SMALL HOLDER FARMERS' PERCEPTIONS AND ADAPTATION STRATEGIES TO CLIMATE CHANGE: THE CASE OF SHEBEDINO WOREDA, SIDAMA NATIONAL REGIONAL STATE

MSc. THESIS

DEGEFU DAFURSA NARAMO

HAWASSA UNIVERSITY, HAWASSA ETHIOPIA

JULY, 2021

HAWASSA ETHIOPIA

CLIMATE CHANGE: THE CASE OF SHEBEDINO WOREDA, SIDAMA NATIONAL REGIONAL STATE.

MSc. THESIS

DEGEFU DAFURSA NARAMO

MAJOR ADVISOR: - ZENEBE WORKU (PhD)

CO- ADVISOR:-TESHOME KASSAHUN (MSc)

A THESIS SUBMITTED TO THE DEPARTMENT OF CLIMATE CHANGE AND SUSTAINABLE AGRICULTURE FACULITY OF ENVIRONMENT, GENDER AND DEVELOPMENT STUDIES, COLLEGE OF AGRICULTURE, SCHOOL OF GRADUATE STUDIES, HAWASSA UNIVERSITY, HAWASSA ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF THE MASTER OF SCIENCE IN CLIMATE CHANGE AND SUSTAINABLE AGRICULTURE

JULY, 2021

HAWASSA ETHIOPIA

ADVISORS'APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

This is to certify that the thesis entitled **"Smallholder Farmers' Perceptions Adaptation Strategies to Climate Change Effect: The Case of Shebedino Woreda, , Sidama National Regional State"** submitted in partial fulfillment of the requirements for the degree of master's with specialization in climate change and sustainable agriculture the graduate program of the faculty of Environment, Gender and Development studies, Collage of Agriculture and has been carried out by Degefu Dafursa IDNO PGSCCSA/006/10 under my/our supervision. Therefore we recommended that the studies that the student has fulfilled the requirements and hence hereby can submit the thesis reports to the department

_____ _____

Student Name Signature Date

Approved by:

_____ _____

Name of Major Advisor Signature Date

DEDICATION

The thesis dedicated to all my beloved family for their constant support, encouragement and unfailing love.

STATEMENT OF AUTHOR

I declare that this thesis is my work and all sources of materials used for this thesis have been duly acknowledged. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Name: Degefu Dafursa Naramo **Signature**……

Place: Hawassa University, College of Agriculture, Hawassa

Date of Submission……

ACKNOWLEDGEMENTS

First of all, I praise God the almighty for allowing me to make my dreams come true after a very difficult journey and a burdensome effort. Secondly, I express my deepest gratitude to my advisors, Zenebe Worku (PhD) and Teshome Kassahun (MSc) for their comments on the main idea of the thesis work at an early stage of the work and for his immeasurable advices throughout the whole work of this thesis. I could say that no words can express his assistance and supervision throughout my thesis work.

I am very glad to acknowledge the sample households for their willingness and patience in responding to my questionnaire at the expense of their invaluable time. Had they not extended their cooperation, it would have been impossible to complete this thesis.

I also extend my grateful thanks to those friends Mr, Eyasu Tadesse, Zenebe Bute, and Shemelis Temesgen , for their kindness in supporting what I need. In the last but not least, I thank my brother: Desalegn Chachu for his direct and indirect support throughout my study.

ABREVIATIONS

CSA	Central Statistical Agency
FGDs	Focus Group Discussion
GDP	Gross Domestic Product
GEC	Global Environmental Change
GHGs	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
NAPA	National Adaptation Program
NGOs	Non-Governmental Organization
NMSA	National Meteorological Services Agency
SNNP	Southern Nations Nationalities and Peoples
UNFCCC	United Nation Framework Convention on Climate Change
WFP	World Food Program
WMO	World Meteorological Organization

TABLE OF CONTENTS

Contents
Pages

LIST OF TABLES

Table Pages

LIST OF FIGURES

Figures
Pages

TABLES IN APPENDIX

Appendix Pages

Smallholder Farmers' Perceptions and Adaptation Strategies to Climate Change: The Case of Shebedino Woreda, Sidama National Regional State of Ethiopia.

By: Degefu Dafursa Naramo

Major Advisor: - Zenebe Worku (Phd)

Abstract

Climate change remains a major threat for smallholder living and sustainable management of natural resources in Ethiopia. Adaptation strategies vary contextually and spatially within communities and even among individuals, so that a given adaptation measures do not necessarily translate from one area to another area. The present study was an attempt to understand and document the smallholder farmers' perception and adaptation strategies to climate change in Shebedino Woreda of Sidama National Regional State. The study employed mixed design which was carried-out by using qualitative and quantitative descriptions. A multistage sampling procedure was used to select 145 study samples and data were collected through household survey, focus group discussion, and key informant interview. Data were analyzed using descriptive statistics, and multinomial logistic regression model. The results revealed that majority (84.02 and 78.31%) of the studied farmers in Woina-Dega and Dega agro-ecological zones respectively were well aware of the existence of climate change in their locality. In association with climate change the farmers of Woina-Dega and Dega agro-ecology has experienced rainfall has decreased, increasing temperature, extended dry season lead to drought, dry spell frequency increased, increase in pests and disease infestation as a result of high humidity, heavy wind which can affect the field crop, drying of rivers and streams, and distortion and destruction of wildlife ecosystems as a result of deforestation. Among the underling factors to which such a change is attributed to includes the change in state of climate has resulted in reduction of livestock productivity, low crop productivity, less pasture/grass for livestock ,crop failure, increased competition for fertile land, increasing scarcity of natural resources (change in forest and biodiversity), abandonment of traditional activities, loss of income, change in water availability for crop and livestock, and increased rural-urban migration for the farmers of Woina-dega and Dega agro-ecological zones. The study reveals that small holder farmers are adjusting their self to the perceived impacts of climate change. The adaptation strategies used were: drought tolerant crop varieties/livestock species,

