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Determinants & welfare implications of the choice of climate change adaptation strategies in the Nile Basin of Ethiopia

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DECLARATION

I hereby declare that this thesis is my original work and all materials and information used are duly acknowledged. The thesis is submitted in partial fulfilment of the requirement for M.Sc. degree in Economics at Addis Ababa University. The copy of the thesis is deposited in the University library for consultation or referencing for anyone interested as per the rules of the library. I solely declare that this thesis is not submitted to any other institution for the award of academic degree, diploma or certificate.

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CERTIFICATION

Addis Ababa University

School of Graduate Studies

Sara Getachew Zicke

This is to certify that the thesis prepared by Sara Getachew Zicke entitled 'Determinants & welfare implications of the choice of climate change adaptation strategies in the Nile Basin of Ethiopia ', and submitted in partial fulfillment of the requirements for the degree of Master of Science in Economics (Economic Policy Analysis) complies with the regulations of the University and meets the accepted standards with respect to its originality and quality.

As members of the boards of the examiners of the M.Sc. thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Sara Getachew and examined the candidate. We recommend that the thesis be accepted as fulfilling the requirement for M.Sc. in Economics.

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External Examiner: ______________________ Signature: ___________ Date: ___________

Internal Examiner: _______________________ Signature: ___________ Date: ___________

Advisor: _______________________________ Signature: ___________ Date: __________

ACRONYMS AND ABBREVIATIONS

AEZs	Agro-ecological zones
ATA	Agricultural Transformation Agency
CSA	Central Statistics Agency
EDRI	Ethiopian Development Research Institute
EEPFE	Environmental Economics Policy Forum for Ethiopia
ERHS	Ethiopian Rural Household Survey
ERSS	Ethiopian Rural Socioeconomic Survey
FAO	Food and Agriculture Organization
FBOs	Farmer-based organization
FDRE	Federal Democratic Republic of Ethiopia
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
IFAD	International Fund for Agricultural Development
ITCZ	Inter-tropical Convergence Zone
LSMS	Living Standards Measurement Study
MVP	Multivariate Probit
NAP	National Adaptation Plan
NGOs	Non-governmental Organizations
NMA	National Meteorological Agency
SLM-CSA	Sustainable Land Management-Climate Smart Agricultural

SSA	Sub-Saharan Africa
SNNPR	Southern Nations and Nationalities Peoples' Republic
TLU	Total Livestock Unit
UNFCC	United Nations Framework Convention on Climate Change

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ABSTRACT

A backdrop of a high risk of climatic shocks have necessitated for climate resilient green economy strategies to be proposed. One of the pillars of the strategies is the use of multiple climate change adaptation strategies which are deemed to be essential for improving household food security. In this study, the effects of household, farm, climatic and institutional factors on farmers' decisions to employ adaptation practices are analyzed. A survey of 902 farm households for study periods of 2015,2016 and 2017 were followed combined with historical climate data in the Nile Basin of Ethiopia. This was explored using multivariate probit model and fixed effect econometric models. Results confirm that land certificate, fertility of soil, TLU, distance to input market, environmental shocks such as erratic rainfall, drought, flood, animal attack, hailstorms, being single, wind, age, extension visit, radio, neighbors, agriculture, watershed, forest, iddir, local government, religious and multipurpose membership, average rainfall and slope of land are important determinants of the choice of the climate change adaptation strategies. The result of the fixed effects model showed that adoption of climate change adaptation strategies made adopters more productive than non-adopters, on average. Adoption of Crop variety, Livestock decrement, Soil and water conservation, Soil and water conservation & Crop variety and Full strategies was found to be paying off. In particular, Crop variety resulted in the highest number of payoffs of yield. The result suggests the need for increasing access to quality extension services to increase the information dissemination, expanding the access to infrastructure, giving property rights to increase land certification and encouraging social networks participation.

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

According to the Intergovernmental Panel on Climate Change (IPCC)'s report, the United Nations Framework Convention on Climate Change (UNFCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global or regional atmosphere and which is in addition to natural climate variability observed over comparable time periods (IPCC, 2001).

Climate change is predicted to have major adverse consequences for the world's ecosystems and societies. Although climate change is a global phenomenon, the severity of its adverse consequences will differ significantly across countries and socioeconomic groups. Countries whose economy relies on natural resources and subsistence agriculture contribute very little to this change but they are the first victims of the adverse effects of global warming (Elias, 2016).

Among these countries, the Sub-Saharan African nations are highly vulnerable to the potential impacts of climate change. This is because the development prospects of Sub-Saharan Africa have been closely associated with climate for the reason of low level of economic diversification and reliance on rain-fed agriculture (IPCC, 2007). Climate models project that climate during the first half of the 21st century will make the Sub Saharan Africa (SSA) a center of food crises of the world (Di Falco and Veronesi, 2012). The fourth Intergovernmental Panel on Climate Change (IPCC), for instance, suggests that at lower latitudes, in tropical dry areas, crop productivity is expected to decrease "for even small local temperature increase such as 1-2 ^{0}C (IPCC 2007). It also continued to indicate that yields from rain fed agriculture could be reduced by up to 50% by 2020 in other African regions as access to food will be severely affected.

Ethiopia is a landlocked country in the Horn of Africa, which has experienced a double-digit economic growth over the past decades. The majority of this growth originated from Ethiopia's dominating agriculture-based economy; the agricultural sector accounts for 37 percent to GDP, one of the highest shares in Sub-Saharan Africa, as well as to 83.9 percent of exports.

Moreover, the sector employs around 72 percent of the total population (FAO, 2018). Besides, it played a vital role in stabilizing the food security status and in raising the income of 12 million farmers in the country. In this regard, the sector was also responsible in reducing the poverty index from 44% to 23.4% (a 20.6% decline) between the fifteen years from 2000 up to 2015 (ATA 2016/2017).

Ethiopia's agricultural growth relies on the ability of its farmers in maintain productive crops using subsistence farming which in turn makes them to be dependent on rainfall. It has two agricultural regions, the lowlands and the highlands and most of Ethiopia's livestock grazing land is found in the lowlands and most of the subsistence farms are found in the highlands. However, the Ethiopian economy, particularly agricultural development, is extremely vulnerable to external shocks climate change, global price fluctuations of exports and imports and other external factors (Shitarek, 2012).

Ethiopia's topography is characterized by large regional differences, which are reflected in its climate. The lowlands in the southeast and northeast are tropical with average temperatures of 25-30^{0}C, while the central highlands (over 1500 meters in elevation, covering about 45% of the country's surface) are much cooler with average temperatures around 15-20^{0}C.(Climate Change Profile: Ethiopia, 2018). It has three rainy seasons; June-September (*Kiremt*), October-January (*Bega*), and February-May (*Belg*). *Kiremt*, which is the main rainy season for most part of Ethiopia, accounts for 50-80 percent of the total annual rainfall over the regions having high agricultural productivity and major water reservoirs(NAP, 2019). It has also two grain growing seasons: *Belg* and *Meher*. *Belg* is the shorter season from February to April, and *Meher* is the main season from May to September. Grain production (including mainly corn, wheat, sorghum, barley and teff) greatly depends on rainfall patterns during the *Belg* season.

Drought, which is the main environmental problem, highly affects agricultural production and livelihood of the farming population. According to the World Bank report, droughts in Ethiopia can reduce total gross domestic product (GDP) by one to four percent. Past droughts resulted in widespread hunger and extremely poor nutritional outcomes. Ethiopia has experienced more than 15 drought events in the last 50 years (World Bank 2017). The greatest loss of life associated with drought in Ethiopia occurred in 1984, 1974 and 1973. In 2002, about 14.2 million people (over 20% of the total population) were affected by drought. Again in 2011, the severe drought in the Horn of Africa affected nearly over 3 million people, mainly in Ethiopia. According to the World Bank climate risk fact sheet of 2011, more than half of all households in the country experienced at least one major drought shock between 1999 and 2004 (Mahoo et al., 2013). The recent drought events also include the 2015/16 Niño drought and the "Indian Dipole" event in 2017 in which despite the different measures taken, the Government of Ethiopia issued a humanitarian appeal in January 2017 for 5.6 million people, at an estimated cost of US$948 million(World Bank 2017).

In order to explain the impact of climate change on Ethiopia, the variability of temperature and precipitation are used (Conway and Schipper 2011). The National Meteorological Agency (NMA) of Ethiopia predicts mean annual temperature to likely increase significantly when compared to the 1961-1990 level by a maximum of 1.1^{0}C by 2030, 2.1^{0}C by 2050 and 3.4^{0}C by 2080. Turning to precipitation, though the IPCC projects a 7% increase for East Africa in the last decade of the 21st century, the NMA reports show the average annual rainfall pattern to remain constant and likely to show little change in the future (Conway and Schipper 2011). Rainfall has been erratic with some areas becoming drier while others becoming relatively wetter.

In response to the recurrent droughts and related environmental calamities, farmers in Ethiopia have developed different adaptation strategies (Belaby et al. 2003; Devereux and Guenther 2007). Climate change adaptation is an adjustment in natural or human systems in response to actual or expected shock factors or their effects, in order to moderate harm or exploit beneficial opportunities. Adaptive capacity, on the other hand is the ability of a system or society to modify its characteristics or behavior so as to cope better with changes brought about by external conditions such as climate change (IPCC 2014).

Livestock producers have traditionally adapted to various environmental and climatic changes by building on their in-depth knowledge of the environment in which they live. Production adjustments, breeding strategies, livestock management systems and capacity building for livestock keepers have been identified as the major livestock adaptation strategies by several experts (IFAD 2009; FAO 2008; Thornton et al 2008; Sidahmed 2008) as ways to increase adaptation in the livestock sector.

Livestock management systems are the efficient and affordable adaptation practices that need to be developed for the rural poor who are unable to afford expensive adaptation strategies. These could include provision of shade and water to reduce heat stress from increased temperature, reduction of livestock numbers in which a lower number of more productive animals leads to more efficient production and lower greenhouse gases (GHG) emissions from livestock production (Batima 2006), changes in livestock/ herd composition and improved management of water resources through the introduction of simple techniques for localized irrigation, accompanied by infrastructure to harvest and more rainwater, such as tanks connected to the roofs of houses and small surface and underground dams.

Livestock adaptation strategies are therefore critical for purposes of mitigating adverse impacts of climate change. Reduction in the number of livestock in which a lower number of more productive animals leads to more efficient production and lower greenhouse gases (GHG) emissions from livestock production may be an adaptation option for farmers.

Soil and water conservation includes grass strips, soil and stone bunds. These practices can improve household food security and reduce vulnerability by increasing soil water availability, decreasing soil erosion and ensuring that nutrients and inputs are maintained in the plot (Delgado et al. 2011). They also help increase groundwater recharge and protect the top soil (FAO 2014).

Changing crop variety includes switching to short maturing varieties and growing drought-resistant varieties. Changing crop varieties in the times of adverse climate change were identified as the major responses undertaken by rain-fed smallholder harmers to climate change (Gadedjisso-Tossou 2015; Taruvinga et al 2016)

Although very informative, factors affecting the choice of any of or the combination of coping methods were not clearly identified. The knowledge of the factors dictating the use of any of the coping methods or a combination of methods assists policy in targeting intervention widows towards effective coping mechanisms to reduce the harmful impacts of climatic extremes.

The current study focuses on the determinants and welfare implications of the choice of climate change adaptation strategies. The research took selected districts from the Nile Basin of Ethiopia. The Basin consists of six regions: Oromia, Tigray, Amhara, Gambella, Beninshangul – Gumuz and Southern Nations and Nationalities People (SNNPR). 2 zones of the *Tigray* region (East and South *Tigray*), 4 zones of the *Amhara* region (North and South *Gondar*, East and West *Gojam*), 4 zones of the *Oromia* region (West and East *Wellega*, North *Shewa, Jimma*), 3 zones of the *Beninshangul-Gumuz* (*Metekel*, *Asosa*, *Kamashi*) and 1 zone of the Southern Nations and Nationalities Peoples Region (SNNPR), *Keta* were taken as samples from the respective regions.

1.2 Statement of the Problem

According to the World Bank report in 2016, 78% of Ethiopians live in rural areas and make their livelihood out of smallholder agriculture. The poverty headcount index for rural Ethiopia which is 26%, begs the need for improving agricultural production and productivity to reduce poverty and ensure food security.

The journey of improving the productivity of agriculture, though, has been hampered by the climatic, social and institutional factors making the agriculture sector unable to feed the population (FAO 2016). The climatic factors, one of which is increase in temperature and decrease in precipitation has been the main threat to this journey. The FDRE 2011 reports that only because of the adverse effects of climate change such as a rise in temperature, drought, flood, erratic rainfall and other environmental disasters, yields from agriculture could fall by 50% in 2020. Hence, to counter the negative effects of climate change on the performance of agriculture, adaptation is one of the policy options recommended by policy makers (Di Falco 2014).

Mendelsohn (1998) and Smit and Skinner (2002) have demonstrated that without adaptation, agricultural production will be severely affected by climate change with the resultant effects of making farmers more vulnerable. Farmers' adaptation to climate change is based on their expectation about the possible benefits that may be generated in the future. This implies there are some costs associated with adaptation to climate change. Maddison (2006) call this cost that one incur in adapting to climate change as "traditional adaptation cost". The use of a particular adaptation strategy can be linked to so many factors. Thus, what is left would be the determinants of the choice of the various adaptation strategies that farmers use in minimizing the effects of climate change on agricultural production.

The decision of a farmer to use adaptation strategy to mitigate the effect of climate change depends largely on certain factors which need to be known. Thus, researchers have acknowledged the fact that in-depth understanding of farmers' choices on climate change adaptations and their determinants is crucial for designing policies to promote effective adaptation in the agricultural sector (Nhemachena et al. 2014). Some farmers are able to adjust and adapt better than others depending on farm management practices, land management practices, farm characteristics, livelihood strategies and farmer socio-demographic characteristics. The understanding of how the various components of these factors affect farmers' decision to choose a particular climate change adaptation strategy is very necessary considering of the choice of livelihood strategies to be pursued in the Nile Basin of Ethiopia. Knowing the determinants of the choice of climate change adaptation strategies is very vital in developing intervention measures on those key determinants perceived to improve farmers' adaptive capacities (Mabe et al 2014). This study will quantify the magnitude and direction of the factors that affects the adoption of the major adaptation strategies by farmers.

