quantitative and qualitative methods.

3.3 Source of Data

The primary data was collected from the smallholder farmers in the sampled villages in Mtubwi and Nsanama EPA using a questionnaire survey to carry out interviews with key stakeholders, a household survey and focus group discussions. The FGD questionnaire covered all the key areas such as awareness and the community's' perception about changes in temperature, rainfall variability, occurrences of disasters, extension services, factors influencing adaptation and challenges and the limitations experienced when adopting these climate change adaptation strategies among others. The focus group interactions consisted of 8-14 members consisting of smallholder farmers, lead farmers, traditional leaders and agricultural community-based organization group members. The information gathered was used to further support the data interpretation of the household surveys.

Precipitation and atmospheric temperature data for the study site was collected from the district Meteorological Service while cross sectional data on the population and sectional distribution of the smallholder farmers was collected from the District Agriculture Development Officer (DADO).

A desk review was carried out to obtain existing information regarding the climate change related initiatives and strategies that have been implemented in the area within the last three decades. For the purposes of the study the use of irrigation, conservation agriculture, improved crop varieties and crop diversification among smallholder farmers were assessed to form the component of climate change adaptation strategies. Thus, a farmer was regarded as an adopter if he/she had adopted at least one of the above-mentioned strategies, or otherwise he was a non-adopter of climate change adaptation strategies. The strategies were sampled for the research due to the following reasons:

1. Based on the literature, researchers' knowledge of the area and the knowledge obtained during the pre-testing phase.
2. The researcher made consultation with Machinga ADD prior to the study in order to identify and categorize the emerging climate change adaptation strategies which were currently in place in the study area. Accordingly, they reported that they are using different adaptation strategies to reduce the negative impact of climate change. The most commonly used were the strategies considered for the study.
3. The researcher also made an extensive review of policies and published literature on the adaptation strategies used by smallholder farmers in the area. Among the reviewed articles were the ASWAP report, NAPA and the socio-economic profile report for Machinga.

3.4 Sampling Method

Machinga district has seven Extension Planning Areas (EPAs) namely: Nyambi, Chikweo, Nampeya, Nanyumbu, Nsanama, Mtubwi and Mbonechera. In order to reduce bias when selecting the EPAs for the study, simple random sampling (SRS) with replacement (SRSWOR) technique was used to sample out the two EPAs from the seven EPAs. The locations of the study areas are shown in Figure 1.

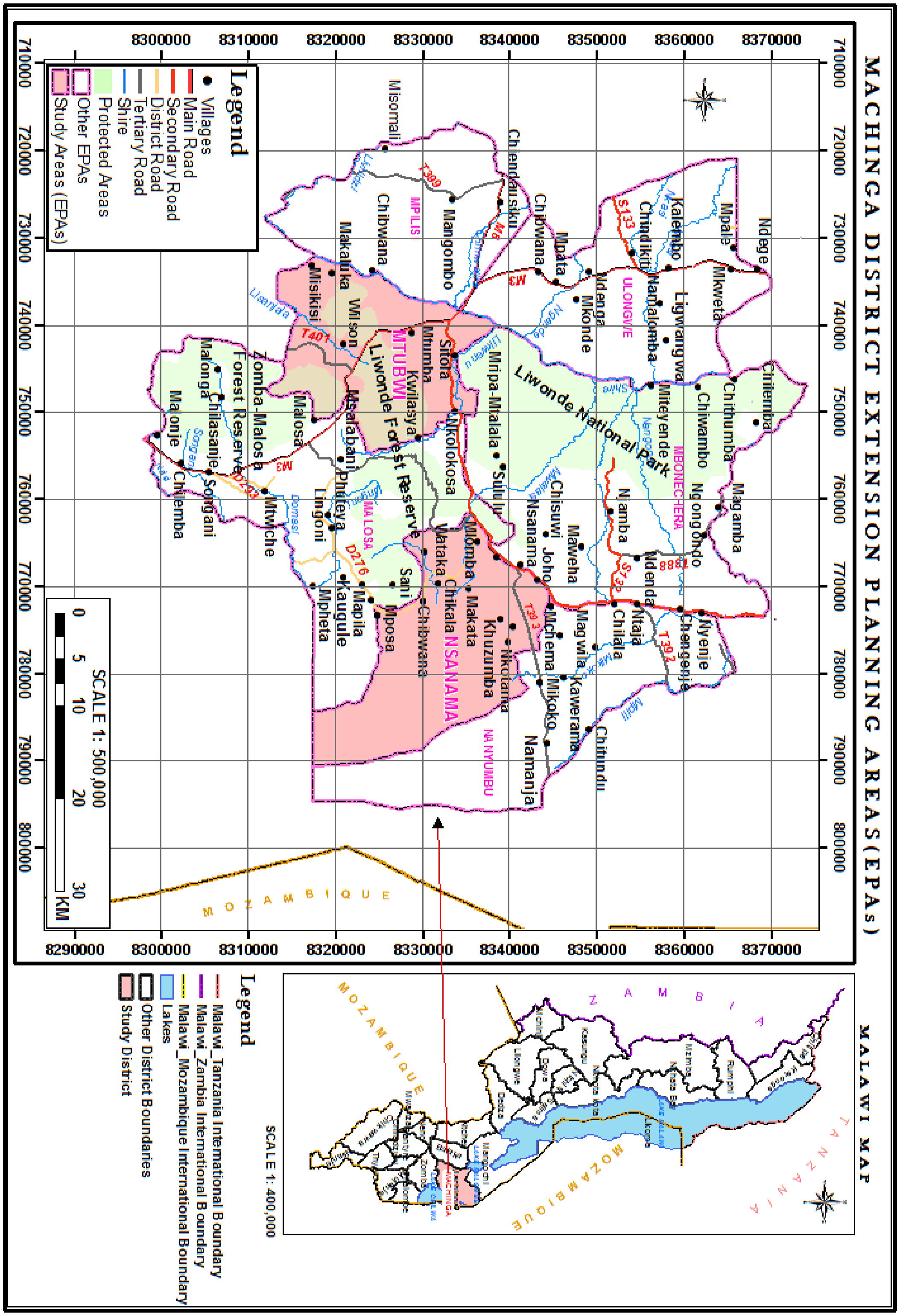


Figure 1: Geographical location of Machinga district and the study EPAs

Source: Map prepared by National surveys Department, Lilongwe, December 2018

The farmers were drawn using a multi-stage sampling procedure which involved, firstly, using simple random sampling selecting the EPAs and then from the EPAs using the same technique to randomly select 12 district agriculture development office administrative sections. In each section, villages were sampled and a total of 36 villages were picked. Finally, systematic sampling was used to select the smallholder farmers for the study. Systematic sampling was used because of the advantages it has over other sampling methods. Systematic sampling is taken as an improvement over a simple random sampling technique since the sampling can be spread more evenly over an entire population. The method is also regarded as an easier and less costly method of sampling and it is conveniently used even in case of large populations like the one that this study has (Kothari, 2004).

The number of respondents from each of the sampled villages was determined based on their population size to ensure that the sample was representative and to enhance precision. The table 1 presents the ratio of the sample size for the populations of Mtubwi and Nsanama EPAs used in the study.

Table 1: Distribution of respondents selected from Mtubwi and Nsanama EPA

EPA	Section	Number of Villages	Number of Smallholder farmers	Number of farmers (n)
Mtubwi	Chabwera	4	480	58
	Chipamba	3	224	27
	Kasupe	2	132	16
	Mliwo	2	239	29
	Msosa	4	322	39
	Mtira	3	308	37
	Nathendo	3	291	35
Total	**7**	**21**	**1,996**	**241**
Nsanama	Khuzumba	4	232	28
	Katundu	3	227	27
	Lambulira	4	349	42
	Mlomba	2	182	22
	Kambulaje	2	120	15
Total	**5**	**15**	**1,110**	**134**

Source: Own survey data, December 2016

3.4.1 Sample size

The total sample of smallholder farmers for the study was established by calculating a representative sample size using the formula developed by Yamane (1967) as shown below.The calculations were done in order to yield a sample which was more representative and appropriate for the analysis. The calculations of the sample size were done at 95 percent confidence interval with a desired level of precision set at 5 percent.

$$n = \frac{N}{1 + N(e)^2}$$

Where,

n= Sample Size

N= Population Size

e= desired level of precision

With a population of 3106 smallholder farmers, the sample size was calculated to be 354 respondents/farmers. An addition 6 percent was included and the sample was then increased from 354 respondents to 375 respondents in order to compensate for nonresponse and to cover for the anticipated non-responses and fouled questionnaires (Patel *et al.,* 2003; Israel, 1992; Okumu , 2013).

3.5 Data Analysis

The collected data from the sample respondents was analysed using both descriptive statistics and inferential statistics. In descriptive statistics, SPSS was used to display data in tables, graphs, percentages, frequencies and figures to support the findings of the study. In addition, an econometric model was used in executing the binary Logit model in order to determine the factors and to evaluate the relative significance of each factor in the adoption of climate adaptation strategies.

Numerous options of econometric models exist for use in adoption studies; for instance, some studies have used count data models to explain intensity of adoption of various technologies. Other studies such as those of Klotz *et al.,* (1995), Fernandez-Cornejo, (1996), and Doss and Morris (2001), have used the probit model to determine the factors that affect the adoption choices of smallholder farmers. This study did not intend to assess the adoption intensity. The use of binary logit or binary probit model for this study may therefore have been more appropriate than using models based on count data model. The main advantage with these models (probit and logit) is that their assumptions are realistic for binary adoption study data.

The use of logit models was found to be more appropriate for this study unlike the competing similar model (probit). The probit model lacks flexibility in that it does not easily incorporate more than one prediction variable (Montgomery *et al.*,2012) unlike the logit model which is more flexible. Logit models also guarantee the estimated probability increases and never cross the range of 0 to 1, and are the most commonly and widely applied.The logit model has also been previously used and endorsed by various academicians to model the factors determining the adoption of agricultural innovations by smallholder farmers in Africa (Deressa *et al.*,2009;Nhemachena and Hassan, 2008; Thole,2011; Navicha, 2010; Nyengere, 2015; Thangata and Alavalapati, 2003;Kaguongo *et al.,* 2012; Tjornhom,1995;Boahene *et al.,* 1999; Komba and Muchaponda, 2012; Abid*et al.*,2015).

The binary logit model was used to identify the determinants influencing the adoption of climate change adaptation strategies using the functional form of binary logit model as expressed by Abid *et al.,* (2015)

The binary logit model is specified as follows:

$$y_{ij}^{*} = \alpha + \sum \beta_k X_k = \varepsilon \; y_{ij}^{*} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

In the equation, $y_{ij}^{*}$is a latent binary variable with subscript *i* depicting the smallholder farmer who adapted to climate variability and *j* depicting four different adaptation measures. $X_k$represents the vector of exogenous explanatory variables that influence the farmers' choice of adopting particular adaptation strategyand *k* in the subscript shows the specific explanatory variable.Thesymbolαdenotes the model intercept, $\beta_k$the vector of binary regression coefficients and$\varepsilon y_i^{*} \cong N(0, \sigma^2)$ is the error term which is normally distributed and homoscedastic(Schmidheiny, 2016).

It is assumed that the probability of observing farmer *i* undertaking any adaptation at all (Y*i*=1) denoted as vector of adaptation options for climate change to be chosen by smallholder farmer depends on a vector of independent variables (X_k), unknown parameters (β_k) and the stochastic error term (ε*i*) (Gujarat, 2003). The probability of observing farmer *i* undertaking any adaptation at all P(Yi=1|X_k) has empirically been modelled as a function of independent variables. The definition of the model variables for logit model have been provided in table 2.

Table 2: Logit Model Specification: Explanatory and Corresponding Binary Variables

EXPLANATORY VARIABLE	UNIT	DESCRIPTION
Adoption	1= adopter 0= non-adopter	*Adoption status of the farmer*
Gender	1=male 0=otherwise,	*Sex of the household head*
Age	years (continuous age of respondent)	*Age of the household head in years*
Land size	acres (continuous variable)	*Acres of total land owned by the household head*
Land certification	1= yes 0= otherwise	*A deed for the farmland (registered land)- legal evidence of the ownership of land.*
Education	1= yes 0= otherwise	*Any form of education attained by the household head (literacy)*
Income	Amount (Continuous Variable)	*Total annual income of the farmer in Kwacha (MK)*
Household size	Quantity (Continuous Variable)	*Number of family members that eat from the same pot*
Marital status	1= Married 0= Otherwise	*Marital status of the household head*
Off-Farm activities (income sources)	1 = Yes 0= Otherwise	*Activities that help the household obtain income from outside of farming activities. (e.g. Remittance, charcoal burning, beer brewing, petty trading, Governmental employer etc.)*
Experience	Years (Continuous variable)	*Continuous variable and represents the experience of the household in the farming activities.*
Extension support	1 = Yes 0= Otherwise	*Communication and information to farmers from the extension officer*
Access to Credit	1= Yes 0= Otherwise	*Households access to credit service*
Farmers group membership	1= Member 0= Otherwise	*If a household is a member to agricultural cooperatives/groups*
Climate Change perception	1=Yes 0= Otherwise	*If the household is aware of climate change*
Training	1=Yes 0= Otherwise	*Trainings being offered to the farmer on climate change*
Food adequacy	1= Yes 0= Otherwise	*If the household has enough food throughout the year*
Culture	1= Yes 0= Otherwise	*Any cultural belief that influences the household's decision to change farming practices or adapt to climate change*
Temperature variability	1= Yes 0= Otherwise	*whether they have observed temperature changes for the past decade*
Rainfall variability	1= Yes 0= Otherwise	*whether they have observed rainfall changes for the past decade*
Information access	1= Yes 0= Otherwise	*Household access to information*

The dependent variable, which in this case is the "adoption of climate change strategies" was dichotomized by assigning a value of one if a farmer is an adopter and zero otherwise. Since the dependent variable is dichotomous, a dichotomous logistic model technique was used to regress adoption on a set of explanatory variables.