change in livestock variety (herd diversification) , change in crop diversity ,agroforestry as farming system which comprises: crop, livestock production and tree planting, implementing soil and water conservation, engaging in off-farm and non-farm activities, using irrigation and changed land-use practices such as crop rotation, and shifting cultivation were the important adaptation strategies used by farmers in Woina-Dega, and Dega agro-ecological zones of Shebedino woreda though extent of using each strategies differ by farmers in both agro ecology. The marginal results of MNL model revealed that farmers' capacity to choose effective adaptation options is influenced by sex, age, family size, farm size, livestock holding, access to credit support, extension service, and information related to climate change. From the results, it is recommended that agricultural extension services, up to date climatic information, training of improved farm technology adoption and infrastructural building should be enhanced to sensitize farmers about climate change thus improving their perception and adaptation strategies.

Key words: Adaptation Strategies; Agro ecology, Climate Change, Perception, Multinomial Logistic Model

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The threat of global climate change has caused concern among scientist's regarding livelihoods, agricultural production and food security of the smallholders could be severely affected by changes in key climate variables(Kichamu *et al.,*2018). Climate change is caused by both natural factors such as cycles and trends in the Earth's orbit, incoming solar radiation, the atmosphere's chemical composition, ocean circulation, the biosphere and volcanic eruption and much more, human induced causes like extensive use of land, widespread of deforestation, the major technological and socioeconomic shifts with reduced reliance on organic fuel, and the accelerated uptake of fossil fuels that increases the emission of greenhouse

gases concentration in the atmosphere (Temesgen *et al.,* 2014). In fact it is not a new phenomenon, but the warming that is occurring today is unparalleled with respect to the rate of change.

Fifth assessment report of Intergovernmental Panel on Climate Change (IPCC, 2014) indicates that the least developed countries (LDCs) have contributed the least to the emission of greenhouse gases but the impacts of climate change are expected to be more pronounced in the developing countries particularly in Sub-Saharan Africa because of their livelihood is dependent on nature which is highly sensitive to climate change. African countries are prone to greater impacts of this change/variability in climate partly because of lack of awareness and adaptive capacity. Smallholder farmers make significant contribution towards food in security sub- Saharan Africa producing up to 80 percent of the food (IFAD, 2013; AGRA, 2014). In Kenya, Ethiopia, Uganda and Tanzania, for example, smallholder agriculture accounts for about 75 percent of agricultural production and over 75 percent of employment (Salami *et al.,* 2010).

Ethiopia is one of African countries, which is vulnerable to climate variability due to its great reliance on climate sensitive sectors, particularly agriculture (Cohn *et al.,* 2017). The impact of climate change in Ethiopia is highly pronounced because agriculture is expected to play a key role in ensuring food security and acts as the backbone of the country's economic development (Aklilu and Dereje, 2010). Despite its high contribution to the overall economy, this sector is challenged by multitudes of factors of which climate related disasters like drought and flood, which often

causes famine, are the major ones (Megersa *et al.,* 2014).

The speed of climate change is inducing and modifying known variability patterns beyond the coping capacity of systems (Bryan *et al.,* 2013). The increasing frequency and magnitude of extreme weather events coupled with unprecedented changes in the climate is also imposing new and potentially overwhelming pressure on the capacity of existing adaptation strategies (Tessema *et al.,* 2013). Therefore, deliberate and conscious adaptation that can cope with these evolving impacts is an immediate concern in agriculture. Particularly in countries like Ethiopia, where agriculture is highly tied with climate, adaptation is a priority measure.

Adaptation is critical and necessary in developing countries, especially in Ethiopia, where the fact that vulnerability is high (Zander, 2011).It is necessary that climate change adaptation is not separated from other development priorities but is integrated into development planning, programs and projects (Yibekal *et al.,* 2013). In the near past, the community is severely challenged by the negative impacts of climate change and the ability to endure these changes is constrained by technical, institutional and financial capacity (Ayana *et al.,* 2011). The government of Ethiopia has taken up the issue of climate change, and adaptation in particular, as a priority agenda in the transformation of the nation's agriculture. In line with the national food security macro-level initiatives, the government is pursuing different adaptation strategies such as operationalizing of agro-weather advisory service extension at full blast and response mechanism, safety net programs and natural resource management (EPCC, 2015).

Adaptation to climate change requires that households first appreciate that climate has changed, identify useful adaptation options and choose among a wide range of adaptation strategies. This therefore, makes households within the same geographical location to use difference adaptation strategies in response to climate change and variability.