This study focuses on adaptation practices used in the household level. The issue of climate change and its remedies has continued to catch the interests of various stakeholders. Particularly researchers and policymakers have given their attention to farmers' decisions to use climate-smart agricultural practices. Thus in order to design appropriate policies that encourage reshuffling of practices, an understanding of factors that lie behind the decision of the choices among various adaptation strategy must be devised.

Previous research studies concentrated on the negative impact of climate change on crop production and net farm revenue in low-income countries (Mendelsohn *et al* 2004; Deressa *et al* 2005; Yesuf *et al* 2008; Muamba and Kraybill 2010). A number of experimental studies have been done on the determinants of the choice of climate change (agro-forestry, livestock diversification, and mulching and soil conservation) adaptation strategies & their welfare implications on farm net revenue. For instance, Beyene *et al*. (2017) found household characteristics' variables to play a role in the decision to adopt a combination of adaption practices. The decision to adopt Sustainable Land Management-Climate Smart Agricultural practices (SLM-CSA) was positively correlated with households with younger heads, large family size, and literate household heads. Parcel characteristics such as soil quality, distance of parcel, slope of parcel and climate variables (rainfall and temperature) have different effect on the probability of adopting the SLM-CSA practices. The occurrence of shocks and extension visits were also positively correlated with some, but not all, of the combination of practices.

The effect of tillage intensity on farm income was found to follow non-linear patterns. Studies have also shown that increasing farm productivity due to tillage is beneficial to the farmer. But those studies have also indicated the cost to the farmer as well as the environment due to the intensity of tillage (Teklewold and Mekonnen. 2017); Teklewold *et al* (2017). Elias, Bezabih and Ferede (2017) found constraint status to be one of the key determinants of the choice of adaptation strategies besides exposure to climatic factors, household demographic characteristics, ownership of livelihood assets and other control variables such as location as does (Teklewold and Mekonnen. 2017). But in the absence of reliable formal credit markets, social capital serve as partial substitutes for formal credit markets as argued by Wossen *et al* (2015). Their study particularly showed that social capital to be a significant factor in the adoption of improved land management practices.

To the author's best knowledge, despite the aforementioned specific studies, empirical evidence on how households' characteristics, farm characteristics and asset ownership affect farmer's decision to adopt adaptation strategies other than farm-level management practices such as livestock diversification with their expected welfare implication is scanty. The existing body of literature concentrates on sustainable land management strategies. Beyene et al (2017) and Teklewold and Mekonnen. (2017), for example, analyzed the factors affecting the choice of land management and tillage practices. Even though Beyene *et al* (2017), for instance, stated that households with a greater number of livestock to adopt more likely, their study haven't included the variable. Another limitation of previous studies was excluding the impact of the different adaptation strategies on welfare. Among the previous studies. Only Di Falco & Veronesi (2013) and Teklewold *et al* (2017) studied the impact of the chosen adaptation strategies on farm net revenue besides identifying the climatic & household socio-economic factors behind the decision among various adaptation strategies.

Furthermore, the most relevant impact studies of adaptation strategies have long focused on a single adaptation practice (e.g., Di Falco *et al*. 2011; Di Falco *et al.* 2012), even though farmers adopt more than one practice to address their overlapping constraints. In addition, the current study uses panel data unlike other studies which used cross-sectional data.

Besides, in an attempt to fill some of the knowledge gaps discussed above and adding to the existing limited literature, this particular research conducted a study on the determinants of choice of adaptation strategies and their welfare implications on total yield using multivariate probit model. This framework has the advantage of controlling for alternative forms of unobserved heterogeneity effects and analytical simplicity (Abay *et al* 2016; Huguenin, 2008)

1.3 Research questions

This study is set out to try and answer the following research questions:

- What are the climatic variables, plot and household level determinants of the choice of climate change adaptation strategies overtime?
- What is the welfare impact of the climate change adaptation strategies on total yield overtime?

In an attempt to answer the above two research questions, this study set the following general and specific objectives.

1.4 Objectives of the study

1.4.1 General objective

The general objective of the study is to evaluate the determinants of choice of climate change adaptation strategies and their welfare implications in the Nile Basin of Ethiopia.

1.4.2 Specific objectives

To identify the key factors that determine the choice of the multiple adoption of livestock decrement, soil conservation and changing crop variety.

To measure the welfare implications of the various climate change adaptation strategies on total yield.

1.5 Significance of the study

Understanding of the factors behind the climate change adaptation choices among farmer households and their welfare implications on crop net revenue is viable for sustainable agriculture sector development. The significance of this study includes: First results of the study can serve as a guidance tool for policy makers in the process of designing appropriate policies. Second, the study’s result in terms of the welfare implications of the multiple adaptation strategies will be useful in choosing the right choice to increase welfare. Finally, the study can also be used as a reference work for researchers in the future in this scope.

1.6 Scope and Limitation of the study

The study is confined to the investigation of the welfare implications of the climate change adaptation strategies on total yield in the Nile Basin of Ethiopia. In order to achieve this objective, the study used multivariate probit model. The study was obliged to be limited in the Nile Basin while it was originally planned to cover other regions of the country. This is because of the unavailability of data. The Ethiopian Rural Socioeconomic Survey (ERSS) which was conducted by the Central Statistics Agency (CSA) in collaboration with the World Bank Living Standards Measurement Study (LSMS) could have been used as a source of data to make countrywide analysis on the determinants of the choice of climate change adaptation strategies and their welfare implications. Unfortunately, it didn’t include soil and water conservation, changing crop variety as a choice of climate change adaptation strategies. In addition, the study also faced lack of enough literatures which employed panel data. Even though panel data literatures were more appropriate to undertake the analysis for the determinants and deduce evaluations about the welfare implications, the study took literatures that employed cross-sectional data.

1.7 Organization of the paper

The remainder of the thesis is organized as follows. Chapter two reviews both the theoretical and empirical studies of climate change adaptation strategies. The theoretical literature focused on the first among the theories for explaining adoption of technology, the Diffusion of Innovation theory; the empirical review part contains literature of developing countries and Ethiopia regarding the determinants of choice of climate change adaptation strategies; whereas a comprehensive review was also done on the climate change system in Ethiopia. This is followed by the methodology part, which is chapter three of the paper. Chapter four presents discussion of the results and the last chapter, chapter five, presents conclusions and some policy recommendations.

CHAPTER TWO

2. LITERATURE REVIEW

This chapter is dedicated for reviewing both the theoretical and empirical literature on the concepts of climate change and adaptation to it. The thematic areas incorporated under these reviews are directly framed from the objectives of the study. The theoretical literature focuses on the construction of the concepts of the study whereas the empirical literature focuses on some comparable empirical evidences from developing countries in general and Ethiopia in particular.

2.1 Concept of Climate change

The United Nations Framework Convention on Climate Change (UNFCCC) as cited in Onyeneke & Maukwe, (2010) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global or regional atmosphere and which is in addition to natural climate variability observed over comparable time periods. IPCC (2007) defines climate change as a change in the state of the climate that can be identified by change in the mean or the variability of its properties and that persists for an extended period typically decades or longer.

Global climate change includes increasing temperature (0.74 °C increase per annum), melting polar icecaps, uncontrolled forest fires and annual average increase in sea level of 3.1mm (Spore 2008). The main cause of greenhouse gas (GHG) emissions is from carbon dioxide (70%), primarily from burning of fossil fuel (petroleum) imported from industrialized countries, while other sources for the emissions are methane and nitrous oxide caused by deforestation and agricultural activities, particularly the use of pesticides (Gebremichael & Kifle 2009). The Paris Agreement on climate change, adopted in December 2015, calls that the causes of climate change are to be addressed through a drastic reduction in greenhouse gas emissions *(mitigation*), its consequences through an equal emphasis on investment in climate resilience *(adaptation*).

Adaptation, in general, means adapting to life in a changing climate involving adjusting to actual or expected future climate. The main goal of adaptation is to reduce the vulnerability of humans to the harmful effects of climate change. Mitigation, on the other hand, refers to efforts to reduce or prevent emission of greenhouse gases. The goal of mitigation is to avoid significant human interference with the climate system, and "stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. This is because as Fussel (2007) pointed out human activities have already affected climate; climate change continues given past trends; the effect of emission reduction or mitigation takes several decades; and adaptation can be undertaken at local or national states as it is less dependent on the actions of others. Thus this study is mainly concerned with adaptation to climate change.

2.2 Concept of Adaptation

Adaptation to climate change is an adjustment made to human, ecological, physical or socio-economic systems, in response to perceived vulnerability or expected and actual climatic stimuli, their effects or impacts (Adger *et al*., 2007; IPCC 2001; Smit, Burton, Klein & Wandel 2000).

Adaptation as defined in the UNDP report of 2005 is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented. Nhemachena and Hassan (2007) explained adaptation to climate change as changes in agricultural management practices in response to changes in climatic conditions.

There are various types of adaptations that can be distinguished. *Anticipatory adaptation* also referred to as *proactive adaptation* takes place before impacts of climate change are observed while *reactive adaptation* takes place after impacts of climate change have been observed. Another type of adaptation is *autonomous adaptation* which does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. It is also referred to as *spontaneous adaptation*. *Planned adaptation* is an adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state. Adaptation that is initiated and implemented by individuals, households or private companies is called *private adaptation*. It is usually in the actor's rational self-interest while *public Adaptation* is initiated and implemented by governments at all levels. Public adaptation is usually directed at collective needs.

Adaptation is an important component of climate change impact and vulnerability assessment. Adaptation responses can be categorized by the level of ownership of the adaptation measure or strategy.

Individual or autonomous adaptations are considered to be those that take place in reaction to climate stimuli (after manifestation of initial impact), that is, as a matter of course without the intervention of any public agency (Smit *et al*, 2001). Autonomous adaptations are widely interpreted to be initiatives by private actors rather than by governments, usually triggered by market or welfare changes induced by actual or anticipated climate change.

Policy-driven or planned adaptation is often interpreted as being the result of a deliberate policy decision on the part of a public agency, based on an awareness that conditions are about to change or have changed, and that action is required to minimize losses or benefit from opportunities(Pittock & Jones, 2000).

Thus autonomous and policy-driven adaptation largely corresponds to private and public adaptation, respectively (Smit *et al*., 2001). As implied, autonomous adaptation responses will be evaluated by individual farmers in terms of costs and benefits. It is anticipated that farmers will adapt "efficiently", and that markets alone can encourage efficient adaptation in traded agricultural goods (Mendelson, 2000). Yet, in situations where market imperfections exist, such as the absence of information on climate change or land tenure insecurity, climate change will further reduce the capacity of individual farmers to manage risk effectively. As a result, an appropriate balance between public sector efforts and incentives, such as capacity building, creation of risk insurance and private investment, needs to be struck so that the burden can shift away from poor producers (Rosegrant *et al*., 2008).

2.2.1 Characteristics of Adaptation

There is a huge number and variety of measures or actions that could be undertaken in agriculture to adapt to climate change (Brklacich, McNabb, Bryant & Dumanski 1997; Kelly &
Granich 1995; Reilly 1995; Reilly & Schimmelpfening 1999; Smit 1993). There also exist numerous characteristics by which adaptations can be distinguished, and which could serve as bases for a typology of agricultural adaptations (Burton *et al.* 1993; Smithers & Smit 1997; Stakhiv 1993). Among the distinguishing characteristics of adaptation are intent and

purposefulness; timing and duration; scale and responsibility; and form which are discussed below.

Intent and purposefulness differentiate between adaptations that are undertaken spontaneously, or as regular part of on-going management from those that are consciously and specifically planned in light of a climatic-related risks (Bryant *et al*. 2000; Smit *et al*. 2000). Within socio-economic systems are usually consciously planned strategies, such as investments in government programmes, but private sector and individual adaptation can be autonomous, planned or a combination of the two (Bryant *et al.* 2000).

Timing and Duration according to Smit and Skinner (2002), timing of adaptation differentiates responses that are anticipatory (proactive), concurrent (during), or responsive (reactive). While logical in principle, this distinction is less clear-cut in practice. Duration of adaptation distinguishes responses according to the time frame over which they apply, such as tactical (short-term) versus strategic (longer-term) (Smit et al. 1996; Stakhiv 1993). In agriculture, tactical adaptations might include adjustments made within a season that involve dealing with a climatic condition, such as drought, in the short-term. Tactical adaptations might include selling of livestock, purchasing feed, plowing down a crop or taking out a bank loan. Strategic adaptations refer to structural changes in the farm operation or changes in enterprise or management that would apply for a subsequent season, or a longer term. Thus, strategic adaptations might include changes in land use, enterprises mix, crop type or use of insurance (Smit and Skinner 2002).

Scale and Responsibility adaptation can be distinguished according to the scale at which they occur and the agent responsible for their development and employment. In agriculture, adaptations occur at a variety of spatial scales, including plant, plot, field, farm, region and nation (Smithers & Smit 1997). At the same time, responsibility can be differentiated among the various actors that undertake or facilitate adaptations in agriculture including individual producers (farmers), agri-business (private industries), and governments (public agencies) (Smit et al. 2000)

Form adaptation in agriculture occurs via a variety of processes and can take many different forms at any given scale or with respect to any stakeholder. Smithers and Smit (1997) considered adaptations according to their administrative, financial, institutional, legal, managerial, organizational, political, practical, structural, and technological characteristics. In their own classification Bryant et al. (2000) identified forms of adaptation at the farm-level, including modification of resource management, purchasing crop insurance and diversification.

2.3 Review of Theoretical Literature

2.3.1 Theoretical literature on Climate Change adaptation strategies

Agricultural adaptation to climate change is a complex, multi-dimensional, and multi-scale process that takes on a number of forms (Bryant et al 2000). According to Smit and Skinner (2002) in the agriculture sector adaptation to climate change is important for impact and vulnerability assessment and for the development of climate change policy. Various adaptation options are proposed with the expectation of having the potential to reduce vulnerability of agricultural systems related to climate change.

