MEKELLE UNIVERSITY

COLLEGE OF BUSINESS AND ECONOMICS

DEPARTMENT OF ECONOMICS

SMALLHOLDER FARMERS' ADAPTATION STRATEGIES TO CLIMATE CHANGE IN ETHIOPIA (THE CASE OF ADWA WOREDA, TIGTRAI REGION)

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A Thesis Submitted in Partial Fulfillment of the Requirement for the Masters of Science Degree (MSc.) in Economics

(Specialization Development and Resource Economics)

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MEKELLE, ETHIOPIA

DECLARATION

This is to declare that this thesis work entitled "**Smallholder Farmers' Adaptation Strategies to Climate Change in Ethiopia: Evidence from Adwa Woreda of Tigrai Region**" submitted in partial fulfillment of the requirements for the award of the Degree of Master of Science in Economics (Development and Resource Economics) to the Collage of Business and Economics, Mekelle University, through the Department of Economics is an authentic work carried out by me. All resources of material used for this thesis have been duly acknowledged.

Kide Gebru Tesfay

Signature___________________

Date_______________________

CERTIFICATION

This is to certify that this thesis entitled "**Smallholder Farmers' Adaptation Strategies to Climate Change in Ethiopia: Evidence from Adwa Woreda of Tigray Region"** submitted in partial fulfillment of the requirements for the award of the Degree of Master of Science in Economics (Development and Resource Economics) to the Collage of Business and Economics, Mekelle University, through the Department of Economics , done by **Kide Gebru** (ID N**o** CBE/PR 031/05) is an authentic work carried out by under my guidance. To the best of our knowledge the matter embodied in this thesis work has not been submitted earlier for award of any degree or diploma.

Dr. Zenebe Gebreegziabher_ (Ass. professor) ____________ ______________

Principal advisor: Signature Date

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Co-advisor: Signature Date

ABSTRACT

The objective of this study was the factors that influence farmers' choice of adaptation measures and identifies adaptation methods to climate change in Ethiopia using Adwa Woreda as a case study. The data was collected from 160 sample households using a survey questionnaire and was analyzed using both descriptive statistics and econometric methods. Multinomial logit model (MNL) was used to identify factors influencing farmers' choice of adaptation strategies to climate change and variability.

The adaptation strategies considered in the MNL model analysis were crop variety, improve crop and livestock, soil and water conservation practices and irrigation. The result from the multinomial logit analysis showed that age, family size, farm income, farm size, distance to the farm, distance to the market, access to credit, livestock holding (TLU), farm to farm extension and access to climate information are significance factors influencing to farmers' adaptation strategies. The basic barriers to climate change adaptation on the farmers' side are luck of knowledge, lack of capital, lack of sufficient land and luck of information. Therefore, future policy should focus on awareness creation on climate change to adaptation through different ways such as mass media and extensions, encouraging informal social net-works, improving the availability of credit and enhancing research on use of new crop varieties are more suited in different agro ecological zones.

Key words: *climate change, adaptation, multinomial logit model, Adwa Woreda*

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Contents Page

List of figures Page

Lists of Tables page

Acronyms

BIC - Bayesian Information Criterion

CSA - Central Statics Agency

ETB - Ethiopian Birr

FAO - Food and Agricultural Organization

GDP - Gross Domestic Product

GTP - Growth and Transformation Plan

IIA - Independence of Irrelevant Alternative

IPCC - Intergovernmental Panel for Climate Change

MNL - Multinomial Logit Model

MNP - Multinomial Probit Model

MOA - Ministry of Agriculture

MoFED - Ministry of Finance and Economic Development

NAPA - National Adaptation Program of Action

NGO - Non-Governmental Organization

NMA - National Metrological Agency

NMSA - National Metrological Service Agency

PANE - Poverty Action Network of civil society organizations in Ethiopia

UNDP - United Nations Development Program

UNFCCC - United Nations Framework Convention on Climate Change

VIF -Variance Inflation Factor

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Agriculture is the dominant sector of the economy in most of least developing countries. Ethiopia is one of the developing counties in which agriculture is the main source of the economy. It contributed 41.6 percent to GDP, 60 percent for employment and 80 percent for export earnings. This sector is expected to have a base and primary determinant for GTP. In line with this environmental conservation it plays a great role in sustainable economic growth and development. The issue of climate change stands at the heart of this transformation agenda. Currently the issue of climate is one of the key agenda worldwide. Ethiopia is highly vulnerable to climate change and low capacity to adopt and perceived. Climate change is a natural phenomenon which influences agricultural production and negative effect on the social and economic activities and lead to food insecurity in particular (MoFED, 2010).

According to IPCC (2007) Africa is one of the regions that will be hard hit by the impact of climate change like increasing in temperature and reduction in rainfall. Agricultural production and food security in many African countries could be affected by climate change and variability. By 2020 some countries rain-fed agriculture could be reduced by up to 50 percent, with smallholders being the most affected. The impact of climate change could be reducing the economic growing in some parts of Africa and these effects are expected to get worse. This implies that reduction in agriculture production of the smallholder farmers and would be further adversely affected food security. To sustain current levels of food production and to meet future challenges smallholder farmers` may have to respond to the impact of climate change using an adaptation strategies. (ibid)

Climate change affects all aspect of economic growth especially in least developing countries. To reduce the impact of climate change and enhance food security, adaptation measures are urgently required. The process of adaptation options are needed to be location, integrated and flexible. This climate change affects to all agricultural sector in a multitude ways. For example, changing weather pattern such as heavy flood and storms makes the agricultural production low and leading to extreme events of poverty and slow down economic development. In general, there is a relationship between climate vulnerability, poverty and food insecurity (FAO, 2011).

Moreover, adaptation is critical and necessary in developing countries, especially in Ethiopia where the fact that vulnerability is high. Most people of livelihoods and living standard are affected by the impact of climate change. Farmers with better knowledge and information on climate change and agronomic practices enable to use adaptation methods to cope up with change in climate and other socioeconomic conditions (Nhemachena & Hassan 2007). A better understanding of the local dimensions of climatic change is also essential to develop appropriate adaptation measures that can mitigate the adverse impact of climate change. Therefore, awareness of the potential benefits from adaptation is an important issue.

According to Deressa et al. (2009) increasing temperature and rainfall variability in different part of Ethiopia were adversely affect the agricultural production of the rural household farmers. To minimize the impact of climate change on stallholder farmers', adaptation strategy is vital instrument. The main critical points such as social, economic, technology and environmental trends are able smallholder farmer's to perceive and adapt to climate change. In addition, knowledge by itself on the adaptation method and factor affecting farmer's choice of the adaptation strategies are enhancing efforts directly towards tackling to the impact of climate change.(ibid)

By understanding all of these facts, effort should focus on finding mechanisms in which smallholder farmer's can reduce these problems and improve effort to strength smallholder farmers' adaptation to climate change. Generally, it is believed that the adaptation strategy of smallholder on agriculture to climate change is imperative to enhance the resilience of agricultural sectors.

Therefore, this study intended to identify smallholder farmers' adaptation strategies to climate change and variability's by taking Adwa woreda as a case study.

1.2. Statement of the problem

Agriculture is the major driver of economic growth especially in developing countries. Ethiopia is one of the least developing countries in which majority of its population depend on agriculture sector. Rising the agricultural production at the national level leads to improve overall economic growth and development. However, currently climate change has become a serious threat to sustainable economic growth (Gebreegziabher *et al.*, 2012).

The impacts of climate change have been adversely affecting the economic growth. These impacts affect all economic sensitive sectors especially agriculture sector. Ethiopia is a poor country and its economy is highly depending on agriculture which had failed to meet the growing food demand. This is due to the fact that the negative effect of climate changes on agricultural production (World Bank, 2007). Moreover, According to Deressa (2007) Ethiopian agriculture sector is negatively affected by climatic related disasters with drought and flood being the major one.

Adaptation is an essential strategy to enable farmers to cope with the adverse effect of climate change and variability which in turn increase the agricultural production of the poor farm households (Yesuf et al., 2008). Similarly, knowledge of the adaptation methods on the side of smallholder farmers may make it better to tackle the challenge of climate change (Deressa et al., 2009).

Climate change is unexpected impact because it is a natural phenomenon that varies with location, socio economic and environmental conditions. The capacity to adapt to climate change is unequal across and within societies. This fact implies that the adaptation measures at micro level farm household are important to get truth and appropriate policies. According to Maddison (2007) there is a difference in the propensity of farmers living in different locations to adapt. Farmers in different area or agricultural zone have unequal propensity and capacity to climate change impact and adaptation. According to Admassie et al. (2008) in-depth study on vulnerability and adaptation should continue. To address this studying one specific site area is appropriate. Therefore, the researcher tried to address this gap of knowledge by studying a single woreda level case study of adaptation strategies to climate change.

Some researchers are done on climate related issues in Ethiopia but most of them are focused on the farmers of Nile Basin as a case study (Deressa et al., 2010; Rengler et al., 2009; Hassan et al., 2008 and Yesuf et al., 2008) .Their findings are interesting to make policy intervention at micro level especially for the farmers who are similar to the socio economic and climatic condition of Nile Basin. But a one size fits all recommendation is inappropriate given difference in agro ecologies. Since adaptation is a local effort, therefore the adaptation method differs within community and even within individuals. According to Fussel (2007) tailoring adaptation practices to specific societies or communities may make it possible to offset the adverse impact of climate change.

Therefore, a better understanding of the local dimensions of the climate change is important to develop appropriate adaptation measures and appropriate policies. Adwa woreda is district central Zone of Tigrai, which is vulnerable to climate change. In this study area the impact of climate change is adversely affecting the agriculture. The existence of warming and rainfall variety leads to reduce the agricultural production of the smallholder farmers. Therefore, the area is seriously affected by the climate change and weather variability. As to the knowledge of the researcher, no earlier study was conducted on the climate change adaptation strategies of smallholder farmers in this study area. Hence, considering this knowledge gap, the researcher would study on the local level of smallholder farmers' adaptation strategies to climate change in Adwa woreda.

1.2.1. Research Questions

The study was attempted to address the following questions:

1. What are the determinant factors that influence farmers' choice of adaptation methods to climate change in Adwa wereda?
2. What kinds of adaptation methods the smallholder farmers' response to climate change in Adwa wereda?
3. What are policies implications from the finding of the study?

1.3. Objective of the study

1.3.1. General objective of the study

The general objective of this study is to determine the factors that influence smallholder farmers' choice of adaptation method and identify adaptation strategies used by farmers' in response to climate change and variability in Ethiopia using Adwa Woreda a case study.

1.3.2. Specific objective of the study

1. To determine factors that influence farmers' choice of adaptation strategies to climate change in Adwa woreda.
2. To identify adaptation strategies used by farmers' in response to climate change and variability in Adwa woreda.
3. To propose some policy implication (recommendation) based on the findings of the study.

1.4. Significance of the study

Purposely this research would intend to study the smallholder farmers' adaptation strategies to climate change in Adwa woreda. This study was conducted at micro level so that it is very interesting to use as guideline document for further research in this study area and to the same climatic, socioeconomic and geographical areas. In addition, it may provide significant contribution to local and national government, NGOs and other bilateral donors in an effort to minimize the impact of climate change design of policy at local level.

1.5. Scope and limitation of the study

This study was carried out on smallholder farmers in Adwa woreda district central Zone of Tigrai region. It was conducted on smallholder farmers' adaptation strategies to climate change by taking a case study approach in order to make a detail analysis. The major limitation of this study was the inclusion of only four climate change adaptation strategies in the model and the sample size was also not large because of financial and time constraint.

1.6. Organization of the paper

This thesis has five chapters. Chapter one presents the introductory parts of the thesis. In chapter two literature reviews was presented which briefly discuss both the theoretical and empirical literatures. Chapter three is about data sources and methods of data collection, theoretical framework, econometric models and model variables. Chapter four provides data analysis using both descriptive statistic and econometric methods. Finally, in chapter five conclusions and policy implications are presented.

CHAPTER TWO

LITERATURE REVIEW

2.1. Theoretical Literature Review

2.1.1. Overview of Climate Change

Climate is a narrow sense usually defined as the average weather or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time from months to thousands or millions of years. Climate change refers any change in climate over time through natural variability or as a result of human activities (IPCC 2007).

(UNFCCC Article 1, 1992).Climate change refers a change of climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and which are in addition to natural climate variability observed over comparable time period.

Africa is highly stressed, low adaptive capacity and easy vulnerable to climate change. The main consequences of this negative impact of climate change or current climatic hazards are poverty, unequal access to resources, food insecurity, globalization trends, social and political conflicts and incidences of diseases such as malaria, tuberculosis and HIV/AIDS. This impact of climate change presents a substantial challenge to regional agricultural development. The sub Saharan Africa country are low adaptation mechanism and vulnerable to the widespread effect of climate change. With this bid serious problem, the coming 2100 year in most part of the continent GDP will predict to loss. For instance 2-7 percent in part of sub Saharan Africa, 2-4 percent in west and central Africa and 0.4-1.3 percent in north and southern Africa (FAO 2009).

According to IPCC 2007 increase in global average temperature above the range of 1.5-2.5^0 which is negatively influences species distribution and survival. In most of developing country where the majority of the population has the dependence on natural resources based livelihoods, this can an impact on socio economic and difficulty to the overall threats to sustainable development. This project report predicts that during 21th century green house gas emission will increase by 25-90 percent. This will be continuing for future period/year.

2.1.2. Climate change and the rural agricultural communities

The agricultural sector remains at the core of developing countries' economies. It plays a critical role in food security for all human being. In spite of their developmental significance, the rural communities are also characterized by poverty and marginalization, which aggravate and are aggravated by the effects of climatic variations, seasonal changes and uncertainty caused by climate change.

According to FAO (2011), farmers in some regions may benefit temporarily from the effects of CO2 emissions in the form of higher yields, the general consequences of climate change are expected to be adverse, particularly for the poor and marginalized who in turn, constitute the main inhabitants of rural agricultural communities. The main reason is that, the rural agricultural communities are dependent on the fragile agricultural activities for their means of livelihoods and they are located in areas of high environmental risk and climatic exposure and easily affected.

Moreover, the subsistence of these communities is largely resource-based. More intense and uncertain weather patterns and extreme events such as floods and droughts contribute to deforestation, desertification, land degradation, depletion of water sources, infrastructural and social damage, among others. This erodes not only local income but ultimately the ability of rural agricultural communities to respond to the challenges posed by a changing climate. This makes rural agricultural communities a priority in the design of innovative climate change responses.

In addition climate-smart agriculture, contributes to the achievement of sustainable development goals. It integrates the sustainable development of economic, social and environmental by jointly addressing food security and climate challenges. It is composed of three main pillars:

1. Sustainably increasing agricultural productivity and incomes;
2. Adapting and building resilience to climate change;
3. Reducing and/or removing greenhouse gases emissions, where possible.

Climate-smart agriculture is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change. The effects of climate change on agricultural systems create a compelling need to ensure comprehensive integration of these effects into national agricultural planning, investments and programs. The Climate-smart agriculture approach is designed to identify and operational sustainable agricultural development within the explicit parameters of climate change FAO (2010).

2.1.3. Climate change and agriculture sector in Ethiopia

There are different ways of classifying the climatic systems of Ethiopia, including the traditional and the agro-climatic zone in classification systems (Yohannes 2003). The most commonly used classification systems are the traditional and the agro climatic zones. According to the traditional classification system, which mainly relies on altitude and temperature for classification, Ethiopia has five climatic zones.

Table 2.1. Traditional climatic zones and their physical characteristics

Zone	Altitude (meters)	Rainfall (mm/year)	Average annual temperature (^{o}C)
Wurch(upper highlands)	3200 plus	900 – 2200	>11.5
Dega(highlands)	2,300 – 3,200	900– 1,200	17.5/16.0–11.5
Weynadega(midlands)	1,500 – 2,300	800 – 1,200	20.0–17.5/16.0
Kola(lowlands)	500 – 1,500	200 – 800	27.5 – 20.0
Berha(desert)	Under 500	Under 200	>27.5

Source: MoA 2000.