1.2 Statement of the Problems

Climate change is the major environmental challenges which face societies in the world. The

poorest countries and the poorest peoples are suffering more than the others, even though their contribution for the change is minimum, (WMO, 2016 and UNEP, 2012). This is because, the economic activities of these countries are mostly depends on natural resource which, are susceptible to climate change.

In Ethiopia too, climatic and ecological changes caused by global warming have resulted in several negative consequences on people's health, economy and livelihoods (Zegeye, 2018)). More importantly, in Ethiopia, the problem is exacerbated by low production and crop loss that mainly caused by low and irregular rainfall among others. Agricultural production is predominantly depending on rainfall. This has made the country's agricultural-based economy extremely fragile and vulnerable to the impacts of climatic variability which often results in partial or total crop failure and subsequent food shortages.

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 (Belay *et al.,* 2017). Similarly, knowledge of the adaptation methods on the side of smallholder farmers may make it better to tackle the challenge of climate change (Bassett, and Fogelman. 2013; Deressa *et al.,* 2009).

Adaptation strategies vary contextually and spatially within communities and even among individuals, so that a given adaptation measures do not necessarily translate from one area to another area (Temesgen *et al*., 2009; Belaineh *et al*., 2013). The capacity to adapt to climate change is unequal across and within societies. Adaptation responses are underpinned by common enabling factors. These include effective institutions and governance, innovation and investments in environmentally sound technologies and infrastructure, sustainable livelihoods and behavioral and lifestyle choices (IPCC, 2014). The agro-ecological setting of farmers also influences the perception of farmers to climate change. According to UNEP (2012), addressing adaptation practices to specific societies or communities may make it possible to offset the adverse impact of climate change.

Sidama's rural livelihoods are at risk due to several factors, an important one being climate change. Climate conditions in the Dega have gradually converted to Woina-dega conditions while the lowlands are transforming into semi-desert conditions. The study area, Shebedino area, is recognized as one of the climatic shocks like as other regions/districts in Ethiopia and has been experienced drought and excessive flooding for several years (Derese, 2018 and SHWEWR, 2019).

As a result, the area is characterized by seasonal failure of crop yields, as well as, long term reduction of agricultural productivity, feed shortage and shortage of potable water. However, there is no empirical findings in detail that shows to what extent the smallholder farming communities and households in Shebedino district are perceiving and responding to mitigate the impact of such changes in their livelihood makings. Therefore, this study mainly focused on smallholder farmers' perception and adaptation strategies to climate change in the study area.

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of this study is to analyze smallholder farmers' perception and adaptation strategies to climate change in the study area.

1.3.2 Specific objectives

i. To examine the existence of climate change;

ii. To identify smallholder farmers' adaptation strategies to climate change;

iii. To determine factors affecting smallholder farmers' adaptation strategies choice to climate change in Shebedino woreda ,Sidama National Regional State.

1.4 Research Questions

- How do smallholder farmers perceive climate change in your area?
- What climate change adaptation strategies have been adopted by smallholder farmers?in the study area?
- What factors influence small holder farmers' the choice of adaptation strategies in

response to climate change?

1.5 Significance of the Study

A research is a systematic way of acquiring new thing and knowledge, and informs the decision makers what to do. This study examined major adaptation strategies to climate change and factors that affecting the farmers' choice of adaptation strategies. The finding of this study could contribute to the strength the existing information regarding the topic and helps to conduct further interventions in the area of study. The study is also expected to contribute contextualized new body of knowledge pertinent in planning and implementation of development intervention towards minimizing the impact of climate change particularly on the livelihood making of smallholder farmers in the area.

1.6 Scope and Limitation of the Study

This study was limited to one woreda administration, three kebeles and 145 respondents. The data of the study was be based on a cross sectional survey. The aim of study focused on assessing the major adaptation strategies to climate change and the factors affecting farmers' choice in the study area. The researcher encountered a number of problems during data collection period. One of the main problems was inaccessibility of respondents because they engaged in different social duties and marketing activities. Moreover, inaccessibility of roads in the community has constrained the transportation facilities and I was enforced to walk longer distance on foot. This made the data collection process longer than it was planned.

1.7 Organization of the study

The study is organized into five parts. Chapter one provides the introduction, problem

statement, objectives, justification and scope of the study. Chapter two gives an overview of

literature relevant to the study. Chapter three outlines the methodology employed to achieve

the objectives of the study. Chapter four presents the results and discussion. Chapter five highlights the conclusion and recommendation of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1. Theoretical and Conceptual Review

2.1.1. The Concept of Climate Change

Climate change refers any change in climate over time through natural variability or as a result of human activities (IPCC, 2012).Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2014).

Climate, however, is only one factor within the dynamic earth system. Changes in the physical and biogeochemical environment, either caused naturally or influenced by human activities such as deforestation, fossil fuel consumption, urbanization, land reclamation, agricultural intensification, freshwater extraction, fisheries over-exploitation and waste production, contribute to global environmental change (GEC), (CCAFS, 2009).

Peoples are experiencing the significant impacts of climate change, which include changing weather patterns, rising sea level, and more extreme weather events. The greenhouse gas emissions from human activities are driving climate change and continue to rise. Therefore Climate change requires an urgent international response. Governments, industries, communities and organizations across the

globe are working together to develop and implement measures to reduce greenhouse gas (GHG) emissions and avoid dangerous climate change (office of climate change, 2010).