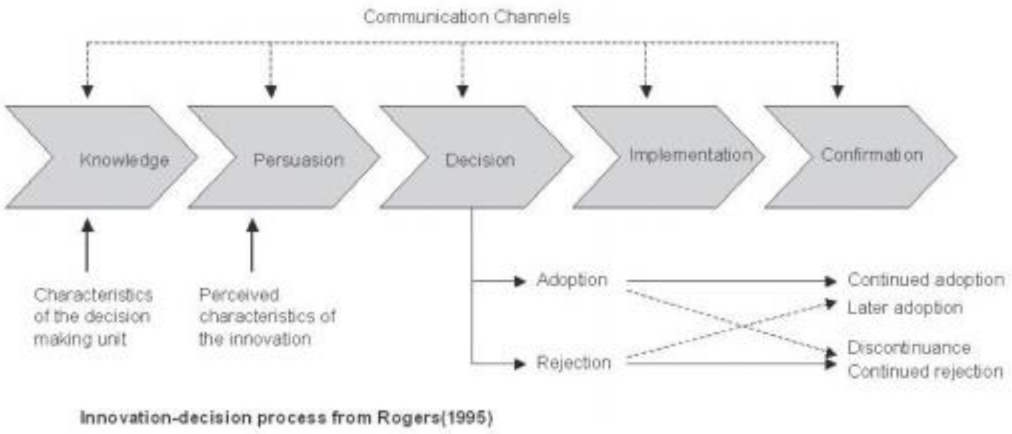
2.3.1.1 Climate Change adaptation theories and models

To improve crop productivity and to increase income, farmers employ multiple adaptation measures in the hope of synergizing and complementarily effects. This is done to overcome overlapping constraints such as biotic stressors, low soil fertility and to respond to perceived changes in climatic conditions income (Dorfman 1996 Khanna 2001, Moyo and Veeman 2004, Fleischer et al 2011).

Following Di Falco (2012), adaptation to climate change can be framed within the standard theory of technology adoption. Thus, the theoretical literature will discuss some of the past theories on technology adoption. Carr (1999) has defined technology adoption as the 'stage of selecting a technology for use by an individual or an organization'.

Everett Roger's work in 1960 is considered as the first among the theories for explaining adoption of technology. His theory also known as the Diffusion of Innovation Theory has been applied by the researchers over the years. The theory explains a process by which an innovation is communicated through certain channels over time among the members of a social system. It has four elements that influence the spread of a new idea i.e. the innovation, communication channels, time and social system. According to Roger the process of diffusion consists of five stages, namely, knowledge, persuasion, decision, implementation and confirmation. It results in six categories of users: innovations, early adopters, early majority, late majority, laggards and the leap-froggers.

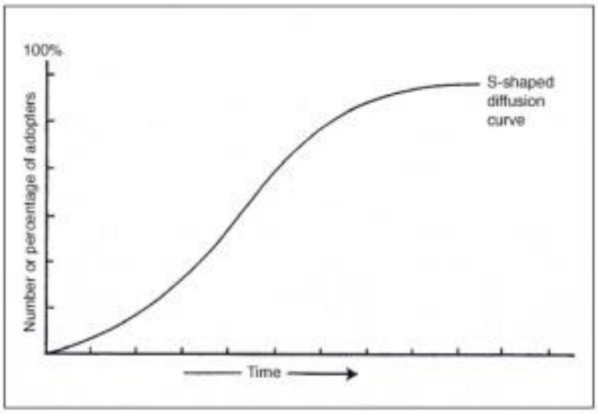
Figure 2.1 The five stages of innovation-decision process (Rogers, 2003)



In the first stage, an individual will become aware about the new technology and how to use it. It is called the knowledge stage. Individuals want to know more about technology thus they will ask critical questions like why, what and how. After having awareness about the technology, the informed individual builds favorable or unfavorable attitude towards the new technology that forms the so-called persuasion. In the third stage called the decision stage an individual decides to use or not to use a given technology. The last stage is implementation where an individual puts the new technology into use, and at confirmation individuals evaluate the results of the new technology and the individual looks for support for his or her decision.

This led to the development of Rogers (1995) S-shaped adoption curve also called as the epidemic model of adoption, which shows the distribution of the cumulative process of adoption of the new technology among farmers over time. According to this curve, spread of infections among the population can be held as an analogy to the pattern of spread of a new technique or idea. Initially the rate of spread will be slow while it accelerates in the mid-range of graph and finally tapers off resulting in an S-shaped curve depicted below.

Figure 2.2 Roger (1983), the S-shaped adoption curve



It depicts that the numbers of people that are exposed to the innovation are few in the beginning, since new technologies are coming from external sources and take time to get accepted by the majority. Over time, however, people in the social system start accept the innovation and they bring it in contact with more and more people. As the rate of adoption increases, the innovation is accepted by most members of a social system and the rate of spread declines as there is no more member left for accepting the innovation, then spread stops completely.

It further depicts that there is a critical “take off point” at which the slope of the growth curve becomes positive and number of members who have adopted the innovation become so large that there are hardly any new members left for adopting it. According to Rogers (1960), this point occurs when nearly 10% to 20% of the members of the social system have adopted the innovation.

2.3.2 Adaptation Decisions

Adaptation decisions are related with perceptions about climate change. Adaptation to climate change is a two-step process which requires that farmers perceive climate change in the first step and respond to changes in the second step through adaptation. The two-step process initially requires farmers’ perception that climate is changing prior to responding to changes through adaptation. Different socio-demographic factors affect the perception of climate change. Farming experience which is most often associated with age played an important role in the perception of climate change (Deressa et al 2014). Bennett (2009) showed that exposure to mass media increased the awareness and concern about the damage associated with climate change.

2.3.3 Dimensions of Adaptations

There are various dimension of climate change adaptation. For example, Owiyo(2017) tried to highlight the gender differences in climate change adaptation among small-holder farmers' and its implication for women's inclusion in decision-making in Ghana. Their finding showed that there are some differences between female and male farmers' adaptation strategies. While men are more into on-farm agronomic practices, women were found to be interested and utilize more off-farm adaptation strategies especially petty trading, in addition to the on-farm agronomic practices. Others Sining C. Cuevas (2018) argue that climate change adaptation operationalization necessitates an institutional perspective, and it advances and generates a more refined understanding of the institutional dimension of climate change adaptation. It shows that climate change adaptation is a matter of institutional change and transformation, which will affect existing institutional systems and institutional arrangements. Martinez (2014) addresses the overlooked social dimensions of climate change adaptation. He postulates that social aspects are key which can influence stakeholders to or not to engage in adapting to a changing climate.

2.4 Review of Empirical Literature

With the aim of attaining food security and alleviating poverty, promotion of practicing a portfolio of climate change adaptation strategies mainly targets at increasing the productivity of poor rural farmers (Fisseha). Adaptation helps farmers achieve their food, income and livelihood security objective in the face of changing climatic and socioeconomic conditions, including volatile short-term changes in local and large-scale markets (Kandlinkar & Risber 2000). Adaptive measures when implemented can protect the livelihoods of poor farmers and ensure food security by reducing the potential negative impacts and reinforcing the advantages associated with climate change (Bradshaw et al. 2004; IPCC 2007, Reid et al. 2007; Bryan et al. 2009).

Though there are a growing number of studies of climate change adaptation strategies and their determinants (Seo and Mendelsohn 2008; Bryan et al 2009; Reidsma et al 2010), adaptation in agriculture varies across countries. Moreover, different adaptation strategies are practiced by farmers depending on the climatic conditions, farm types and other conditions such as political, economic and institutional factors (Deressa et al. 2009; Reidsma et al. 2010; Hisali et al. 2011). More precisely, adaptation choices are context-specific and change from area to area and over time (Smit and Wandel 2006). Therefore, country-specific or area-specific studies of climate change adaptation are required. In this study context, research studies for developing countries are very limited.

The empirical literature review has three components: the first part is dedicated on the factors that determine the choice of climate change adaptation strategies among farmers in developing countries; the second part focused on the relation between climate change adaptation and welfare; and lastly the third part focused on the empirical evidence from Ethiopia.

2.4.1 Empirical literature from developing countries

When coping with the aftermath of a natural disaster such as climate change rural households in developing countries have in most cases a very limited portfolio, including reducing current spending on food and other items, if possible, given the constraints set by subsistence, and disposing of assets such as livestock and land. One of the reasons for this limited choice set is the unavailability of formal strategies because of weak public services and a lack of penetration of market-based instruments because of, for instance, a lack of institutions to provide finance or a lack of collateral. Another reason for the limited choice set is the nature of the disaster, i.e., in many cases, the disaster affects the majority of individuals simultaneously, a covariate risk, and therefore informal insurance structure, e.g., family and social networks, do not provide effective relief either (Helgeson et al 2013)

Previous studies on developing countries regarding adaptation to climate change have identified its major determinants, including different household and farm characteristics, infrastructure, and institutional factors. The most commonly cited household characteristics include age, education, farming experience, marital status, gender of the household head and wealth. Farm characteristics include farm size and slope and soil fertility; institutional factors include access to extension and credit while infrastructure includes distance to input and output markets (Norries and Batie 1987; Asfaw and Admassie 2004; Maddison 2006). Other characteristics include conducting research on use of new crop varieties and livestock species and encouraging informal social networks (Deressa et al 2008).

Mulwa et al (2017) assessed the role of information, household demographics and farm characteristics to study the response to climate risks among smallholder farmers in Malawi using a multivariate probit. The study was based on a primary survey of 1786 households over 16 districts across Malawi’s three administrative regions. The data which was collected in 2011 included household and plot level data. It was found that plot characteristics, credit constraints an availability of climate-related information explain the adoption of several of these practices. A unique result was even when financial limitations are binding, making climate-related information available can still motivate farmers to adapt. Policy implications are that the deepening of extension access with information on the appropriate adaptation strategies is crucial to help farmers make adaptation choices. The need to foster credit markets for easy accessibility and affordability by farmers or otherwise strengthening access to assets is also important.

Others Kassie et al (2012) in Tanzania, Arun GC in Nepal and Boansie et al (2017) employed multivariate probit technique to assess the determinants of farmers' decisions for climate change adaptations. Demographic characteristics such as age, gender and education of household head, credit access, farm area, rain-fed farming and tenure, are much influencing as compared to other factors. Furthermore, climatic extremes such as rainfall shocks, insects and disease shocks, government effectiveness, tenure status of plot, social capital, plot location and size and asset ownership all influence the adoption decision of sustainable practices.

Maddison (2006) applied a Heckman model to determine factors that influence adoption of adaptation strategies towards climatic and weather variability in Africa. The study revealed that education, gender, extension and experience significantly influenced households in adapting towards climatic change. It was also found that education and gender increased the probability of adoption of adaptation strategies by 0.03% and 6% respectively. Study findings recommended that education and extension should be emphasized to appropriately adapt towards changes in climate. Using a Heckman probit model Gbetibouo (2009) was able to determine whether the climate has changed, whether farmers perceive climate change and variability and what characteristics differentiate farmers who perceive changes from those who do not in South Africa. The study was conducted on 794 households and the results showed household size, farming experience, wealth, access to credit, access to water, tenure rights, off-farm activities, and access to extension are the main factors that enhance adaptive capacity.

Langyintuo and Mekuria(2008) used a tobit model to analyze the effects of household characteristics on adoption of improved varieties among Mozambican farmers. The study found a significant contribution of social networks to technology adoption. It was suggested that government should invest in farmers' associations to facilitate high technology adoption. Similarly, Phiri(2011) applied the translog production and tobit models to examine the impacts of adaptation strategies on food production and food security in Malawi that flood, droughts, gender and education are important factors on influencing household choice of adaptation strategies. Climatic information, input markets and credit accessibility deterred households from adapting to climatic and weather variability. Based on the Normalized Translog Production and Tobit Models' results, irrigation farming increased crop production and household food security by 80% and 21% in the study area, respectively. On the other hand, shifting planting dates reduce crop production and household food security by 50% and 9% in the study area, respectively. The study recommends that projects should mainstream barriers and choice of adaptation strategies in the farming system.

Taruvinga et al (2016) on the paper entitled " determinants of rural farmers' adoption of climate change adaptation strategies: evidence from the Amathole District Municipality, eastern Cape Province, South Africa" using a cross sectional survey sample of 200 rural farmers from the Amathole district municipality of the Easter Cape Province of South Africa estimated farmers' climate change adaptation strategies, adaptation portfolio diversity and factors that condition farmers' adoption behavior. A simple linear regression model was developed to identify factors affecting rural farmers' implementation of climate change adaptation techniques. The results showed that age, level of education, level of wealth status, land ownership, access to formal and informal credit, access to extension services had a positive effect on the ability of farmers to adopt climate change adaptation portfolios. On the other hand, a one standard deviation positive change in family size, holding other predictor variables constant, resulted a decrease in the adoption of climate change strategies. The reason that was found was adoption costs hinder larger households who normally focus their resources on sustaining immediate family members' needs at the expense of adaptation strategies. As a recommendation, public policies should create a supportive rural institutional framework and promote rural education, rural income initiatives and climate change awareness campaigns.

Nashiru et al (2010) sought to examine the factors that influence the choice of climate variability adaptation strategies employed by maize farmers in the Mion Districs of the Northern Region of Ghana on the paper entitled "Factors influencing adaptation strategies to cope with climate variability: A study of maize farmers in Northern Ghana". The study employed survey research design where mixed research methodology (qualitative and quantitative) was used to ascertain and determine the influential factors in farmers' choice of adaptation strategies. A simple random sampling technique was used to select 140 household respondents. Through one-on-one interview using a questionnaire data was gathered from these households. Ordered logit regression (OLM) model was used to analyze the factors influencing the choice of climate variability adaptation strategies by farming households. One of the regression results show that gender of the household head had a positive influence on the likelihood of the farmers adopting the adaptation strategies, implying that a male household head had a higher probability of adopting the indigenous strategies as a way of adapting to the variability of climate as compared to their female counterparts. Age of the household head also had a significant effect on the adoption of adaptation strategies. As age of a farmer increases, he is more likely to adopt climate change adaptation strategies. Adaptation by farmers also increased when they have higher years of education. In a similar study, Mabe et al (2014) on their paper entitled “Determinants of choice of climate change adaptation strategies in northern Ghana” analyzed the factors that affect the choice of climate change adaptation strategies of farmers in Northern Ghana. Using semi-structured questionnaires, 155 farmers were randomly sampled from purposively selected three Northern Regions in Ghana. Farming experience, farm income, access to phones, mixed farming, farmers’ perception on reduction in rainfall amount and access to weather information significantly and positively affected the choice of at least five climate change adaptation strategies. The paper recommends agricultural extension service to be intensified through organization of adult education programmes or field schools for farmers to educate them on some climate change adaptation strategies. Establishment of agro climatic information centers at vantage points in farming communities to enable farmers seek for information to help them revise their climate change adaptation decisions for specific time and agricultural activity. In addition, affordable climate change adaptation technologies should be designed and make available to poor farmers to adopt.