The characterization for the adopting farmers in this study used Rogers (1995) definition which categorizes an adopter as an individual who decides to make full use of climate change adaptation strategies as the best course of action and the definition from Kabwe (2010) and Nyengere (2015) who defined an adopter of agricultural technologies as the farmer who continuously uses the climate change adaptation strategies for consecutive three or more growing seasons (>5 years), while a non-adopter is the rejecter of the climate change adaptation strategies. The study categorized adopters as farmers who had used at least one of the following strategies for not less than five years or for not less than three consecutive growing seasons: conservation agriculture, irrigation, crop diversification and improved crop varieties.

3.0 Statistical and Specification Tests

Before carrying out the final model regressions, all the hypothesized explanatory variables were checked for some statistical problems such as the issue of multicollinearity, heteroscedasticity, correct model specification and endogeneity. Before running the model, the study checked all the twenty explanatory variables for multicollinearity using Variance Inflation Factor (VIF). In order to overcome any kind of heteroscedasticity, robust was used when running each model. The intuition was to get robust standard errors. Furthermore, in order to test whether the model had been properly specified, a link test was run after any single-equation estimation command. The tests were done in order to prevent problems that may arise due to a linear relationship among explanatory variables (Gujarati, 2003; Woodridge, 2002).

The data from Meteorological Services was analysed for evidence of climate change using the non-parametric Mann–Kendall (MK) test statistic on the plotted rainfall and temperature trend as recommended by the World Meteorological Organisation (Mann 1945; Kendall 1990). The Mann–Kendall (MK) test statistic was set at 95percent confidence interval.

3.1 Pre-test survey

Pre-testing of the questionnaires was conducted two weeks before the actual data collection. The pretesting methodology was adopted from Grimm (2010); it consisted of a sample size often respondents from the target group, two FGDs and one key informant interview. This was done in order to ensure that all kinds of errors that are associated with survey research and research instruments are reduced. The pre-test helped to improve the quality of the data significantly through identification and correction of errors on the instruments before the main survey. The pre-test also functioned as the training session for research enumerators.

3.2 Limitations of the Study

Due to limited time and resources the study could not be conducted in all the seven EPAs in Machinga district and two EPAs were sampled for the study. The study was based on the inclusion of only four climate change adaptation strategies in the model which is not the exhaustive list of climate change adaptation options used by smallholder farmers in Machinga district.

Another limitation which can be highlighted is the unavailability and limited data on rainfall for Machinga district. For instance, the 30-year period of rainfall data had two consecutive years missing rainfall data for the years 1995 and 1996.

The study used multiple data collection tools and sources as one way of diversifying the information with the intention to address some of the limitations. The collected data was cross checked with each other accordingly. For instance, the respondents' perception on environmental conditions collected from the household questionnaire was cross checked with the data obtained from meteorological department. By obtaining data from different potential sources it helped reduce the chances of reaching false conclusions (Ndaki, 2014).

3.3 Ethical Considerations

The permission to administer household questionnaires and conduct key informant interviews was consensual. If the respondents demonstrated or articulated any discontent the interviews were either re-scheduled or cancelled. Respondents were verbally requested for their consent. In addition, during the consent seeking, the respondents were informed that should any parts of their interview be used in a publication, their names would not be recorded and any details related to their privacy would be kept confidential. All efforts were made to ensure that all the anticipated objectives and research questions of the study were addressed accordingly.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents the results of the analysis of the key findings in the study using the methodology discussed in chapter three. The chapter is divided into five sections. Firstly, the chapter discusses the socio-economic and demographic characteristics of the smallholder farmers. The Second section presents results on farmers' perceptions on climate change and variability indicators against the empirical evidence. The third section presents the results on the challenges limiting the adoption of climate change adaptation strategies. The fourth section presents results on the awareness and the adoption status of the climate change adaptation strategies. Finally, the last section presents the Logit regression model results on factors that influence adoption of climate change adaptation strategies.

4.1 Socio-economic and demographic characteristics of the smallholder farmers

The first specific objective was to examine the characteristic differences of the smallholder farmers. The objective was achieved by the use of descriptive analysis of the selected household heads' characteristics. The characterization was done in order to determine how the socio-economic and demographic characteristics varied across farmers in the study area. The results for continuous and descriptive characteristics are given in table 3 and 4respectively. Characteristics that were measured quantitatively are presented using t-test analysis while were categorical were subjected to chi-square analysis.

The t-test analysis was used to test for significant differences between the adopters and non-adopters based on land size, age, household size, farm experience. The t-test analysis results are presented in table 3 below. The results reflected statistically significant differences in land size, household size, age and farm experience among the adopters and non-adopters of the adaptation strategies at 1percent significance level. 1.21 0.100

Table 3: Descriptive characteristics of the household head

Variable	**Mean (adopters)**	**Mean (Non-adopters)**	**T-value**	**Probability**
Land size (acres)	2.32	1.20	1.946	0.050
Age	51.60	40.28	-3.549	0.001
Household size	6.60	3.72	-3.906	0.000
Farming Experience	20.0	13.40	-3.031	0.003

Source: Own survey data, December 2016

Results from Table 3 indicate that the average household size for the respondents was with the mean value of 6.60 for adopters and 3.72 for non- adopters. This means that average household size for non-adopters differs significantly from those who have adopted the climate change adaptation strategies (t=-3.906; p= 0.000). This implies that climate change adaptation strategies were affected significantly by household size; farmers with a larger household size had higher probability to adopt. The t-test results on household size are typical outcomes, since adoption of agricultural technologies is a labour-intensive practice. Household size (labour supply) is found to positively minimize the problem of labour shortage if a farm has a bigger household size than those with a small household size(Endalew , 2015). Households with many family members can participate actively in agricultural activities such as the adoption of climate change adaptation strategies and this may influence the households to adopt agricultural technologies. It is argued that a larger household size enables the adoption of technologies by availing the necessary labour force at hand (Croppenstedt *et al*., 2013). Household size can influence adaptation, due to its associated with labour endowment (Tesfay, 2014). A study by Batz *et al.*, (1999) on Kenyan dairy farmers further complements the outcome of this study. Their study observed that farmers who exprerienced labour shortages barely adopted technologies that required more labour.

Average land holding size for adopters was found to have a mean value 2.32 acres per household, while for non-adopters it was 1.20 acres. The results indicate that the average size of farm land for non-adopters differed significantly from those who have adopted the climate change adaptation strategies (t= 1.946; p =0.050). This shows that climate change adaptation strategies are affected significantly by land size and farmers with larger farms have higher probability to adopt. Land availability to the farmer is considered an important factor since most of agricultural technologies need cultivable land in order to be successful (Nyengere, 2015). Ajibefun and Fatuase (2011) found land size as one of the major factors positively influencing adaptation to climate change among arable crop farmers in Ikogosi warm spring communities of Ekiti state Nigeria. When it comes to adoption of agricultural technologies associated with productive capacity of agricultural land, farmers who own bigger land are often assumed to be in a better position to easily adopt since they have a higher potential of increased production which enables them to invest and gain more from the technology. In farming activities, land is among the main necessary inputs. For example, a farmer who has a larger farm size has a chance to practice multiple technologies which in turn diversifies agricultural output while households with smaller land holding sizes are un able to fully adopt technologies that require use of more land (Thangata and Alavalapati, 2003). The findings of this study, corroborated the above presented information where the mean value of land size was found to be higher for those who adopted as compared with those who did not adopt. However, contrary to the above findings, other studies have found small land size to influence adoption of agricultural technologies. For instance, Polson and Spencer (1997) found that migrant farmers in Nigeria with small land sizes are more likely to adopt improved cassava varieties than large land owners. This is because migrant farmers are less privileged in terms of access to land and other farming resources. The use of high yielding varieties helps them maximize production.

Experience in farming increases the probability of uptake of adaptation measures to climate change (Maddison, 2007; Nhemachena and Hassan, 2008; Gbetibouo, 2009; Deressa *et al.*, 2009). Farm experience relates to the respondents' ability and capacity to make full use of new farming technologies. Caswel *et al.*, (2001) argued that number of years of farming (farmers experience) could positively affect the probability for a farmer to adopt resource-conserving technologies. Farmers who have been agricultural producers for many years are expected to be more proficient at integrating new technoloies into their production. A study by Nhemachena and

Hassan (2007) also found that experience in farming increased the probability of uptake of irrigation, crop diversification and different crops as adaptation measures to climate change. Inconformity with the previous studies mentioned above, this study also found that adopters had a greater number of years in farming with mean of 20.0 as compared to the non-adopters who had an average mean of 13.40. The average farm experience for non-adopters differed from those who have adopted the climate change adaptation strategies (t=-3.031; p=0.003). This indicated that climate change adaptation strategies were affected significantly by farm experience. Farmers with more years of farming experience had a higher probability to adopt the strategies than their counter part.

Age was another important demographic characteristic in the study. Table 3 shows that the majority of the adopters were the older generation with an average age of 51.60 and non-adopters had an average age of 40.65 years. Age for non-adopters differed significantly from those who have adopted the climate change adaptation strategies (t=-3.550; p=0.001). This suggests that the possibility of adopting the climate change adaptation strategies was affected significantly by age and older farmers had a higher probability to adopt the strategies.

This finding is not consistent with Rogers' theory which regards the youth to be more involved in the adoption process rather than the aged. Rogers stipulated that the younger generation (youth) are more energetic than the older generation and agricultural technology adoption is labour intensive such that older people could lack the physical energy required for the adoption purpose. There can be a number of reasons to explain why the current study had contradicting results to the theory by having many older adopters than young adopters. For instance, Machinga is one of the districts in Malawi that has many of its young people migrating to South Africa, Mozambique and other urban areas within Malawi to look for employment and business opportunities (GoM., 2014). In so doing, the population of farmers is concentrated within the older generation that remains in the village. Even though some of the technologies are labour intensive, they still adopt them to maximize food production for their survival. This is so because these older people do not have any alternatives to earn a living so they have to make a living out of an age-old occupation. Furthermore, the older household heads are more likely to adopt agricultural technologies such as crop diversification, because they believe that traditional ways of farming are still the best and crop diversification is among the oldest ways of cultivation in smallholder agriculture in which farmers have been cultivating and enjoying the benefits of crop diversification long before climate change and variability adaptation programmes(Moyo, 2014).

Table 4 below presents results on the following descriptive household characteristics of farmers in the study area: gender, marital status, education level, extension service, access to credit, farmers' group membership and off-farm income sources of the smallholder farmers.

Table 4: Descriptive characteristics of the smallholder farmers

		Adopter		Non-adopter		Chi-square test
		Count	Percent	Count	Percent	p-value
Gender	Male	196	78.1	86	69.4	0.001
	Female	55	21.9	38	30.6	
Marital Status	Married	213	84.9	95	76	0.050
	Single	38	15.1	30	24	
Education Level	Primary	174	70.4	50	43.9	0.001
	Secondary	37	15	36	31.6	
	Tertiary	0	0	2	1.8	
	Informal	18	7.3	7	6.1	
	None	18	7.3	19	16.7	
Extension Service	Yes	215	85.7	96	77.4	0.046
	No	36	14.3	28	22.6	
Access to credit	Yes	175	69.2	43	35.2	0.026
	No	78	30.8	79	64.8	
Farmers group membership	Yes	160	65	69	53.5	0.0027
	No	86	35	60	46.5	
Off-farm income	Yes	144	56.9	70	57.4	0.1676
	No	109	40.1	52	42.6	

Own survey data, December 2016

Gender of an individual plays a role in adoption of technologies. Even though respondents were randomly sampled, the highest response came from the males as most of the households are headed by them. The chi-square results showed that the adoption status had a significant relationship between adoption status and gender of the smallholder farmer (chi-square test, x^2=31.58, df=1, p<0.001). There were More male headed households (78.1percent) as compared to female headed households (21.9percent) probably because most African societies have different roles for men and women (Lwesya, 2004). The roles are often acquired through socialization; in most Malawian societies men usually take up the role of household head. In addition to being decision makers at household level, men also have access to information and technical help from the extension workers since most of agricultural extension workers approach the household heads. Male-headed households are often considered more likely to get information about new technologies and take risks in adopting new technologies than female-headed households (Asfaw and Admassie, 2004). A study by Wiyo *et al.,* (2002) on impact assessment of treadle pumps in Malawi, pointed out that male headed households have a higher probability to adopt agricultural technologies than female headed households. Wiyo *et al*., (2002) further noted that in some societies, women do not feel comfortable in using the treadle pumps in irrigation as they feel exposed and undignified. A study by Tenge and Hella (2004) and Okumu (2013) found that due to traditional social barriers, most women may have restricted access to information, land, and other resources. This often undermines their capacity to embrace labour intensive agricultural innovations and may result in low probability of females in adopting climate change adaptation strategies.