Climate change may be due to natural processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.The Global warming is defined in the terms of a regular raise in the average temperature of the earth's atmosphere and it's on the oceans, shifting the earth climate situation. The scientist from intergovernmental panel were established on climate change associated to global warming is that the average temperature of the earth has increase between 0.4 and 0.08ocover the past 100 past years ago. in addition to that, the increased carbon dioxide and other greenhouse gases are out by the burning of fossil fuels, land clean-up, agriculture and other human process are believed to be the primary sources of the global warming that has happened over the past 50 years (IPCC, 2007).

The World Meteorological Organization (WMO, 2016) and IPCC (2014) states that the concentration of carbon dioxide has increased from 280 parts per million (ppm) in the preindustrial times (1750s) to 370 ppm at the present this has lead the global climate change in to dangerous conditions and it is expected that, with the present tendency, the concentration will range between 540 and 970 ppm and also the global temperature could be increase between 1.4 and 5.4^{o}c in the year 2100.

Other studies, for instance (UNFPA *et al.,* 2011) noted that the importance of smallholder agricultural growth for poverty reduction through its impacts on labour

and grain markets. On the other hand, smallholder farmers and Poor farmers in particular lack assets, social networks, mobility, and political power, commonly Cited as being critical for adaptation (Zegeye ,2018).These conditions are compounded by limited information available for adaptation decision-making (Including poor climate information from meteorological records, limited dissemination, and low Scientific understanding of climate change and its impacts on development), weak institutions and governance (including unclear mandates, weak planning systems, un-inclusive service delivery, and a lack of accountability or participation in decision-making), and lower resources with which to respond (Abid *et al.,* 2015).

2.1.2 Theoretical Approaches Regarding Climate Changes

Now-a-days, under these conditions, climate changes are mostly regarded as a threat upon mankind rather than as a threat on specific and limited human collectivity as countries and nations. When we generally speak about climate changes as a security problem, a question arises in terms of what is being represented as a referent object for climate protection. If we look back at the conditions in the beginning of the 90s in the previous century, that are related to the climate regime which has been developing in the context of the Convention for climate changes at the UN since 1992, it will be noticed that it has been created as a response to the public and scientific concern who dates back from the 80s in the past century. Climate changes are viewed as a “degree of a natural change”, degree which could be initiated from different parameters, amongst which are the temperature, the amount of rainfall, the frequency and intensity of extreme weather

occurrences (events) etc. Hence, a question has been asked to what degree of climate changes could the ecosystems and the social activities arise, before the condition becomes threatening? According to Pielke there are two general strategies that serve as an answer to the climate changes. It is about a strategy for alleviating and accommodation (Kirton *et al.,* 2014).

This research from today's perspective of apprehension from the conditions about the climate changes will constitute the mosaic of the numerous contemplations and researches for this subject which are in direction of raising the reason of the dangers that come out of the climate changes and the alertness in term of creating and practicing measures and activities in direction to what nowadays is called "climate security" Imbach *et al.,* 2017

Climate changes cause different effects on the population. The most exponent problem surely is the health condition. There are numerous works that treat this kind of discourse and also large number of countries has adopted proper legal and normative acts that treat the phenomenon - climate change. More and more decisions are drawn on global levels that treat the relations between the climate changes and health. Such are "The declaration for the climate changes and health" carried out and signed in 2016, "the Minister's declaration of health, environment and climate changes" also from 2016 which is a product from the 22nd session of the Conference of the Parties to the UN Framework Convention on Climate Change (UNFCCC COP 22) in Marrakech on 15 of September 2015. Next is "The Declaration from Doha for climate, health and welfare" from 2012, as well as "the Declaration of Delhi for health and climate changes", adopted on the 60-th General congress of the

World's medicine association in 2009. A "National strategy for adaptation in the health sector" has been reached as an answer to the world's trends related with health and climate changes in the Republic of Macedonia UNFPA *et al.,* 2011.

Special and scientific literature is more focused on research which is related with health and climate changes in the context of global ruling. Thereto, a new complex is apostrophed on mutually connected challenges which affect health and capacities on the global ruling for realistic and timely answer. There at the global ecological determinants are specifically highlighted in comparison with the more familiar socio-economic determinants UNEP, 2012.

Climate changes manifested through the process of warming on large scales will influence many aspects of human's life, because they will make changes on the temperature and rainfall, growth of the sea level and the changes in the distribution of fresh water. Among many of the effects that will be made out of these conditions, surely the productivity of agriculture will be affected. Numerous scientific studies which served as a reference literature in this research are already pointing on such consequences in agriculture. An interesting research for climate changes and agriculture are making Anita Wreford, Dominic Moran and Neil Adger in their report for "Climate changes and agriculture influences, adaptations and alleviating" published by the Organization for economic collaboration and development (OECD). In this report, concretely are analyzed the projected influences of the climate changes in the agricultural sector, the solution for these influences through the strategies for adaptation and alleviation (UNFCCC, 2016).