Devkota et al (2018) on their paper entitled “Perception, determinants and barriers for the adoption of climate change adaptation options among Nepales Rice farmers” estimated the perceptions, determinants and barriers regarding the adoption of climate change adaptation options among Nepalese rice farmers. A multi-stage sampling technique was used to source respondents for the study, and structured questionnaire technique was used to collect data from 773 households across seven districts. Using a binomial logistic regression, the results revealed that farmers face several barriers in adaptation decisions such as capital inadequacy, high cost of agricultural inputs, poor adaptation information provided to farmers, inadequate access to credit facilities and inadequate awareness about adaptation regarding the adoption of such options. Household size, irrigation facilities, availability of credit, access to roads, extension service availability, access to the market center, and the availability of subsidies have found to be a significant factor. The paper suggested that government policies should target the improvement of these significant determinants to boost farmer adaptations and thus reduce vulnerability. For instance, investment in education, the supply of adequate agricultural inputs, raising awareness about the use of chemical fertilizers and other adaptation options can be used as appropriate policy options in order to minimize the effect of climate change on rural farmland in Nepal.

Islam and Paul (2018) on their paper entitled “People’s perception on agricultural vulnerabilities to climate change and sea level rise in Bangladesh: adaptation strategies and explanatory variables” evaluated people’s perception on vulnerabilities of agriculture and to explore effective adaptation options with identifying the underlying demographic, socio-economic and other relevant variables that influence the adaptation strategies in the sea level rise hazard induced coastal areas of Bangladesh. The study was conducted on three villages using both secondary and primary data. The primary data were collected through key informant interviews, direct observations, household survey and as well as via focus-group discussions. The results revealed that age, gender of the household head, education level, agricultural land, household income and occupation were identified as the demographic and socio-economic factors that had a high dependency and inter-relations with the adaptation options for agriculture considering the time and intensity of climate change and sea in level induced hazards in coastal Bangladesh.

2.4.2 Empirical evidence from Ethiopia

Wossen et al (2015) on their paper “Social capital, risk preference and adoption of improved farm land management practices in Ethiopia” presented an analysis on the effects of social capital on smallholder adoption of improved land management systems. It examined the differential effects of social capital on technology adoption across households with heterogenous levels of risk aversion and formal credit accesses. The study used data from 2004 & 2009 rounds of the Ethiopian Rural Household Survey (ERHS). A random effect probit and fixed effect logit model was used to estimate the effects of social capital. The result showed social capital to be a significant determinant of adoption of improved land management practices. Membership in labor sharing arrangements, membership in informal local saving and credit association and connection to local authorities were found to have a positive and significant effect on the probability of adopting improved land management practices. Contrary, other forms of social capital such as having large number of relatives and membership in funeral insurance arrangements were found to have a negative effect on adoption. The study also found some forms of social capital to be partial substitutes for formal credit markets since the latter are few in number in farmer households. In conclusion, the study points out the attention that should be given to farmer’s attitudes towards risk. It further confirmed that the effect of social capital across households holding heterogeneous risk-aversion levels is different. Along with this the study recommended policy interventions that consider promoting formal credit access as well as scaling up the capacity of informal social networks through provision of initial resources.

Elias, Bezabih and Ferede(2017) on their paper entitled **“**The Impact of Credit Constraints and Climatic Factors on Choice of Adaptation Strategies” empirically investigated the links between alternative adaptation strategies and different forms of credit constraints in selected areas of Amhara region using two waves of rural household surveys conducted in 2011 & 2013. The paper categorized credit constraint statues into three: risk rationed, discouraged and unconstrained borrower. It also combined with climate information from the adjacent meteorological stations. Soil conservation and tree planting, irrigating the farm land, crop diversification, selling(depleting) productive assets, using cash savings or dis-saving, participation in a safety net program, receive assistance from NGOs were the chosen alternative adaptation strategies. The study used a multivariate probit regression model. The paper disintegrated the effects of credit constraint status to each of the chosen adaptation strategies.

Thus, credit constraint adversely affected the probability of participation in off-farm employment while coefficient of rainfall & drought shock had no significant role on the decision to participate in off-farm employment. On the other hand, being a female head had a positive effect to participate in off-farm employment.

Turning to the decision to adopt crop diversification, the paper found mixing result for the different credit constraint categories. While quantity constrained households tend to diversify more discouraged borrowers diversify less. This is because crop diversification demands significant amount of cash to purchase inputs such as seeds and fertilizers. It was also found that the coefficient of variation of rainfall, drought shocks and other socio-economic variables such as household size, marital status, plot characteristics to have a none effect on the decision to follow crop diversification as a climate change adaptation strategy. As expected, farmers who had no educational background and possessing larger household holdings diversify less. Socio-economic control variables except for age were found to be non-significant in the choice of irrigation while drought shock was the main driver of investment in small-scale irrigation. Being in the risk rationed borrower’s category significantly increased the likelihood of depleting productive assets in the time of climate shocks. Land management choices such as soil conservation and tree planting were found to be unresponsive to credit constraints since they are highly subsidized by the government. But older heads of household, household size & education were positively associated with the decision of conserving the soil to adapt. The paper concluded that the type of credit constraint matter for the choice of adaptation strategies to households. Furthermore, the severity of credit constraints depends on both the nature of the credit constraint and the type of adaptation investment. Though the study emphasized on the role of credit constraint on the choice of adaptation strategies, its policy recommendation included the strengthening & enhancement of institutional support in enhancing the adaptive capacity of households.

Mihiretu et al (2019) studied the determinants behind the choices of climate change adaptation in the agro-pastoral dry lands of Northeastern Ethiopia. A sample of 260 household heads were interviewed using a structured interview on their household characteristic and adaptation behaviors. The study employed a multivariate probit regression. The farmers in the area applied both a crop and livestock adjustment to cope up with the changing climate. The result from the model revealed that education level, gender, farming experience, family size, farmland sie, livestock size, farm and non-farm income, frequency of extension contact, access to credit and climate information were significant factors for adaptation choice decisions. The study went on to recommend provision of services resembling to eminence extension, vocational trainings, affordable credit, empowering vulnerable groups, community radios as well as local meteorology.

Bedeke et al (2019) tried to identify how maize-dependent smallholders in *Wolaita* zone of Ethiopia adapt to climate change. To carry out the study, a household survey was conducted that included 252 household heads from the study area. Additionally, 659 farm plots were selected from the study districts, using similar sampling techniques. Questionnaires informed about adaptation strategies and the biophysical features of the plots, farms and villages as well as household demographic, soico-economic and institutional conditions. Findings indicate that the likelihood of adopting soil and water conservation practices, drought-resistant varieties and chemical fertilizers significantly increase among young and male-headed households as well as farmers having confidence in extension agents and membership in local organizations. Therefore, policies should aim at further building agricultural extension agents' capacity by providing effective and continuous education and training on climate change impacts and responses. Also, promoting family ties and household memberships in local organizations through facilitating mutual cooperation and communication among farming communities would help to foster adoption of climate change adaptation strategies.

Teklewold and Mekonnen (2017)'s study entitled "The Tilling of Land in a Changing Climate: Panel Data Evidence from the Nile Basin of Ethiopia" aimed to examine the determinants of a household's decision to tillage intensity and to quantify the effect of tillage frequency on farm net returns. It used a sample survey of 1000 households that was conducted from March to May in 2013 and 2015 in the Nile Basin. It applied a random effect ordered probit endogenous switching regression model. Credit constraints, social capital and amount of rainfall to have a positive effect on the intensity of tillage while bio-physical characteristics such as plot access, rainfall satisfaction index and rainfall variability negatively affect the tillage intensity. Concerning the impact of tillage, adoption of more than one round of tillage resulted higher net farm income compared with low-tillage practices, defined as zero or one tillage. The greatest farm income (3.7 thousand birr per hectare) is obtained from four rounds of tillage. Compared with low tillage, plowing the farm more than four time still increases farm income by 11 percentage points. But this productivity-enhancing effect of tillage declines when tillage exceeds four rounds of tillage. These results point out the nonlinear effect of tillage intensity on farm income. The study also found that lower frequency of tillage provided higher returns at the lower quantile of the rainfall amount.

A paper entitled "Does Intensive Tillage enhance productivity and reduce risk exposure? Panel Data evidence from Smallholders' agriculture in Ethiopia" by Teklewold et al (2017) analyzed the impact of intensity of tillage on wheat productivity and risk exposure using a survey done on the main wheat producer areas in the year 2009/10 and 2013/14. To control for selection bias, the study used an endogenous switching regression treatment effects model. The results found indicated that high intensities of tillage were generally associated not only with higher yields but also with lower risk exposure. The findings suggested that farmers use tillage as a strategy to increase productivity and minimize production risks. Among the current wheat farmers in Ethiopia, though intensive tillage exacerbates soil erosion, the net effect tends to be positive; high expected yield and low risk exposure.

Mogues(2006) on the paper entitled "Shocks, livestock Asset Dynamics and Social Capital in Ethiopia" used a household survey panel data of 416 rural households to study livestock asset dynamics in the north-east of Ethiopia. The household survey covered three rural weredas (districts) in South Wollo Zone (Dessie Zuria, Legambo, and Jemma weredas) and one rural wereda in Oromiya Zone (Bati wereda**).** It was conducted in seven rounds over the period of June 2000-July 2003 and data for households' livestock holdings for the year 1996-1999 were also captured. The conceptual framework used was by first describing the nature and timing of the weather-related shocks households experienced in South Wollo in the late '90s and early 20s. Then a brief account of the evolution of households' asset endowments in the form of livestock (oxen in particular) is laid followed by an outline of social institutions and extra-village social ties which serves as a background to assess that social capital's role as a determinant of asset holdings in drought shocks. An estimation method that produces consistent and efficient estimator was employed which is Arellano and Bond. The paper found that more well-endowed households engaged in consumption smoothing by reduction in their herd in times of food shortage through increment of net sales while asset poorer households were reluctant to trade away their already exhausted livestock holdings. This suggests that initial holdings of assets by the particular household determine whether the household will engage in consumption-smoothing behavior through changing its livestock stock. As a recommendation, a better grasp of how social connectedness contributes to protecting assets from becoming eroded by shocks should be followed.

"Adaptation to climate change in Ethiopia and South Africa: options and constraints" by Deressa et al (2009) tries to study the adaptation strategies used by farmers in both countries and analyzes the factors influencing the decision to adapt. Using a total of 1800 surveyed farm household from both countries, the Ethiopian dataset of 1000 households came from 20 districts(woredas) in 5 regions of the country (Tigray, Amhara, Oromia, Beninshangul-Gumuz and Southern Nations and Nationalities Peoples or SNNP). For the analysis, a discrete choice model was chosen: the probit model. The results from the model suggested that wealth, access to extension, credit and climate information were found to influence the choices of adaptation by farmers in the selected regions. It suggests that policy makers should support adaptation by increasing access to information, credit and markets, reaching out to small-scale subsistence farmers who have limited resources to confront climate change.

A unique study was by Berhanu and Beyene (2015) "Climate Variability and Household Adaptation strategies in southern Ethiopia" which examined the determinants of climate change adaptation strategies in the context of traditional pastoralist. The primary data for the study was collected from 281 households from six pastoral village sites of the Borana rangelands through household interviews, community level focused group discussions, key informant interviews, and field observations. The study categorized the adaptation choices followed by pastoralists into two: adjustment in pastoral practices and shifts to non-pastoral livelihoods. Probit regression was used to derive the results and it was found that the likelihood of pastoral household adoption of adaptation is significantly explained by age, gender, wealth status, degree of pastoral household shock resilience and climatic variables. The study suggests that local administrators should discourage private rangeland enclosures by wealthy stock owners to be consistent with the natural adaptation system of traditional pastoralism.

Tembo et al. (2018) conducted a study in Southeast Tigray of Ethiopia using *teff* producing farmers. It aimed at studying the factors influencing choice of adaptation strategies among *teff* farmers in Ethiopia. Using a stratified simple random sampling technique, the study selected 210 farm households as respondents from three agro-ecological zones. A multivariate model was run to analyze the data obtained from farm households. The study then found that age, education of the household head, household size, distance to produce market, farm to farm extension services, access to credit facilities, average temperature, climate information on weather and climate and agro ecology have significant influence on adaptation strategies. Thus, policies of government on adaptation to climate change should be given emphasis in order to enhance the adaptive capacity of *teff* farming community.

2.5 Climatic systems in Ethiopia

2.5.1 Agro-ecological features of Ethiopia

The seasonal migration of the Inter-tropical Convergence Zone (ITCZ), which follows the position of the sun relative to the earth and the associated atmospheric circulation, in conjunction with the complex topography of the country mainly controls the Ethiopian climate (NMSA 2001). There are different ways of classifying the climatic systems of Ethiopia, including: the traditional, the Köppen’s, the Thornthwaite’s, the rainfall regimes, and the agro-ecological zone classification systems (Yohannes 2003).

The traditional and the agro-ecological zones (AEZs) are the most commonly used classification systems. The traditional classification system relies on altitude and temperature and according to this system Ethiopia has five climatic zones.

Table 2.1 Traditional climatic zones and their physical characteristics

Zone	**Altitude (meters)**	**Average annual temperature (ºC)**
Wurch(upper higlands)	3200+	>11.50
Dega (highlands)	2300 -3200	11.50 – 17.50
Weynadega (midlands)	1500-2300	16.00 – 20.30
Kola (lowlands)	500 – 1500	20.00 – 27.50
Bereha (desert)	Under 500	>27.50

Alternatively, the AEZs classification method combines growing periods with temperature and moisture regimes. According to this classification method, Ethiopia has 18 major AEZs which are further subdivided into 49 AEZs. The Ministry of Agriculture in 2000 has grouped these AEZs under six major zones namely arid, semi-arid, sub-moist, moist, sub-humid and humid and per-humid.