For marital status, respondents that were single, divorced, separated and widowed were pooled and identified as single to aid the interpretation of the results. Among the adopter's, total number of married household heads in the survey was 213 (84.9percent) while 38 (15.1percent) were from single headed households. For non-adopters, 76percent (95) of the respondents were married and 24 percent (30) respondents were from single headed households. This indicates that a majority of the adopters were married. The chi-square results showed that the adoption status had a significant relationship between adoption status and the marital status of the smallholder farmer (chi-square test, x^2=22.15, df=1, p=0.050). These results are not very surprising since married people are considered more responsible than their counterpart and are settled and willing to make investments and provide for their home. Machinga being a matrilineal area, the husband who is a marital immigrant, staying at his wife’s village is required to work in his wife’s garden and he is also expected to help out in his mother in-law’s gardens if she is divorced or widowed. Hence, most men work extra hard in order to maximize food production so as to fulfil their customary duties and this encourages them to adopt agricultural output maximizing strategies such as improved crop varieties, diversification, irrigation and conservation agriculture.

The research findings point out that most of the respondents have had some level of formal education as it may be inferred from Table 4. The table shows that the majority of the household heads 299 (82.8 percent) had attained some formal education followed by 27 (10.2percent) respondents who had attended informal education (adult literacy classes) and a minority of the household heads 25 (6.9percent) did not attain any education. The results also show that among the educated, the majority 224 (74.9percent) household heads had attended primary education and 73 (24.4percent) had gone through to secondary education while 2 (0.7percent) had a tertiary education, which was the highest level of education and the least common. The adopters registered the highest number of the respondents who had at least attended some form of education including informal education with a total of 324 (89.7percent) household heads and the non-adopters were a total of 95

(26.3percent) household heads. The percentage of the adopters attaining education is higher than that of the non-adopters, suggesting that education may contribute to the adoption of new technologies. The chi-square results showed that the adoption status had a significant relationship between adoption status and education status of the smallholder farmer (chi-square test, x^2=13.56, df=1, p<0.001). This complements the Diffusion of Innovations theory that states that innovators and early adopters tend to be more educated and more risk oriented than the laggards who tend to be least educated and are very conservative (Rogers, 1995). The results correspond with what Rahm and Huffman (1984) found when evaluating the role of human capital and other factors in adoption of reduced tillage technology in corn production. They established that farmers' education and experience play a crucial role in facilitating technology adoption. Higher educational credentials of the household head are known to increase the knowledge base which makes it easier for household heads to understand new farming systems and technologies (Komba and Muchapondwa, 2015; Deressa *et al*. 2011).

On extension services, the results in Table 4 indicate that more farmers had access to extension services 311 (82.9percent). Among the adopters, 215 (85.7percent) of the respondents had access to extension services while 36 (14.3percent) had no access to extension services. The chi-square results further showed that the adoption status had a significant relationship between adoption status and extension services received by the smallholder farmer (chi-square test, x^2=21.16, df=1, p=0.046]. This outcome was rather unexpected to have farmers without access to extension services adopting climate change adaptation strategies. This could be attributed to the influence of indigenous knowledge which farmers have inherited (Moyo, 2014). For instance, smallholder cultivation incorporates mixed cropping, inter cropping, multiple cropping which is an old agricultural practice but also regarded as a means of crop diversification hence making a farmer an adopter of crop diversification even in the absence of extension services. The results correlate with studies by Wozniak (1984) and Adesina and Forson (1995) where both of these studies indicated that agricultural extension is important for adopting agricultural technologies. The results are also consistent with the findings of Koundouri *et al*., (2006) whereby a study conducted on irrigation technology adoption showed that farm households that had extension services and information on agricultural technologies were more likely to adopt new technologies than those without. The results also show that 96 (77.4percent) of the non-adopters had access to extension services. The results were very surprising, since it is mostly likely projected that farmers with extension services should adopt agricultural innovations. Extension services play a significant role at influencing smallholder farm households to adopt climate change adaptation strategies and those households that do not get any extension services are less likely to adopt climate change adaptation strategies.

The study results in Table 4 on access to credit, reveal that a total of 218 (58.1percent) farmers had access to loans while 157 (41.1percent) farmers did not have access to loans. The adopters had the highest number of the respondents 175 (69.2percent) who had access to loans while the non-adopters had a lower number of respondents 43 (35.2percent) who had accessed the loans. Furthermore, 316 (84.3percent) respondents reported that they had experienced financial constraints in undertaking their usual farming activities, farmers were unable to purchase agricultural inputs such as fertilizer, seeds, pesticides, herbicides, oxen, treadle pumps and watering canes. On the other hand, 15.7percent (59) of the households indicated that they had not experienced any financial constraints in undertaking their farming activities. In support of the study findings, other studies have reported that access to credit helps to stimulate technology adoption (Mohamed and Temu, 2008). It is also believed that access to credit promotes the adoption of technologies through relaxation of the financial constraint. Availability of credit allows farmers to buy inputs such as fertilizer, improved crop varieties and irrigation tools. Studies on adoption of agricultural strategies have shown that there is a relationship between the level of adoption and availability of credit (Yirga, 2007). However, the results from this study also showed that not all farmers have access to credit due to a number of barriers. For instance, the farmers said they could not get a loan because some of them did not know where they could get the loans, and some complained of high interest rates while others tried to get the loan but were unsuccessful because of the restrictions imposed by the lending institutions such as the use of collateral. Muzari *et al.*, (2013) also found that in some societies, access to credit has been found to discriminate against the poor and is gender biased. For example, in situations where a farmer cannot provide collateral or where the household is female headed, they are discriminated against by credit institutions, and as such they are unable to finance yield-raising technologies, leading to low adoption rates.

Table 4 results on farmers group membership shows that 61.1percent (229) of the respondents were members of a farmers group or club or organization (i.e lead farmers, village development committee (VDC), village natural resources management committee (VNMC) and village food banks. Amongst the adopters, majority of respondents 65percent (160 small holder farmers) belonged to a farmers group. For the non-adopters, the proportion with group membership was not different from those without group membership, 53.5percent (69 small holder farmers) of the respondents had membership to a farmers group and 46.5percent (60 small holder farmers) had no membership to any farmers group. The results show that the majority of the adopters belonged to a farmers group (chi-square test, x^2=9, df=1, p=0.0027]. This is an expected outcome since farmer groups are a conduit for information about new strategies through extension workers who normally approach the members with newly introduced technologies. Farmers from the farmers group share information and learn from each other on the benefits and usage of a new agricultural technology and they also provide technical support to each other (Uaiene *et al*., 2009; Oloo, 2013). Information from extension workers also includes facilities and mechanisms that enhance farmers' access to productive inputs and product markets (Meinzen-Dick *et al*., 2004). In support of the above arguments, when studying the effect of community-based organizations in adoption of corm-paired banana technology in Uganda, Katungi (2007) noted that farmers who participated more in community-based organizations were likely to engage in social learning about the technology, hence raising their likelihood to adopt the technologies.

On Off-Farm Income Sources**,** the results in Table 4 indicate that 212 (56.8percent) of the household heads had off-farm income sources and 163 (43.4percent) had no other sources of income apart from agriculture. For adopters, those who had off-farm income sources were 144 (56.9percent) respondents while 109 (43.1percent) had no off-farm income sources and were solely depending on farming as their livelihood. Furthermore, the results also show that for non-adopters, 70 (57.4percent) household heads had off-farm sources of income and 52 (42.6percent) had no off-farm sources of income. Based on these results, there was no significant relationship between adoption status and the status of off-farm income sources (chi-square test, x^2=52.95, df=1, p=0.833]. However, the results of this study showed that the majority of the farmers who had multiple income sources had adopted climate change adaptation strategies as compared to farmers who had one source of income. The farmers disclosed during focus group discussions that most of farmers in the community were relying on off-farm sources of income for the households' livelihood rather than agriculture that has for the past years performed badly due to frequent dry spells, flash floods and inability to purchase fertilizer without subsidy. As a result, most farmers in the study area have found means to supplement their income by diversifying their sources of income through having off-farm sources of income. During focus group discussions, it was also made known that the farmers used the money from off-farm sources of income to buy food during shortfalls; buy fertilizer, improved seed, treadle pumps for irrigation, acquire labour for farm operations and other farm inputs. Hence, off-farm income sources help the farmers remove the financial constraints that may limit their adoption of agricultural technologies. Off-farm income provides farmers with liquid capital for purchasing inputs such as the ones stipulated above.

4.2 Local Perceptions of Climate and Climate Change

Knowledge on climate change and variability, rainfall and temperature pattern, enhances the efficiency of decision-making regarding adoption of the strategies for daily farming activities by putting into account the climatic variability and weather changes at farm level (Mwangi and Kariuki, 2015). This section assessed the smallholder farmers' perception of the changing climate against empirical evidence by presenting the results on the respondents' perceptions on the concepts of climate change and variability. In order to get critical information and insight into farmers' observations, the farmer perceptions were further used to cross-reference with actual climate data of the study area using the rainfall and temperature trends derived from data collected from the Department of Meteorological Services of Malawi.

4.2.1 Climate change and variability indicators

The changes of climatic conditions in the area have and continue to manifest in various ways. During FDGs, the respondents pointed out that from the year 2000 to the present years there has been a tremendous yield decline among the farmers and communities have been experiencing food insecurity problems. The farmers have not been able to harvest notable yields for the past years due to climate variability. Even though the problem of food insecurity is a resultant of a number of factors, the respondents attributed the problem of low yields to the high incidences of pests that occur due to dry spells. The dry spells result into the spreading of army worms, the spells could also lead to the mass wilting of crops, making the crops dry up before their mature stage. Respondents also pointed out that the annual occurrence of floods causes waterlogging in the farmers' gardens, thus causing the wide spreading of pests and diseases that in return has affected farmers' annual yields. With this information, it was identified that the local people have their own parameters and techniques for identifying the manifestations of these effects of climate change. Figure 2 below presents the results on the respondents' perceptions based on the climate change and variability indicators.

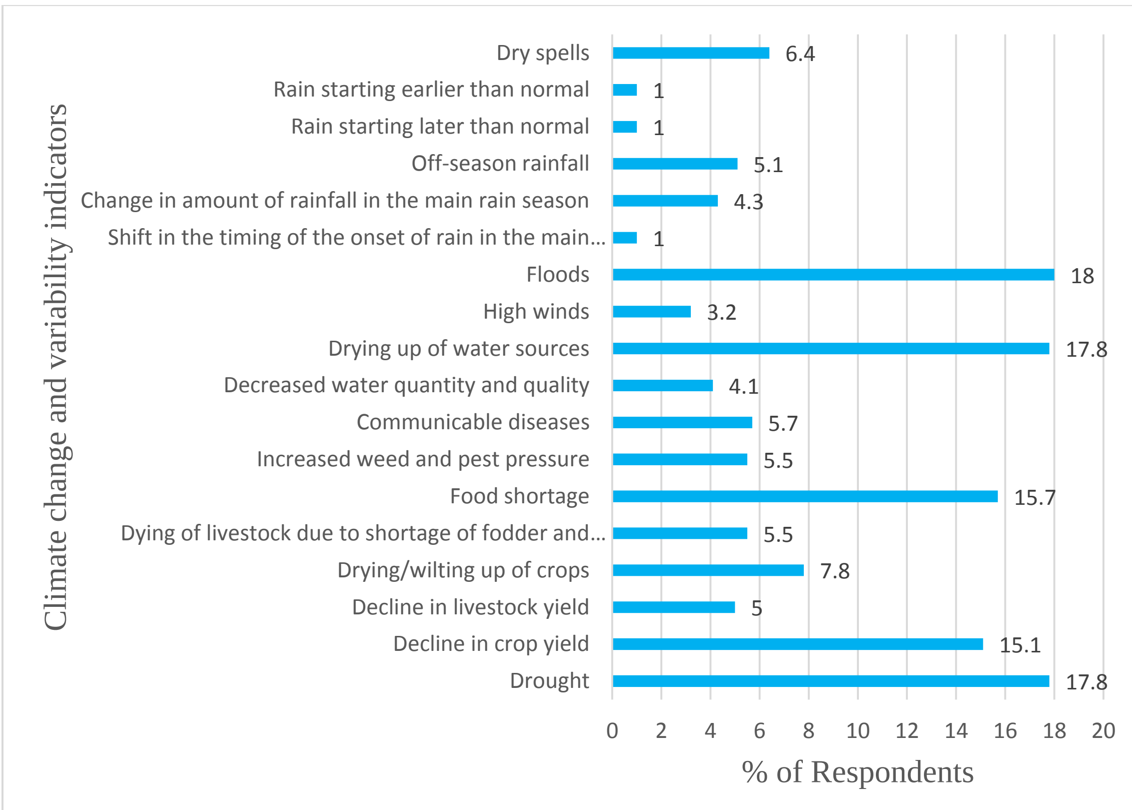


Figure 2: Climate change and variability indicators

Source: Own survey data, December 2016

The results presented in figure 2 above, demonstrated that a higher proportion of the household respondents had experienced a problem of drought (17.8 percent) and drying up of water sources (17.8percent) in the past decade, followed by many other problems as indicated in figure 2 above. Drought and drying up of water sources are currently the most common disaster in Machinga district (GoM, 2014). Drought and drying up of water sources tremendously affect the crop production system, making irrigation impossible and difficult. In the year 2014/2015 growing season, due to *El Niño* a phenomenon associated with warm and drier weather conditions. The problem was so severe that most farmers ended up dis-investing in irrigation because of the drying up of water sources (personal communication, 2016). This had also stirred up problems of communicable diseases among the communities and multiple water user conflicts among villages. Another intense notable climate change and variability indicator as experienced by farmers, was food shortage (15.7percent) which was mostly related to other variability indicators such as decline in crop yield, drying and wilting of crops and decline in livestock yield.