It is worth to mention that the developing countries, especially the poorest, are very

dependent from agriculture, which is the climate's most sensitive from all the sectors in the economy and they suffer from inappropriate health and public services followed with low quality. Thirdly, their low income and vulnerability make the adaptation of climate changes especially difficult [IPCC, 2014].

Poverty and spreading of diseases are also a serious problem as a consequence from the climate changes. Poverty is closely related with agriculture activities. Decreased yielding and income on agriculture will increase poverty and will decrease the capability of households to invest for better future, forcing them to use the humble savings only to survive. On a national level, climate changes will decrease incomes and will increase spending needs exacerbating the public finances (WFP, 2013).

The concept of tenable development, climate changes and poverty represent urgent themes who demand stakes related to countries, regions and communities. Hence, there are numerous scientific and expert works which articulate the dynamic relation between the two possibly central global concerns: poverty and climate changes (World vision, 2015).

Periodical fluctuations, as well as the seasonal and yearly climate variable, cause appearance of many infective diseases. The characteristics of geographical distribution and seasonal variations of many infective diseases are a key proof for the relation between time and climate. Many scientific studies point to the fact that temperature, rainfall and humidity have an impact on many diseases and that is why they can potentially make an impact on time and the intensity of the appearance of different epidemics. However, spreading of the diseases is also dependent on

factors such as sewerages and public services for health, population density and demographic characteristics, changes in using of the land and travel destinations (Jotzo *et al.,* 2012).

Automobile industry is a remarkably significant sector which has a noticeable contribution in the production of CO_2. Nowadays orientation of the massive automobile producers is on the direction of finding a way to reduce the production of carbon dioxide through innovative solutions. These solutions refer to the hybrid technologies, gas-electronic and diesel-electronic engines which produce less exhaust gases or a complete transition towards electrification on the machinery of the automobiles i.e., producing automobiles which would use hydrogen as operative fuel and would only emit aquatic steam as exhaust fumes. In that context, alternative operative fuels such as the liquid oil gas should be mentioned which has an advantage regarding the emissions of carbon dioxide over the gas engines but not over diesel engines. Methanol also has a specific useful value but is not widely used because of its own corrosiveness and toxicity(Backstrand *et al.,* 2012).

Raising the awareness of climate changes and the consequences emerging out of those changes is a serious issue and needs a special attention to be devoted on it. In that context, non-governmental organizations, state institutions and academic establishment have their own place in the process of alleviating and dealing with the consequences that emerge from the climate changes. Especially, the place that belongs to the non-governmental organizations should be noted which can have diverse character. Namely, their role in the domain of the climate changes is in the process of monitoring and implementation of international agreements and also in

the process of organizing and development of projects and their significance in the presentation and education of the civil society. This way positioned, with clear and concrete obligations, mission non-governmental organizations are respected from the international organizations as well as the national governments. Larger parts of the agencies at UN collaborate with the non-governmental organizations and that is why they play a serious role in the numerous conventions for the environment (UNFCCC, 2016).

2.1.3 The Impacts of Climate Change

Climate change which manifests itself as a change in rainfall patterns and temperature adversely impacts the economic and social survival of the majority of the population in Africa and particularly in sub Saharan Africa. The major sources of livelihood for rural poor in Africa such as water resources, agriculture (crop production and animal husbandry), health, ecosystems and biodiversity, forestry and coastal zones are the most vulnerable areas or sectors to climate change. Climate change remains a major threat for food security and sustainable management of natural resources. Studies indicated that if adequate measures are not taken to cop up the impacts of climate change in sub-Sahara Africa, there will be a predicted loss of 2-7% of GDP by 2100 in parts of sub-Sahara Africa; 2-4% and 0.4-1.3% in West and central Africa, and northern and southern Africa respectively (FAO, 2009).

Sub Saharan Africa is among the most vulnerable regions to climate change impacts due to the fact that the majority of the population highly dependent on rain-

fed agriculture for their economic activities as well as for sustenance of their livelihood (Juana *et al.,* 2013). The poor performance of the agriculture sector and rapid population growth, in combination with the adverse impacts of climate change causes the large segment of the sub-Sahara African population to live in abject poverty. If the current trend continues to lead to significant long term changes in rainfall patterns and temperature, which affect agriculture, it is highly likely that this situation will lead to significant reduction in food security, worsening water security, increase in animal and crop pests and disease infestation, among others (African Partnership Forum, 2007).

The impact of climate change on agricultural production is not uniform across regions of the world; low latitude and developing countries are expected to suffer more, reflecting their disadvantaged geographic location, greater agricultural share in their economies, and limited ability to adapt to climate change (Zhai and Zhuang, 2009; Newton *et al.,* 2010). It affects agricultural production and productivity both directly and indirectly. It directly affects agriculture by affecting the weather variables such as temperature, solar radiation, rainfall, wind speed and humidity (Sowunmi and Kintola, 2009) and indirectly through disease and pest outbreak as well as favoring the development of climate related diseases like malaria that affect the workforce (Ngigi, 2009). Newton *et al.,* (2010) also indicated that climate change affects the complex interactions between crop and pathogens leading to increased outbreaks of pests and diseases. The concern of food security and climate change in the developing world would be threatened due to anticipated to experience significant change in temperature and rainfall patterns, their developing

economy heavily relays on climate sensitive business and they totally depend on agriculture as a source of food, which seriously affected by climate change (Newton *et al.*, 2010).