Table 2.2 Agro-ecological Zones of Ethiopia

Agro-Ecological Zone	Area in Ha (in millions)	% of the country	Characteristics
Arid	53. 5	31.5%	Less productive Pastoral
Semi-arid	4	3.5 %	Less harsh
Sub-moist	22.2	19.7%	Highly periled by erosion
Moist	28	25 %	Favorite for agriculture Cereals are the dominant crops
Sub-humid and humid	17.5	15.5%	Stable and ideals for annual & perennial crops Home to the forest & wildlife
	4.4	4%	
Pre-humid	1	1%	Suited for perennial crops and forests

Source: MoA, 2000

These diverse AEZs cause mean annual rainfall and temperature to vary widely. Mean annual rainfall ranges from about 2000 millimeters over some pocket areas in the southwest to less than 250 millimeters over the Afar lowlands in the northeast and Ogaden in the southeast. Mean annual temperature varies from about 10^0C over the high table lands of the northwest, central, and southeast to about 35^0C on the northeastern edges.

2.5.1.1 Past climate trends in Ethiopia

Looking back in time, the Ethiopian climate is characterized by a history of climate extremes, such as: droughts and floods; and increasing and decreasing trends in temperature and precipitation, respectively. Among these climate extremes, drought is not a new phenomenon in Ethiopia. Recorded history of droughts in Ethiopia dates back to 250 BC. Since then, droughts have occurred in different parts of the country at different times (Webb and von Braun 1994). Even though there is a long history of droughts in Ethiopia, studies show that the frequency of droughts has increased over the past few decades, especially in the lowlands (Lautze *et al.* 2003; NMS 2007).

Studies also indicates that mean temperature and precipitation have changed over time. According to NMSA (2001), the average annual minimum temperature over the country has increased by about 0.250c every 10 years, while the average annual maximum temperature has increased by about 0.10C every decade. The average annual rainfall of the country showed a very high level of variability over the past years, even though the trend remained more or less constant (NMS 2007). Over the past 60 years, some of the years have been characterized by dry rainfall conditions resulting in droughts and famine whereas the others are characterized by wet conditions. Droughts in Ethiopia can shrink household farm production by up to 90% of a normal year output (World Bank 2003). Most often, many farmers die of hunger or depend on foreign food aid during extreme drought periods. For instance, during the 1983/84 drought periods, about one million people died due to drought that led to famine. Many households have also been affected during drought periods over different years in the same vein.

For the period of 1990-2015, 46 natural disasters are reported in Ethiopia according to the emergency events database (EM-DAT), among which floods and droughts are the most frequently observed disasters accounting for 63 per cent of total disasters in Ethiopia. The scale of impacts of those two disasters, in terms of affected populations, is also the largest: approximately 129,150 population per flood and 5,421,320 population per drought were negatively impacted through these two disasters. In addition to those frequent and mass-scale climate events, heavy reliance on rain-fed farming and lack of flood-control interventions make Ethiopian farmers vulnerable to rainfall fluctuation.

2.5.1.2 Projected Climate in Ethiopia

Models predicting precipitation give controversial results of both increasing and decreasing precipitation, all models agree that the temperature in Ethiopia will increase in the coming years. Strzepek and McCluskey (2006) showed that, based on different models, precipitation will either increase or decrease. However, they continue to point that, under all models temperature will increase. Strzepek and McCluskey (2006) used three climate prediction models based on two scenarios from the IPCC Special Report on Emission Scenarios (SRES). The models are: the Coupled Global Cimate Model (CGCM2) (Flato and Boer 2001), the Hadley Centre Coupled Model (HadCM3) (Senior and Mitchell 2000) and the Parallel Climate Model (PCM) (Washington et al 2000). The two SRES scenarios used in the study are the A2 and B2 scenarios. The A2 scenario describes a world in which population growth, per capita economic growth and technological changes are heterogenous across regions. The B2 scenario describes a world in which the population increases continuously across the globe at a rate less than A2. This scenario is an intermediate level of economic development that is oriented towards environmental protection and social equity with a focus on local and regional levels (IPCC 2001). Additionally, forecasts by NMS (2007) indicate that the temperature in Ethiopia will increase in the range of 1.7 – 2.1^{0}C by the year 2050 and 2.7-3.4^{0}C by the year 2080.

Table 2.3 Climate predictions for 2050 and 2100 (Changes from a 1961- 1990 base for SRES A2 and B2)

Model	**Temperature in ^{0}C**		**Precipitation change in %**	
	2050	**2100**	**2050**	**2100**
CGCM2				
A2	3.30	8.00	-13.00	-28.00
B2	2.90	5.10	-13.00	-28.00
HadCM3				
A2	3.80	9.40	9.00	22.00
B2	3.80	6.70	9.00	22.00
PCM				
A2	2.30	5.50	5.00	12.00
B2	2.30	4.00	5.00	12.00

Source: Deressa (2009)

CHAPTER THREE

3. METHODOLOGY

3.1 Study Area

The study area for this research is the Nile Basin of Ethiopia. The basin covers six different regional states of Ethiopia with different proportions. From the six regions, zones were selected as samples for the study. Thus, two zones of the *Tigray* region (East and South *Tigray*), four zones of the *Amhara* region (North and South *Gondar*, East and West *Gojam*), four zones of the *Oromia* region (West and East *Wellega*, North *Shewa*, *Jimma*), three zones of the *Beninshangul-Gumuz* (*Metekel*, *Asosa*, *Kamashi*) and one zone of the Southern Nations and Nationalities Peoples Region (SNNPR), *Keta* are the selected sample zones.

The Nile basin covers a total area of about 358,889 square kilometers, equivalent to 34% of the total geographic area of the country. Moreover, about 40% of the population of Ethiopia lives in this basin. The basin covers six regional states of Ethiopia in different proportions: 38% of the total land area of *Amhara*, 24% of *Oromia*, 15% of *Benishangul-Gumuz*, 11% of *Tigray*, 7% of *Gambella*, and 5% of Southern Nations Nationalities and Peoples (SNNP) Regional States (Deressa et al 2010). The farming system of the basin can be broadly categorized as a mixed crop-livestock farming system, where over 90% of the cultivated area is covered by cereal-based farming systems (Erkossa et al. 2014)

The basin consists of three major rivers: the *Abbay* River, which originates in the central highlands; *Tekeze* River, which originates in the northwest; and *Baro-Akobo* River, which originates in the southwestern part of the country. The total annual surface runoff of the three rivers is estimated at 80.83 billion cubic meters per year, which amounts to nearly 74 percent of Ethiopia's 12 river basins (Deressa et al 2010)

Out of the four traditional agro-ecological settings of Ethiopia (*Bereha* or desert which is below 500m a.s.l; *Kolla* or lowland which ranges from 500-1500m a.s.l; *Weynadega* or middle land ranging from 1500-2500 a.s.l. and *Dega* or highland ranges from 2500-3500m a.s.l), the survey districts fall in three of them: *Dega*, *Weynadega*, *Kolla*.

Tigray region consists of 4 administrative zones, 1 special zone, 35 *weredas* and 74 towns. It is located at the northern tip of the country sharing common borders with Eritrea in the north, *Afar* in the east, *Amhara* in the south and Republic of Sudan in the west. The region has an estimated area of 80,000 square kilometers. 39% of the region's climate is characterized as "*Kolla*" or semi-arid while 49% and 12 % of the region is "*Woina dega"* or warm temperate and "*Dega"* or temperate respectively. The average annual rainfall is between 450 – 980 mm. This study took 2 *weredas* (*Hawzein, and Atsbi Wonberta*) from East *Tigray* and 1 *wereda* (*Endamehoni*) from South *Tigray* as sample.

Amhara region consists of 10 administrative zones, 1 special zone, 105 *weredas*, and 78 urban centers. The region is located in the north western and north central part of Ethiopia. It is bordered by the state of *Tigray* in the north, *Afar* in the east, *Oromia* in the south, *Beninshangul-Gumuz* in the south west and the Republic of Sudan in the west. It covers an estimated area of 170,752 square kilometers. The region is topographically divided into two main parts: highlands and lowlands. This study takes 3 *weredas* (*Debark, Chilga, and Wogera*) from North *Gondar*, 1 *wereda* (*Libo Kemkem*) from South *Gondar*, 1 *wereda* (*Bichena)* from East *Gojam* and 1 *wereda* (*Quarit)* from West *Gojam.*

The highlands are above 1500 meters above sea level and comprise the largest part of the northern and eastern parts of the region. The highlands are also characterized by chains of mountains and plateaus. The lowland part covers mainly the western and eastern parts with an altitude between 500 – 1500 meters above sea level. Areas beyond 2300 meters above sea level fall within the *"Dega"* climatic zone, and areas between the 1500 – 2300 meter above sea level contour fall within the *"Woina Dega"* climatic zone; and areas below 1500 contour fall within the *"Kolla"* or hot climatic zones. The *Dega, Woina Dega* and *Kolla* parts of the region constitute 25%, 44% and 31% of the total area of the region respectively. The annual mean temperature for most parts of the region lies between 15°C-21°C. The region also receives the highest percentage, 80%, of the total rainfall in the country.

Oromia sprawls over the largest part of the country and consists of 12 administrative zones and 180 *weredas*. Of the 12 zones, *Bale* and *Borena* account for 45.7 % of the region's total area but only comprise about 14% of its population. The region borders *Afar*, *Amhara* and the state of *Benshangul-Gumuz* in the north, Kenya in the south, state of Somalia in the east, the Republic of Sudan and the state of *Benishangul-Gumuz* in the west, state of Southern Nations

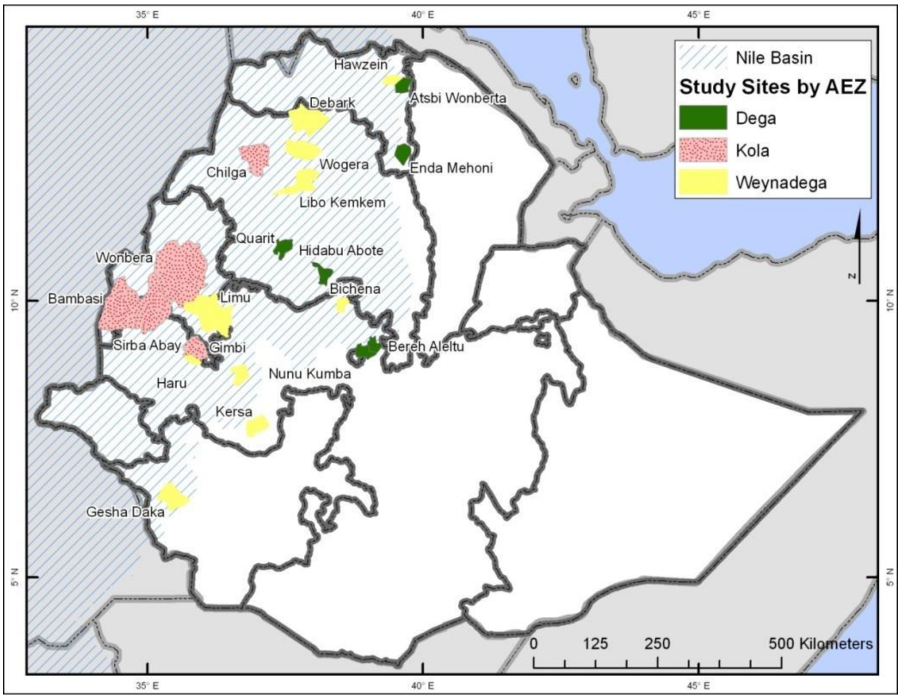
Nationalities and Peoples Region (SNNPR) and the state of *Gambella* in the south (GOE, 2012).

The climatic types prevailing in the region is grouped into 3 major categories: the dry climate, tropical rainy climate and temperate rainy climate. The dry climates is characterized by poor sparse vegetation with annual mean temperature of 27°C to 39°C, and mean annual rainfall of less than 450 mm. The hot semi-arid climate mean annual temperature varies between 18°C and 27°C. It has a mean annual rainfall of 410 – 820 mm with noticeable variability from year to year. The region's highlands experience temperate climate of moderate temperature with mean temperature of the coolest month being less than 180°C and ample precipitation 1200 – 2000 mm. This study takes 4 *weredas* (*Gimbi, Haru, Bereh Aletlu, and Hidabu Abote*) from West *Wellega*, 2 *weredas* (*Limu*, *Nunu Kumba*) from East *Wellega* and 1 wereda (*Kersa)* from *Jimma*.

SNNPR: The state of Southern Nations, Nationalities and Peoples' comprises 10% of the total area of the country administratively divided into 9 zones, 72 *weredas* and 5 special *weredas* with a total of 77 *weredas* and 149 towns in the state. It lies in the southern part of the country bordering with Kenya in the south, the Republic of the Sudan in the south west, the state of *Gambella* in the northwest and the state of *Oromia* in the north and east. It has an estimated area of about 105,887.18 square kilometers. About 56% of the total area of the state is found below 1500 meters elevation, which is categorized largely as hottest lowland *"Kolla"* while the rest 44% is found in the temperate climatic zone. The mean annual rainfall of the state ranges from 500 – 2200 mm. Its intensity, duration and amount increases from south to northeast and northwest. The mean annual temperature of the region in general ranges from 15°C to 30°C. This study takes 1 *wereda* (*Gesha*/*Daka*) from *Keta* as sample.

Beninshangul- Gumuz: This study takes 1 *wereda (Wonbera)* from *Metekel*, 1 *wereda* (*Bambasi)* from *Asosa* and 1 *wereda* (*Sirba Abay*) from *Kamashi*.