The agro-ecological classification method is based on combining growing periods with temperature and moisture regimes. According to the agro-ecological zone classification system, Ethiopia has 18 major agro ecological zones, which are further subdivided into 49 sub agro-ecological zones. These agro-ecologies are also grouped under six major categories (MoA 2000), which include the following:

1. Arid zone: This zone is less productive and pastoral, occupying 53.5 million hectares (31.5 percent of the country).

2. Semi-arid: This area is less harsh and occupies 4 million hectares (3.5 percent of the country).

3. Sub moist: This zone occupies 22.2 million hectares (19.7 percent of the country), highly threatened by erosion.
4. Moist: This agro ecology covers 28 million hectares (25 percent of the country) of the most important agricultural land of the country, and cereals are the dominant crops.
5. Sub humid and humid: These zones cover 17.5 million hectares (15.5 percent of the country) and 4.4 million hectares (4 percent of the country), respectively; they provide the most stable and ideal conditions for annual and perennial crops and are home to the remaining forest and wildlife, having the most biological diversity.
6. Per-humid: This zone covers about 1 million hectares (close to 1 percent of the country) and is suited for perennial crops and forests. Over these diverse agro ecological settings, mean annual rainfall and temperature vary widely.

Agriculture is the back bone of the Ethiopian economy. In line with this climate is the key determinant factor for economic growth and development. This is due to the fact that most of population in Ethiopia is the dependence of rain fed agriculture sector. This sector is an important for the communities and also use as an engine for the country's economic growth. The agriculture sector they expressed in the form of crop production, livestock production, forestry, fishery etc. Each of them contributed to agriculture sector, for instance crop production is estimated to contribute about 60 percent, livestock 27 percent, forest and other sub sector around 13 percent of the total agricultural value in the country (NMSA 2001).

According to Yosuf et al. (2008), Ethiopia as one of the country's the most vulnerable to climate change with the least capacity to respond. Indeed, Ethiopia has experienced at least five major national droughts since 1980, along with literally dozens of local droughts. Cycles of drought create poverty traps for many households, constantly thwarting efforts to build up assets and increase income. Food shortage and famine associated with rainfall variability cause a situation of high dependency on international food aid. And Ethiopia is one of the biggest food aid receipt countries in Africa that accounts to 20-30% of all food aid to sub-Saharan Africa (Bezu and Holden, 2008). This is due to the fact that agricultural production in Ethiopia is adversely affected by climate change and weather variability's, which is decreasing crop yield, decrease in livestock feed availability, affecting animal health, expansion of tropical dry and expansion of desertification. Morover, agriculture sector is the key determinant to the life of human being. However, it is affected by drought, floods, storms and rainfall failures. This effect is attributed to the fact that those factors that affect by climate change can be seriously depressing agricultural production in the country. As a result the country leads to shock the economy as a whole and loss malnutrition of livelihood for the households in particular (PANE 2009).

The effects of climate change on agricultural production of Ethiopia is manifested through shortening of maturity period and then decreasing crop yield, changing livestock feed availability, affecting animal health, growth and reproduction, depressing the quality and quantity of forage crops, changing distribution of diseases, changing decomposition rate, contracting pastoral zones, expansion of tropical dry forests and expansion of desertification, etc. Rainfall is highly erratic, most rain falls with high intensity, and there is a high degree of variability in both time and space.

According to IPCC (2007), the successes and failures of crops have always been subject to prevailing environmental factors. Crop production is increasingly vulnerable to risks associated with new and evolving climatic changes. These are variations in environmental conditions that pose significant challenges to smallholder farmers. The planet is facing more extreme weather events, such as heavy precipitation, higher coastal waters, geographic shifts in storm and drought patterns and warmer temperatures.

Besides, Climate change is regularly listed as a major contributor to the food insecure state of Ethiopia and drought remains the top priority by the government (Coates et al., 2010). Farmers also reflect this in their claims that the weather is indeed different to what it was a few decades ago (Amsalu et al., 2007). However, evidence does not bear out any significant change in rainfall; although it has some changes in the pattern of rainfall have been observed.

According to NMA (2007), there has been a warming trend in the annual minimum temperature over the past 55 years. It has been increasing by about 0.37^0C every ten years. The country has also experienced both dry and wet years over the same period. The trend analysis of annual rainfall shows that rainfall remained more or less constant when average over the whole county. Ethiopia is the vulnerable country to climate variability and change due to lower adaptive capacity, low level of socio economic development, high population growth, inadequate infrastructure and lack of institutional capacity and heavy reliance on natural resource based socio economic activities which are highly climate sensitive. The country will experience an increasing level of temperature and precipitation in the coming decadence. (ibid)

The heavy rainfall and temperature patterns in the different regions in Ethiopia and the differences in the level of socio-economic development implies that the regions differ in their vulnerability and adaptive capacity to changing climate related hazards. According to Deressa T., Hassan M., Ringler C., (2008) found that Afar, Somali, Tigray and Oromiya regions more vulnerable to climate change than other rigion of the country. The study revealed that Afar and Somali is attributed to their low level of rural service provision and infrastructure development and that of Tigray and Oromiya to the higher frequency of drought and flood, lower access to technology, fewer institutions and lack of institutions. This increasing frequency of droughts and floods have negatively affected agricultural production, demonstrating agriculture's sensitive to climate change.

According to World Bank (2007), in Ethiopian context agriculture is the dominant sector of the economy. It contributes near half of the GDP and for the vast of majority of the employment, for generating income, foreign currency and also supplying basic needs of food security. Even though, Ethiopia is highly vulnerable to climate variability and change. Due to the fact that highly depend on rain fed and traditional practices in major part of the area.

2.1.4. Projected climate change in Ethiopia and its impacts on agriculture

Over the coming year all models agree that temperature will be increase in Ethiopia, models predicting precipitation give controversial results of both increasing and decreasing precipitation. similarly, According to the World Bank (2007) Climate change is projected to reduce yields of the wheat staple crop by 33% in Ethiopia .This amounts to a serious threat to food security and to the achievement of major developmental goals.

Hence, there is a strong observable link between climate change variations and overall economic performance. The models predicting future climate change scenario in Ethiopia put conclusion that temperature will increase in the coming decades. However, there is conflicting results concerning the predicted level of precipitation (Tadele et al, nd). There is constant, decreasing and increasing level of projected precipitation level are generated using different models.

According to NMA (2007) indicate that temperature will increase in the range of 1.7 – 2.1C^0 by the year 2050 and 2.7 – 3.4C^0 by the year 2080 over Ethiopia. The country will experience an increasing level of temperature and precipitation in the coming decades. However, it stated that a small increase in rainfall can be expected. Studies indicate that Ethiopia in the coming year will face a decrease in agricultural production due to the adverse impact of climate change and variability's (Tadele et al, nd).

This suggests that agricultural production as an engine of growth and development and vulnerable to climate change and climate variability. While the more pronounced effects on crops and livestock are likely to materialize in later decades, efforts to enhance the resilience to climate shocks of crop yields and livestock production should be improve, this mechanism become increment in agricultural output and lead to achieve the overall objective of Ethiopian growth and transformation plan.

2.1.5. The concept of adaptation and climate change

There are different definitions of adaptation to climate change. These definitions are given as follows.

Adaptation - Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2001).

Adaptation - Practical steps to protect countries and communities from the likely disruption and damage that will result from effects of climate change. For example**,** flood walls should be built and in numerous cases it is probably advisable to move human settlements out of flood plains and other low-lying areas…" (Website of the UNFCCC Secretariat).

Adaptation - Is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented (UNDP, 2005).

All these three definitions differ from one another in several ways. First, all are used different words to describe the definition of adaptation. The first key words in the definition that express adaptation as ‘adjustment’, ‘practical steps’ and ‘process’ can be interpreted differently by various stakeholders. ‘Process’ seems to be a very broad and open ended term that does not include any particular time or subject references and can easily incorporate ‘steps’ and ‘adjustments’. ‘Adjustment’ seems to imply a process that leads toward some standard or goal.

These seemingly small differences might create different expectations from different stakeholders, depending on the meaning of the term that they decide to use.

The IPCC provides a broad definition by distinguishing various types of adaptation (e.g., anticipatory, reactive, public, planned adaptation, etc.) and focuses not only on technical adaptation measures but also on institutional responses. The IPCC definition also includes adaptation of natural systems not just human. One can already see that some stakeholders (e.g., community-based adaptation practitioners) use a more technical interpretation of the term (the one closer to the definition from the UNFCCC Secretariat website), while others (e.g., adaptation policymakers) use a broader definition and emphasize the institutional/policy side of adaptation.

These varied interpretations could have serious financial implications. Adaptation and mitigation are two split policy responses to climate change. Both are; however, basically linked.

Mitigation is needed to reduce the impacts and allow for adaptation to takes place, for ecosystems these boundaries are generally narrower than for human systems. Because mitigation measures will not be able to immediately avoid global warming (Parry *et al,* 2007), adaptive measurements will be needed to avert the negative consequences of climate change at the short term. On the longer term mitigation measures will be able to avoid further warming or even reduce the effect.

Numerous studies have consequently emphasized the need to pursue adaptation in addition to mitigation strategies. The IPCC noted that adaptation through changes in processes, practices or structures is a crucial element in reducing potential adverse impacts or enhancing beneficial impacts of climate change (IPCC, 2001).

There are many different strategies that the farmers can implement to reduce the risk of climate change impacts. Farmers use different adaptation strategies that fit with the types of the problems caused by climate change they faced. This is due to the fact that impact of the climate change is unevenly distributed over different geographic areas and hence the adaptation mechanisms also vary with types and level of the impact of climate change. Therefore, adaptation strategies that the farmers used to reduce the impact of climate change in different way: for instance changing crop variety, changing planting dates, mix crop and livestock production, decrease livestock, moving animals/temporary migration, change livestock feeds, soil and water management, planting trees, change from livestock to crop production, change animal breeds, seek off-farm employment, planting short season crop, and irrigation/water harvesting are among some of the several strategies available to enhance social resilience in the face of climate change (Bradshaw *et al.*, 2004; Nhemachena and Hassan, 2007).

Adaptation strategies are differing among individual farmers depending on their capacity and willingness to adopt. There are factors that are restricting adaptive capacity and willingness to adopt as a potential source of limits and barriers to adaptation. The main constraints and barriers to adaptation are biophysical, economic, social, and/or technological in nature.

According to FAO (2011) Climate change has strong impact on the agricultural sectors and forestry by modifying or degrading productive capacities and by directly and indirectly increasing the risks associated with production. Due to the fact, most of developing countries are particularly vulnerable to the adverse effects of climate change. In coming decades, millions of people whose food and livelihood security depends on farming, fishing, forests and livestock-keeping are likely to face climatic conditions that are unprecedented in the history of agriculture. To sustain current levels of food production and to meet future challenges adaptation is often underestimated by the international community.

Climate-smart agriculture seeks to maximize benefits and minimize negative trade-offs across the multiple objectives that agriculture is being called on to address: food security, development, climate change adaptation, and mitigation. The key elements include increasing productivity and resilience, reducing GHG emissions or enhancing sequestration, and managing interfaces with other land uses. Climate-smart agricultural options will in many cases be sustainable agriculture practices that take into account the need for climate change adaptation and mitigation. Increasing productivity and the resilience of agricultural systems to climate change impacts, both from extreme events and slower-onset changes, as well as enhancing agricultural adaptation by altering exposure, reducing sensitivity, and increasing adaptive capacity, are considered fundamental to the continued viability of agriculture sector (FOA 2010).

Information on climatic condition very important in order to response the impacts of these changes. Therefore understanding the linkage between climatic condition and socio-economic activities are essential method to minimize impact of climate change. The understanding of adaptation to the impact of climate change can be decrease the adverse effect of climate change at the presence as well as for future climate. Adapting to present climate is not the same as adapting to future climate change. The responsible bodies can be learned from the past for the future about adaptation options and the process of their adoption. this is due to the fact that the responsible body can be learn from the past satiations. Studies of adaptation to current climate also make it clear that human activities are not now always as well adapted to climate as they might be. In the development context, therefore, a prudent adaptive response to the threat of climate change may be to improve adaptation to existing climate and its variability, including extreme events. Improving adaptation to current climate variability is not an alternative to preparing for adaptation to longer term changes in climate. It is an adjunct, a useful first and preparatory step that strengthens capacity now to deal with future circumstances (UNEP, 1998 cited in Muleta, (2011) Adaptation is initiatives and measures to reduce the vulnerability of nature and human systems against or expected climate change effect. There is various type of adaptation, for example anticipatory and reactive, private and public, and autonomous and planned. Adaptive capacity is intimately connected to social and economic development but it is uneven distributed to the societies. There are a lot of limitations that barriers the effectiveness of adaptation measures. The adaptive capacity is depend on the community productive bases, capital asset, social network, human capital and institutions, government, national income, health and technology. But societies with high adaptive capacity may be vulnerable to climate change (IPCC, 2007). Agricultural sector is adversely affected by climate change and variability. This can minimize the negative impact by using adaptation strategies like adjustment of planting and crop variety, crop relocation, improved land management (e.g. erosion control and soil protection through tree planting) (ibid).

Similarly, adaptation strategies that the smallholder farmers' used to reduce the impact of climate change. These adaptation strategies are like changing crop variety, changing planting date, mix crop and livestock production, planting trees, soil and water management, off-farm employment and irrigation/water harvesting (Deressa el al., 2009, Nhemachena and Hassan, 2007)

Farm-level adaptation strategies is important to provide information that can be used to formulate policies that enhance adaptation as a tool for managing a variety of risks associated with climate change in farm household (Nhemachena & Hassan, 2007). Adaptation strategies are also necessary to tackle adverse impacts from higher temperature and changing precipitation patterns (Kurukulasuriya & Mendelsohn, 2007). Therefore, a key component of climate adaptation includes building resilience, where resilience is the capacity of a system to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes (FAO, 2009).

2.2 Empirical Literature Review

2.2.1 Adaptation strategies and determinant to adaptations

Hassan and Nhemachena (2007) analyze the determinant of farm level climate adaptation measures in Africa using multinomial choice model fitted to data from a cross-sectional survey from 11 countries. The results indicate that specialized crop cultivation (mono-cropping) is the agricultural practice most vulnerable to climate change in Africa. In this study better access to markets, extensions and credit services, technology and farm assets (labor, land and capital) are critical for helping African farmers adapt to climate change.

Similarly Gbetibouo (2009) studied understanding farmers' perceptions and adaptation to climate change and variability in the Limpopo Basin of South Africa for the farming season 2004-2005. The study applies both the Heckman probit and the multinomial logit models to the data were collected using a farm survey. Its major finding indicates that household size, farming experience, wealth, access to credit, access to water, tenure rights, off farm activities, and access to extension services are the main factors that enhance adaptive capacity of farmers to climate change.

Maddison (2007) uses a Heckman probit model to study the perception and adaptation to climate change in Africa. The study is based on a large scale survey of agriculturalist in 11 African countries. His survey reveals that significant numbers of farmers believe that temperatures have already increased and that precipitation has declined.

Juana et al. (2013) study on farmers' perception and adaptation to climate change in sub-sahara Africa using a survey date from farmers in sub-sahara Africa. His finding revealed that most of farmers in sub-sahara Africa are aware that the continent is getting warmer, and precipitation or rainfall patterns have changed. In addition the precipitation patterns in are different for different regions in Africa. The result indicates crop diversification, planting different crop varieties, changing planting and harvesting dates, irrigation, planting tree crops, water and soil conservation techniques are the major adaptation to the changing of pattern of precipitation. In this case the year of farming experience, household size, year of education, access to credit, access to extension service and off-farm income are among the significant determinant of adopting climate change adaptation measures.