Agriculture is ranked as the most susceptible sector to climate change impacts and so do the livelihoods of subsistence farmers and pastoralists (Melissa *et al.,* 2017) Climate change exerts multiple stresses on the biophysical as well as the social and institutional environments that impacts agricultural production. Its impacts disproportionately affected (Tessema *et al.,* 2013). Sub-Saharan African countries such as Ethiopia because their economies are highly dependent on climate-sensitive activities such as rain-fed agriculture. Some of the induced changes are expected to be immediate, while others involve gradual shifts in temperature, vegetation cover and species distributions. Climate change is expected to and in parts of Africa has already begun to alter the dynamics of drought, rainfall and heat waves, and trigger secondary stresses such as the spread of pests, increased competition for resources, and biodiversity losses (Thornton *et al.*, 2015).

2.1.4 Adaptation to Climate Change

Adjustment in natural or human systems is response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptations can be distinguished such as anticipatory, autonomous and planned adaptation (IPCC, 2007). According to UNFCCC adaptation is defined as 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.

2.2. Review of Empirical Findings

2.2.1 Climate Change in Ethiopia

Ethiopia is highly vulnerable to the impacts of climate variability and change. Its agriculture is heavily dependent on natural rainfall, with irrigation agriculture accounting for less than 1% of the total cultivated land (Temesgen *et al.*, 2009.). Thus, temperature, the amount and temporal distribution of rainfall and other climatic factors during the growing season are key determinants to the crop yields. Smallholder farmers and pastoralists are already feeling these impacts in their food security and livelihood opportunities (Oxfam International, 2011).

Ethiopia ranks 10th in the list of countries most at risk of climate change in 2014, according to the climate change vulnerability index, prepared. The low-level of development and dependence on agriculture are the main reasons for this vulnerability (WFP, 2013). Climate variability and extreme events (drought and heavy rains) are causing significant damage to life, property, natural resources and economy in Ethiopia; making the

most
important economic systems highly vulnerable (EPCC, 2015). This is because 90% of rural
households rely on agricultural activities (livestock, crop production, or a combination of
the two) as the main occupation of their household head and irrigation coverage levels are
very low (WFP, 2013).

The Climate Trend Analysis of Ethiopia which is built by US Geological Survey, USAID and the Famine Early Warning Systems raise out that there is a main reduction in rainfall and increases in temperature over the period from mid- 1970s to 2000s in various areas of the country (Keffyalew, 2011).

In addition to disparities in different parts of the country, the Ethiopian climate is also categorized by a history of climate extremes, such as drought and flood, and increasing and decreasing trends in temperature and precipitation, respectively. The history of climate extremes, especially drought, is not a new phenomenon in all over parts of Ethiopia. Although there was a long record of drought, Lautze *et al.,* (2003), NMA, (2007) in their studies show that the occurrence of drought has increased over the past few decades, mainly in the lowlands (Lautze et al., 2003; NMSA, 2007).

Some of Studies also indicate that mean temperature and precipitation have been changing over time. According to NMSA (2001), the average annual minimum temperature over the country has been growing by about 0.25^{o}C in every 10 years,

whereas the average annual maximum temperature has been increasing by about 0.1^{o}C in every decade. The average annual rainfall of the country also showed a very high level of variability over the past years even if the trend continued more or less constant (NMSA, 2007). Droughts in Ethiopia can shrink household farm production by up to 90 % of a normal year output (World Bank, 2003).

2.2.2. Climate Change and Agricultural Sector in Ethiopia

The economy of Ethiopia is mainly based on rain-fed agriculture which is the source of livelihood for the majority of its population (CSA, 2007). Ethiopia exhibits different agro-ecological zones attributed to varied microclimates. There are different ways of classifying the climatic systems of Ethiopia, including the traditional and the agro-climatic zone in classification systems (Yohannes, 2003). Among the different ways of classifying the climatic systems of the country, the traditional and agro-ecological classifications are the most common ones (Temesgen*et al.,* 2010). The agro-ecological zone classification system combining growing periods with temperature and moisture regimes has 18 major agro-ecological zones which are further sub-divided into 49 agro-ecological zones. According to MoA, 2012), these agro-ecological zones can be grouped into six major categories which include Arid zone (31.5%), Semi-arid (3.5 %), Sub-moist (19.7%), Moist (25%), Sub-humid and humid (19.3%) and Per-humid which covers close to 1 % of the Country. The traditional classification, based on altitude and temperature, shows the presence of 5 climatic zones (NMA, 2007). Based on traditional classifications, agro-climatic zones of Ethiopia could be divided as

Wurch(upper highlands), *Dega*(highlands), *WeynaDega*(midlands), *Kola* (low lands) and *Berha*(desert) (MoA, 2012). Climate is the main determinant of Ethiopian economic growth. This due to the fact that agriculture sector is continued to be the engine of the country‟s economic growth. Agriculture includes crop production, livestock husbandry, forestry, fishery and others. Out of 39% of contribution of agriculture to the country‟s GDP, crop production is estimated to contribute to the agriculture sector on average about 70.2%, livestock sub-sector accounts around 20.3% and forestry and other subsectors around 9.5% of the total agricultural value in the country at the end of 2014/15 (FDRE, 2015).