Figure 3.1 Survey districts along with their agro-ecological settings in the Nile Basin of Ethiopia



3.2 Data description

The data for the study comes from the survey conducted in 2015, 2016 and 2017 on farm households. The Environment and Climate Research Center (ECRC) at the Ethiopian Development Research Institute (EDRI) collects a survey of agricultural production and technology adoption every year. The sampling frame selected the *weredas* or districts in such a way that each class in the sample matched to the proportions for each class in the entire Nile Basin. The procedure resulted in the inclusion of 20 *weredas.* Then 1 peasant associations (administrative units smaller than districts) were also purposely selected from each *wereda* to include households that irrigate their farms. Once the peasant associations were chosen, farm households were selected. The number of farm households selected from each peasant association differ among themselves. Thus, the lowest number of farm household selected was 37 while the highest number of farm household selected was 50. Differences of the selected farm households was not only among the peasant associations but also across the study periods. That is, the number of households randomly selected from one peasant association in 2015 was higher than the number of households randomly selected from the same peasant association in 2016. The same applies in 2017 i.e. 922 households participated in 2015 but in 2017 the number decreased to 904 households being interviewed. After merging the three data sets, 902 households were found to be followed across the periods. Therefore, the study will be based on these households (902).

The data contains household and plot-level information. The data includes 1) household roster: gender, age, marital status, literacy and highest level of formal education. Employment and other income, household and farm asset table, social protection and emergency relief 2) land characteristics including type of land tenure, land size, land management practices/climate-smart agriculture, production activities for seasonal crops, inputs for production, crop yields and rainfall assessment 3) expenditure on input: fertilizer, modern seeds, agro-chemical, average wage for male labor, average wage for female labor 4) livestock production the last one year: number of cow, oxen, calf, sheep, goats, poultry, beehives, donkey, horse, mule and other 5) water storage facilities used for crop and livestock production 6) markets: walking distance from the input markets, walking distance from the output market, means of transport 7) credit: source of credit in the last 12 months, reason for not obtaining a loan last year, access to credit, purpose of the credit 8) extension: extension visits, type of extension activities participated, frequency of the extension visit, organization from which the extension agent came, confidence on the skills of extension workers 9) social capital and network: number of relatives and non-relatives that the household rely on for critical support within his/her village and outside his/her village, membership and participation in groups 10) climate change: noticeable changes in climate, type of changes noticed 11) adaptation: multiple decisions done to protect oneself, family and community from the noticeable climate change 12) expenditure on food and non-food items in the last 12 months.

3.3 Definitions of the variables used in the analysis

The farm households in this study have undertaken a portfolio of adaptation measures. Among these adaptation strategies, this study chose changing crop varieties, soil & conservation and decrease the number of livestock. They were chosen because they are mainly yield related. For example, soil & water conservation practice can improve household food security and reduce vulnerability by increasing soil water availability, decreasing soil erosion and ensuring that nutrients and inputs are maintained (Delgado et al., 2011). These adaptation measures were implemented both in isolation and jointly. Soil & water conservation and changing crop varieties are strategies to adjust crop production while decrease the number of livestock strategy is an adjustment towards the livestock stock. In addition, a farm household also adopts other strategies such as change crop type, increase fertilizer applications and other non-yield related strategies such as migrating to another piece of land, seeking off farm employment and setting up food storage facilities.

The choice of the explanatory variables is based on data availability and literature. Therefore, a range of household, farm and plot characteristics, institutional factors, agro-ecological setting and climate attributes variations are hypothesized to influence farmers' adaptation choice to climate change. Thus, different variables were included:

Gender can be used to capture whether the household is male headed or female headed. Studies (Asfaw and Admassie, 2004) show that male-headed households are more likely to get information about new technologies and undertake risky businesses than female-headed households. Thus, this study hypothesizes that household headed by male increases the probability of adapting to climate change.

Age refers to the age of the head of the household, which is assumed to represent a farmer's experience in farming. The effect is believed to stem from accumulated knowledge and experience with his/her farming system obtained over the years and may favor reacting to climate change. Accordingly, it is hypothesized that older and more experienced farmers have a higher likelihood of perceiving and adapting to climate change.

Marital status represents the marital status of the head of the household. It is hypothesized that being married would likely reduce the probability of adapting to climate change.

In addition to age, education can also be used to approximate experience. Education refers to the number of years of schooling of the head of the household. Education increases the ability of farmers to obtain and apply relevant information concerning the changing climate, which thereby increases farm level adaptation options. In this study, it is hypothesized to positively affect choice of climate change adaptation.

Number of relatives as a proxy variable for social network represents the number of people the farm household rely on for critical support in times of need both within this village and outside this village. This study expects the sign of this variable to be positive.

Family size refers to the number of family members living in a household. Review of the literature on climate change adaptation showed that household size has a mixed impact on farmers' adoption of agricultural technologies. While large family size is expected to enable farmers to take up labour intensive adaptation measures, other studies found that increasing household size did not significantly increase the probability of adaptation. For this study we presumed that farm households with a large family size are better able to adapt to changes in climate.

Erratic rainfall pattern is chosen representing the environmental shock that the household might experience in the past. This study hypothesizes that erratic rainfall pattern will affect households to adapt positively.

Slope of parcel, land tenure security and plot distance from home are chosen as a proxy for land characteristics. Plot distance from home is hypothesized to influence climate change adaptation negatively.

Land tenure security represent whether the parcel is certified or not to make the decision to adapt to climate change. This study hypothesizes that a certified parcel increases the probability to adaptation.

Land size refers to a household’s land holding. Farmland holding size is expected to play a significant role in influencing farm households’ choices in subsistence agriculture. In this study, we hypothesized that farmers with large farm size would be more likely to adapt.

Livestock plays a very important role by serving as a store of value and by providing traction (especially oxen) and manure required for soil fertility maintenance (Yirga, 2007). Thus, for this study livestock ownership are hypothesized to increase adaptation to climate change.

Access to credit eases the cash constraints and allows farmers to buy purchased inputs such as fertilizer, improved crop varieties, and irrigation facilities (Deressa et al., 2009). This study hypothesizes that there is a positive relationship between availability of credit and adaptation.

Soil characteristics were represented by fertility of the soil i.e. whether the soil has a high or moderate level of fertility and erosion incidence of the soil either no occurrence of erosion or severe erosion.

Plot-variant variables which are inputs for productivity of the farm were also chosen as an explanatory variable. Thus, use of fertilizer and seed are included.

Extension visit refers to a household’s access to agricultural services. Extension visit are a crucial source of information on agronomic practices as well as on climate. Through extension agents, access to information on climate change is believed to create awareness and favorable conditions for adoption of farming practices suited to climate change (Maddison, 2006). In this study, it is assumed that the availability of better climatic and agricultural information helps farmers make comparative decisions about alternative adaptation options enabling them to cope better with changes in climate. Thus, availability and frequency of contact with extension service agent is expected to influence adaptation positively.

Information is an ingredient in the building of one’s perspective of the world. Thus, people rely their decision on the information they are fed. Climatic information coming from different sources such as extension agents or radio are vital in the decision of a household pursuing a climate change adaptation strategy. This study assumes that climate information affects adaptation positively.

Distance to input and output markets refers to the average time it takes a farmer to travel from to the market where he/she buys inputs and sells products (Gebrehiwot and Veen, 2013). This study assumes the relationship between adaptation and distance to input and output markets to be negative.

Membership in at least one local formal organization are captured in the four groups: agricultural membership, finance membership, livestock membership and watershed membership. It is hypothesized that membership in at least one of the four groups positively affects adaptation to climate change.

Climatic factors such as long-term average rainfall, long term average temperature and perception can be used to capture climatic conditions. It is hypothesized that long term average rainfall and long-term average temperature are expected to have positive effect.

Table 3.1 Variables' definition

Variable name	Definition
Dependent variables	
yield	harvested crop yields in kg
Strategies	
soil and water conservation only	dummy = 1 if the farm household adopted *only* soil conservation as adaptation strategy, 0 otherwise
changing crop varieties only	dummy = 1 if the farm household *only* changed crop varieties as adaptation strategy, 0 otherwise
decrease the number of livestock only	dummy = 1 if the farm household *only* decreased the number of livestock as adaptation strategy, 0 otherwise
changing crop variety and soil and water conservation	dummy =1 if the farm household changed crop varieties *and* adopted soil & water conservation as adaptation strategy, 0 otherwise
decrease the number of livestock and soil and water conservation	dummy =1 if the farm household decreased the number of livestock *and* adopted soil & water conservation as adaptation strategy, 0 otherwise
changing crop variety and decrease the number of livestock	dummy =1 if the farm household changed crop varieties *and* decreased the number of livestock as adaptation strategy, 0 otherwise
changing crop variety, decrease the number of livestock and soil and water conservation	dummy =1 if the farm household changed crop varieties, decreased the number of livestock *and* adopted soil & water conservation as adaptation strategy, 0 otherwise
Explanatory variables	
Farmer head and farm household characteristics	
age	age of the household head
Education	highest level of formal education attained by the household head
family size	family size
male headed household	dummy =1 if the household head is male, 0 otherwise
marital status	dummy =1 if the household head is married, 0 otherwise
number of relatives	number of relatives within and outside the village
erratic rainfall experience	dummy =1 if the farm household experienced an erratic rainfall pattern
Land characteristics	
slope of parcel	dummy = 1 if plot has flat slope, 0 otherwise
land tenure security	dummy =1 if plot is certified, 0 otherwise
plot distance from home	plot distance from home in minutes
Resource constraints	
Credit	dummy =1 if household had access to credit
land size	total land size in hectare (ha)
livestock size	number of livestock in Tropical Livestock Unit (TLU)
Soil characteristics	

high fertile	dummy =1 if the soil has a high level of fertility, 0 otherwise
moderate fertile	dummy =1 if the soil has a moderate level of fertility, 0 otherwise
no erosion	dummy=1 if the soil has no erosion, 0 otherwise
severe erosion	dummy=1 if the soil has severe erosion, 0 otherwise
Inputs	
Fertilizers	fertilizers used per hectare (kg)
Seeds	seeds used per hectare (kg)
Social capital & network	
agriculture producer's membership	dummy = 1 if the household is a member in agricultural producer's group, 0 otherwise
livestock producer's membership	dummy =1 if the household is a member in livestock producer's group, 0 otherwise
finance membership	dummy =1 if the household is a member in at least one finance related group, 0 otherwise
Information sources	
climate information	dummy =1 if extension officers are the main sources of information on expected rainfall and temperature, 0 otherwise
distance to the output market	walking distance to the output markets in minutes
distance to the input market	walking distance to the input markets in minutes
Climatic factors	
Rainfall	coefficient of variation for long term average rainfall for the past 30 years
Temperature	coefficient of variation for long term annual temperature for the past 30 years

3.1 Conceptual framework

Adaptation to climate change comes in a range of choices to farm households. In a time of dire situations, farmers diversify their adaptations strategies to buffer themselves and their household members against the risk. In a multiple adoption setting, farmers' simultaneous adoption of decreasing the number of livestock, changing crop variety and soil conservation leads to seven possible combination options that a farmer could choose. Farmers endogenously self-select themselves into adapters/non-adapters decisions, so decisions are likely to be influenced by unobservable characteristics that may be correlated with the outcome of interest. This requires a selection correction estimation method. Thus, a multivariate probit model is applied to correct. The MVP approach simultaneously models the influence of the set of explanatory variables on each of the different practices, while allowing for the potential correlation between unobserved disturbances, as well as the relationship between the adoptions of different practices (Belderbos et al., 2004).In the first stage, farmers' choice of combinations/packages of adaptation strategies is modeled using a multivariate probit model while recognizing the inter-relationships among the choices. In the second stage of the estimation, the impacts of each combination of the strategies on the outcome variables are evaluated using fixed effects.

Table 3.2 Alternative choices of climate change adaptation strategies

No.	Choice
1	Changing crop variety only (Cv)
2	Soil and water conservation only (Sw)
3	Decrease the number of livestock only (Livdecr)
4	Changing crop variety *and* Soil and water conservation (Cv & Sw)
5	Changing crop variety *and* Decrease the number of livestock (Cv & Livdecr)
6	Soil and water conservation *and* Decrease the number of livestock (Sw &Livdecr)
7	Changing crop variety, Soil and water conservation *and* Decrease the number of livestock (Cv, Sw and Livdecr)
8	Other strategies (Os)

3.2 Analytical framework

The approaches to assess the adaptation of agriculture to climate change are divided into two models: the partial and economy-wide (general equilibrium) models. Economy wide models are analytical models, which look at the economy as a complete system of independent components while partial equilibrium models are based on the analysis of part of the overall economy. In agriculture, partial equilibrium models analyze adaptation at farm or household levels whereas general equilibrium models are employed to analyze the impact and adaptation at national or global levels (Deressa 2010)

Among the partial equilibrium models, the use of discrete or binary choice models in climate change adaptation research is a relatively new approach which is gaining momentum. Based on the conceptual framework similar to agricultural technology adoption, climate change adaptation and other related models involving decisions to whether adopt or not to adopt, the model underlies latent variable model and it describes the functional relation between the probability of adoption and various explanatory variables. In its simplest definition, agricultural technology adoption assumes that the adoption decision of a given technology is made if the net utility derived from new technology is greater than the traditional or the old method.

Decisions involving discrete choices are logit, probit, and tobit models. Binary Probit or logit models are employed when the number of choices available are two (whether to adopt or not). When the number of choices available are more than two, the extensions of these models called multivariate models are used. The multivariate model enables to simultaneously examine the relationships between each adaptation option and a common set of explanatory variables. The advantage of using multivariate model over univariate is that it explicitly recognizes and controls for potential correlation among adaptation options and therefore provides more accurate estimates of relationships between each adaptation option and its explanatory variables.

The multivariate probit model is used to analyze the determinants of farmers' choice of adaptation strategies in the Nile Basin of Ethiopia. The multivariate probit model is a generalization of the probit model used to estimate several correlated binary outcomes jointly. It is an appropriate tool for jointly predicting these two choices on an individual-specific basis.

3.3 Multivariate Probit Model (MVP)

Farmers adopt a mix of technologies to deal with a multitude of agricultural production constraints, so the adoption decision is inherently multivariate. Attempting univariate modelling would exclude useful economic information about interdependent and simultaneous adoption decisions (Dorfman, 1996).