The respondents acknowledged the existence of change and variability in rainfall and temperature. The farmers were asked to disclose their perception with regards to temperature and rainfall variability experienced over the past years. These experiences are built on their understanding of the local climate and which in turn was compared to data collected from Malawi Meteorological Department. From the study results, it was noted that the majority of the farmers had observed changes in the trends of rainfall and temperature. A total of 363 (98.6percent) respondents were aware of changes happening with climatic conditions of the area. This information was also crosschecked with key informant interviews, where they all confirmed to have experienced climatic changes. There was consensus during FGDs about observed climatic changes through observation of rainfall changes (mostly insufficient rain), increased experiences of drought, rising of temperature and flash floods. The household interview results on the local perception of temperature and rainfall trends is presented in figure 3 below.

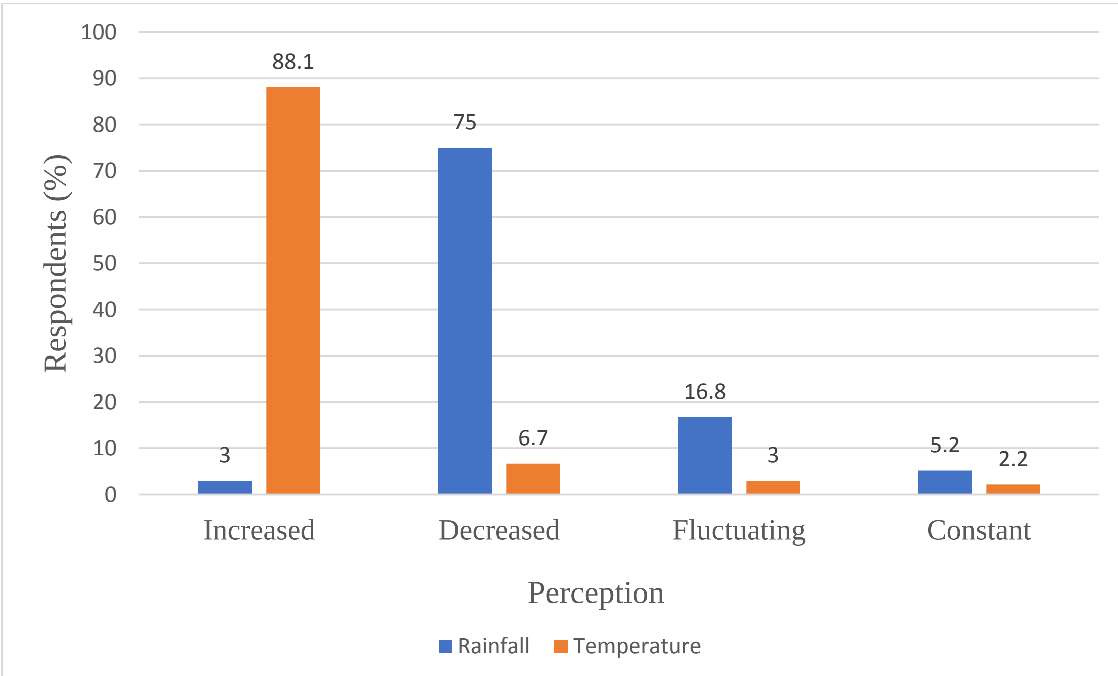


Figure 3: Respondents' perceptions on the trend of rainfall and temperature

Source: Own survey data, December 2016

About 75percent of the respondents acknowledged to have experienced rainfall decline as the main observation on the trend of rainfall. Followed by those that had observed the fluctuating rainfall trend (16.8percent) and about 5.2percent of the respondents noticed no change in the rainfall trend (constant rainfall). The farmers also cited to have experienced a decline in the trend of crop production (even though this problem may be as a result of several factors). 26 (7percent) respondents reported that their crop productivity trend for the past decade had been constant while 35 (12percent) respondents cited to have observed an increase in the households' crop productivity trend and they gave credit to the use of the multiple agricultural technologies. Whereas the remaining 304 (81percent) of the farmers cited to have experienced a decline in crop production. The respondents' observations correlate with kurukulasuriya and Rosenthal (2003) who noted that the increased frequency changes in temperatures and precipitation (including droughts and floods) can result into agricultural losses which result into decline of crop and livestock production and food insecurity. Furthermore, when describing the great importance for the need to reduce the effects of climate change on agriculture, Kurukulasuriya *et al*., (2006) also explained that in the absence of climate change adaptation strategies, climate change can affect agriculture in a number of ways. For instance, the changes in temperature and precipitation can directly affect crop production by altering the distribution of agro-ecological zones.

4.2.1 Temperature and Rainfall trend of the area

For the past years, starting from the year 2000 to the present year. Machinga district has been experiencing an increasing level of temperature and dwindling and fluctuating precipitation levels (GoM, 2014). The annual rainfall trend and anomalies graphs for Mangochi district have been presented in figure 4 showing annual variability of rainfall.

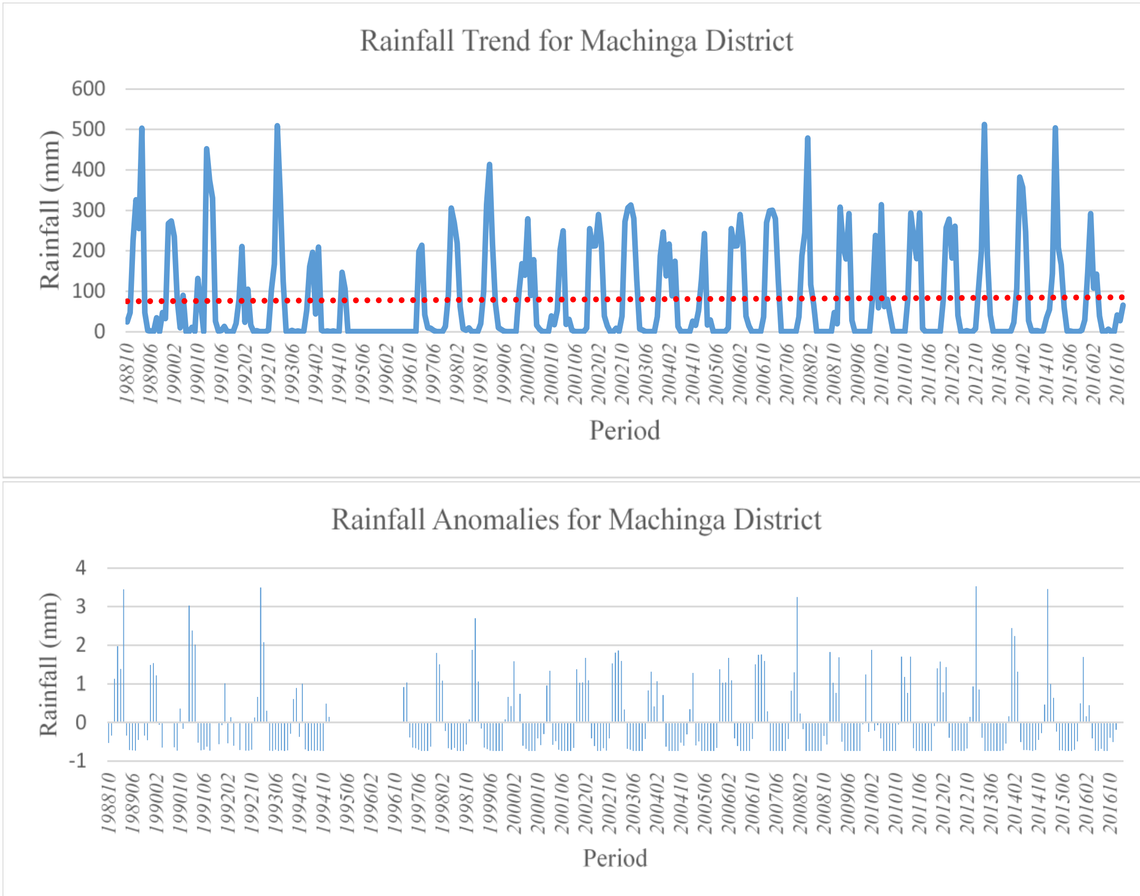


Figure 4: Rainfall Trend anomalies for Machinga district from 1987/88 to 2015/16

Source: Computed based on data from meteorological services of Malawi (2016)

The results for rainfall trends for Machinga district from the agricultural year of 1987/88 to the agricultural year 2015/16 was assessed using the WMO recommended Mann-Kendal (MK) statistic at 95percent significance level. The results in figure 4 showed that there was no significant difference in positive or negative trend from the agricultural year 1987/88 to agricultural year 2015/16 at α=0.05 significance level. This showed that the trends and seasonal distribution of annual rainfallwas within the same ranges of 989mm across the years. However, it was observed that there was a shift of the onset rains for the rainy season from October to November with more frequent persistent dry spells, common flood occurrences and a high concentration of rains towards the end of the rain season. This explains why the respondents perceived a change in rainfall trend since the farmers assessed the amount of rainfall based on the days the rains had fallen during the growing period and not in the accumulative state as it should be. The respondents cited to have experienced intense temperatures during the growing season and the heat conditions were accompanied by persistent dry spells which sometimes went up to 21 days. As a result, the farmers lost the crops due to mass wilting. The respondents also reported to have experienced the shifting of the agricultural planting season. In the past, farmers from the district and its surrounding catchments were cultivating as early as mid-September, then the season shifted to October and now it has shifted to late November and in other areas it is now December. This has resulted in having more rainfall towards the end of the growing season leading to increased incidences of flooding and water logging. A study by Ngongondo *et al*., (2011) on annual, seasonal and monthly series analysis of rainfall for the whole of Malawi also revealed statistically non-significant trends at $\alpha = 0.05$ level. The results showed no discernible upward or downward trends in rainfall variables including annual, seasonal, and monthly rainfall during 1961 to 2006. Another study by McSweeney *et al*., (2008) found seasonal projections indicating a decreasing trend in rainfall for Malawi. McSweeney *et al.*, (2008), further reported that mean cumulative rainfall for the growing season has not changed in most parts of Malawi.

The computed annual rainfall anomalies for Machinga district in figure 4 revealed that rainfall in most years is below average with a twisted distribution having most of the district's rainfall in very few but intense events not suitable for rain fed agriculture. The rainfall anomalies depicted a generally positive anomaly indicating increasing rainfall in the 1980s which was the period of prolonged *La Niña* accompanied by extreme floods. After the 1980s *La Niña*, the negative anomaly is also observed in the early 1990s and in the year 2000 to 2002 as an extreme negative anomaly. Based on the historical climatic events in Malawi, there was a decline in rainfall in the early 1990s and an intense drought in 2000 which marked the prolonged period of *El Niño.* As it can be observed on the rainfall trend anomalies graph, the two climatic conditions (*El Niño* and *La Niña*) have interchangeably taken place up to the recent event of *El Niño* in the agricultural growing season of 2014/15 and 2015/16. These are indications that there are changes in the seasonal rainfall even though there is no significant change in cumulative annual rainfall.

In addition to observing the trends of rainfall, the farmers were also asked to give a review on their perception of temperature trends of the area. The majority of the respondents (88.1percent) had observed changes in the trends of temperature. The results were in agreement with the Malawi Vulnerability Assessment climate modelling results which showed there was a gradual increase in average annual temperature in most parts of Malawi which is likely to continue(USAID, 2013). The other farmers interviewed thought the temperature trend of the area was fluctuating (3percent), followed by those who observed a decline in temperature (6.7percent) while 2.2percentof the farmers did not notice any changes in the temperature (constant. The maximum and minimum temperature trends plus the anomalies graphs are in figures 5 showing annual variability of temperature with extreme projections in the maximum temperature.