2.2.3. 1Adaptation strategies to Climate Change in Ethiopia

According to PANE (2009), in Ethiopia, agricultural output is highly affected even by changes in a single climate variable, i.e. rainfall. The same is true for the country‟s GDP as it heavily relies on agriculture (PANE, 2009). This is true in studies of (Megersa *et al.,* 2014; Legesse *et al.,* 2013) indicated that under future climates many regions of Ethiopia will face decreases in agricultural production. This suggests that agricultural production as an engine of growth is 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 stepped up as soon as possible, particularly on account of the efforts required to strengthen research systems and to transfer and adopt findings from the lab to the field. In this case, the Growth and Transformation Plan supports a number of actions that, by boosting growth, will contribute

to the enhancement of Ethiopia's resilience to climatic shocks Aragie (2013).

The studies of Ayana *et al.,* 2011 and Bewket *et al.,* 2015 indicate that in the Ethiopian, 58% of farmers who claimed to have observed changes in climate over the past 20 years had responded to it by undertaking some adaptation measure (Deressa *et al.*, 2009). In fact, several studies report agricultural adaptation measures such as the use of crop varieties, planting trees, soil conservation, changing planting dates, and irrigation as the most used adaptation methods in African countries (Mideksa, 2010; and Bryan *et al.*, 2013). However, it is clear that not all farmers will adapt to climate change for various reasons. According to the study by (Deressa *et al.,* 2011) education and gender of the head of the household, size of the household, livestock ownership, availability of credit and environmental temperature significantly influence the presence of farmers‟ adaptation to climate change. For those farmers who undertake any adaptation at all, the choice of particular adaptation methods depends on a number of factors including socioeconomic, environmental and institutional factors as well as the economic structure. Thus, the choice of adaptation methods depends on a range of variables which are considered important for the availability, accessibility and affordability of particular adaptation methods. Several studies have identified specific variables which may positively or negatively affect the choice of particular adaptation methods. Skambraks, 2014 concluded that farmers‟ education, access to extension and credits, climate information, social capital and agro-ecological settings have great influence in farmers‟choice of adaptation methods to climate change while financial constraints and lack of information about adaptation methods hinders the

farmers‟ uptake of other adaptation methods.

2.2.4. 1Adaptation Strategies and Determinants of Farmers' Choice of adaptation Measures to Climate Change

The study by Juana *et al.* (2013) on farmers' perception and adaptation to climate change in subsahara 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 Juana *et al.* (2013).

Another study, (Ramirez-Villegas, and Thornton, 2015) 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 lackof 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 (Tesso *et al.,*2012).

Adaptation to climate change had challenging factors as identified by researchers. The IPCC (2001) has emphasized that Africa is characterized by a low adaptive capacity. An additional challenge to the already mentioned challenges was the heavy reliance on natural resources to support agriculture. Climate change such as increased temperatures and reduced precipitation rates were bound to lead to overall reduction in agricultural productivity and yields. Maddison (2006) analyzed perception and adaptation strategy of African's to climate change. The analysis was focused mainly on the economic impacts of climate change on agriculture and the farming communities in Africa. The result of the analysis shows that farmers with the greatest farming experience were more likely to notice changes in climatic conditions. In addition, farmer's experiences, access to extension services and markets are important determinants of adaptation.

In Ethiopia, Temesgen *et al.* (2008) analyzed the determinants of farmers‟ choice of adaptation methods in the Nile Basin. The study found that the adaptation methods currently practiced in the study area. Such as changing planting dates, using different crop varieties, planting tree crops, irrigation, soil conservation and not adapting. The farmers reported that the reasons for not adapting are lack of information on climate change impacts and adaptation technologies, lack of financial resources, labor constraints and land shortages. Level of education, age, sex and household size of farmers were found to be significant determinants of adaptation to climate change in the study area.

Mahmud *et al.* (2008) analyzed the impact of climate change and adaptation on food production in Ethiopia. The results of the study revealed that changing crop variety, soil and water conservation, water harvesting, planting of trees and changing planting and harvesting dates are the adaptation measures employed by the farmers. The study also showed that household wealth represented by farm and non-farm income and livestock ownership, increases the likelihood or probability of climate change awareness and adaptation.

Yibekal *et al.,* (2013) examined smallholder farmers‟ level of perception about climate change in eastern Hararghe zone of Ethiopia. Planting trees, early planting, terracing, irrigation and water harvesting are the most commonly employed adaptation options. Results of the multinomial logit model showed that non-farm income, farmer- to-farmer extension, access to credit, distance to selling markets, distance to purchasing markets, and income affect the choice of adaptation strategies. Jeffcott (2013) studied adaptation strategy of farm households to climate change and variability in eastern Ethiopia. The result indicated that factors determining choice of climate adaptation options were sex of household head, family size, education status of household head, agro-ecology, distance to market, cultivated land, use of fertilizer, credit access, precipitation and change of temperature.