Multivariate probit model is defined as follows:

Consider the *i*th farm household (*i*= 1….,N) that is facing a decision on whether or not to adopt an available practice on plot (*p*= 1……,P). Let U0 represents the benefits to the farmer from non-adoption, and let Uk represents the benefit of adopting the kth practice, where k denotes the choice of crop variety(Cv), livestock decrement(Livdecr), soil and water conservation(Sw), Changing crop variety *and* Soil and water conservation(Cv & Sw), Changing crop variety *and* Decrease the number of livestock (Cv & Livdecr), Soil and water conservation *and* Decrease the number of livestock(Sw & Livdecr), Changing crop variety, Soil and water conservation *and* Decrease the number of livestock(Cv, Sw & Livdecr) and other strategies (Os). The farmer decides to adopt the kth practice on plot 'p' if $Y_{ipk}^{*} = U_k^{*} - U_0 > 0$. The net benefit ($Y_{ipk}^{*}$) from adoption of the kth practice is a latent variable determined by observed household, plot and location characteristics (X_{ip}) and the error term (ε_{ip}):

$$Y_{ipk}^{*} = X_{ip}'\beta_k + \varepsilon_{ip}$$

k = Cv, Livdecr, Sw, Cv & Sw, Cv & Livdecr, Sw & Livdecr, Cv, Sw & Livdecr, Os

$$Y_{ipk} = \begin{cases} 1 & if\ Y_{ipk}^{*} > 0 \\ 0 & otherwise \end{cases}$$

In the multivariate model, where the adaptation of several practices is possible, the error terms jointly follow a multivariate normal distribution (MVN), with zero mean and variance normalized to unity.

The symmetric covariance matrix Π is given by

$$\Pi = \begin{vmatrix} 1 & \rho_{12} & \rho_{13} & .... & \rho_{1m} \\ \rho_{21} & 1 & \rho_{23} & ... & \rho_{2m} \\ \rho_{31} & \rho_{32} & 1 & ... & \rho_{3m} \\ . & . & . & 1 & . \\ \rho_{m1} & \rho_{m2} & \rho_{m3} & . & 1 \end{vmatrix}$$

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Descriptive statistics

The current study uses the data collected from the Environment and Climate Research Center (ECRC) at the Ethiopian Development Research Institute (EDRI) covering agricultural production and other technology adoption. The data were collected from 2 zones of the *Tigray* region, 4 zones of the *Amhara* region, 4 zones of the *Oromia* region, 3 zones of the *Beninshangul-Gumuz* and 1 zone of the Southern Nations and Nationalities Peoples Region (SNNPR). This study is based on a balanced panel data for 2,706 households (902 for each of the three study periods: 2015, 2016 and 2017). According to Table 4.1., most of the sampled households i.e. 5.54% and 5.43% of them reside in *Endamehoni* and *Atsbi Wonberta* respectively and both of them come from the *Tigray* region.

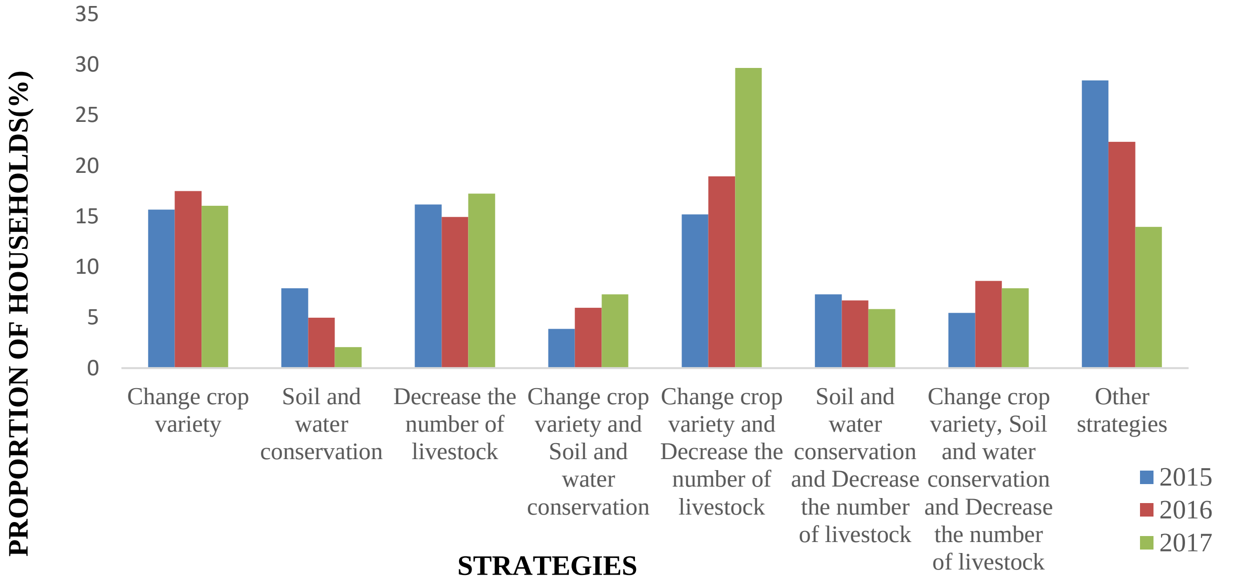
Table 4.1 Sample household distribution by *wereda*

Wereda	Freq.	Percent
Hawzein	46	5.1
Atsbi Wonberta	49	5.43
Endamehoni	50	5.54
Debark	48	5.32
Chilga	48	5.32
Wogera	48	5.32
Libo Kemkem	48	5.32
Bichena	45	4.99
Quarit	46	5.1
Gimbi	40	4.43
Haru	46	5.1
Limu	46	5.1
Nunu Kumba	45	4.99
Bereh Aleltu	40	4.43
Hidabu Abote	37	4.1
Wonbera	40	4.43
Bambasi	48	5.32
Sirba Abay	40	4.43
Kersa	48	5.32
Gesha Daka	44	4.88
Total	902	100

4.1.1 Proportion of climate change adaptations

The climate change adaptations with their percentage frequency are depicted in the table below. Screening the table, it can be concluded that the percentage of households that adapted by changing crop variety only, by decreasing the number of their livestock and adopting the three climate change strategies in combination (change crop variety, decrease the number of livestock and soil and water conservation) was fluctuating over the three periods. For example, out of the sampled households in 2015, 15.67% of them adapted by changing their crop variety this figure increased to 17.5% in 2016 but slowed down to 16.04% by the following year, 2017. On the other hand, the number of households that adapted the remaining strategies increased as time went from 2015 to 2016 and to 2017. For instance, the number of sampled households that adapted by combining changing crop variety and soil and water conservation was 3.89% in 2015, 5.95% in 2016 and 7.29% in 2017.This begs the question to examine the underlying factors that can serve in explaining these farmer households' behaviors. Finally, out of the 902-sample household surveyed over the three given study periods, 823 households were found to adjust to climate change by taking the measure of adaptation while the remaining 79 households have chosen "Did nothing" to adjust themselves and their households to the changing climate change.

Figure 4.1 Proportion of choice of climate change adaptation strategies in the sample (%)



4.1.2 Descriptive Statistics of Explanatory variables

The descriptive statistics of explanatory variables used in the analysis are presented in Table 4.3. The explanatory variables' mean value of non-adopters (No adaptation) is used as a reference category to compare with mean values of adopters (Crop variety, Livestock decrement, Soil and water conservation, Crop variety and Livestock decrement, Crop variety and Soil and water conservation, Livestock decrement and Soil and water conservation, Full strategies and Other strategies). The result shows that the mean values of explanatory variables are significantly different across alternatives.

Household characteristics such as age, education, family size, marital status, gender of the household head, number of relatives and household's rainfall experience are the explanatory variables which affect the choice of climate change adaptation strategies. i.e. 58 percent of CV and 52 percent of LIVDECR adopters were male headed households, while 44% percent of non-adopters were male headed. Additionally, non-adopters are less educated (1 year of education) than adopters (CV is 1.98 and LIVDECR is 1.95). Further, on average adopters were the oldest (55.49 years old). Furthermore, non-adopters have the smallest family size (7 members) than adopters (CV is 7.68).

Land size, households' access to credit and number of livestock are proxy variables, which are used to indicate the resource constraint of the households. Both i.e. non-adopters and adopters own the same amount of land size (2.13 ha). Soil & water conservation and Crop variety adopters have the highest number of livestock (1.47 TLU) followed by Crop variety (1.43 TLU), LIVDECR & CV (1.39 TLU) and Soil & water conservation adopters (1.36 TLU). Surprisingly, non-adopters have more access to credit (54%) than adopters (37%).

Access to information and input are other factors which affect the adoption decision. As depicted in table 5, the average distance of non-adopters from the nearest input market is significantly higher than Soil & water conservation adopters. Moreover, they have lower extension visit on expected rainfall and temperature. The proportion of non-adopter (14%) who are member of social network such as agriculture related groups is significantly lower than adopters (20 percent of LIVDECR & CV and 29 percent of SW & CV).

Soil fertility and erosion are other factors which affect the adoption decision. These variables have significance difference among adopters and non-adopters. The proportion of full strategy adopters' fertile land was found to be higher (37%) than that of non-adopters and mixed adopters. Whereas, the proportion of land which was mildly damaged by erosion is significantly higher (38%) for adopters than non-adopters.

Table 4.2 Descriptive statistics of explanatory variables used in the analysis

Variables	No adaptation	CV	LIVDECR	SW	SW & CV	Full strategies
Rainfall	1.11	1.10	1.09	1.13	1.14	1.18
Temperature	0.08	0.08	0.08	0.08	0.08	0.08
Age	52.33	51.81	52.36	52.31	55.49	53.82
Education level	1.85	1.98	1.95	1.86	1.77	2.00
Family size	7.00	7.68	7.39	7.54	7.65	7.51
Male headed household	0.52	0.58	0.52	0.44	0.60	0.59
Married	0.42	0.44	0.43	0.33	0.50	0.45
Single	0.23	0.28	0.25	0.35	0.27	0.26
Number of relatives	2.26	2.26	2.13	2.30	2.24	2.37
Erratic rainfall pattern	0.21	0.29	0.35	0.29	0.25	0.34
Drought	0.08	0.11	0.16	0.14	0.16	0.29
Flood	0.04	0.07	0.07	0.07	0.05	0.14
Animal attack	0.16	0.07	0.06	0.05	0.06	0.06
Land slide	0.00	0.00	0.01	0.00	0.00	0.00
Hailstorms	0.17	0.19	0.11	0.15	0.22	0.17
Wind	0.04	0.03	0.02	0.01	0.09	0.02
Pests	0.06	0.04	0.05	0.05	0.06	0.06
Flat	0.61	0.59	0.56	0.63	0.55	0.58
Slight	0.32	0.32	0.33	0.27	0.34	0.30
Certified	0.64	0.82	0.85	0.82	0.87	0.86
Plot distance from home	3.42	3.16	3.10	3.19	3.17	3.22
Credit	0.54	0.45	0.45	0.47	0.41	0.49
Land size	2.13	1.88	1.75	1.98	1.90	1.66
Tropical Livestock Unit (TLU)	1.31	1.43	1.26	1.36	1.47	1.39
High fertility of soil	0.29	0.36	0.29	0.29	0.37	0.37
Moderate fertility of soil	0.55	0.47	0.53	0.57	0.45	0.49
No erosion	0.52	0.58	0.48	0.58	0.50	0.46
Mild erosion	0.36	0.31	0.38	0.35	0.36	0.38
Agriculture membership	0.14	0.24	0.10	0.12	0.29	0.15
Watershed membership	0.09	0.16	0.18	0.27	0.17	0.18
Forestry membership	0.03	0.10	0.05	0.13	0.08	0.07
Iddir membership	0.57	0.78	0.83	0.72	0.70	0.88
Local government membership	0.35	0.52	0.40	0.38	0.52	0.50
Religious membership	0.56	0.68	0.69	0.59	0.77	0.81
Multipurpose membership	0.24	0.30	0.35	0.29	0.43	0.53
Extension	0.34	0.59	0.39	0.63	0.67	0.68
Radio	0.22	0.39	0.29	0.41	0.44	0.49
Mobile phone	0.00	0.01	0.01	0.00	0.00	0.00
Neighbors	0.25	0.30	0.45	0.51	0.38	0.49

NGO	0.00	0.00	0.00	0.00	0.00	0.01
Distance from output market	3.68	3.87	3.93	3.79	3.85	4.02
Distance from input market	3.44	3.67	3.61	3.28	3.69	3.72
Number of observations	237	405	398	123	141	181

4.2 Econometrics Result

The econometrics result has two parts where in the first part the result of the multivariate probit model is discussed while the second part is the result of the impact. To verify the validity of the model, various types of tests were undertaken. The MVP specification was found to be appropriate to model determinants of climate change adaption practices of households from the result of the Chi-square test which rejected the null hypothesis (i.e. all regression coefficients are jointly equal to zero) with chi2(10) = 285.062; $P > 0.00$.

4.2.1 Factors determining the choice of climate change adaptation strategies

The objective of this study was to estimate the factors behind choice of climate change adaptation strategies of households located in the Nile Basin of Ethiopia particularly on soil & water conservation, Livestock decrement and changing crop variety. To employ this, multivariate probit model was applied and the results are depicted in Table 4.3.

The estimation of the model normalized one category called the reference or base category to make a comparison with the results of other climate change adaptation strategies. The normalized category was No adaptation. The regression result only considered 5 adaptation strategies (Crop variety, Livestock decrement, Soil & water conservation, Soil & water and Crop variety and Full strategies)

The study tried to include all theoretically important factors in the fitted model. However, out of these variables, only those which were found statistically significant at 5%, 1% and 10% alpha levels or less and had a strong relation with the alternative climate change adaptation strategies are discussed.

Age is used as a representative of the farming experience of the head of the household and it had a significant positive effect on the adoption of Soil & water conservation and Crop variety adaptation strategies in the study area. This indicates that the older head of the household head, the more likely the chance for adaptation. It is attributable to the experiences, cumulative knowledge and skills. This result is similar with Mulwa et al (2017), Nhemachena (2014), Ahmed (2016).

Being single was found to be positively affecting the decision of climate change adaptation strategies particularly Soil & water conservation strategy in contrast with divorced. This may be attributed for the reason that there may be an ease of responsibility when a household has a single head and will devote his/her time to follow the changing of the climate and recommend a resolution through adaptation strategies. This result was in similar with Mandleni and Anim (2011) and (Addisu et al 2016).

Environmental shocks were represented by erratic rainfall, drought, flood, animal attack, hailstorms and wind. These variables were positively and significantly influencing the choice of all climate change adaptation strategies (Crop variety, Livestock decrement, Soil and water conservation, Soil & water conservation and Crop variety and Full strategies) contrary to no shock. Similar finding was also confirmed by Feleke et al (2016) and Tasie et al (2018).