Ajibefun and Fatuase (2011) Analysis of perception and adaptation to climate change among arable crop farmers in Ikogosi warm spring communities of Ekiti state Nigeria. The study discovered that almost all the farmers interviewed perceived changes in climate. The outcome of the perception questions using Likert Rating scale revealed that majority of the respondents perceives changes in climate over the twenty years. Furthermore, the result of factors affecting farmers' perception decision using ordered logit regression analysis showed that gender, age, and level of education were statistically significant in making decisions on the level of perception made by the farmers. Finally they are used a multinomial login regression model to analyze the factor that is influencing farmers' choice of adaptation on climate change and variability. The result reveald indicate gender, age, farming experience land tenure, farm size, access to extension services, access to loan, engage in non-farming activities, temperature and rainfall as the major factors influencing farmers' choice of adaptation to mitigate effect of climate change.

Ringler et al. (2009) they studied on adaptation to climate change in Ethiopia and South Africa: options and constraints. Based on the finding they pointed out that, climate change is expected to adversely affect agricultural production in Africa. Because agricultural production remains the main source of income for most rural communities in the region, adaptation of the agricultural sector is imperative to protect the livelihoods of the poor and to ensure food security. A better understanding of farmers' perceptions of climate change, ongoing adaptation measures, and the decision-making process is important to inform policies aimed at promoting successful adaptation strategies for the agricultural sector. They were used data from a survey of 1800 farm households in South Africa and Ethiopia. The study presented the adaptation strategies used by farmers in both countries and analyzes the factors influencing the decision to adapt. They find out that the most common adaptation strategies include: use of different crops or crop varieties, planting trees, soil conservation, changing planting dates and irrigation. However, despite having perceived changes in temperature and rainfall, a large percentage of farmers did not make any adjustments to their farming practices. The main barriers to adaptation cited by farmers were lack of access to credit in South Africa and lack of access to land, information, and credit in Ethiopia. They are also used a probit model to examine the factors influencing farmers' decision to adapt and perceived climate changes. Factors influencing farmers' decision to adapt include wealth, and access to extension, credit, and climate information in Ethiopia; and wealth, government farm support, and access to fertile land and credit in South Africa. They are used a pooled dataset to analysis the factors affecting the decision to adapt to perceived climate change across both countries reveals that farmers were more likely to adapt if they had access to extension, credit, and land. Food aid, extension services, and information on climate change were found to facilitate adaptation among the poorest farmers. They conclude that policy-makers must create an enabling environment to support adaptation by increasing access to information, credit and markets, and make a particular effort to reach small scale subsistence farmers, with limited resources to confront climate change.

Deressa et al. (2008) studies analyzing the determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. The study was used a multinomial logit model to determine the smallholder farmers' adaptation measures to climate change. Their result revealed that the methods identified included use of different crop varieties, tree planting, soil conservation, early and late planting and irrigation. The results from the discrete choice model employed indicate that the level of education, gender, age, wealth of the head of household, access to extension and credit, information on climate, social capital, agro ecological setting, and temperature all influence farmers' to choice adaptation method. The main barriers include lack of information on adaptation methods and financial constraints. Moreover, whose analysis reveals that age of the household head, wealth, information on climate change, social capital, and agro ecological settings have significant effect on farmers' perceptions of climate change.

Deressa et al. (2009) analyses the determinants of farmers' choice of adaptation methods in the Nile Basin of Ethiopia using cross sectional data from a survey of farmers. They are used a multinomial logit model to analyze the determinant of farmers' choice of adaptation strategies. In this study found that the adaptation methods are changing planting dates, using different crop varieties, planting tree crops, irrigation, soil conservation and not adapting. According to the finding the most common adaptation method was use of different crop varieties while irrigation was the least common method. The result indicated that the reasons for not to adapting are lack of information on climate change impacts and adaptation technology, lack of financial resources, labor constraints and land shortages. The levels of education, age, sex, household size of farmers' were to be significant determinants of adaptation to climate change in the study area.

In addition, Deressa *et al.* (2010) was used the Heckman model to the same data where a Multinomial model referred to above was used to assess farmers' adaptation to climate change. This model initially assesses farmers' perceptions that climate is changing followed by examination of the response to this perception in the form of adaption. Thus, the Heckman model has two equations; the selection equation and the outcome equation. The study reveals that education of the household head, household size, whether household was male, livestock ownership , use of extension services on crop and livestock production, availability of credit and temperature all positively and significantly affected adaptation to climate change. However, large farm size and high annual average precipitation were negatively related to adaptation.

Tessema et al. (2013) study examined smallholder farmers' about climate change, types of adaptation strategies, factors influencing adaptation choices and barriers to adaptation Eastern Hararghe Zone, Ethiopia. The data collects from smallholder farmers' in the study area and employed a multinomial logit model. The result revealed that planting tree, early planting, terracing, irrigation and water harvesting. Planting tree is the major adaptation method. Results of multinomial logit model showed that non-farm income, farm to farm extention, access to credit, distance to selling markets, distance to purchasing markets, income affect the choice of adaptation strategies. Finally, the study identified that lack of information as the most important barrier to climate change adaptation. the other barrier include; lack of farm input, shortage of land, lack of money, lack of water and shortage of labor.

Similarly, the finding of legesse et al. (2012) studies on smallmolder farmers' perceptions and adaptation to climate variability and climate change in Doba district, western Harerghe, Ethiopia. They are investigated the determinant factors influencing adaptation strategies to climate variability and change. The adaptation strategies were crop diversification and the use of soil and water conservation practices, integrated crop and livestock diversification, engaging in off-farm income activities and rain water harvesting. The result of the MNL model revealed that agro-ecological location, sex, family size, plot size, off-farm income, livestock holding, frequency of extension contact and training are the determinant of factors influencing adaptation strategies.

According to Aemro Tazeze, Jemma Haji and Mengistu Ketema, (2012) studied on identify the determinants of farmer's choice of adaptation strategies to climate change in the Babilie district of Eastern Ethiopia. They collect and used the data both primary and secondary for this study. Primary data were collected from a randomly selected 160 sample households interviewed through a semi-structured questionnaire, key informants interview and focus group discussion. Multinomial logistic regression analysis was used to estimate analyze the factors influencing households' choice of adaptation strategies to climate change. The multinomial logit analysis reveal that that sex of the household head, age of the household head and education of the household head, family size, livestock ownership, household farm income, non/off farm income, access to credit, distance to the market center, access to farmer-to-farmer extension, agro ecological zones, access to climate information, and extension contact have a significant impact on climate change adaptation strategies. And also they give as a policy recommendation on awareness creation on climate change through different sources such as mass media and extension, encouraging informal social net works, facilitating the availability of credit, enhancing research on use of new crop varieties that are more suited to drier conditions and different agro ecological zones.

Social-economic team Mekelle University (2010) has deeply studied on farm-level climate change perception and adaptation in drought prone area of Tigray, Northern Ethiopia. By using the data from a survey of farm householders in four tabias of Tigray, Northern Ethiopia, this study presents the adaptation strategies used by farmers and analyze the factors influencing the decision to adapt. They are used a descriptive statistics to characterize farmers' perception on temperature and rainfall changes. The result indicate that the most common adaptation strategies include; use of different crop variability, soil conservation, changing planting dates, use of external fertilizer, borrowing lost local crops from community and using short growing crops. They are used Multinomial probit model to identify the factors that influence to choice adaptation method. Extension service, livestock ownership gender of the household head being female, access to climate change information and perceived change in temperature have positive and significant impact on adaptation to climate change.

The study conducted by Tegal (2012) in three districts of Tigrai, northern Ethiopia was focused on the farmers' perception of change in climatic attributes and the factors that influence the farmers' decision to choice adaptation measures to climate change and variability. He used multinomial logit model to determine the factors that influence farmers' choice of adaptation measures to climate change. The results revealed that level of education, age, and wealth of head of household; access to credit agricultural services; information on climate, and temperature all influences farmers' choice of adaptation. Moreover, lack of information on adaptation measures and lack of finance are the main factors inhibiting adaptation to climate change.

Generally, in Ethiopia most the study have been done by authors such as Deressa et al, Di Falco et al, Ringler et al. Yesuf et al and others focused the Nile Basin as a case study repeatedly by changing its methodology. Given the need for agro-ecologically based policy measures for climate change, there is no strong evidence for aggregating their findings across country. Therefore, studying at micro level farm household in different agrological zone is appropriate to make policy implications. Therefore, the researcher intended to study on micro level smallholder farmers' adaptation strategies to climate change by taking in Adwa woreda as a case study.

CHAPTER THREE

METHODOLOGY OF THE STUDY

3.1. Description of the Study Area

Adwa woreda is a district centeral Zone of Tigrai, Ethiopia and it is bordered on the south by Werie Leke, on the west by Lailay Maychew, on the north by Mereb Leke, and on the east by Enticho. The woreda has a total population of 99,711. Out of them 49,546 are men and 50,165 women; with an area of 1,888.60 square kilometers and total of 20,141 households were counted in this woreda (CSA, 2007).

3.2. Data Type and Sources

This study was conducted on smallholder farmers' adaptation strategies to climate change in Adwa Woreda by using cross-sectional data in the production period 2013/2014. The study focused on the determinant factors that influence farmers' choice of adaptation to climate change. To undertake this study primary data was used.

3.3. Methods of Data Collection

The primary data was collected from the smallholder farmers of the Adwa Woreda using a questionnaire through interview method. The survey questionnaire was prepared in English and then translated to local language (Tigrigna) so as to get accurate information from the households since this language is used by all of the residents in this Woreda.

3.4. Sampling Method and Sample Size

Adwa Woreda has 18 rural Kebeles and has two agro-ecological zones namely: Woina dega and Kola. In this study, a sample of 160 households was taken from Adwa Woreda smallholder farmers. In order to select these respondents a two-stage sampling approach was employed. First, two Kebeles were selected out of 18 rural Kebeles in the Woreda purposively based on agro-ecological zones and the intensity of the impact of the climate change and variability. Accordingly, these two Kebeles are Weyenti (from Woina dega) and Selam(from Kolla) (see figure 3.1).

Second, using systematic sampling method households were selected from each of the two Kebeles proportionally. In this case the lists of the households were collected first from the manager of each Kebele. An element of randomness is usually introduced in systematic sampling method by using random numbers to pick up the unit with which to start. This sampling procedure is useful when sampling frame is available in the form of a list. In such a design the selection process starts by picking some random point in the list and then every n^{th} element is selected until the desired number is secured.

Systematic sampling has certain plus points. It can be taken as an improvement over a simple random sampling in as much as the systematic sampling is spread more evenly over the entire population. It is an easier and less costly method of sampling and can be conveniently used even in case of large populations (Kothari, 2004).

Table: 3.1. Sampled Kebeles for study, number of households and sample size

No	Name of kebeles	Agro-climatic zone	Household size	Sample size
1	Weyenti	Woina dega	1567	91
2	Selam	Kolla	1181	69
Total			2748	160

Source: Adwa Woreda Administration, (2012/13)

Finally, the data enumerators were carefully selected and trained for one day on the content of the questionnaire and interviewing procedures. Two data enumerators were hired for this study with one assistant for enumerator assigned to Weyenti Kebele. All of them were agricultural extension officers employed in their respective Kebele where they assigned to collect the data. In addition, all of them are fluent speakers of the local language (Tigrigna). Hence, the interview questionnaire was conducted in Tigrigna.

3.5. Method of Data Analysis

After the data are collected from the sample respondents, the researcher employed both descriptive statistics and econometrics model in order to analysis and interpret the data and give meaning full analysis. Descriptive statistical tools such as percentages tables and figures were employed to strengthen the findings of econometric methods. Multinomial logit model (MNL) was used to identify factors influencing choice of adaptation strategies by sample households to climate change and variability.

3.6. Theoretical Model

In this study it is interesting and necessary to develop theoretical framework on farm household. This theoretical framework draws on adopting a version of model based on the random utility model as specified by (Green, 2003). This random utility model is commonly use as a framework in determining of farmers' choice for different adaptation options. We can specify a common formulation of linear random utility model as;

$$U_{ij} = \beta_j X_{ij} + \varepsilon_{ij} \qquad \text{for } j \in J \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Following Greene (2003), we can modify it to adapt the objective of the study. Where, i = 1,…., N are the individual farmer and j = 1,…..J are the alternative adaptation methods, X_{ij} vector are the factors that influence farmers' choice an adaptation method to climate change and ε_{ij} is the random error term /disturbance term. To elaborate the model, we assume that farmers' are rational decision makers who maximize the utility from adaptation strategies in their farming activities. And also assuming that farmers face climatic change in their farming activities was looked for adaptation strategies.

If farmer *i* make choice *j* adaptation in particular, then we assume that U_{ij} is the maximum utility among the *J* adaptation methods.

$$\text{Prob}\,(U_{ij} > U_{ik}) \qquad \text{for all other } k \neq j.$$

The probability of that a particular farmer will choose a particular alternative *j* is given by the probability that the utility of that alternative to the farmer is greater than the utility to that farmer of all other alternative *J*.

3.7. Econometrics Model

In order to achieve the objective, the study employed multinomial logit model. Multinomial logit was used to determine factors that influence farmers' choice of adaptation method to climate change and identifying the farmers' adaptation strategies in response to climate change (first and second objective). The mathematical specifications of this model are given as below.

3.7.1. Multinomial logit model

The MNL model is easy, simple in calculating the choice probability and expressible in analytical form (Tse, 1987). The main limitation of the model is the independent of irrelevant alternative (IIA) property, which states that the ratio of the probability of choosing any two alternatives is independence of the attributes of any other alternative in the choice set (Tse, 1987; Hausman and McFadden, 1984). The multinomial probit (MNP) model specification for discrete choice model does not require the assumption of the IIA (Hausman and Wise, 1978). Due to the fact that this MNP model an inconvenient specification test as compared to the MNL model (Hausman and McFadden, 1984).

The MNL model was used by many researchers to the model climate change adaptation practices of smallholder farmers (Deressa et al., 2009, Nhemachena and Hassan, 2008). Therefore, the multinomial logit model is appropriate to the model of climate change adaptation practice of smallholder farmers in this study area.

To describe the multinomial logit model, let Y denoted vector of adaptation options for climate change to chosen by farmer household. Assuming the adaptation option farmers' choice are depends on climatic factors, institutional factors and socioeconomic characteristic of the farmers'.

The Multinomial logit model for the adaptation choice can be specified as in the following relationship between the probability of choosing option and a set of explanatory variables X Greene (2003).

$$\text{Prob}(Y_i = j) = \frac{e^{\beta'_j x_i}}{\sum_{k=0}^{5} e^{\beta'_k x_i}} \quad , \quad j=0,1,2,\ldots\ldots\ldots5 \qquad (1)$$

Equation (1) is normalized to remove indeterminacy in the model by assuming $\beta_0 = 0$ and the probabilities can be estimated as:-

$$\text{Prob}(Y_i = j/x_i) = \frac{e^{\beta'_j x_i}}{1+\sum_{k=0}^{J} e^{\beta'_k x_i}} \quad , \quad j = 0,1,2,\ldots\ldots\ldots J \ , \quad \beta_0 = 0 \ \ldots\ldots\ldots\ldots(2)$$

Maximum likelihood estimation of equation (2) yields the log-odds ratio

$$\ln\left(\frac{P_{ij}}{P_{ik}}\right) = x_i'(\beta_j - \beta_k) = x_i'\beta_j \quad , \qquad \text{if } k = 0 \ \ldots\ldots\ldots\ldots\ldots \quad (3)$$

The dependent variable of any adaptation option is therefore the log of odd in relation to the base alternative.