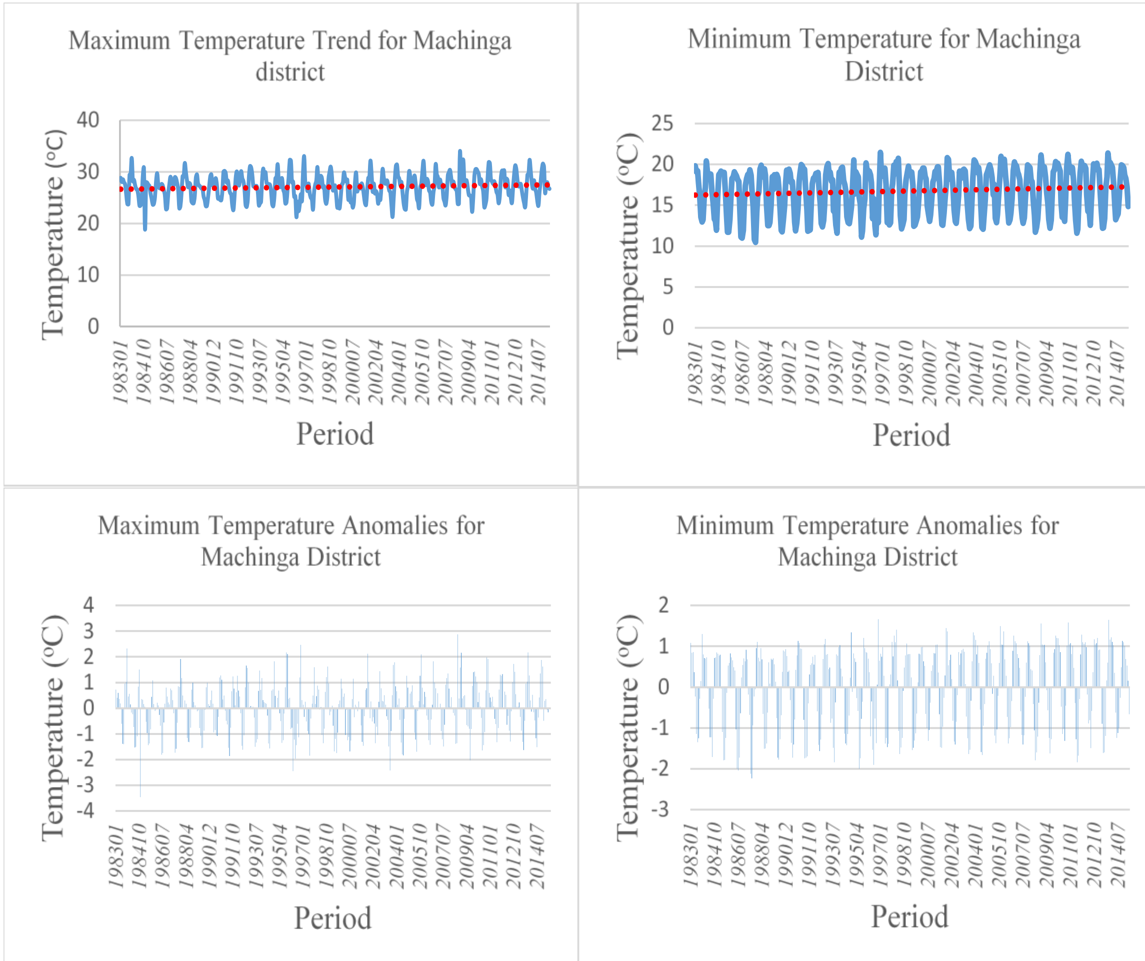


Figure 5: Temperature Trend anomalies for Machinga District from 1983 to 2015

Source: Computed based on data from meteorological services of Malawi (2016)

The results in Mann-Kendall (MK) statistics in figure 5 showed significant change in the minimum and maximum annual temperature trends [-1.96, 1.96] at $\alpha = 0.05$ significance level. These results conform to the perceptions of the smallholder farmers (see figure 3 on page 60), that temperature for the past thirty years has an increasing trend in the area (see figure 5). The statistically significant change in annual temperatures in Malawi is broadly consistent with previous findings of McSweeney *et al*., (2008) who found a temperature increase of 0.9ºC between 1960 and 2006.Kalanda *et al*., (2011) also observed temperature changes in the Lower

Shire, they found a 2.3percent increase in mean annual minimum temperatures with a 2percent increase in the mean annual maximum temperature between 1970 to 2001. Furthermore, studies by Ngongondo *et al.*, (2011) found temperature to be highest in the Lower Shire River valley and along Lake Malawi with Mann-Kendall trends suggesting statistically significant positive trends in mean annual temperature from the year 1971 and 2000. Furthermore, a study by Joshua *et al.*, (2016) on temperature projections for Malawi shows similar trends. The country's mean annual temperature is projected to increase between 1.9ºC to 2.5ºC by the year 2060 and from 2.2ºC to 4.3 ºC by the year 2090.

The anomalies graph as can be seen in figure 5 showed that on average maximum and minimum temperatures in some years were above and in other years below normal temperature. The temperature change is coupled with many years of increased annual temperatures. The maximum and minimum temperature anomalies also showed annual variability of temperature with extreme projections in the maximum temperature. Other similar analyses include those by Ngongondo (2006) and Mbano *et al*., (2008) which examined rainfall trends at two stations in southern Malawi and had also found a significant increase in temperature. Temperature increase suggests that Malawi has become warmer in recent years and this outcome correlates with the communities' perception on climatic conditions of the area. Studies in India (Vedwan and Rhoades, 2001), Kenya (Okumu, 2013) and South Africa (Gbetibouo, 2009) had similar findings whereby the farmers' perceptions of climate change of the area corresponded with the climate data from meteorological services.

4.3 Awareness and adoption status of climate change adaptation strategies

This section presents information on the awareness and adoption status of the four climate change adaptation strategies among sampled households.

All the sampled households were aware of the emerging problem of climate change but not all of them responded by adapting to the changing climate. Subsequently, the obtained results on awareness of climate change showed that an overwhelming majority of the households were aware of the adaptation strategies. The results reflected that the adopters (98percent) and the non-adopters (80percent) were conscious and mindful about conservation agriculture, crop diversification, irrigation and improved crop varieties as adaptation strategies to climate change. The results further reflected that for each of the climate change adaptation strategies reported, there were more farmers that were aware and had knowledge of the technologies as compared to those that had actually adopted. Adoption of new technologies is a gradual process characterized by a sequence of stages where there exists a time delay or lag period between farmers' initial awareness on a new technology and their subsequent decision to adopt a technology (Masuki *et al.*, 2006). Farmers go through a transitional phase in adopting newly introduced technologies, the discrepancy can be as a result of lag period that exists within the adoption. This disparity can also be explained by using the Innovation Diffusion Theory, where it can be observed that other likely adopters can be those farmers that are in the adoption lag period and those farmers that decide not to adopt at all(Rogers, 2003).

The adoption status for the adaptation strategies is presented in figure 6.

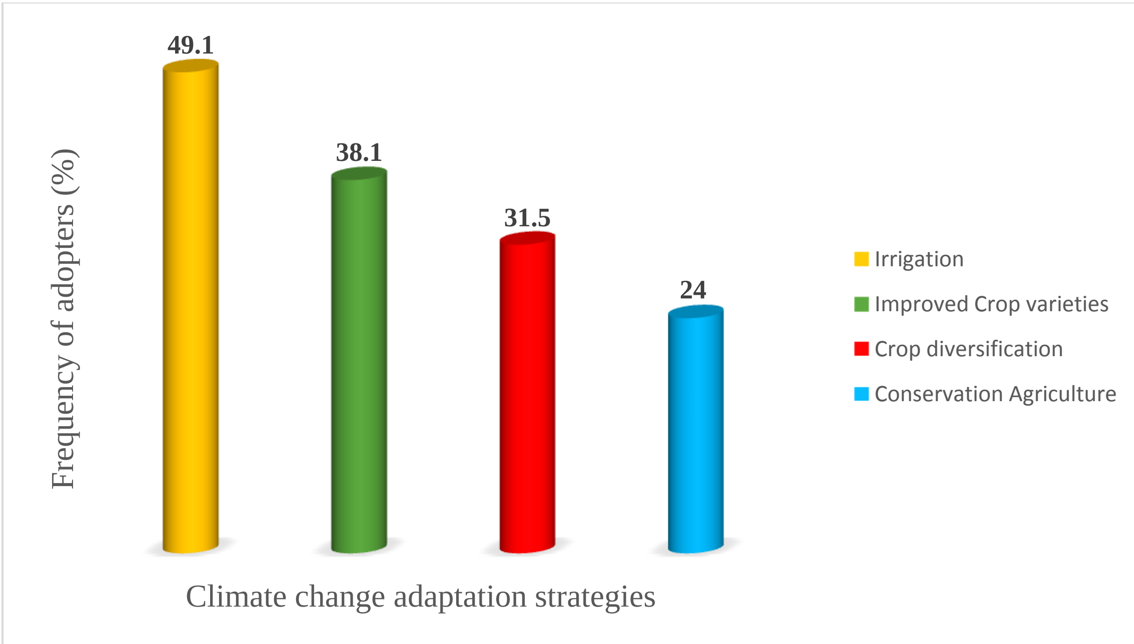


Figure 6: Adoption status of climate change adaptation strategies

Source: Own survey data, December 2016

From the results in figure 6, the most highly preferred climate change adaptation strategy among the four strategies was irrigation agriculture as cited by 49.1 percent of farmers. Whereas, the use of improved crop varieties was cited by 38.1 percent of farmers, crop diversification was cited by 31.5 percent of farmers and conservation agriculture was cited by 24 percent of farmers.

It was noted that majority of the farmers in the study area had irrigation agriculture as the most common adaptation strategy adopted as compared to other adaptation mechanisms. This could be due to the problem of rainfall and temperature variability in the study area as it was indicated by the farmers. For example, the problem of inadequate rainfall and occurrence of extreme weather events in the area such as persistent dry spells and droughts have influenced farmers to widely substitute irrigation for the unreliable and inadequate precipitation. Similarly, a study by Uddin *et al.*, (2014) also found similar results which ranked irrigation first among the assessed farm climate change adaptive measures. Study by Deressa *et al.*, (2008) correspondingly noted that farmers who had prior experience of increased incidents such as droughts and floods were more likely to adapt to climate change through the adoption of the climate change adaptation strategies.

Improved crop varieties using drought resistant and short maturing varieties of crops was the second most adopted adaptation strategy in the study area. The farmers were planting improved varieties, since the varieties are selected for survival under intense weather conditions such as droughts and dry spells, early maturing and some are selected for disease tolerance(Mugabe , 2003). Hence, farmers have found refuge in using them against climate change even though not all the smallholder farmer are able to afford. High use of improved varieties in the area is possibly due to extension support services from both NGOs and Government who have played a role by distributing free seedlings and the use of the Farm Inputs Subsidy Programme (FISP).

Crop diversification through mixed cropping, intercropping, shift cultivation and dividing farm lands into varying crops was the third common adaptation strategy among the sampled respondents. Most of the farmers in the area have been using crop diversification for a very long time throughout their cultivation history by the use of intercropping, multiple cropping and mixed cropping. The system is passed from generation to generation hence some of the farmers in the study area regard crop diversification as a traditional way of cultivation, not as an adaptation to climate change. The study revealed that farmers diversify crop types as a way of spreading risks on the farm which also serves as insurance against rainfall and temperature variability. These results correlate with the research findings of Orindi and Eriksen (2005); Lema and Majule (2009) and Sani *et al.,* (2016). A study by Nguluu *et al*., (1996) further acknowledges that when smallholder farmers are exposed to innovations, they mostly take the components that they perceive as useful and in this case household heads that have big family size with small land holdings likely perceive the benefits and importance of adopting crop diversification for the benefit of their livelihood.

With respect to conservation agriculture, the results of the study show that conservation agriculture was the fourth and least practiced strategy by farmers (see figure 6). Conservation agriculture is a collection of multiple technologies whose aim is to improve soil fertility, cation exchange capacity and hard pan, to maximise rainfall capture as well as to minimise evaporation, run-off and loss of top soil(Sato, 2016). However, some technologies are widely practiced as compared to other conservation agriculture technologies. Manure production was found to be the most frequently used technique by smallholder farmers to boost fertility and help in soil moisture management. This finding is consistent withNyengere (2015) who found high adoption of mature production among the conservation agriculture technologies. The current study discovered that in the absence of adequate organic fertilizer, farmers were producing highly effective manure known as the witman fertilizer (see *Appendix*). Witman fertilizer is a manure-fertilizer mixing technology combined with other cheaper and locally available materials (25kgs *khola* manure, 10kgs wood ash, 15kgs NPK/Urea, 25g soda and 10g yeast). In the absence of enough inorganic fertilizer, witman fertilizer increases the yield of production, enhances soil fertility of the farmland, thus improving nutrient availability to the plants, conserves soil moisture and it increases soil productivity. Witman fertilizer has proven to be cost effective as compared to the expensive inorganic fertilizer option which most smallholder farmers are unable to purchase without FISP coupons.

The study results further indicate adoption of multiple climate change strategies by the smallholder farmers. The results show that among the 251 adopters, 36.25percentof the farmers had adopted one adaptation strategy, 32.27percent of the farmers adopted a combination of two of the adaptation strategies,13.55percent of the farmers adopted a mixture of three of the adaptation strategies and lastly a total of 17.93percent of the farmers had adopted all the four climate change adaptation strategies.