Distance to input market positively and significantly influenced the choice of full adoption Crop variety, Soil & water conservation and Soil & water conservation and Crop variety. The implication of this result is that farmers travelling further to output markets may access larger markets where they are likely to be introduced with diverse outputs or technologies. Similar finding is found in Tessema et al., (2013).

Slope of land is characterized with flat and slight slope compared with the category of steep slope. These two variables had a negative impact on Soil & water conservation and Full strategies. Similar finding was found by Aryal (2018) and Kanyenji (2020).

Tropical Livestock Unit (TLU) as a proxy variable for the number of livestock was positively affecting the choices of Crop variety, Livestock decrement and Soil & water conservation and Crop variety adaptation strategies. This is because ownership of livestock increases the chances of adjusting planting time and planting drought-tolerant crops. Kabubo-Mariara (2008) and Jairo MN et al (2019) found similar result.

Being a member of agriculture, watershed, forest, iddir, local government, religious and multipurpose membership has a positive effect on all choices of climate change adaptation strategies compared with farmers who are non-members. Farmers belonging to cooperative organizations have higher likelihood of using adaptation practices due to their capacity to share information, discuss problems, share ideas and take collaborative decisions. This result is consistent with findings reported in Southern Africa by Nhechema and Hassan, (2007) Ndamani & Watanabe, (2015) in Ghana and T. Wossen et al (2015)

Long term average rainfall had a positive and significant relation with $Sw_0Cv_1Ld_1$. Areas with high annual mean temperature were more likely to adapt to climate change through climate change adaptation strategies. To cope with increased temperatures, farmers tend to use drought-tolerant crop varieties as well as reduce their livestock through selling them. Similarly. Deressa and others (2009) and Kurukulasuriya and Mendelsohn (2008) reported that farmers living in regions with relatively high temperatures had an increased likelihood of adapting.

The beta coefficient for extension visit, radio, neighbors was positive and significant with all choices of climate change adaptation. The implication here is that, farmers who got information on expected rainfall and temperature from extension officers, radio or neighbors were more likely to use and adopt multiple climate change adaptation strategies. Maddison, (2006) found that access to information on climate change through extension agents is believed to create awareness and favorable conditions for adoption of farming practices suited to climate change. Yirga (2007) report a strong positive relationship between access to information and the adoption behavior of farmers.

Fertility of soil was also another driver in the choice of climate change adaptation strategies. By taking infertile soil as a reference, high soil fertility had a positive and significant effect of climate change adaptation. This happens due to the risk aversion behavior of farmers; if their land's soil is fertile then they will have better confidence to be more productive and profitable; hence would be adopters of various adaptation strategies than becoming non-adopters. But if the soil type is infertile, they may lose confidence of being profitable thus they could become less interested in adaptation. Additionally, the perception of having highly fertile soil increases the probability that farmers will change their amount of land under cultivation. These findings are consistent with Di Falco, Veronesi and Yusfu (2011), Koundouri, Nauges and Tzouvelekas (2006) and Gbetibouo (2009)

The last explanatory variable that determines climate change adaptation strategies was farmland security. Having land certificate had a positive and significant (at 5 percent level of significance) impact on the adoption of Livestock decrement. This is probable because when farmers have land, they won't incur additional cost to pay for the rent thus to minimize other input costs by selling their livestock. This result contradicts with the study by Hailu et al (2014) and Asfaw et al (2013).

The interrelationships among the adaptation strategies is indicated by the results of variance-covariance coefficients (rho21- rho54). The coefficients were found to be negative and significant in all cases implying that there is a substitutability between the adaptation strategies. This may be attributed for the reason that as a farm household adopts one adaptation strategy it requires resources such as time, strategy and financial tools for its implementation.

Table 4.3 Determinants of the choice of climate change adaptation strategies - A Multivariate Probit model

	Crop variety only		**Livestock decrement only**		**Soil and water conservation only**		**Soil and water conservation and Crop variety**		**Full**	
VARIABLES	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.
Rainfall	0.031	0.179	-0.413**	0.19	0.207	0.285	0.39	0.258	0.773***	0.256
Temperature	3.528	2.866	-2.656	3.172	3.058	4.34	3.265	4.007	3.816	3.49
Age	-0.003	0.003	-0.002	0.003	-0.002	0.004	0.009***	0.004	0.003	0.003
Education level	0.004	0.011	0.004	0.011	-0.013	0.017	0.009	0.016	0.018	0.014
Family size	0.01	0.013	0.012	0.013	-0.006	0.019	-0.001	0.018	-0.014	0.017
Male headed household	0.062	0.072	-0.02	0.072	-0.164	0.102	0.002	0.101	0.133	0.09
Married	0.001	0.085	0.033	0.084	0.014	0.123	0.078	0.121	-0.094	0.106
Single	0.023	0.087	-0.015	0.088	0.201*	0.12	0.066	0.124	-0.129	0.111
Number of relatives	0.011	0.029	0.006	0.03	0.026	0.041	-0.035	0.039	0.049	0.034
Erratic rainfall pattern	0.07	0.072	0.185***	0.071	-0.025	0.105	-0.061	0.103	0.017	0.086
Drought	-0.198**	0.099	0.134	0.095	-0.054	0.141	0.044	0.128	0.352***	0.101
Flood	0.029	0.127	-0.041	0.128	0.077	0.184	-0.187	0.195	0.302**	0.135
Animal attack	-0.062	0.119	-0.203	0.125	-0.369*	0.193	-0.155	0.178	-0.093	0.161
Landslide	-0.305	0.575	0.012	0.466	-3.53	261.354	-3.667	230.66	-3.783	187.622
Hailstorms	0.241***	0.084	-0.214**	0.096	0.014	0.128	0.123	0.116	-0.044	0.111
Wind	-0.052	0.193	-0.243	0.234	-0.438	0.44	0.709***	0.205	-0.123	0.319
Pests	-0.109	0.151	-0.033	0.147	0.113	0.211	0.088	0.19	0.181	0.18
Flat	-0.116	0.148	-0.093	0.142	-0.394*	0.212	-0.21	0.192	-0.324**	0.162
Slight	-0.043	0.144	-0.128	0.138	-0.461**	0.207	-0.119	0.184	-0.243	0.157
Certified	-0.108	0.089	0.191**	0.095	-0.026	0.129	0.091	0.135	-0.131	0.117
Plot distance from home	-0.032	0.037	-0.037	0.037	-0.055	0.054	-0.026	0.051	-0.028	0.047
Credit	0.014	0.062	0.026	0.064	0.029	0.092	-0.101	0.087	0.087	0.078

Land size	-0.007	0.024	-0.018	0.026	0.049	0.033	-0.013	0.034	0.005	0.034
Tropical Livestock Unit (TLU)	0.092*	0.054	-0.156***	0.053	0.059	0.079	0.176**	0.075	0.009	0.066
High fertility of soil	0.009	0.104	-0.083	0.105	-0.098	0.162	0.144	0.146	0.327**	0.129
Moderate fertility of soil	-0.085	0.098	-0.071	0.096	0.063	0.148	0.076	0.136	0.2	0.124
No erosion	0.268**	0.132	-0.05	0.127	0.564**	0.228	-0.089	0.17	-0.013	0.146
Mild erosion	0.115	0.129	-0.004	0.121	0.505**	0.22	-0.048	0.162	0.076	0.14
Agriculture membership	0.213***	0.082	-0.326***	0.098	-0.129	0.14	0.331***	0.109	0.001	0.111
Watershed membership	-0.122	0.087	0.108	0.086	0.256**	0.113	-0.053	0.118	-0.054	0.105
Forest membership	0.015	0.114	-0.12	0.133	0.258*	0.152	-0.17	0.171	-0.087	0.157
Iddir membership	0.057	0.077	0.219***	0.083	-0.093	0.108	- 0.294***	0.101	0.314***	0.109
Local govt membership	0.094	0.067	-0.218***	0.067	-0.175*	0.1	-0.002	0.093	-0.007	0.084
Religious membership	-0.084	0.072	0.009	0.073	-0.223**	0.102	0.125	0.106	0.093	0.099
Multipurpose membership	-0.099	0.068	0.034	0.068	-0.145	0.101	0.206**	0.091	0.305***	0.081
Extension	0.243***	0.067	-0.375***	0.069	0.209**	0.099	0.254***	0.095	0.224***	0.086
Radio	0.014	0.069	-0.205***	0.071	0.096	0.098	0.142	0.094	0.215***	0.082
Mobile phone	0.028	0.407	0.405	0.439	-3.878	174.036	-3.863	174.179	-3.409	180.811
Neighbors	-0.259***	0.067	0.250***	0.067	0.225**	0.092	-0.067	0.092	0.083	0.081
NGO	-4.076	224.274	0.547	0.661	-3.598	397.604	-4.076	280.186	0.324	0.704
Distance from output market	-0.093	0.058	0.077	0.056	0.091	0.074	-0.12	0.079	0.075	0.075
Distance from input market	0.101**	0.051	-0.023	0.047	-0.227***	0.058	0.119*	0.07	0.072	0.062
Constant	-1.435***	0.355	-0.18	0.378	-1.634***	0.525	- 2.996***	0.52	- 4.030***	0.508
Observations	2,706		2,706		2,706		2,706		2,706	
Model chi-square	492.7		492.7							
Pseudo R2	2706		2706							

rho21	-0.378***	0.051	-7.390	0.000	-0.474	-0.274
rho31	-0.216***	0.071	-3.020	0.003	-0.351	-0.072
rho41	-0.332***	0.065	-5.090	0.000	-0.453	-0.199
rho51	-0.247***	0.061	-4.070	0.000	-0.362	-0.125
rho32	-0.277***	0.073	-3.770	0.000	-0.414	-0.128
rho42	-0.169**	0.068	-2.480	0.013	-0.299	-0.033
rho52	-0.264***	0.064	-4.130	0.000	-0.384	-0.135
rho43	-0.051*	0.083	-0.610	0.540	-0.212	0.112
rho53	-0.025*	0.075	-0.330	0.738	-0.171	0.122
rho54	-0.219***	0.080	-2.730	0.006	-0.370	-0.057

4.3 The impact of climate change adaptations on yield

One of the objectives of this study was to evaluate the economic implication of the choice of various climate change adaptation strategies. Thus, fixed effects estimation is used for the analysis. Table 4.4 presents harvested crop yields in kg of the farm households adopted a particular strategy to adapt to climate change and those that did not adapt. Thus, it was found that Soil & water conservation, Livestock decrement and Full strategies do not seem to significantly impact yield. Contrarily, adaptation to climate change based on the Crop variety and Soil & water conservation and Crop variety significantly increases farm households' yield.

From the result, it can be seen that adopting Soil and water conservation & Crop variety in combination is highly significant (at the 1% statistical level) than when a farm household implements the remaining strategies. Among the strategies, adoption of Livestock decrement delivers the lowest yield i.e 1,581.015 kg. The impact of Full strategies was the second highest productive strategy. Total amount of yield harvested was 206,956.269 kg. Interestingly, when Crop variety is implemented in isolation, it delivers a whopping yield of 512,655.78 kg.

Table 4.4 The impact of climate change adaptation on yield

Strategies	Impact (kg/Ha)
Full strategies	206,956.269*
	(2227.484)
Soil and water conservation & Crop variety	2,940.598***
	(806.620)
Livestock decrement	1,581.015*
	(887.816)
Crop variety	512,655.786**
	(237,227.667)
Soil and water conservation	149,214.129*
	(882.2321)

CHAPTER FIVE

5. CONCLUSIONS AND POLICY RECOMMENDATION

5.1 Conclusion

With majority of its population living below the poverty line, Ethiopia is one of the poorest countries in the world. Out of the many reasons for its poverty is the dependence of the economy on agriculture which in turn depends on rain. Despite some success stories, agriculture had failed to meet the growing food demands of the population and left the nation dependent on food aid. The poor performance of the agricultural sector is attributable to many reasons of which one is poor climatic conditions especially recurrent droughts. In response to the recurrent droughts, farmers have devised methods whereby adaptation to climate change is pursued. In relation to this, the current study focused on analyzing the choices of climate change adaptation strategies employed by the households located in the Nile Basin of Ethiopia.

The study examined the determinants of choices of climate change adaptation strategies and their impact on yield by using EDRI's data which is collected from 2 zones of the *Tigray* region, 3 zones of the *Amhara* region, 4 zones of the *Oromia* region, 3 zones of the *Beninshangul-Gumuz* and 1 zone of the Southern Nations and Nationalities Peoples Region (SNNPR).

The multivariate probit selection model result revealed that the choice of climate change adaptation strategy is influenced by observable household and plot characteristics and institutional features. More specifically, the choice of climate change adaptation strategy is positively related to land certificate, fertility of soil, TLU, distance to input market, environmental shocks such as erratic rainfall, drought, flood, animal attack, hailstorms, being single, wind, age, extension visit, radio, neighbors, agriculture, watershed, forest, iddir, local government, religious and multipurpose membership and average rainfall. However, choice of climate change adaptation strategies had negative relation with slope of land.

In order to investigate the impact of the climate change adaptation strategies a fixed effect estimation was run. The result of the fixed effects model showed that adoption of climate change adaptation strategies made adopters more productive than non-adopters, on average. Adoption of Crop variety, Livestock decrement, Soil and water conservation, Full strategies and combination of Crop variety & Soil and water conservation was found to be paying off. In particular, Crop variety resulted in the highest number of payoffs of yield.

5.2 Policy Implication

The findings of this study are particularly important to design policies for effective promotion of climate change adaptation strategies in the Nile Basin of Ethiopia. Hence, this study draws the following policy implications to enhance the choice of climate change adaptation by the households.

- Having information on climate and adaptation measures are necessary to better cope with climate change in Ethiopia. Thus, the government should increase access to information by increasing access to quality extension services to increase the information dissemination.
- Distance from the input market increases adaptation to climate change. Thus, the government should increase the access to infrastructure.
- Additionally, government policies and investment strategies should increase the number of lands that has to be certified for tenure security in the form of property rights.
- Here In addition, social networks that are both informal and formal should be encouraged to develop and increment of participation among the households should be promoted.

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