According to Greene (2003), the MNL coefficients are difficult to interpret and associating the β_j with the j^{th} outcome is tempting and misleading. Marginal effect is useful to interpret the effect of independent variable on the dependent variable in terms of probabilities.

$$\frac{\partial P_j}{\partial x_i} = P_j\left(\beta_j - \sum_{k=0}^{J} P_K \beta_J\right) = P_j(\beta_j - \beta) \ldots\ldots\ldots\ldots\ldots (4)$$

The marginal effects, measure the expected change in probability of a particular choice being made with respect to a unite change in explanatory variable Greene (2003).

3.8. Statistical and Specification Tests

Before carry out the final model regressions, all the hypothesized explanatory variables were checked for some statistical problems such as the issue of multicollinearity. Basically, multicollinearity problem may arise due to a linear relationship among explanatory variables and the problem is that, it might cause the estimated regression coefficients to have wrong signs, smaller t-ratios for many of the variables in the regression and high R-square value. Besides, it causes large variance and standard errors with a wide confidence interval. Hence, it is quite difficult to estimate accurately the effect of each variable on the dependent variable (Gujarati, 2004; Woodridge, 2001).

There are different methods suggested to detect the existence of multicollinearity problem between the model explanatory variables. Among these methods, variance inflating factor (VIF) technique is commonly used and is also employed in the present study to detect multicollinearity problem among the explanatory variables (Gujarati, 2004).

Gujarati (2004) defined that VIF shows how the variance of an estimator is inflated by the presence of multicollinearity. Larger value of the VIF is an indicator for presence of the problem of multicolinearity among the explanatory variables. If the VIF of a variable exceeds 10 then that variable is said be highly collinear. Correlation Matrix method was also used to detect the degree of association explanatory variables. These variables are said to be collinear if the value of the coefficient correlation Matrix is greater than 0.75.

In addition, the model specification test was conducted for Multinomial login model. In this case three models were estimated and the model comparison was undertaken using Bayesian Information Criterion (BIC) and chi-square statistics and the model with lowest BIC was selected. Following the model specification test, the validity of assumption of independence from irrelevant alternative (IIA) tests was also conducted and ended up with accepting the null hypothesis of IIA holds. This indicates that, the multinomial logit model is appropriate.

3.9. Definition of the Model variable for Multinomial Logit Model

Dependent variables

The dependent variables of this study were the adaptation options that the farmers' employed in response to climate change. The most common adaptation methods cited in the literatures include; different crop varieties, mixed crop and livestock farming, soil conservation, tree planting, changing planting date, diversifying from farm to nonfarm activity and irrigation (Hassan and Nhemachana 2007, Deressa et al 2008).

Based on the literatures and researchers knowledge in area, the study used the endogenous variables such as crop varieties, improving crop and livestock farming, soil and water conservation, irrigation and no adaptation.

Crop variety: This means that farmers could change the date of planting crops with respect to the change in the climate (early or late planting) that survive in adverse climatic conditions.
Improving crop and livestock: This includes planting of short duration crop, drought tolerant crop and improved livestock variety both for milk and meat
Soil and water Conservation: Includes soil erosion preservation, management and care of soil in order to make it suitable for their crops, dam construction, conservation of rain water for watering the crops in times too little rain, ground water harvesting and agro forestry , etc
Irrigation: Includes irrigation development from rivers or lakes in order to cope up with the challenges of climate change

No adaptation: Is the other option that smallholder farmers may not response (not use an adaptation method) to climate change.

Independent variables

The independent variables are the factors that affect choice of adaptation methods to climate change. Different literatures were reviewed on the factors that affecting farmer' choice of adaptation method to climate change. Majority of them have been focused on household characteristics, farm characteristics, institutional factors and environmental factors. Accordingly, the researcher was conceded the following as exogenous variables i.e. factors influence farmers choice of adaptation strategies to climate change.

Age of the household head (age):- This is a continuous variable and represents the experience of the household in the farming activities. This variable was expected a positive sign.

Gender of the household head (sex): Gender is a dummy variable which indicate 1 if male household head and 0 otherwise. The expecting sign of this variable was indeterminate.

Level of education of the household head *(edu):* This is the number of years spent by the head of the household for acquiring education and the expected sign was positive. As the level of education of the household head increased the farmers' proximity for new information and the probability of accepting new technology also increase.

Household size (hhsize): household size is the total family member of the household. Large number of family member can adopt the effect of climate change easily. Therefore, it was expected that household size has a positive sign for the farmers' who are used adaptation method to climate change. This variable is also a continuous variable.

On farm income (onfarm): on farm income is an income return to the household from farming activities. This was measured in the form of Ethiopian Birr. This is a continuous variable and expected a positive sign for the farmers' who were used adaptation method to climate change.

Off farm income (offarm): this is an income of household obtains from outside of farming activities. For example trade, remittance and governmental employer are among others. Such income is makes the farmers not to follow up or motives properly to agriculture. Therefore, the expected sign of this variable was negative for the farmers' who are used adaptation method to climate change and it is a continuous variable. This variable also measure in Ethiopian Birr.

Access to credit service (credit): The availability of credit is important for the farmers' in order to make adaptation strategies. Credit can be use as for the farmers to introduce new technology, to buy modernize crop, fertilizers and oxen. Therefore, thus was expected a positive sign for the farmers' who are used adaptation method to climate change and is a dummy variable indicating 1 if the farmers has access to credit 0 otherwise.

Agricultural extension service (agriexs): This is a formal service and plays a great role that affects for farmers' to adopt strategies in response to climate change. This variable is also a dummy which represent 1 if farmers' get agricultural extension service 0 otherwise and the expecting sign was a positive.

Availability of farm to farm extension service (ffexts):- This service is crucial to make farmers' to adopt strategies. The farm to farm extension service serves as a source of information and exchange and sharing of experience among farmers'. This variable is a dummy variable which indicating 1 if the farmer has available of farm to farm extension service 0 otherwise. The expected sign of this variable was a positive.

Farm size: - Farm size is the total landholding of the farm household that uses for the farming activities. The farm household with holding big farm land has more to use adopted and the farm size measure in terms of hectare. Therefore, the variable is continuous and it's expected was a positive sign for the farmers' who were used adaptation method to climate change.

Livestock holding (TLU): - livestock holding is the total livestock that farmers can own on the livelihood. Livestock is a vital instrument in the case of climatic change to adopt. This is due to the fact that livestock is essential for farm household to use as for harvesting, transportation and also for financial purpose by selling them. This implies that farmers with more numbers of livestock is the richer and can respond to the adverse impact of climate change through adaptation method. This is a continuous variable and expected a positive sign for the farmers' who were used adaptation method to climate change.

Distance from home to the farms (*dfarm*): This variable is a continuous variable represented by walking time (in minute) from farmers' residence/home to their farming place. We consider this as possible factor in farmers' decision to undertake adaptation to climate change impact. We expect that the farmer whose farm is far from his residence is less likely to continuously follow up his farm as compared to those whose farm nearer to their home. Thus, it is expected that farmers who live near to their farm are likely to have regular follow up of their farm, hence motivated to respond to the impact of climate change on their agricultural activities. Therefore the expected sign is negative for the farmers' who were used adaptation method to climate change.

Distance to the market (dmkt):- This is a continuous variable which measures in terms of time spend from the residence of farm household to the market area. The residences of farmers' are nearest to the market they get a lot of opportunities as compare to the far ones. Because the nearest one obtains agricultural inputs, information's and experiences. Therefore, this is variable was expected a negative sign for the farmers' who were used adaptation method to climate change.

Access to climate information(climinfor): This is dummy variable indicating 1 if the household head access to climate change 0 other wise. This variable is also expected a positive sign for the farmers' who were used adaptation method to climate change.

CHAPTER FOUR

RESULTS

This chapter includes both descriptive statistical analysis under section 4.1 and econometric estimation results and discussion under section 4.2. The data employed for the analysis of this study was collected from 160 sample farm household head from the two selected agro-ecological zones of Adwa Woreda.

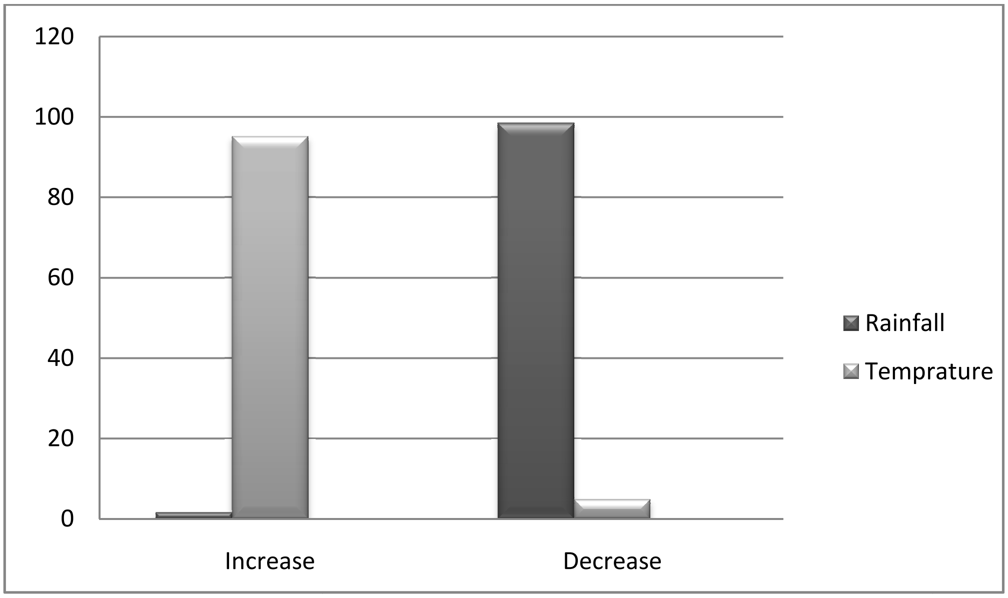
4.1. Descriptive Analysis Method

Under this section the responses of the farm households of Adwa Woreda was analyzed by using descriptive statistical method. The results found in this part could help us for the later econometric methods in section 4.2. Additionally, it is also important for analyzing some of the necessary information which is not easily captured by the econometrics methods. Here we have started from respondents' perception of the change in the level of rainfall and temperature during the last 15 years.

4.1.1. Farmers' perceptions to climate change in Adwa woreda

The farmers were asked whether they have perceived changes in the rainfall and temperature in their locality area. Then those who have perceived the change in rainfall and temperature were again asked to identify the direction of the change they had perceived. The graph below shows the direction of the perceived changes in rainfall and temperature level by the farmers in the study area. As figure 4.1 indicate that about 1.6% and 95.2% of the respondents perceived an increment in the level of rainfall and temperature respectively while about 98.4% and 4.8% of the respondents had perceived a reduction in the level of the rainfall and temperature respectively. From the blow table we can conclude majority of the farmers in the study area perceived a decrease in the level of the rainfall but an increase in the level of temperature.

Figure 4.1: Farmers perceived change in the rainfall and temperature in Adwa woreda

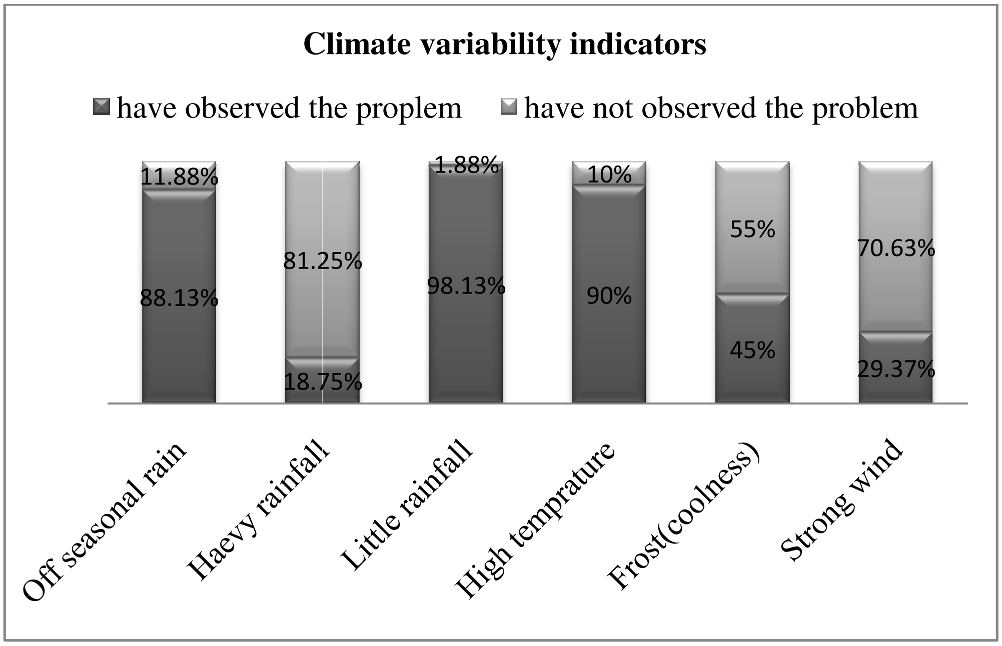


Source: Own survey results, 2014

4.1.2. Indicators of climate change and variability observed by the farmers in Adwa Woreda

The figure below shows the farmers' observation of indicators of climate change and variability in the study area. As it is indicated below, some of respondents have not observed these indicators. For example, about 88.13% of the respondents confirm the presence of off-seasonal rainfall, the remaining 11.88% of the respondent revealed that there is no problem of off-set-rainfall in their locality. On the other hand, about 18.75%of the respondents perceived the presence of heavy rainfall but the remaining 81.25% of the respondents perceived otherwise, 98.13% of the respondent show the presence of too little rainfall in the study area and the remaining 1.88% of the respondent perceives otherwise. In addition, 90% of the respondent perceives high temperature while 10% otherwise. About 45% of the respondent perceived the presence of coolness and the remaining 55% of the respondent perceives otherwise. On other hand, the problem of strong wind is observed by 29.37% of the respondents while the remaining 70.63% the respondents revealed as there is no exist such problem.

Figure 4.2: Farmers response about observation of indicators of climate change variability

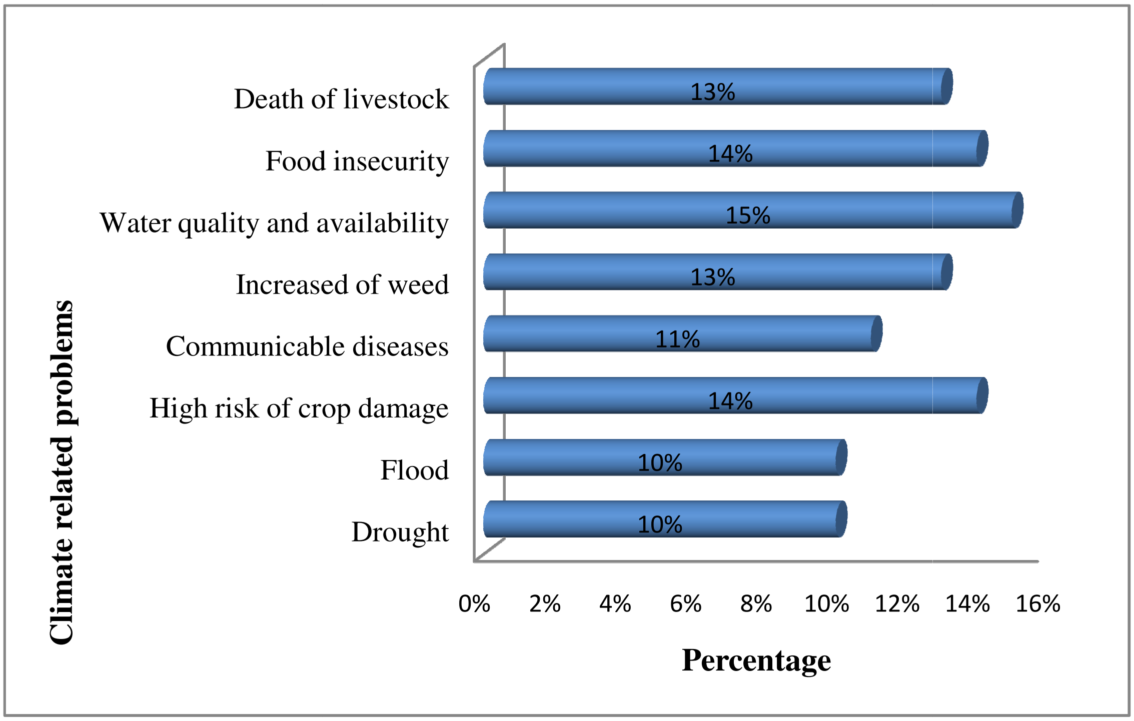


Source: Own survey results, 2014

4.1.3. Climate related problems in Adwa Woreda

There are different climate related problems which could impact the farm households in their usual farming activity. However, the intensity of these problems is not the same across regions and even it is not the same within a region too. In this study the farmers were asked to identify the intensity of different climate related problems in this Woreda. Based on their response the intensity of these problems is shown in the following figure 4.3.