In general, the majority of the smallholder farmers in Mtubwi and Nsanama are adapting to the adverse impact of climate change and variability through the adoption of irrigation, conservation agriculture, improved crop varieties and crop diversification. The study encompassed 375 farmers, of which 251 (66.9percent) farmers had either adopted all the four adaptation strategies or multiple strategies or at least adopted one adaptation strategy of their choice.

4.4 Factors hindering the adoption of Climate Change Adaptation Strategies

The study found that both the adopters and non-adopters had experienced challenges that had limited the adoption of climate change adaptation strategies. Figure 7 summarizes the main factors that hinder the respondents with regards to the use and adoption of climate change adaptation strategies.

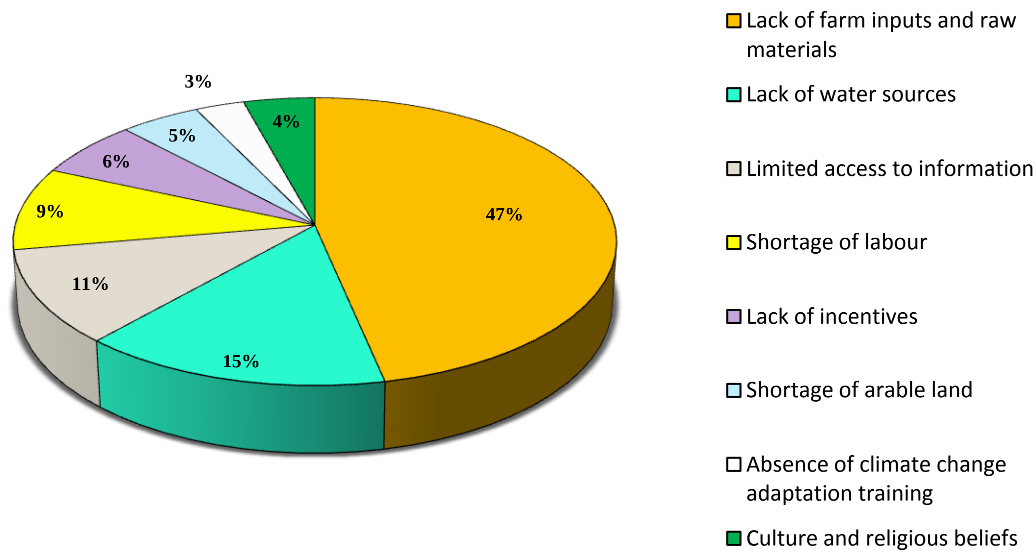


Figure 7: Factors hindering adoption of climate change adaptation strategies

Source: Own survey data, December 2016

Lack of raw materials and inputs: The availability of inputs and raw materials increases efficiency of the performance of climate change adaptation strategies while insufficient resources reduce the efficiency of the strategies which may discourage other farmers from continuing with these technologies. Results from the study revealed that 47%of the respondents lacked farm inputs and raw materials. For example, they mentioned that at times they had unsuccessfully implemented conservation agriculture since the implementation of conservation agriculture requires a lot of residues and this becomes a challenge for farmers with big farms. The collection of crop residue creates competition for crop residues between people and livestock and a farmer is torn apart in deciding whether to use the residue for conservation agriculture or for livestock feed. Nyengere (2015) also noted that most farmers prefer allocating the raw materials to livestock production other than for these climate smart agriculture technologies. Raw materials such as crop residues are mostly used as feed for livestock and not materials for conservation agriculture.

On the other hand, the absence of inputs and resources is also encouraging the farmers to adopt other low-input technologies such as climate smart agriculture; the households' in-ability to purchase inputs such as fertilizer makes them opt for the use of manure rather than fertilizer. The majority of the farmers who had small land size yet with big family size, were among the many households that preferred the adoption of crop diversification through a mixed cropping system as a means of diversification of household food sources and maximization of production.

Deficiency of water sources: In addition, the respondents were asked if their farms had access to any other water sources apart from rain water. The results indicated that 191(50.9percent) respondents had no access to water while 184 (49.1percent) said they had access to water. The unavailability of water sources limited the owners from adopting some of the climate change adaptation strategies such as irrigation. However, other farmers indicated that lack of water sources had also motivated them to start using drought tolerant varieties and crops that do not need much water such as cassava. Furthermore, not all the farmers who had access to the water sources were able to practice irrigation. For instance, among the 184 farmers who had access to other water sources apart from rain water, only 107(58.2percent) were able to use the water for irrigation while the rest could not. Some of the reasons for not utilizing the water sources was due to lack of inputs while others suspected it was labour intensive to set up an irrigation scheme. Furthermore, some of the farmers were unable to practice irrigation farming because the water sources were unreliable since they dry up sometimes hence investing in irrigation was somehow regarded as a loss. The results complement with study findings of Abid *et al.*,(2015) whose results also indicated that adaptation to climate change was constrained by several factors such as shortage of irrigation water in the study area, lack of information, lack of money and resources constraints for setting up an irrigation scheme and water pump systems. The study by Uddin etal., (2014) also observed that in spite of the different support and technological interventions being available to smallholder farmers, lack of available water, shortage of cultivable land and unpredictable weather ranked highest as the farmers' constraints to coping climate change effects.

Lack of information: Farmers with no access to information and technical support were unable to use some of the modern technologies such as those promoted for climate change adaptation. For example, a farmer needs the necessary information in order to set up a sustainable irrigation scheme or when a farmer needs to manufacture witman fertilizer he or she needs to know the required ingredients. In all this, the farmer needs information and technical support. Exposure to community sensitization, awareness and training on climate change adaptation strategies influences the households to make a choice regarding the adoption of the strategies. Information provides the farmers with the necessary skills and expertise which can be used at home for implementation of the strategies. However, for farmers without information, it is hard for them to adopt the strategies.

Lack of information on climate of the area, especially information of the rainfall and temperature, affects farmers' choices at farm level. For example, knowing in advance whether the rainfall will be normal, below or above average could help them choose the right crop varieties, adjust their cropping practices or take other necessary measures like soil and water conservation strategies to maximize benefits or minimize losses as explained by Rao *et al*., (2005). However, in Malawi, this kind of information is sometimes not made available to the smallholder farmers and sometimes when it gets disseminated to the general public, it does not reach the targeted individuals (for example, the smallholder farmers) mostly because of the mode of communication. It was noted that most of the respondents from the individual survey questionnaire had no or little access to the media only 17(4percent) of the respondents used the media. Unfortunately, most of the information in Malawi is disseminated using different forms of the media and this disadvantages the farmers. Malawi national agricultural policy of 2016, argues that weak agricultural extension services delivery is a key constraint for sustainable agricultural production and productivity in Malawi. Nzeadibe *et al*., (2011) also point out that the factors responsible for hindering adaptation are inadequate information, limited awareness and knowledge about adaptation methods, and poor Government attention to the existence of climate change. A study by Deressa *et al*., (2009) also indicated lack of information as another issue hindering farmers' uptake of climate change adaptation methods.

Shortage of Labour*:* The farmers complained that some of the technologies were very involving and exhausting especially irrigation and conservation agriculture.

Households that do not have enough labour force and are unable to hire extra labour to help with the farm activities found it hard to adopt most of the labour-intensive technologies. For example, those using treadle pumps in irrigation complained of exhaustion from peddling the pumps especially on sunny days and those farmers practicing conservation agriculture complained of the labour involved in gathering and spreading the crop residues across the fields for moisture and soil conservation. They also complained of the manure making process and digging of swales which requires a lot of energy and commitment that most farmers with off-farm activities are unable to commit. Contrary to most respondents (59 percent) who considered manure production to be a tough activity and labour intensive some respondents (51 percent) found it reasonable and tolerable.

Lack of incentives: The lack of incentives for smallholder farmers who are doing the work of providing extension services through their roles of 'lead farmers' discourages and demotivates people from taking part in the project. As such, the implementation is slowed down. Furthermore, some projects are known to perform best when incentives are made available to the farmers, but without them farmers end up dis-adopting the technologies. For instance, smallholder farmers in Nsanama and Mtubwi reported that the majority of the farmers extensively adopted the use of hybrid maize and inorganic fertilizers because of the subsidy programmes. During focus group discussion, farmers revealed that even when the farmers are fully sensitized and trained, there was still lack of implementation by the smallholder farmers due to lack of incentives to back-up the strategies, a development which had brought demotivation among the farmers. The community members are used to handouts; a syndrome perpetrated by NGOs and this makes it hard for Government extension workers to influence the community members to adopt a new farming technology without such an incentive. The need for incentives among the communities has led to dis-adoption of several agricultural technologies. Some farmers abandon the technologies after the end of the project and the distribution of incentives despite being provided with enough extension services. This could also be noted from a similar dis-adoption circumstance that took place in Malawi in the late 1990s during an intensive promotion campaign for intercropped green manures led by research scientists, Government and NGOs, the majority of the farmers had responded by adopting the intercropped green manures, the widespread farmer adoption of intercropped green manures was however short lived; the initiative vanished from the fields of smallholder farmers, together with the seed market for the legume trees, when the incentives and the intensive promotion campaigns stopped(Giller *et al.*, 2009).

Shortage of arable land: Land is among the main inputs necessary for farming activities. Land size also determines which technology can be adopted since some technologies require substantial amount of land: smaller land size reduces the farmer's adoption ability. It is also noted that households that possess large pieces of land have higher potential of increased production which enables them to invest and gain more from the technologies(Navicha, 2010). Availability of land also affects the farmers cropping patterns. For example, those with large farm size can have a chance to produce multiple cropping, double cropping and intercropping which in turn influences the adoption of crop diversification. Farmers without enough land are unable to multi-crop, double crop and intercrop.

Absence of climate change training programs: Access to climate change adaptation training programs has also been found to be a key aspect in technology adoption. The respondents' opinions correlate with the study by Sani *et al.*, (2016) who noted that participation in climate variability and change related training programmes enhance awareness of farmers about the impact of climate change which in turn helps farmers build up resilience against the adverse conditions that are associated with it. Farmers are usually informed about the existence as well as the effective use and benefit of new technology through the climate change adaptation training programmes (Mwangi and Kariuki, 2015). Inability to access such training programs has several implications on farmers. For instance, the farmer may not have prior knowledge on executing the adaptation options and in the situation where the farmer implements the strategies without getting informed on proper measures of implementation. This may affect the technical performance of the technology which leads to poor performance and unexpected outcomes that may frustrate the farmer causing them to lose faith in the climate change adaptation strategies and dis-adopt the technology which if properly implemented could have been beneficial to them.

Culture and religious beliefs*:* The community taboos, cultural beliefs and religious beliefs affect the ability to receive and understand new information hence affecting the farmers 'participation towards the use of farming technologies. Kapanda *et al.*, (2005) noted that new technologies that are introduced without addressing the communities' culture may not be sustainable. Community cultures and some religious beliefs have made some farmers resist using the modernized agricultural technologies.

The beliefs and myths surrounding the use of hybrids is another problem affecting the adoption of improved varieties. There has been resistance in the use of high yielding crop varieties among the traditional smallholder farmers, most of whom consciously or sub-consciously perceive the use of hybrids with prejudice (Mazonde, 1993). Smallholder farmers are reluctant to switch from the local varieties to the use of hybrids claiming that hybrid seeds have poor taste, poor storability and poor processing quality (e.g. when processing hybrid maize into flour).

During the FGDs, it was made known that there are other farmers within the communities that resist change because of ignorance due to religious beliefs they do not believe in the science of climate change. They suggest that weather changes are as a result of curses and punishment from Allah due to this generation's way of life and they believe that when Allah forgives them everything will go back to the normal state hence no need to intervene in what God is doing. This shows that other people are still unaware and are ignorant of the emerging issues of climate change. On the contrary, some traditional practices have been positive in enhancing adoption such as the practice of intercropping, a traditional practice that has made it easy for most farmers to adopt crop diversification. Therefore, despite culture being a challenge to adopting some technologies it can also positively affect the adoption of other technologies by influencing their uptake.

4.5 Determinants for adoption of Climate Change Adaptation Strategies

The main objective of the study was to determine the factors influencing the adoption of climate change adaptation strategies used by smallholder farmers in response to climate change in Machinga. In order to achieve this objective Logit Model was used and marginal effects were used to show the extent to which each of the factors influence the adoption of climate change adaptation. The regression marginal effect results of Logit Model are presented in the table 5 with statistical significance at 1percent, 5percentand 1percent probability level.

A composite component of the four adaptation strategies was created and labelled climate change adaptation strategies to aid the analysis. As such, interpretation of results was made on the factors influencing climate change adaptation adoption as a composite of the four strategies and not the individual strategies. Specified results of the individual analysis of the strategies have also been provided. The inclusion of other socio-economic, demographic and environmental variables such as gender, age, household size, food adequacy, marital status, off-farm income sources, total income, training attendance, climate change perception, rainfall variability, access to credit, membership of farmers group, extension support, land certificate and culture of the farmer rendered all models insignificant in interpreting the model, hence were dropped. The interpretation of the marginal effect results of the Logit Models' regression for adoption of climate change adaptation strategies have also been provided.