Figure 4.3: Climate related problems in Adwa woreda



According to 15% of the respondents, the problem of water quality and availability is the most severe problem. This problem is followed by food insecurity and high risk of crop damage which are identified as an intense climate related problem in each by 14% of the respondents. Death of livestock and increased weeds are also a climate related problems indicated by each 13% of the respondents. Besides, according to the respondents 11% of communicable diseases are the problems existing in this Woreda. Following this, there is also problem of flood and drought due to climate change as each of these problems are indicated as intense problem by 10% of the respondents.

4.1.4. Perception and adaptation decision by farmers across agro-ecological zone in Adwa Woreda

The perception and adaptation measure to climate change of farmers across agrological zone. This disparity is clearly shown with help of cross tabulation given below.

Table 4.1: Cross tabulation of agro-ecological zone and adaptation decision

Agro-ecological zone	Perception status in percent (%)		Adaptation status in percent (%)	
	Yes	No	Yes	No
Weyna-dega	86.8	13.2	87.5	12.5
kola	88.75	11.25	90	10
Total	92.5	7.5	88.75	11.25

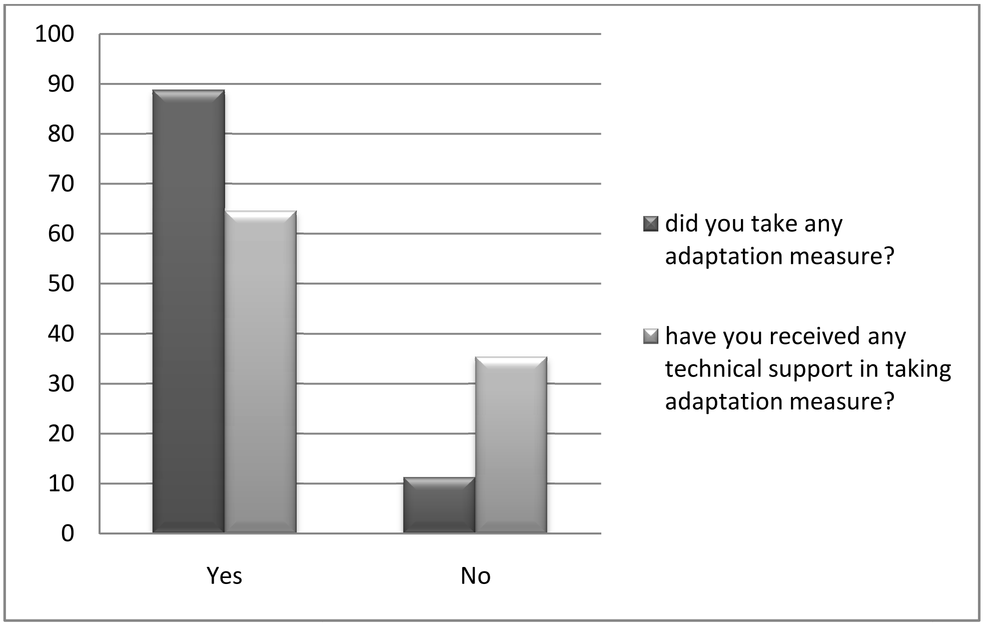
Source: Own survey results, 2014

The above table shows that, about 86.8% and 87.5% of the respondents from Weyna-dega agro ecological zone had perceive and taken adaptation measures to climate change respectively, while the remaining 13.2% and12.50% did not. In the same way 88.75 and 90% the respondents from kola agro ecological zone had already perceived and taken adaptation to climate change. However, as compared to the farmers between kola and woina-dega agro-ecological zones, the respondents who perceived and take adaptation measures from woina-dega agro-ecological zone are relatively lower. Hence, there are about 13.2% and 12.5% of the respondents did not yet perceive and taken adaptation measures to climate change from woina-dega agro-ecological zone as compare to kola agro-ecological zone. This is may be due to the fact that the intensity of climate related problems gets lower and lower as one goes from Kola to woina-dega. Therefore, this proportion could also be an indicator of where the climate related problems is a little bit more sever.

4.1.5. Presence of technical support and adaptation decision of farmers in Adwa Woreda

The farmers were asked if they had received any technical assistance in taking climate change adaptation measures. This technical assistance includes: training which help the farmers to strengthen their knowledge related to climate change, climate change adaptation strategies, and in the form of capital such as equipment needed for small scale irrigation and others. In this case the responses of the sampled farm households show the presence of technical assistance for this purpose. About 64.6% of the respondents received technical support which could help them to take climate change adaptation measures. Whereas, the remaining 35.4% of the respondents have not yet received the technical supports which strengthen their effort in taking adaptation measures.

Figure 4.4: The presence of technical support and adaptation decisions by farmers in the study area



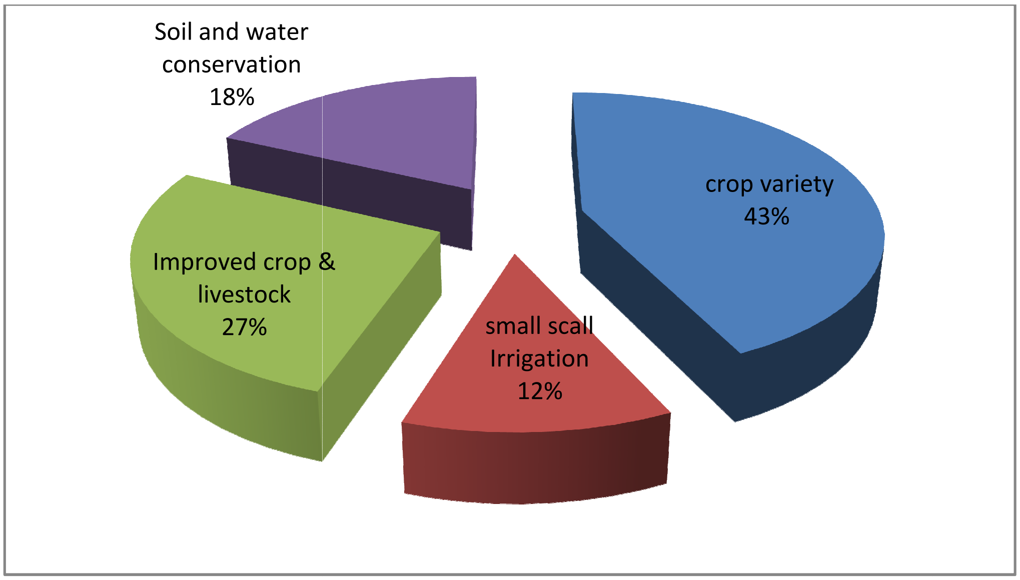
Source: Own survey results, 2014

On the other hand, while about 88.75% of the respondent had already taken adaptation measures, the remaining 11.25% of the respondents didn't take climate change impact adaptation measures on their farm due to different reasons. These reasons would be discussed later in this chapter. In general, the majority of the farmers in Adwa weroda had already taken adaptation strategy to the adverse impact of climate change.

4.1.6. Adaptation strategies to climate change used by farmers in Adwa woreda

Farmers were asked which climate change adaptation measure they have been using so far. Thus, the result of their response was shown using a pie chart which indicates the farmers' taken adaptation strategies to reduce the impact of climatic change. In this case, crop variety is highly preferred climate change adaptation strategy as it is indicated by 43%. Whereas, improve crop and livestock (by 27%) and soil and water conservation (by 18%). As it was indicated by the farmers, there is a problem of rainfall variability in the study area. For example the problem of little rainfall rains and off-seasonal is among the major which calls for farmers to take adjustment such as different crop varieties, improve crop and livestock and soil conservation were done based the requirements to tackle the issue of climate.

Figure 4.5: Adaptation strategies used by the farmers in Adwa



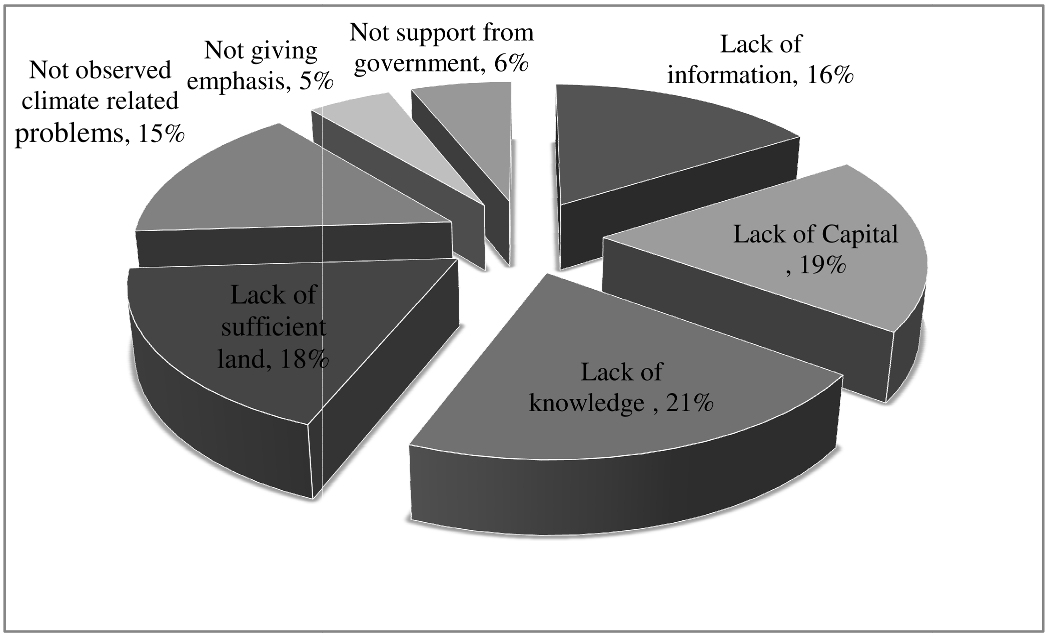
Source: Own survey results, 2014

In the study area, irrigation is also used as climate change adaptation strategy by 12% of the respondents. In general, majority of the farmers in the study area different crop variety is the common adaptation strategy used as compare to other adaptation mechanism to tackle the adverse impact of climate change.

4.1.7. Barriers to Climate change Adaptation in Adwa Woreda

In this study following the question which helps us to identify adopters and non adopters, follow up question was asked to the respondents who did not take adaptation measures. The response of the farmers to the question why they didn't take any measure which could help them reduce the impact of climate change is discussed here under with help of the following figure 4.6.

Figure 4.6 Barriers to climate change adaptation in the study area



Source: own survey 2014

The majority of the respondents who did not yet take adaptation measures answered it was due to lack of knowledge. The above figure show lack of knowledge is the major reason for taking climate change no adaptation measure. Accordingly, the problem accounts for 21% of reason for not taking adaptation measure. The problem of Lack of capital is also among main barrier to adaptation; hence, 19% of the reason why the farmer did not take any adaptation measure in the study area was this factor. This is for the reason that capital includes human capital, physical capital as well as financial capital. Therefore, having this capital, for instance, will strengthen the farmers' adaptive capacity. Hence, adaptation to climate change needs money to purchase improved crop and livestock variety and adoption of new technology. Similarly, lack of sufficient land is also among the main barriers to adaptation. Hence, about 18% of the reason for not taking any adaptation measures relies on this barrier. In farming activities land is among the main inputs necessarily required. It also direct impact on farmers' income and their adaptive capacity. For instance, the farmer who has large farm size can have a change to produce multiple cropping which in turn has a curial role for risk diversification against climate related problem. Similarly, lack of information, lack of support from government and not giving emphasis by the farmers themselves are also among the barriers to climate change adaptation in the study area.

4.2. Econometric Estimation, Results and Discussions

In this section the data analysis researches using econometric method are presented. Before conducting econometric estimation different tests which are very necessary for multinomial logit model were undertaken. The multinomial Logit model was also employed to determine the factor that influences farmers' choice of adaptation method as well as identifying different adaptation strategies of the farmers' in response to climate change. The model was fitted using STATA version 12 and test like assumptions of independence of irrelevant alternatives (IIA) were done. Specifically, to analyze smallholder farmers' adaptation strategies to climate change in Adwa Woreda, the cross sectional data collected through questionnaire was used. Moreover, the Multinomial logit regression model was employed to determine the factors that influence farmers' choice of adaptation method to climate change with 14 explanatory variables.

Besides, the existence of multicollinearity problem is checked using Variance Inflating Factor (VIF) and correlation matrix methods prior to running the final regression analysis. The results of the test indicate the presence of no severe problem of multicollinearity among the explanatory variables. Since, the VIF for each explanatory variable is less than 2 with mean of 1.34.

4.2.1. Model specification

The model specification test was done by refitting the model after dropping the variables which are found collinear with other variables and highly insignificant in explaining the model. In this model on farm income and off farm income variables were converted in to natural logarism(Ln). Taking log usually narrows the range variables such case by considerable amount makes to estimate less sensitive to the outlay or extreme observations in the dependent variable or independent variable. Initially the model runs nineteen variables and result of measure of overall fitness of the model is given in the table 4.2. From the first model (Model 1) chi square 171.743 and Prob > LR 0.000 indicate the overall significance of the explanatory variables in explaining the model. Bayesian Information Criterion (BIC) in the first model equal 721.842. Bayesian Information Criterion (BIC) helps us to compare fitness of the models.

The variance inflation factors and correlation matrix in the first model shows that, age and age square and distance to input and distances to output market show high multicollinearity problem. In addition, the result from Wald test show farm experience of the household head and physical characteristics of farmers' are highly insignificant variables in explaining the model. Therefore, the second model is fitted after dropping one highly insignificant variable and the variables which show multicollinearity problem, i.e., age and age square, respectively. In this model we have employed average market distance instead of distance to input and output market. From this model, chi-square 155.119, Prob > LR 0.000 and Bayesian Information Criterion (BIC) was 677.564. In this case BIC in model 2 is less than model 1. Accordingly, the second model is better than the first model hence the less BIC is the better that fits to the model. After fitting the model we have conducted a Wald test so as to determine the significance of each explanatory variable included in the model. In addition, presence of multicollinearity problem is also tested using the variance inflation factor (VIF) after each regression.

Table 4.2: Model specification test result for MNL

Measures	Model 1	Model 2	Model 3
Log-Likelihood	-157.914	-166.226	-175.603
LR statistics	171.743	155.119	136.364
Prob > LR	0.000	0.000	0.000
BIC'	721.842	677.564	655.717

Source: Own survey results, 2014

Again we have employed the Wald test and the tests to check the presence of multicollinearity problem using VIF and correlation matrix methods. In the second model, there is no exaggerated multicollinearity problem. However, still there are variables which are highly insignificant hence we dropped two highly insignificant variables, i.e., Access to training and active lobour force in the farm household head. In the third model, we have chi-square 136.364, Prob > LR 0.000 and BIC equal 655.717. Thus, for our case third model is better for fitting the model. Hence, the final model is fitted using 14 explanatory variables. In the final model, the Wald test shows that four variables out of the total fourteen variables are insignificant. The four insignificant variables are level of sex, education of the household head, off farm income and access to agriculture extension services. After estimating the model with 14 explanatory variables we have conducted a test to detect if there is problem of multicollinearity in our model. Here we have mean VIF of 1.34 and variance inflation factor less than 2 for each explanatory which indicate that multicollinearity is not a severe problem. The result of VIF is indicated under appendix A.

4.2.2 Independence of irrelevant alternative (IIA) test for MNL model

As it is discussed earlier, the MNL model requires the fulfillment of the assumption of the Independence of Irrelevant Alternatives (IIA), otherwise the model will be inappropriate. Different literatures suggest different ways to handle the problem of IIA and to test the fulfillment of the assumption. For instance, McFadden (1973) forwarded that models with independence of irrelevant alternative assumption should be used in cases where the alternatives can plausibly be assumed to be distinct and weighted independently in the eyes of each decision option. Moreover, Multinomial login models are work well when the alternatives are dissimilar. Additionally, two most common methods that are used to test Independence of irrelevant alternative (IIA) are Hausman-McFadden (HM) test and Small-Hsiao (SH) test and are suggested to test the IIA by Hausman & McFadden, and Small & Hsiao, respectively.

In this model five categorical outcome tests of IIA are reported here. Then the study computed the model using no adaptation as a base category. The study was used Hausman-McFadden test of independence of irrelevant alternatives. The chi-square results along with the degrees of freedom and probability values are presented in Table 4.3. Although none of the tests reject the Ho that IIA holds, the results differ considerably, depending on the outcome considered.

Table 4.3: Hausman-McFadden Tests Results for IIA Assumption

Adaptation strategies restricted/ omitted	Chi^2	df	$P> ch^2$	evidence
No adaptation	11.340	45	1.000	Support Ho
Different crop variety	28.551	45	0.973	Support Ho
Improve crop and livestock	16.570	45	1.000	Support Ho
Soil and water conservation	26.997	45	0.985	Support Ho
Irrigation	16.419	45	1.000	Support Ho

Source: Own survey results, 2014

Note: A significant test is evidence against Ho

Tests of the IIA involve comparing the estimated coefficients from the full model to those from the restricted model that excludes at least one of the alternative adaptation strategies. If the test statistics is significant, the assumption of the IIA is rejected indicating that the multinomial Logit model is inappropriate. The Hausman-McFadden tests results from the above table indicate that we fail to reject the null hypothesis indicating that our assumption for independence of irrelevant alternatives (IIA) is satisfied.

4.2.3. The summary statistics for explanatory variables

Table 4.4 below represents the mean values of the independent variables along with the respective standard deviation of that variable.

Table 4.4: The summary statistics for fourteen independent variables

Independent variables	Description	Summary statistics			
		Mean	Std. Dev.	Min	Max
Gender of the hh head	**Dummy 1 if male, 0 otherwise**	**.93**	**.26**	**0**	**1**
Age of the household head	**continuous variable**	**47.74**	**11.25**	**25**	**77**
Level of education of the hh head	**continuous variable**	**1.29**	**1.78**	**0**	**10**
Family size of the hh head	**continuous variable**	**6.03**	**2.45**	**1**	**11**
Farm income	**In ETB (continuous variable)**	**5612.75**	**3916.2**	**600**	**23000**
Off Farm income	**In ETB (continuous variable)**	**105**	**481.2**	**0**	**5800**
Farm size	**In hectare (continuous variable)**	**.31**	**.22**	**0**	**1**
Access to credit	**Dummy 1 if yes, 0 otherwise**	**.86**	**.31**	**0**	**1**
Distance from home to the farm	**continuous variable (in minute)**	**26.61**	**26.06**	**2**	**180**
Average market distance	**continuous variable (in k.m)**	**21.88**	**4.65**	**15**	**25**
Livestock size	**continuous variable**	**3.51**	**1.81**	**0**	**9.54**
Agricultural extension	**Dummy if 1 yes, 0 otherwise**	**.84**	**.37**	**0**	**1**
Farm to farm extension	**Dummy if 1 there, 0 otherwise**	**.84**	**.36**	**0**	**1**
Access to climate information	**Dummy if 1 there, 0 otherwise**	**.46**	**.50**	**0**	**1**

Source: Own survey results, 2014

4.2.4 Estimated results of the multinomial logit model

The results of MNL model showed how factors that influence farmers' choice of adaptation measures in the study area. The MNL adaptation model with these restructuring choices was run and showed some significant levels of the parameters estimates. Table 4.5 represented the results of MNL Regression model. The likelihood ratio statistics as indicated by ch2 statistics (LR chi-square (56) = 136.36 are highly significant P < 0.0000), suggesting the model has a strong explanatory power. In all cases, the estimated coefficients should be compared with the base category of no adaptation. Therefore, Table 4.5 presents the MNL results along with the levels of statistical significance.

Table 4.5: Parameter estimates of the multinomial logit climate change adaptation model

Explanatory variable	Crop variety Coef. P-value	Improve crop& livestock Coef. P-value	Soil&water conservation Coef. P-value	Irrigation Coef. P-value
sex	**.5456**	**.4269**	**.0865**	**-.4407**
	0.618	**0.782**	**0.9530**	**.744**
age	-.0276	-.0082	.0222	-.0346
	0.399	0.837	0.531	0.402
edu	.3961	.4650	.4450	.5477
	0.196	0.151	0.154	0.114
fsize	.2989***	.1634	.0232	-.2261
	0.087	0.422	0.901	0.302
lnonfarm	1.4376**	1.4020***	.6673	2.3580*
	0.046	0.084	0.390	0.006
lnoffarm	.0263	.07163	-.0198	.2230
	0.874	0.686	0.911	0.249
lsize	1.7349	-1.6349	-.5539	1.1491
	0.388	0.509	0.808	0.627
dfarm	-.0256**	-.0580*	-.0325**	-.0437**
	0.030	0.005	0.026	0.039
dmkt	-.2043***	-.2648**	-.2311**	-.2201***
	0.058	0.020	0.041	0.085
credit	.6414	-1.7710	-.1195	-.7146
	0.546	0.101	0.920	0.596

agriexts	1.0586	1.1487	2.1330***	1.0394
	0.242	0.348	0.075	0.389
ffexts	-.5343	2.6864***	.5529	1.1280
	0.566	0.085	0.644	0.482
climinform	2.1619**	2.1745**	3.6056*	3.5256*
	0.032	0.043	0.001	0.005
TLU	2.1527**	.0862	-1.5149	-1.5752
	0.034	0.944	0.158	0.172
cons	-5.6993	-7.3300	-1.5318	-11.9607***
	0.335	0.302	0.815	0.098

Base category	No adaptation
Number of observations	160
LR chi2(56)	136.36
Log likelihood	-175.6034
Prob > chi2	0.0000
Pseudo R-Square	0.2797

Notes: *, **, *** = significant at 1%, 5%, and 10% probability level, respectively

Source; own survey study 2014

- Coefficient estimations from the multinomial logit model can tell about the direction effect not the magnitude effect. We see how we can compute the magnitude of effect by using stata command mfx2 after multinomial logit regression and it gives marginal effect or elasticities.

Table 4.6 Marginal effects from the multinomial logit climate change adaptation model

Explanatory Variable	Crop variety Coef. P-value	Improve crop& livestock Coef. P-value	Soil & water conservation Coef. P-value	Irrigation Coef. p-value	No adaptatoin Coef. p-value
sex	**.1178**	**.0203**	**-.0482**	**-.0738**	**-.0161**
	0.599	0.895	0.842	0.564	0.795
age	-.0075	.0006	.0079***	-.0016	.0006
	0.174	0.862	0.065	0.431	0.675
edu	-.0063	.0084	.0083	.0103	-.0207
	0.845	0.669	0.710	0.449	0.172
fsize	.0683**	.0002	-.0316	.0287**	-.0082
	0.011	0.991	0.115	0.020	0.289
Lnonfarm	.0926	.0223	.1331***	.0816**	-.0634
	0.334	0.721	0.084	0.041	0.1121
lnoffarm	-.0047	.0053	-.0126	.0138	-.0018
	0.841	0.695	0.508	0.113	0.812
lsize	.5758**	-.3298	-.2584	.0419	-.0294
	0.036	0.100	0.305	0.685	0.752
dfarm	.0032	-.0039***	-.0001	-.0009	.0016**
	0.230	0.068	0.961	0.495	0.040
dmkt	.0030	-.0081	-.0047	-.0007	.0106**
	0.805	0.242	0.623	0.893	0.040
credit	.3396*	.3767**	.0497	-.0281	.0156
	0.010	0.029	0.718	0.747	0.638
agriexts	-.0570	-.0032	.1614	-.0099	-.0913
	0.738	0.980	0.125	0.887	0.285
ffexts	.3393**	.1960*	.0915	.0542	-.0024
	0.021	0.001	0.482	0.290	0.954
climinform	-.1505	-.0432	.2525*	.0752	-.1342 **
	0.162	0.483	0.004	0.191	0.022
TLU	.3144**	. 2394**	.0018	-.0039	.0771
	0.019	0.016	0.986	0.933	0.104

Notes: *, **, *** = significant at 1%, 5%, and 10% probability level, respectively

Source; own survey study 2014

4.2.5. Interpretation of significance determinant factors of adaptation strategies from the marginal effect result

Age of the household head: - is one of a significant explanatory variable in which its coefficient has a positive sign. A one year increase in age of the household head, the probability of farmers' use soil and water conservation adaptation strategy increases by 0.79%, holding other variable constant. This means that the likelihood of taking up climate adoption measures was higher among older farmers. Because as the age of the household head increases, the person is expected to acquire more experience in weather forecasting and that helps increase in likelihood of practicing different adaptation strategies to combat climate change. This might be attributed to the experience of older farmers perceiving changes in climatic attributes. This result is in line with the findings of Deressa et al. (2008); Ajibefun and Fatuase (2011); Nhemachena and Hassan (2007); Maddison (2007) and Ishaya and Abaje (2008).

Family Size: - family size also has significant and positive effect on adaptation strategies to climate change. A one unit increase in the family size, the probability of farmers use crop variety and irrigation adaptation methods increase by 6.8% and 2.9% respectively, keeping other variables constant. Because household size can influence adaptation, due to the fact that its association with labor endowment. It is argued that a larger household size enables the adoption of technologies by availing the necessary labour force in one hand (Croppenstedt et al. 2003) and enabling the generation of additional income from extra labor invested in off-farm activities (Yirga 2007). The finding of this study was similar with of the result of Tagel (2013).

Farm size: - is also a statistically significant explanatory variable in this model. That means farmers' adaptation strategy to climate change is also significantly affected by the amount of farm size that the households owned. For instance, a one hectare increases in the farm size, the probability of the farmers use crop varieties adaptation strategy increases by 57.58% at 5% level of significance, holding other variables constant. Farm size may also associate with grater wealth and it is hypothesized to increase adaptation to climate change. Whereas, some literatures on adoption of agricultural technologies indicate that farm size has both negative and positive effect on the adoption showing that the effect of farm size on technology adoption is inconclusive (Bradshaw et al., 2004). However, the result of this study revealed that households with relatively big farm size were more likely to take up more adaptation strategies when compared to farmers with small farm size. This indicates that the bigger the size of the farm, the greater the proportion of land allocated for different crop varieties as an adaptation strategies that the farmers are likely to adopt. Because farm size is always associated with greater wealth, more capital and resources, the larger the farmer's farm size, the more likely the probability of adapting to climatic change in the study area. This result is also in line with the outcome of Mengistu et al. (2012); Tessema et al. (2013); Ajibefun and Fatuase (2011) and Tesso et al. (2012).

Farm income: - Farm income of the household also a significant explanatory variables as shown in the above table (table 4.6). The result of this analysis reveals that farm income of a household had a positive and significant influence on irrigation and soil and water conservation adaptation methods in response to climate change.

A one percent (ETB) increases in the income of the household from the farm, the probability of farmers' to use adaptation strategies of soil and water conservation and irrigation increases by 13.3% and 8.1% respectively, holding other variables constant. The impact of income on adoption found a positive correlation (Franzel 1999; as cited in deressa et al., 2008). Higher-income farmers may be less risk averse and have more access to information and a longer-term planning horizon (CIMMYT, 1993). When the main source of income in farming would increase, farmers tend to invest on productivity smoothing options, for example irrigation option. This finding is consistent with studies of Tagel (2013); Deressa et al. (2009) and Mengistu et al. (2012).

Distance to the farm is a significance variable in the model. The result of this variable was natively affected to the adaptation strategies of improve crop and livestock users, whereas positively affect for the farmers who give a response no adaptation. As farmers take one more minute to arrive at the cultivated area from their residence, the probability of using improved crop and livestock adaptation method decreases by 0.39%, holding other variables constant. As farmers take one more minute to arrive at the cultivated area from their residence, the probability of farmers not to use any adaptation method increase by 0.16%, holding other variables constant. This is due to the fact that a farmers' residence is far away to the farm land or cultivated plot so that they may not follow up their farm land.

Distance to the market: Distance to the market center is also significantly and positively affect these farmers who are not use an adaptation method to climatic change. Market is an important determinant for adaptation method because it serves as a means of exchanging information with other farmers (Maddison, 2006). A one kilometer increase in average distance to market center, the probability of farmer's not to use adaptation strategies to climate change increase by 1.1% at 5% level of significance, holding other variable constant. Because if farmers' are far away from the residence to the market center, they would not obtain better information, experience sharing and it is difficult farmers to buy new adaption technologies and other important inputs.

Access to credit is also a significant variable. As compared to the farmer who has no access to credit, the probability of using crop varieties and improve crop and livestock adaptation strategies to climate change for the farmer who has credit access increases by 34% and 37.7% respectively, keeping other variables constant. Adaptation method to climate change needs money to purchase improved inputs such as fertilizer and improved better seeds. The result of this study is similar with the findings of Deressa et al. (2009); Di Falco et al. (2011); Tesso et al. (2012) as well as Aemro et al. (2012).

Access to climate information is also one of a significant explanatory variable. Getting information about seasonal forecasts and climate change, the probability of using adaptation soil and water conservation increase by 25.25% compared to not getting information, keeping other variables constant. While, getting access to climatic information, the probability of farmers' no to use any adaptation strategy decrease by 13.4% as compared to farmers' not getting climatic information, keeping other variables constant. Thus, access to information from different sources has significant impact on the adaptation to climate variability. Indeed, it is an important precondition for farmers to take up adaptation measures (Madison 2006).

Farmers-to-farmers' extension service is also among the significant explanatory variable in this model. As compared to the farmers who have no access to farmers to farmer's extension service, the probability of using crop variety adaption methods to climate change increases by 33.9% for farmers' who have access farmers-to-farmers' extension service, keeping other variables constant. Moreover, As compared to the farmers who have no access to farmers to farmer's extension service, the probability of use improve crop and livestock adaption methods to climate change increases by 19.6% for farmers' who have access farmers-to-farmers' extension service, keeping other variables constant. Different farmers have different skills, working habits, and experience. Therefore, sharing of experience among farmers is very important to build up the knowledge of the farmers and will help them to take the adaptation measures. This result is also similar with the finding of Deressa et al. (2010) and Tessema et al. (2013).

The number of the livestock owned by the farmer is significant explanatory variable in this study. Its sign was positively influencing the farmers' decision of taking different crop variety and improve crop and livestock adaptation measures. A one unit increase in the number of livestock owned by the household, the probability of using crop varieties and improves crop and livestock adaptation methods increase by 31.4% and 23.9% respectively, keeping other variables constant. In this case, livestock is considered as an asset for the farmers and plays a very important role by serving as a source of income in order to purchase improved crop variety. Therefore, having a large number of livestock can strengthen farmers' adaptive capacity to climate change. On the other hand, livestock rearing is one part of agricultural activities which is also subject to climate change impact. Consequently, as the number of the livestock increased the farmers will look for adaptation measures that safeguard their assets against climate related problems. This result is also similar with Aemro et al. (2012); Legesse et al. (2012) and Tesso et al. (2012)

CHAPTER FIVE

CONCLUSIONS AND POLICY IMPLICATIONS

5.1. Conclusions

This chapter provides summary and conclusion based on research findings on smallholder farmers' adaptation strategies to climate change in Adwa woreda, centeral zone of Tigrai, Ethiopia. The study used cross-sectional data collected from 160 households in the production year 2013/2014, and applied descriptive and econometric approaches to analyze the data.