Table 5: Average Marginal Effects from Logit Regression

Variables	Conservation Agriculture	Irrigation	Crop Diversification	Improved Crop Varieties	Climate Change Adaptation
	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx
Gender	-0.076(0.385)	-0.025(0.788)	-0.142(0.186)	-0.086(0.433)	-0.123(0.085)
Marital status	-0.127(0.260)	0.025(0.806)	-0.031(0.799)	0.170(0.171)	0.073(0.492)
Age	0.000(0.894)	0.006(0.032)	-0.001(0.734)	0.006(0.117)	0.005(0.081)
Education status	0.095(0.072)	0.197(0.001)	0.164(0.041)	0.373(0.000)	**0.255**(0.015)**
Household size	-0.012(0.232)	0.000(0.985)	0.021(0.053)	-0.012(0.342)	0.021(0.068)
Farm experience	0.001(0.512)	0.004(0.102)	0.010(0.001)	0.010(0.003)	**0.007*(0.005)**
Off-farm income	0.053(0.269)	-0.006(0.919)	0.137(0.050)	0.065(0.414)	0.023(0.701)
Total Income	-1.3808(0.927)	4.5607(0.006)	-1.9407(0.378)	-6.9608(0.697)	6.2908(0.674)
Land size	0.034(0.011)	-0.007(0.707)	0.133(0.000)	0.101(0.002)	**0.063**(0.022)**
Land certificate	-0.069(0.422)	-0.152(0.041)	0.164(0.241)	0.377(0.000)	0.136(0.160)
Food adequacy	-0.155(0.000)	-0.080(0.204)	0.019(0.799)	-0.143(0.087)	-0.147(0.052)
Credit access	-0.090(0.046)	0.092(0.083)	-0.132(0.035)	-0.299(0.000)	-0.080(0.122)
Extension	0.179(0.000)	-0.113(0.274)	0.022(0.833)	-0.060(0.586)	0.001(0.992)
Membership	0.144(0.002)	0.057(0.339)	0.094(0.171)	0.077(0.311)	0.028(0.650)
Information	0.013(0.823)	0.048(0.496)	0.005(0.952)	0.212(0.014)	**0.231*(0.007)**
Training	0.122(0.025)	0.243(0.000)	0.187(0.010)	0.218(0.005)	0.077(0.206)
Perception	-0.061(0.783)	-0.267(0.171)	-0.099(0.648)	0.265(0.157)	0.214(0.279)
Rainfall variability	0.469(0.000)	-0.100(0.257)	0.394(0.001)	-0.194(0.131)	0.030(0.807)
Temperature variability	0.020(0.749)	-0.055(0.416)	-0.030(0.700)	0.112(0.218)	**0.151*(0.006)**
Culture	-0.014(0.768)	-0.154(0.006)	-0.302(0.000)	-0.167(0.035)	0.052(0.378)
*Notes: Standard errors in parentheses * p<0.01 and ** p<0.05 respectively*					

Source: Own survey data, December 2016

Education status of the household head: Education results indicates a positive significant (at 5percent significance) relationship with climate change adaptation strategies showing that education (ranging from adult literacy classes to tertiary education) of the household head increases the possibility of adopting climate change adaptation strategies by 25.5 percent, holding everything else constant. Educated individuals are believed to be more flexible in accepting a new innovation than those with no education. Education is assumed to be associated with access to information on improved technologies and higher productivity since it increases awareness about the consequence of climate change on agricultural productivity (Norris and Batie, 1987). The farmers with education are able to be articulate and understand the importance of adapting to climate change more than those who have no prior understanding of the situation. The implementation of some of the climate change adaptation strategies (conservation agriculture, irrigation, crop diversification and the use of improved crop varieties) requires the acquisition of appropriate knowledge and skills hence acquisition and utilization of such skills and knowledge demands some education. Maddison (2007); Sani *et al.,* (2016); Mwangi and Kariuki (2015) and Uddin *et al.,* (2014) also reported a positive relationship between education and adaptation to climate change. Furthermore, Adesina *et al.,* (2000)found that educated farmers are more likely to adopt new agricultural technologies because the education attained provides flexibility towards change unlike with the none educated farmers.

Farm experience of the household head: Farming experience has a positive and significant (at 1percent significance) impact on the likelihood of adopting climate change adaption strategies. A unit increase in one year of farming experience results in an increase in the probability of adapting to climate change by 0.7 percent, holding everything else constant. Experienced farmers are more likely to have more information and knowledge on changes in climatic conditions of the area having lived there for a long time and also with the help of indigenous knowledge in detecting weather outcomes of each growing year as compared to inexperienced farmers. Therefore, they can easily adjust themselves to climate change stresses. This result is consistent with Hassan and Nhemachena (2007); Kebede (1990) and Shiferaw and Holden (1998).

Land holding size of the household head: Land size has a positive and significant (at 5% significance) impact on the likelihood of adopting climate change adaption strategies. A unit increase in land acreage increases the probability of adapting to climate change by 6.3 percent, holding everything else constant. This implies that farmers who have more land are likely to take up climate change adaptation options as compared to farmers with small farm size. The reason could be if the farmer has more land holding, they can be able to adopt various technologies including those that require more land. Technologies such as irrigation require a substantial amount of land for setting up the irrigation scheme hence a reduction in land size could limit the adoption of such technologies. Thangata and Alavalapati (2003) in similar studies found that households with smaller land size tend to be more risk averse due to uncertainities related to the use of new agricltural technologies. These findings are similar to those of Tesfay (2014); Tessema *et al*., (2013); Ajibefun and Fatuase (2011).

Access to information: As expected, access to information has significant (at 1percentsignificance) and positive impact on adoption of climate change adaptation strategies. A unit increase in access to climate change information increases the likelihood of adopting climate change adaptation by 23.1 percent, holding everything else constant. This result implies the important role information play in promoting the use of adaptation strategies. Acquisition of information about a new technology is another factor that determines adoption of technology. Farmers need to know the existence of the technology, its benefits, and its usage for them to adopt it. The information enables farmers to learn and have information of climate change for the area and the adaptations options available to them. Farmers who are aware of changes in climatic conditions have higher chances of taking adaptive measures in response to observed changes (Sani *et al.*, 2016). This is the case because information is an important precondition for farmers to acceptance and adopt adaptation measures (Madison 2006). Access to information also reduces the uncertainty about a technology's performance hence may change individual's assessment from being subjective to objective over time (Bonabana-Wabbi, 2002). The results are consistent with Yirga (2007) who reported a positive relationship between access to information and adoption of climate change adaptation strategies. The results are an indication that access to information plays a role in the adoption of climate change adaptation strategies.

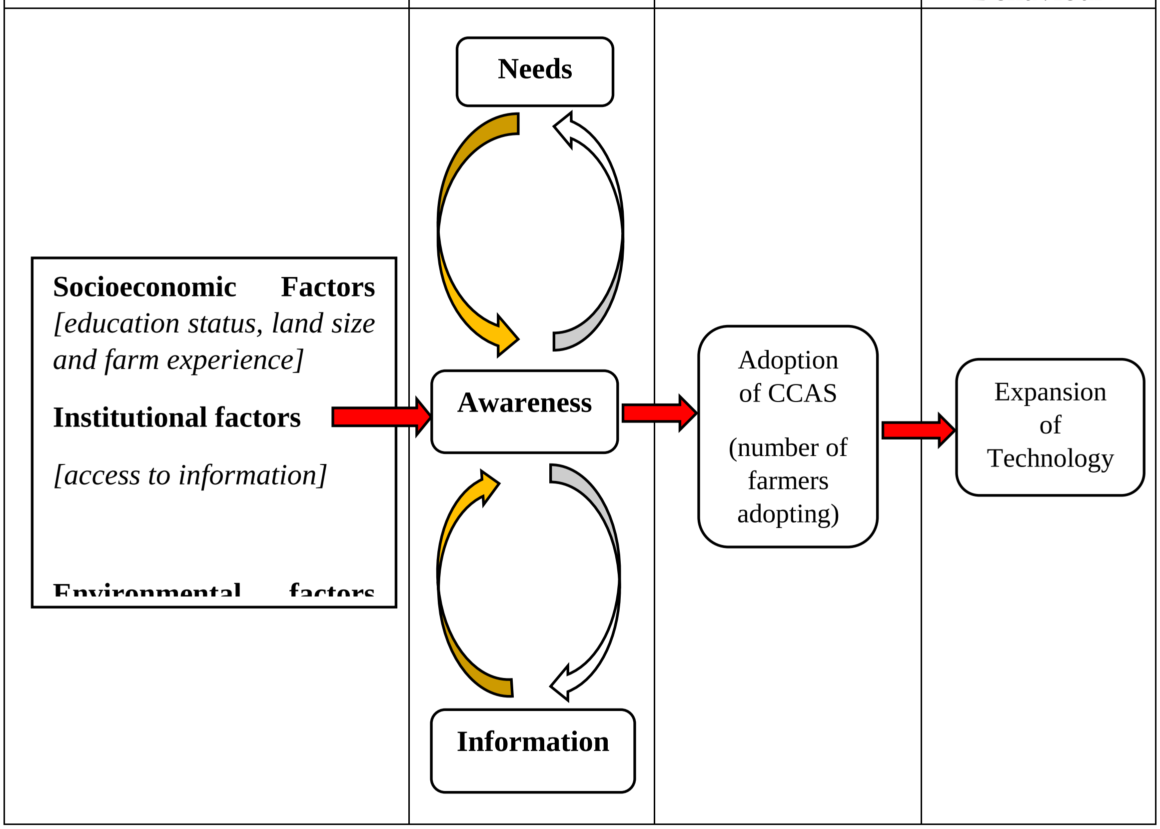
Temperature variability of the area: Temperature variability of the area significantly influence the choice of adopting to climate change adaptation strategies as compared to when there is no temperature variability (at 1percent significance).

This implies that for every additional change in temperature of the area, the probability of the household head making the decision to adopt climate change adaptation strategies is increased by 15.1 percent as compared to the area not having temperature variability, holding everything else constant. This implies that as the household head notices and experiences temperature variability, a farmer is more willing to use the technologies that help him or her adapt to climate change. The results are consistent with Deressa *et al*., (2010), Gbetibouo (2009) and Nhemachena and Hassan (2007) who all reported a positive relationship between temperature and uptake of climate related technologies.

The decision of smallholder farmers to adjust their farming practices in order to adopt climate change adaptation strategy depended on several factors since the process of adoption is dynamic and various factors are likely to influence each other. Based on results from this chapter, it can be be noted that the adopters and non adopters had socio-economic characteristics differeces and a few similarities existed among them. For a clear comprehension, the results from the logit model have been fitted into a modified version of the Düvel (1991) conceptual framework for the Adoption Behavior model which is presented in table 6.

Table 6: Adoption Behaviour model for climate change adaptation strategies

Human (Psychological)- Environmental Factors		**Economic-Technical Factors**	
Independent	*Intervening*	*Dependent Variables*	
		Behaviour	Consequences of Behaviour



Modified from Thangata and Alavalapati (2003)

The study further notes that adoption of these climate change adaptation strategies could be enhanced among the smallholder farmers in Mtubwi and Nsanama EPA if the farmers' socio-economic factors, environmental factors, demographic factors and mental processes are to be considered in promoting the willingness of the farmers to adopt the strategies. Correspondingly, previous studies have endorsed better understanding of local factors and dimensions of climate change adaptation as a key element to modifying appropriate adaptation measures and policies that can help more farmers adopt.

Chapter 5 will further present a highlight of the research summary, conclusion and recommendations.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter is in two sections. The first section presents the summary of results and conclusion of the key findings. The last section presents recommendations on suggested areas for future research.

5.1 Summary of the results

Climate change adaptation options remain a top priority in most developing countries including Malawi. This is because climate change adaptation strategies lead to an increase in farm productivity and they enable the nation to build resilience to climate change under erratic rains and changing climatic conditions. A better understanding of the local dimensions of climate change adaptation is crucial in disclosing useful information that may guide stakeholders to assist the farmers adopt the adaptation measures that will mitigate the adverse consequences of climate change. The information acquired from studies like these if properly employed has the likelihood to increase the probability of more farmers' willingness and ability to participate in project activities intended for smallholder farmers in the study area.

The household survey data was collected from 375 smallholder farmers with hundred percent of respondents acknowledging the existence of climate change and its emerging issues. Farming was the primary occupation for all of the sampled households although some households combined farming with some level of non-farming income sources. While most smallholder farmers did not understand the scientific dynamics of climate change on the environment, they clearly shared their experiences on the manifestations of climate change through their personal observations.

The overall objective of the research was to determine factors that influence the adoption of climate change adaptation strategies by smallholder farmers in Machinga. Specifically, the research study examined the socio-economic and demographic characteristic differences of the adopters and non-adopters of climate change adaptation strategies. The results from the logit model revealed gender, age, household size, food adequacy, marital status, off-farm income sources, total income, training attendance, climate change perception, rainfall variability, access to credit, membership of farmers group, extension support, land certificate and culture of the household head do not significantly influence the adoption of climate change adaptation strategies. On the other hand, farm experience, education, land size, access to information and temperature variability are very important factors that determine the likelihood of the farmer to adopt climate change adaptation strategies. Certain modifications had been made to the behaviour adoption model; the study excluded the use of other socio-economic, demographic and environmental variables which had insignificant results from the binary logit model since they rendered all models insignificant in interpretation.