In this study area, almost all of the farmers were aware about the change in the level of precipitation and temperature during the last 15 years. Majority of the respondents about 98.4% perceived reduction in rainfall and 95.2% of the respondent's perceived increment in temperature over the last 15 years. In spite of this disparity in the perceived direction of changes in these elements of climatic change, the adaptation strategies such as different crop variety and improve crop and livestock are the most commonly practiced adaptation strategies to climate change by the households. Moreover, strategies such as soil and water conservation and irrigation have been exercised by some proportion of the farmers. In general, based on the respondents around 88.75% of the farmers have taken at least one adaptation measure in response to climate change.

Indicators of climate change and variability have been observed in the study area includes: off-seasonal rainfall, heavy rain, too little rainfall, high temperature, coolness as well as high winds. On the other hand, the farmers in the study area have been highly encountered the intensity of climate related problem like water quality and availability, food insecurity, high risk of crop damage. Some of the sample respondents in this study area have not taken adaptation measures to climate change due to different constraint factors. These includes: lack of knowledge, lack of capital, lack of sufficient land, lack of information and unobserved climatic related problems are the major ones. In addition, lacks of support from the governmental body as well as not giving emphasis by the farmers themselves are also among the barriers to climate change adaptation in the study area.

Multinomial logistic regression analysis was employed to determine the factors influencing farmers' choice of adaptation strategies to climate change. The result from the multinomial logit analysis shows that age, family size, farm size, farm income, distance to the farm, distance to the market, access to credit, farmer-to-farmer extension, access to climate information and number of livestock owned by the household have a significant influence on farmers' choice of climate change adaptation strategies.

For instance, age of the household head has positive effect on the probability of farmers to use soil and water conservation adaptation strategy to climate change. An increase in age of the household head, increase the probability of farmers to use soil and water conservation adaptation strategy. On the other hand, a family size of the household has positively influence on the probability of farmers to use crop variety and irrigation adaptation strategies. An increasing in family size of the household head, increase the probability of farmers to use different crop variety and irrigation adaptation strategies. Similarly, the household income from farm is also positively effects on the probability of farmers to use irrigation and soil and water conservation adaptation methods. An increase in household income from farm, increase the probability of farmers use irrigation and soil and water conservation adaptation methods. Farm size of the household head has positively influence the probability of farmers' to use crop variety adaptation strategy. Moreover, Access to climate information has also positively influence the probability of farmers to use soil and water conservation strategy to climate change.

In addition, access to credit, farm to farm extension and livestock size are positively determines the probability of farmers use different crop variety and improve crop and livestock adaptation strategies to climate change. Distance to the farm and distance to the market are also positively influence on the probability of farmers no to adopt any adaptation strategies to climate change. On the other hand, distance to the farm is negatively determine the probability of farmers' to use improve crop and livestock adaptation strategy.

In general, age, family size, farm income. farm size, distance to the farm, distance to the market, access to credit, farm to farm extension service, number of livestock owned by farmer and access to climatic information are the main factor that influences farmers' choice of adaptation method to climate change.

5.2. Recommendation and Policy Implication

Based on the findings of this study, the following recommendations were forwarded for reducing the impacts of climate change on agriculture. Strengthening efforts on enhancing the farmers' adaptive capacity to climate change and variability is an important policy measurement. The government and any concern body should give emphasis to address this issue of climatic change through paying greater attention. In the study area problem of food insecurity is a common by the farmers of this Woreda especially when there is crop failure due to off-seasonal rainfall and little rainfalls. Therefore, effort and strengthen the farmers' adaptive capacity to climate change through providing early maturing crop to farmers has an important mechanism.

Besides, Social and physical infrastructure should be improved and institutions dealing with climate related issues including the meteorology agency be strengthened to increase adaptive capacity and also access climate information is very crucial for pre-informing the farmers about the future weather condition. Therefore, in this case the role of metrological agency is very worthwhile in communicating information about weather condition to the farmer using different mechanisms like radio and/or television. This awareness creation effort should be combined with the different types of crop and livestock production and management practices that farmers could use different adaptation mechanisms to climate change.

Policies aimed at promoting farm-level adaptation need to emphasize on the crucial role of providing information on better production techniques and enhancing farmers' awareness on climate change to enable farmers adapt to climate change.

In addition, addressing the climate related problems calls for the government as well as NGOs working on this issue to first tackle the barriers to climate change adaptation in the study area. These include provision of the necessary capital inputs at reasonable price, initiating the farmers to give emphasis for the issue of climate by creating detailed awareness about the causes and consequences of climate change as well as the adaptation methods together with continuous follow up from agricultural extension officers. For example, provisions of material and technical support for the farmers necessary to tackle the adverse impact of climate changes.

Moreover, Government policies should support the provision of access to education, credit, extension services on crop and livestock production, and information on climate and adaptation measures are necessary to better cope with climate change in the study area. Additionally, policy interventions that encourage informal social networks i.e farm to farm extension services can promote group discussions. This is very necessary for farmers to share experience, information and knowledge among them. Therefore policy program which is intended at reducing the climate related problems should also focus on accessing improved inputs such as better seeds, improved livestock and fertilizer to farmers with fair price.

In addition, provision of crop and livestock insurance has very crucial role in supporting the smallholder farmers to recover from risks against climate related problems.

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Appendices

Appendix A: The Variance Inflation Factors for Multinomial Logit Model

Variable |	VIF	1/VIF
lnonfarm |	1.58	0.632595
ffexts |	1.56	0.641837
agriexts |	1.50	0.664833
fsize |	1.48	0.677784
age |	1.40	0.712185
dmkt |	1.39	0.721896
climinform |	1.38	0.725914
TLU |	1.35	0.742035
dfarm |	1.33	0.754032
sex |	1.24	0.806824
lnoffarm_1 |	1.23	0.814197
lsize |	1.13	0.882255
credit |	1.10	0.912607
edu |	1.10	0.912683
Mean VIF |	1.34	

Source: Own survey results, 2014

Appendix B: Correlation Matrix

	adapta~a	sex	age	edu	fsize	lnonfarm	lnoffa~1
adaptation~a	1.0000						
sex	-0.0389	1.0000					
age	-0.0730	0.1353	1.0000				
edu	0.0340	0.0738	0.1176	1.0000			
fsize	-0.1203	0.1395	0.4124	0.0813	1.0000		
lnonfarm	0.2592	-0.1706	0.0290	-0.0387	0.1844	1.0000	
lnoffarm_1	0.1579	-0.0530	0.1196	-0.1622	0.0176	0.0662	1.0000
lsize	-0.0135	0.0352	0.1803	0.0293	0.1008	0.1945	-0.0720
dfarm	-0.0281	-0.2153	-0.2413	-0.0078	-0.2861	0.2072	-0.1443
dmkt	-0.0048	-0.1920	0.1012	0.0963	-0.0796	-0.1462	0.2670

```
      credit |   0.0350  -0.0212  -0.0929  -0.0001   0.0708   0.0240  -0.0131
    agriexts |   0.1180   0.2605  -0.0418   0.0633   0.2204   0.0614  -0.0719
      ffexts |   0.3033   0.0735  -0.0221  -0.0935   0.1604   0.2922   0.0126
  climinform |   0.4005  -0.0690  -0.0794  -0.0757  -0.0785   0.2908   0.2176
         TLU |   0.1646  -0.0458   0.1138  -0.0140   0.2403   0.4229   0.1017

             |    lsize    dfarm     dmkt   credit agriexts   ffexts climin~m
-------------+---------------------------------------------------------------
       lsize |   1.0000
       dfarm |   0.0522   1.0000
        dmkt |  -0.1480   0.0652   1.0000
      credit |  -0.0371  -0.0879  -0.0574   1.0000
    agriexts |   0.1186  -0.0327  -0.1873   0.1230   1.0000
      ffexts |   0.0757   0.0433  -0.2159   0.1868   0.4637   1.0000
  climinform |  -0.0018   0.1731   0.2197   0.1164  -0.0331   0.2266   1.0000
         TLU |   0.1823  -0.0411  -0.0738  -0.0207   0.1669   0.2319   0.1959

             |      TLU
-------------+---------
         TLU |   1.0000
```

Appendix C: Conversion Factors for Tropical Livestock Unit (TLU)

	Animal Category	Tropical livestock unite (TLU)
1	Calf	0.25
2	Weand calf	0.34
3	Heifer	0.75
4	Cow and Oxen	1
5	Horse	1.10
6	Donkey (adult)	0.7
7	Donkey (Young)	0.35
8	Camel	1.25
9	Sheep and Goat (adult)	0.13
10	Sheep and Goat (young)	0.06
11	Chicken	0.013

Source:storck et al.(1991)

Appendix D:. Estimation Result of multinomial logit model

```
. mlogit adaptationstra sex age edu fsize  lnonfarm lnoffarm_1 lsize dfarm dmkt credit
agriexts ffexts climinform TLU,baseoutcome(> 0)


Iteration 0:   log likelihood = -243.78562
Iteration 1:   log likelihood = -186.36776
Iteration 2:   log likelihood = -176.53079
Iteration 3:   log likelihood = -175.62087
Iteration 4:   log likelihood = -175.60343
Iteration 5:   log likelihood =  -175.6034


Multinomial logistic regression                   Number of obs   =        160
                                                   LR chi2(56)     =     136.36
                                                   Prob > chi2     =     0.0000
Log likelihood =  -175.6034                        Pseudo R2       =     0.2797
------------------------------------------------------------------------------
adaptation~a |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
cropvariety  |
         sex |   .5456242   1.094347     0.50   0.618    -1.599256    2.690504
         age |  -.0275552   .0326808    -0.84   0.399    -.0916083     .036498
         edu |   .3960595   .3063986     1.29   0.196    -.2044706    .9965896
       fsize |   .2988734    .174854     1.71   0.087     -.043834    .6415809
    lnonfarm |   1.437578   .7215355     1.99   0.046     .0233948    2.851762
  lnoffarm_1 |   .0262674   .1662677     0.16   0.874    -.2996113    .3521461
       lsize |   1.734938   2.011574     0.86   0.388    -2.207675     5.67755
       dfarm |  -.0255901   .0118179    -2.17   0.030    -.0487528   -.0024274
        dmkt |  -.2042772   .1077711    -1.90   0.058    -.4155047    .0069502
      credit |   .6413559   1.061261     0.60   0.546    -1.438677    2.721389
    agriexts |   1.058602   .9041106     1.17   0.242    -.7134221    2.830626
      ffexts |  -.5342568   .9305798    -0.57   0.566     -2.35816    1.289646
  climinform |   2.161872   1.009094     2.14   0.032     .1840845     4.13966
         TLU |   2.152655   1.017827     2.11   0.034     .1577516    4.147559
```

_cons	-5.699281	5.915673	-0.96	0.335	-17.29379	5.895225
crop&lives~k						
sex	.4268579	1.542887	0.28	0.782	-2.597145	3.450861
age	-.0081729	.0398049	-0.21	0.837	-.0861891	.0698434
edu	.4649618	.3234233	1.44	0.151	-.1689362	1.09886
fsize	.1633855	.2035309	0.80	0.422	-.2355277	.5622988
lnonfarm	1.401956	.811477	1.73	0.084	-.1885096	2.992422
lnoffarm_1	.0716277	.1771586	0.40	0.686	-.2755968	.4188522
lsize	-1.634938	2.475707	-0.66	0.509	-6.487234	3.217358
dfarm	-.0579677	.0205002	-2.83	0.005	-.0981474	-.0177881
dmkt	-.2647922	.1134411	-2.33	0.020	-.4871326	-.0424518
credit	-1.771028	1.078753	-1.64	0.101	-3.885346	.3432899
agriexts	1.148699	1.224772	0.94	0.348	-1.25181	3.549208
ffexts	2.686384	1.557497	1.72	0.085	-.3662552	5.739022
climinform	2.174475	1.075127	2.02	0.043	.0672656	4.281685
TLU	.0862125	1.236653	0.07	0.944	-2.337583	2.510008
_cons	-7.330002	7.102587	-1.03	0.302	-21.25082	6.590814
soil&water~s						
sex	.0865396	1.456078	0.06	0.953	-2.76732	2.940399
age	.0221732	.0353794	0.63	0.531	-.0471692	.0915156
edu	.4449691	.3123161	1.42	0.154	-.1671591	1.057097
fsize	.0231563	.1868885	0.12	0.901	-.3431385	.3894511
lnonfarm	.667265	.775591	0.86	0.390	-.8528655	2.187396
lnoffarm_1	-.0197998	.1766346	-0.11	0.911	-.3659973	.3263976
lsize	-.5538842	2.273504	-0.24	0.808	-5.00987	3.902102
dfarm	-.0324769	.0146344	-2.22	0.026	-.0611599	-.0037939
dmkt	-.231104	.1131044	-2.04	0.041	-.4527846	-.0094234
credit	-.1194619	1.185592	-0.10	0.920	-2.443179	2.204255
agriexts	2.13298	1.199225	1.78	0.075	-.217457	4.483418
ffexts	.552887	1.197405	0.46	0.644	-1.793983	2.899757
climinform	3.60558	1.068366	3.37	0.001	1.51162	5.699539

```
         TLU |  -1.514929   1.073819    -1.41   0.158    -3.619576    .5897174

       _cons |  -1.531673   6.554589    -0.23   0.815    -14.37843    11.31509

-------------+----------------------------------------------------------------

irrigation   |

         sex |    -.44067    1.34755    -0.33   0.744    -3.081819    2.200479

         age |  -.0345787    .041238    -0.84   0.402    -.1154036    .0462463

         edu |   .5476505   .3467547     1.58   0.114    -.1319762    1.227277

       fsize |  -.2261337   .2189612    -1.03   0.302    -.6552898    .2030224

    lnonfarm |    2.35799   .8510195     2.77   0.006     .6900222    4.025958

  lnoffarm_1 |    .222988   .1935271     1.15   0.249    -.1563182    .6022942

       lsize |   1.149085   2.363353     0.49   0.627    -3.483002    5.781171

       dfarm |  -.0437441   .0212253    -2.06   0.039    -.0853449   -.0021432

        dmkt |  -.2200864   .1277302    -1.72   0.085    -.4704329    .0302601

      credit |  -.7146096   1.348443    -0.53   0.596    -3.357509     1.92829

    agriexts |   1.039442   1.206747     0.86   0.389    -1.325738    3.404622

      ffexts |   1.128003   1.602912     0.70   0.482    -2.013647    4.269653

  climinform |   3.525619   1.243143     2.84   0.005     1.089104    5.962135

         TLU |  -1.575202   1.152308    -1.37   0.172    -3.833686    .6832807

       _cons |  -11.96066    7.23351    -1.65   0.098    -26.13808    2.216757

------------------------------------------------------------------------------

(adaptationstra== notadaptation is the base outcome)

Model mlogit_mfx (Marginal effects after mlogit)
-----------------------------------------------------------------------------------------
----------------
------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
notadaptat~n |
         sex |  -.0160653   .0619181    -0.26   0.795    -.1374225    .1052919
         age |   .0006316   .0015071     0.42   0.675    -.0023224    .0035855
         edu |  -.0206765     .01514    -1.37   0.172    -.0503503    .0089972
       fsize |  -.0082036   .0077341    -1.06   0.289    -.0233621    .0069548
    lnonfarm |  -.0633669   .0398586    -1.59   0.112    -.1414884    .0147546
  lnoffarm_1 |  -.0018078   .0076151    -0.24   0.812    -.0167331    .0131176
       lsize |   -.029437   .0933222    -0.32   0.752     -.212345    .1534711
       dfarm |   .0016204   .0007909     2.05   0.040     .0000702    .0031705
        dmkt |    .010638    .005172     2.06   0.040     .0005011    .0207749
      credit |   .0156203   .0331727     0.47   0.638     -.049397    .0806375
    agriexts |  -.0913255   .0854034    -1.07   0.285    -.2587131    .0760622
      ffexts |  -.0023821   .0415509    -0.06   0.954    -.0838203    .0790562
  climinform |  -.1341501   .0583691    -2.30   0.022    -.2485514   -.0197487
         TLU |   .0770651   .0474223     1.63   0.104     -.015881    .1700111
-------------+----------------------------------------------------------------
cropvariety  |
```