The study used descriptive analysis to assess the smallholder farmers' perceptions of climate change. The descriptive statistics results showed that about 97.8percent of the farmers in the study area had observed change in temperature and also 94.8percent of the farmers had observed change in the amount of rainfall. The study showed contrasting trend of the respondents' perception on the changing rainfall against the climate data on the trends from meteorological station. The data showed there was no significant change while the computed anomalies showed variabilities in terms of negative and positive anomalies corresponding to some of the respondents' observations. Climate data on the trends of temperature from meteorological stations correlated with the respondents' personal observations. The respondents' perception results on temperature trend indicated that Machinga district was getting hotter and drier and that there were definite changes in the timing of rains, increased incidents of floods and prolonged dry spells. The Mann-Kendal analysis also reflected significant change on the temperature trends and the computed anomalies also reflected some variabilities in terms of negative and positive anomalies.

From the study sample, it was noted that farmers had adopted different strategies to reduce the consequences of climate change and to manage future patterns in climate change. In order to establish the adoption status of climate change adaptation strategies, the study used descriptive statistics. 251 (66.9 percent) of the sampled farmers had adopted either multiple strategies or at least one of the adaptation strategies. This means that for every three smallholder farmers, at least two of them had adopted one or multiple adaptation strategies. The most frequently adopted was use of improved crop varieties followed by crop diversification, irrigation and the least adopted was conservation agriculture. However, it can be noted that adoption sustainability mostly depends on perceived or realized advantages of a new technology over an older technology in meeting the farmers' needs. The results further revealed that in spite of the high adoption status in the area, the farmers were facing a number of challenges that was making it difficult for them to uptake some of the technologies. The study further attempted to disclose the challenges limiting the farmers' ability to adopt the four climate change adaptation strategies. The study found the following challenges to be the main hindrances to the use and adoption of climate change adaptation strategies by the smallholder farmers: shortage of farm labor, deficiency of water sources, lack of raw materials and farm inputs, lack of information, shortage of arable land, culture and religious beliefs, lack of incentives and lack of climate change training programs.

5.2 Conclusion

The adoption behaviour of the farmers was determined by the following factors; farm experience, education, land size, access to information, temperature variability that were governed by a set of intervening variables;

(a) Individual needs [the need to ensure enough food to feed their families, reduce labour and input costs, make better use of their limited resources, minimise the risk of crop failure, create food safety net and earn money to meet basic needs and more]

(b) Information [knowledge about the use and implementation of the adaptation strategies]

(c) Individual awareness [with regards to the existence of climate change and the insight regarding the available adaptation strategies].

The study concludes that adoption of these climate change adaptation strategies could be enhanced among the smallholder farmers in Mtubwi and Nsanama EPA if the farmers' socio-economic factors, environmental factors, demographic factors and social cultural processes are to be considered in promoting the willingness of the farmers to adopt the strategies. Correspondingly, previous studies have endorsed better understanding of local factors and dimensions of climate change adaptation as a key element to modifying appropriate adaptation measures and policies that can help more farmers to adopt.

5.3 Recommendations

Listed below are the recommendations that could help promote the adoption and sustainable implementation of climate change adaptation strategies.

- In order to broaden the scope of extension service provision, there is need for the Government to Increase access of information on the newly introduced climate change adaptation strategies. This may raise awareness on the available adaptation options which can lead to an increase in the adoption of the strategies.
- The extension service providers should not only focus on the agricultural innovation and technology implementation process but should also focus on how to help the farmers sustain the strategies even in the absence of incentives. The communities should be trained about ownership of the project in order to enhance sustainability of the project introduced in the community.

5.4 Suggested areas for further research

The study has revealed some research gaps that need to be explored further. The researcher proposes the need for future studies to concentrate on the following areas:

(a) A similar study should be conducted at large scale with a comprehensive list of all the agricultural technologies and strategies that are considered as climate change adaptation strategies.

(b) Evaluate the significance of climate change adaptation strategies to smallholder agriculture and household food security.

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APPENDICES

Appendix 1: Smallholder Farmer Household Questionnaire

Questio\nnaire number	

My name is **Elina Mkandawire** from chancellor college, University of Malawi. I am writing a thesis entitled ***"Determination of factors that influence the adoption of climate change adaptation strategies by smallholder farmers here in Machinga district"*** in partial fulfilment for MSc in Environmental Sciences. I am here to learn about factors that influence the adoption of climate change adaptation strategies. The objective of this study is to identify the socioeconomic, institutional and environmental factors affecting the adoption of climate change adaptation strategies used by smallholder farmers in response to climate change in Machinga district. You are among the several smallholder farmers in this area who have been selected for this study. All the information given will be treated with confidentiality and be used for academic purposes of the study only.

Do you consent to the interview? Yes ☐ Proceed with interview

No ☐ Thank the person and look for next respondent

PART I: Identification

QN	QUESTION	RESPONSES	
1.	Name of respondent		
2.	Phone # of the respondent		
3.	Date of the interview		
4.	Name of T/A		
5.	Name of Village		
6.	District	Machinga	
7.	Name of EPA	1= Nsanama, 2=Mtubwi	
Part II. Questions on household head demographic characteristics			
8.	Gender of the household head	1= Male, 2=Female	
9.	Marital status	1= Married, 2= Single, 3= divorced, 4=separated 5= widowed	

10.	Age of the household head	INSERT_________________ (in years)	
11.	What is the highest level of Education completed by the household head?	1=Primary School, 2= Secondary School, 3=Tertiary School, 4= Informal 5= none	
12.	Main occupation of the household head	1=Peasant farmer, 2=Semi-commercial farmer, 3=wage labourer, 4=fisherman, 5=Artisan, 6=Housewife, 7=Business person; 8=Student, 9=Civil servant, 10=None	
13.	Number of total family members	INSERT_________________	
14.	Farm experience of household head	INSERT_____________ (in years)	
Part III. Questions on household socio-economic characteristics			
15.	Does the household sell farm/agricultural products	1=Yes, 2= No	
16.	How much income did you generate from your farming activities during last production year?	INSERT_________ (in kwacha)	
17.	Do you/any members of your family have any sources of off-farm income	1=Yes, 2= No	
18.	What are your main off farm income source? (More than one choice is possible)	A=Crop sales, B=Livestock production, C=Business, D-=Employment, E=Casual labour, F=Remittance, G=land rentals, H= Farming, I=House rentals, J=Bicycle taxi, K=Stone quarrying, L=Produce trading, M=pension, N=fishing	
19.	How much money you/your family make during last production year from off-farm activity? Please specify in kwacha	INSERT___________ (in kwacha)	
Part V. Questions on institutional factors			
20.	Total farm land operated (including rented land and excluding rented out land) during last production year	INSERT___________ (in Acres)	
21.	Do you have certificate for your land?	1=Yes, 2= No	
22.	Have you planted any newly introduced crops/crop varieties in response to climate change in order to reduce the	1=Yes, 2= No	

	impacts of climate change		
23.	Does the farm/garden have access to any other water source apart from the rains	1=Yes, 2= No	
24.	Do you use these water sources to irrigate the garden/farm or part of it	1=Yes, 2= No	
25.	What's the trend of your household crop productivity for the past decade?	1= increased, 2=decreased, 3=no change	
26.	Does your household have adequate food throughout the year from own production and purchases?	1=Yes, 2= No	
27.	If no, how many months in a year does this household experience food shortage?	INSERT____________	
Part V. Questions on institutional factors			
28.	In undertaking your usual farming activities have ever faced shortage of finance? For example, to purchase agricultural inputs like fertilizer, oxen, and others	1=Yes, 2= No	
29.	Do you have access to any formal/ informal credits in time you face shortage of money?	1=Yes, 2= No	
30.	In the past years have you received any extension support or information in implementing climate change adaptation strategies/technologies?	1=Yes, 2= No	
31.	What are the services you get from the extension workers? (More than one choice is possible)	INSERT________________	
32.	Who is the main extension service provider for the community	INSERT________________	
33.	How often do you meet with extension agents	1=daily, 2=Weekly, 3=Fortnightly, 4=Once a month, 5=Once in three months, 6=Once in six months, 7=Once a year, 8= Never	
34.	What is the mode of meetings? (More than one choice is possible)	A=Farm visits, B=Group visits, C=Field days, D=Office visits, E=household visits	

35.	Does the household belong to any farmer's group in the area?	1=Yes, 2= No	
36.	Do you have any communication devices and materials like TV, newspapers, internet, radio, mobile phone, so on?	1=Yes, 2= No	
37.	Have you attended any training on climate change adaptation strategies/technologies?	1=Yes, 2= No	
Part VI. Questions on responsiveness to climate change			
38.	Have you perceived any changes in climate?	1=Yes, 2= No	
39.	What climate change and variability indicators have you experienced for the past decades?	A= Drought, B=Decline in crop yield, C=Decline in livestock yields, D=Drying/wilting up of crops, E=Death of livestock due to shortage of fodder and water, F=Food shortage, G=Increased weed and pest pressures, H=Communicable diseases, I=Decrease of water quality and quantity, J=Drying up of water sources (rivers, wells, boreholes etc) , K=High winds, L=Floods, M=Shift in the timing of the onset of rain in the main season, N=change in amount of rainfall during main rain season, O=Off-seasonal rainfall, p=Rain starting later than normal, Q=Rain starting earlier than normal, R=Dry spells	
40.	what has been the trend of temperature for the past years according to your personal observation	1= Increasing, 2=Decreasing, 3= Fluctuating, 4= constant	
41.	In response to climate change, have you made any adjustments (adaptation measures) in your farming practices?	1=Yes, 2= No	
42.	What climate change adaptation strategies have you employed in your farm in past decade? (More than one choice is possible)	INSERT_________________	
43.	What are the challenges that affect adoption of the technologies that are	A=Lack of information, B=Lack of capital, C= shortage of labour,	

	under climate change adaptation strategies that you are aware of? (More than one choice is possible)	D=Lack of law materials and inputs, E=Lack of incentives, G=Shortage of farming land, H=Cultural beliefs, I= lack of training, L=lack of water sources	
44.	Do you have any cultural beliefs that limit the adoption of Climate adaptation strategies/technologies?	1 = Yes, 2 = No	
45.	Have your own climate adaptation activities been affected by any cultural beliefs	1 = Yes, 2 = No	

Part VII. Questions on awareness of climate change and adaptation methods					
	D	D1	D2	D3	D4
No.	List of Climate change adaptation technologies	Awareness	Adoption	How did you know of these technologies?	For how long have these CC adaptation strategies been used
A.	Conservation agriculture				
B.	Irrigation farming				
C.	Improved crop varieties				
D.	Crop diversification				

CODES	
D1	1=Aware, 2 = Not aware
D2	1=Adopted, 2=Not adopted
D3	1 = extension field officers, 2 = fellow farmer 3 = NGOs (specify), 4 = radio/newspaper/TV, 5= farmer's club/cooperative, 6= CBO, 7= local leaders, 8=school
D4	**1** = <1yr, 2= 1 to 5yrs, 3 = > 5 years

Appendix 2: Institutional level checklist interview questionnaire– key informant

Facilitator:	
Date:	
EPA:	
District:	
Name of organization:	
Name of key informant:	
Position:	
Contact:	

1. In the past few years, have you noticed significant changes to weather patterns?
2. If yes, what have these changes been?
3. Explain the adverse impact of climate change in the livelihoods of the community?
4. Which group of people are seriously affected by climate change?
5. How have these changes affected crop production in the area?
6. How has the community been adapting to these changes?
7. Describe any agricultural technologies/strategies brought about by climate change.
8. Describe any factors that have influenced the adoption of climate change adaptation strategies.
9. List the challenges that farmers are facing when implementing the climate change adaptation strategies/technologies in their farms?
10. What do you recommend to be done that will enhance the fight towards climate change?

Appendix 3: Institutional level checklist interview questionnaire– KII

Facilitator:	
Date:	
EPA:	
District:	
Name of organization:	
Name of key informant:	
Position:	
Contact:	

1. In the past few years, have you noticed significant changes to weather patterns?
2. If yes, what have these changes been?
3. Explain the adverse impact of climate change in the livelihoods of the community?
4. Which people are seriously affected by climate change?
5. How have these changes affected crop production in the area?
6. How has the community been adapting to these changes?
7. Describe any agricultural technologies/strategies brought about by climate change.
8. Describe any factors that have influenced the adoption of climate change adaptation strategies.
9. List the challenges that farmers are facing when implementing the climate change adaptation strategies/technologies in their farms?
10. What do you recommend to be done that will enhance the fight towards climate change?
11. Would you like to add any other information?

Appendix 4: Picture with respondents during FGD and household interviews

Source: Picture captured by the Author, December 2016

Appendix 5: A farmer In Nsanama demonstrating how witman fertilizer works

Source: Picture captured by the Author, December 2016