sex	.1177504	.2238137	0.53	0.599	-.3209164	.5564171
age	-.0075265	.0055416	-1.36	0.174	-.0183877	.0033348
edu	-.0062534	.0318913	-0.20	0.845	-.0687592	.0562524
fsize	.0682815	.0267058	2.56	0.011	.0159391	.1206238
lnonfarm	.0925637	.0957823	0.97	0.334	-.0951662	.2802936
lnoffarm_1	-.0047209	.0235789	-0.20	0.841	-.0509346	.0414929
lsize	.5757767	.2741934	2.10	0.036	.0383675	1.113186
dfarm	.00321	.0026743	1.20	0.230	-.0020317	.0084516
dmkt	.0029644	.0119812	0.25	0.805	-.0205182	.0264471
credit	.3395471	.1315627	2.58	0.010	.0816889	.5974054
agriexts	-.0569669	.170396	-0.33	0.738	-.3909369	.2770031
ffexts	.3393321	.1469112	2.31	0.021	.0513916	.6272727
climinform	-.1504481	.1075582	-1.40	0.162	-.3612584	.0603621
TLU	.3144343	.1338383	2.35	0.019	.0521161	.5767525
crop&lives~k						
sex	.0202619	.1530011	0.13	0.895	-.2796148	.3201385
age	.0006409	.0036843	0.17	0.862	-.0065802	.007862
edu	.0083887	.0195912	0.43	0.669	-.0300093	.0467868
fsize	.0001897	.017454	0.01	0.991	-.0340194	.0343989
lnonfarm	.0222862	.0624965	0.36	0.721	-.1002047	.1447772
lnoffarm_1	.0053425	.0136261	0.39	0.695	-.0213641	.0320491
lsize	-.3298284	.2005384	-1.64	0.100	-.7228765	.0632197
dfarm	-.003861	.002114	-1.83	0.068	-.0080044	.0002823
dmkt	-.0081209	.0069469	-1.17	0.242	-.0217366	.0054948
credit	.3767213	.172255	2.19	0.029	.0391076	.7143349
agriexts	-.0032035	.1304354	-0.02	0.980	-.2588522	.2524452
ffexts	.196016	.0564558	3.47	0.001	.0853646	.3066673
climinform	-.0431483	.0615366	-0.70	0.483	-.1637579	.0774613
TLU	.2394258	.0990908	2.42	0.016	.0452113	.4336402
soil&water~s						
sex	-.0481499	.2415212	-0.20	0.842	-.5215228	.4252229
age	.0078848	.0042655	1.85	0.065	-.0004755	.0162451
edu	.0082787	.0222989	0.37	0.710	-.0354264	.0519837
fsize	-.0316167	.0200542	-1.58	0.115	-.0709222	.0076889
lnonfarm	.1330875	.0769081	1.73	0.084	-.2838245	.0176496
lnoffarm_1	-.0126333	.0190814	-0.66	0.508	-.0500321	.0247656
lsize	-.2583824	.2517747	-1.03	0.305	-.7518517	.235087
dfarm	-.0001041	.0021231	-0.05	0.961	-.0042652	.0040571
dmkt	-.004753	.0096684	-0.49	0.623	-.0237028	.0141968
credit	.0496787	.1375759	0.36	0.718	-.2199651	.3193225
agriexts	.1614241	.1051701	1.53	0.125	-.0447054	.3675537
ffexts	.0915278	.1300395	0.70	0.482	-.163345	.3464005
climinform	.2525048	.0876819	2.88	0.004	.0806514	.4243582
TLU	.0018058	.1050641	0.02	0.986	-.204116	.2077276
irrigation						
sex	-.073797	.1279205	-0.58	0.564	-.3245165	.1769225
age	-.0016308	.00207	-0.79	0.431	-.0056879	.0024263
edu	.0102625	.0135591	0.76	0.449	-.0163128	.0368378
fsize	.0286509	.0122878	2.33	0.020	.0045673	.0527345
lnonfarm	.0816045	.0398412	2.05	0.041	.0035172	.1596918
lnoffarm_1	.0138194	.0087108	1.59	0.113	-.0032534	.0308922
lsize	.041871	.1032439	0.41	0.685	-.1604833	.2442252
dfarm	-.0008652	.001267	-0.68	0.495	-.0033484	.001618
dmkt	-.0007285	.0053937	-0.14	0.893	-.0112999	.0098429
credit	-.0281248	.0871436	-0.32	0.747	-.1989232	.1426735
agriexts	-.0099282	.0700155	-0.14	0.887	-.1471562	.1272997
ffexts	.0541705	.0511939	1.06	0.290	-.0461677	.1545086
climinform	.0752417	.0575159	1.31	0.191	-.0374873	.1879707
TLU	-.0038623	.0456752	-0.08	0.933	-.093384	.0856594

Appendix E: Survey Questionnaire

My name is Kide Gebru. I am writing a thesis entitled "Smallholder Farmers' Perception and Adaptation Strategies to Climate Change in Ethiopia" in partial fulfillment for MSc in Resource and Environmental Economics. The objective of this study is to identify and assess determinants farmer's perception and adaptation decision to climate change. Confidently this research has a significant contribution in an effort to reduce the climate change relate problems of the farmers of this Woreda especially. Therefore, your valid contribution by giving accurate information is highly valuable in achieving the objective of this research. The information we will collect from you will serve only the academic purpose and it will be kept confidential. Thus, please feel free to convey the required information honestly.

Thank you in advanced for your cooperation.

General Directions

- Put (**x**) marks in space provided for closed-ended questions and write your response on space provided for open ended questions.

Part I. Supportive Information

i. Name of interviewer: .... Code.............

ii. Date: ..../......../............ Time spent for interview: From............to............

iii. Name of respondent...ID.code

iv. Name of Kebele: ....

v. Agro-ecological Zone; Woina-dega ☐ Dega ☐ Kola ☐

Part II. Questions on Household Head Demographic Characteristics

1. Gender of the household head: Male ☐ Female ☐
2. Age of the household head (in years)...........................
3. Marital status: a) Married: b) Single; c) divorced: d) widowed: e) Other (specify)_________________
4. Educational level of household head

   Illiterate ☐ Literate ☐
5. The highest level of formal education completed if the household head is literate.....................
6. Number of total family members: Male............ Female.................

7. Number of active household members aged between 15-64 years

   Male............ Female.................

8. Farm experience of household head----------------------

9. Dear respondent! The followings are indicators of good personal characteristics. Please tick as much as it explains your characteristics.

   i. Sociability/good social interaction ☐
   ii. Cooperative ☐
   iii. Mediator in case there is disputes/disagreement within society ☐
   iv. Positive thinkers/Open mindedness ☐
   v. Other specify...

Part III. Questions on Household Head Socio-economic Characteristics

10. Farming system you follow currently

   i. Crop production only ☐
   ii. Livestock rearing only ☐
   iii. Mixed farming ☐ iv. Others (please specify).................

11. How much income can you generate from your farming activities during last production year (i.e., Tir 1, 2005E.C to Tahisas 30, 2006 E. C)? Please specify in Birr:

   i. From crop production..............................
   ii. From selling livestock and livestock products..............................
   iii. Selling of fruits and vegetables...
   iv. Others (please specify)...

12. Do you/any members of your family has any sources of non-farm income i.e. income from remittance, petty trade, employment in government or private enterprise, etc?

   Yes ☐ No ☐

13. If yes to the above question, how much money you/your family make during last production year (i.e., Tir 1, 2005E.C to Tahisas 30, 2006 E. C)from off-farm activity? Please specify in Birr: ....

14. How much is your total expenditure during last production year(i.e., Tir 1, 2005E.C to Tahisas 30, 2006 E. C)? Please specify in Birr: ....

15. Total farm land operated including any grazing land (including rented land and excluding rented out land) during last production year_(in hectares)___________

Size of land rented in ____________ Size of land rented out___________

16. Do you have certificate for your land? Yes ☐ No ☐

17. What are the physical characteristics of your farm, in terms of its exposure to erosion?

Susceptible to erosion ☐ moderately susceptible to erosion ☐

Not susceptible at all ☐

18. How is the fertility of the soil of your farm in general?

Very fertile............... Moderate................ Poor/ infertile

If you have more than one plot, answer the following questions

a. plot 1: (a) Highly fertile __ (b) Fertile __ (c) medium__ (d) low _

b. Plot 2: a) Highly fertile __ (b) Fertile __ (c) medium__ (d) low__

c. Plot 3: a) Highly fertile __ (b) Fertile __ (c) medium__(d) low ___

19. How long does it take to reach your farm from your home? In case you have more than one plots take its average distance and/or time. (Specify one way only):

Distance (in KM)..................... In terms of time it takes (in min).........................

20. How many quintals of yield have you harvested per hectare in 2005 E. C?

Maize........................... Wheat.......................

Teff............................ Barley.......................

Bean/pea................ Others (specify if any)............................

21. Do you have any communication devices like TV, radio, mobile phone, so on?

Yes ☐ No ☐

22. If your answer for question 20 is "Yes" what types of communication devices you have?

TV ☐ Mobile Phone ☐ Radio ☐ others specify......................

23. Dear respondent! How many of the following types of livestock do you have? Please fill in the head count column.

s/no.	Types of livestock	Head count
1	Cattle	
2	Calf	
3	Oxen	

4	Horses	
5	Donkey	
6	Camels	
7	Goats	
8	Sheep	
9	Poultry	
10	Beehives	
11 (others)		

Part IV. Questions on Institutional Factors

24. How far the market where you buy your agricultural inputs is (e.g. hoes, seeds, fertilizers, etc)?

Distance in KM............ ……… In terms of time it takes (in hour)................

25. How far is the market where you sell your agricultural outputs?

Distance in KM..................... . In terms of time it takes (in hour)..................

26. In undertaking your usual farming activities have ever faced shortage of finance? For example to purchase agricultural inputs like fertilizer, oxen, and others

Yes ☐ No ☐

27. Do you have access to any formal credits (DCSI) in time face shortage of money?

Yes ☐ No ☐

28. Do you have access to any informal credits (from neighbours, friends, relatives etc)?

Yes ☐ No ☐

29. If yes to '26&27' where you look for credit to fill your financial constraints? More than one choice is possible. From:

Relatives ☐ Friends ☐ Non-formal money lenders ☐

Microfinance Institutes ☐

30. Do you have access to agricultural extension services in your kebele?

Yes ☐ No ☐

31. Do you receive any support from agricultural extension which could help improve your farming activities?

Yes ☐ No ☐

32. Please specify any kind services you get from them.

....

……………………………………………………………………………………

33. Have you ever got any kind of formal training which helps improve your farm productivity? This might be how to (protect soil from erosion, conserve rain water, use modern agricultural inputs, reduce post harvest loss, etc)

Yes ☐ No ☐

34. Did you have non-formal training of the above kind from farmers or did you give training to other farmers in your locality? (Farmers-to-farmers extension services)

Yes ☐ No ☐

35. If yes to '32 & 33' how do find it in terms of its contribution to improve your farming income?

Very important ☐ important ☐ Has no effect ☐

Part V. Questions on Perception of Climate Change and Adaptation Methods Employed

36. Comparing the 1990s with the recent past 15years i.e. 2005s, have you perceive any changes in climate? Yes ☐ No ☐

37. Comparing the 1990s with the recent past 15 years i.e. 2005s, have you noticed any changes in the rainfall patterns? Yes ☐ No ☐

38. If yes, please specify the pattern of the change in rainfall you have noticed.

Increasing ☐ Decreasing ☐

39. Comparing the 1990s with the recent past 15 years i.e. 2005s, have you noticed any changes in temperature? Yes ☐ No ☐

40. If yes, please specify the pattern of the change in temperature you have noticed.

Increasing ☐ Decreased ☐

41. Dear respondent please fill the following if you are experienced with it.

no.	Have you experienced with the following types of climate change and variability indicators?	Response		How often? (in past decade)
		Yes	No	
1	Drought			

2	Floods			
3	Off-seasonal rainfall			
4	Too much rain			
5	Too little rainfall			
6	Higher temperature			
7	Frost (coolness)			
8	High winds			
9	Others (specify			

42. Have you observed the following climate change related impacts in last decade?

no.	Climate change related impacts	Yes	No
1	Decline in crop yield		
2	Increase in crop yields		
3	Decline in livestock yields		
4	Increase in livestock production		
5	Death of livestock due to shortage of fodder and water		
6	Food shortage /insecurity		
7	Increased weed and pest pressures		
8	Communicable diseases		
9	Decrease of water quality and quantity		
10	Higher risk of crop damage from drought		

43. In response to climate change, have you taken any adaptation measures in order to reduce the impacts of climate change? Yes ☐ No ☐

44. If your answer to question no. 42 is no, why?

No.	Reasons for not taking adaptation	Yes	No
1	Lack of information		
2	Lack of capital		
3	Lack of knowledge		
4	Shortage of farming land		
5	Not observing the climate related problems		

6	Giving less emphasis to climate change problems		
7	Others		

45. If Yes to question no.43, have you employed any of the following climate change impact adaptation strategies in your farm in past decades?

No.	Climate change adaptation	Response		If no, please specify the reason why not?
		Yes	No	
1	Buying insurance			
2	Change crop variety			
3	Mixed farming			
4	Temporary migration			
5	Planting early maturing crop			
6	Soil and water management			
7	Planting trees			
8	Irrigation			
9	Changing planting dates			
10	Seek off-farm employment			
11	Reduce number of livestock			
12	Others (specify if any			

46. In the past two years do you received any agricultural technical support from the Government in implementing adaptation? Yes ☐ No ☐

47. If yes, what kind of technical support do you received in your effort to reduce the impacts climate change and improve your farming system? Please list

i. ……………………………………………………...............................

ii. ....

iii. …………………………………………………………………………

48. If no, what kind of support would you want to receive? Please list

i. ……………………………………………………....................................

ii. ……………………………………………………...................................

iii. ……………………………………………………………………………

49. Do you have access to climate information?

Yes ☐ No ☐

50. If question no. 48 No, please specify the reason…………………………………………………………………………………
………………………………………………………………………………………
……………………………………………………………………………..

51. What do you suggest to be done to reduce the impacts of climate change in yours woreda?
....
....
……………………………………………………………………………………

52. I have selected four climate change adaptation strategies. Thus, as stakeholders please select one adaptation strategies to climate changes which is the most comfortable for implementation in your farm.

Option	Adaptation strategies	Description
1	Different crop varieties	This means that farmers could change the date of planting crops with respect to the change in the climate (early or late planting).
2	Improving crop and livestock	This includes planting of short duration crop, drought tolerant crop and improved livestock variety both for milk and meat and etc.
3	Farming, soil and water conservation	Includes soil erosion preservation, management and care of soil in order to make it suitable for their crops, dam construction, conservation of rain water for watering the crops in times too little rain, ground water harvesting , etc
4	Irrigation	Includes irrigation development from rivers or lakes in order to cope up with the challenges of climate change.

Now using the above given adaptation strategies, please specify the best one adaptation strategies from listed above. ………………………….........................

Thank You!