Bewket (2010) analyzed farmers‟ adaptation in Choke Mountain of Ethiopia based on farm-level data collected from 100 households. Based on the study result, majority of respondents believed that temperature had increased. Crop

diversification, changing planting dates, implementing soil conservation practices, water welling and irrigation, adjustment to crop and livestock management, using fertilizer and off-farm activities are the most commonly used adaptation options in the area. However, lack of knowledge, improper policy and lack of land use policy implementation, labor and water shortages, and information among other factors were identified as barriers to adaptation. Size of productive labor, frequency of extension visits, resource endowment, and farming experience as main factors that encourage private adaptations; and by contrast, it is discouraged by male headed household, credit usage, access to media information, and higher soil fertility status.

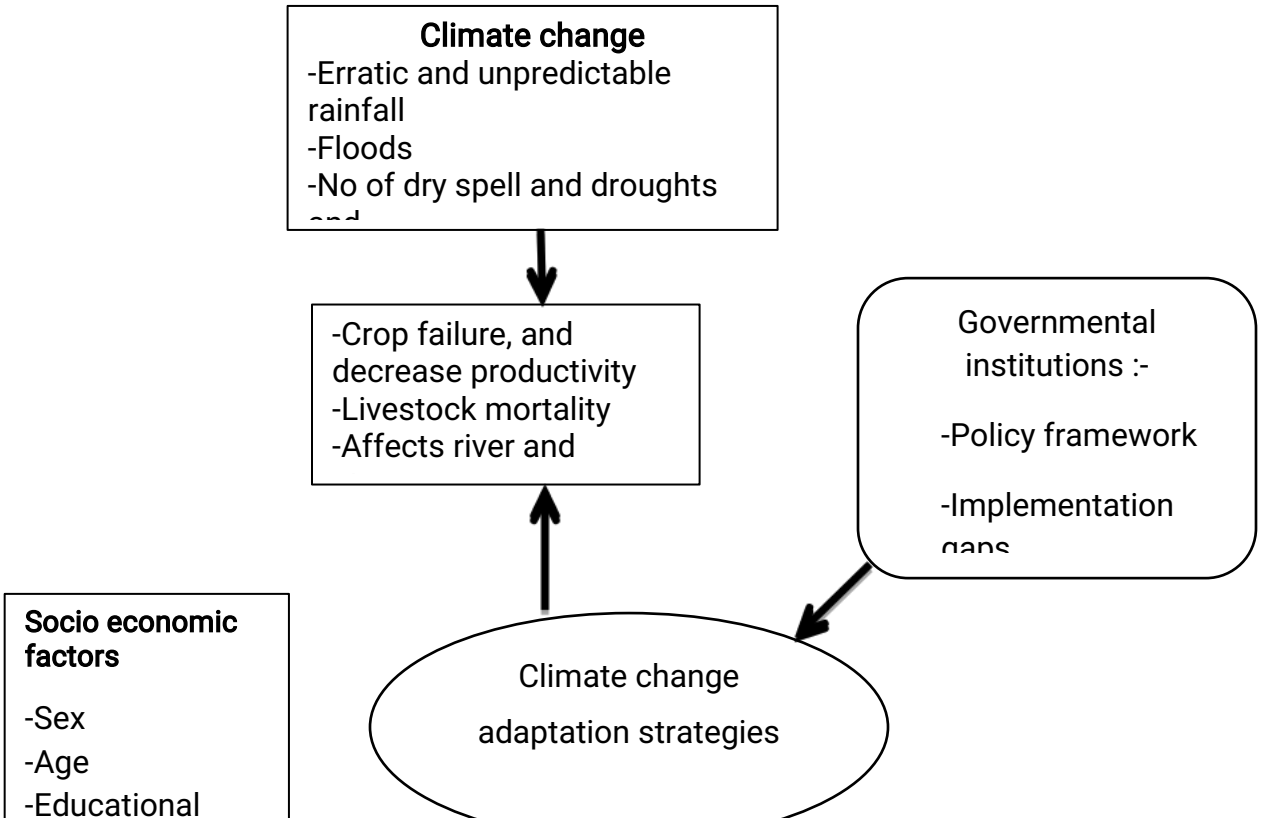
A study has conducted by Fosu-Mensah *et al.* (2012) on farmers‟ perception and adaptation to climate change Sekyedumase district in Ghana. The major adaptation strategies identified included crop diversification, planting of short season varieties, change in crops species, and a shift in planting date. Results of logit regression analysis indicated that the access to extension services, credit, soil fertility, and land tenure are the four most important factors that influenced farmers‟ perception and adaptation. The main barriers included lack of information on adaptation strategies, poverty, and lack of information about weather.

2.3. Conceptual Framework

In this study, adaptation strategies used by small holder farmers is dependent variable. Measures of (independent variable) influences climate change adaptation strategies those engaged in different livelihood rural (dependant) rely on factors such as socio-economic and institutional factors, , and structural arrangements

within community of Shebedino district to cope with those effects. The moderating Variable in this study is government policies which are very crucial to community members of Shebedino woreda for putting in place measures to avert the issues of climate change. In fact, there are a number of adaptation options from which farmers made a choice. Finally, farmers‟ adoption of particular adaptation measures was subject to various household and institutional factors.

Figure 1 the conceptual framework of this study is based on the assumption that adaptation to climate change/ variability is depend on perception and adaptive capacity of farmers, which is determined by different socio-economic and institutional factors. Therefore, the information value of farmers will be important to the analysis of data of this study.



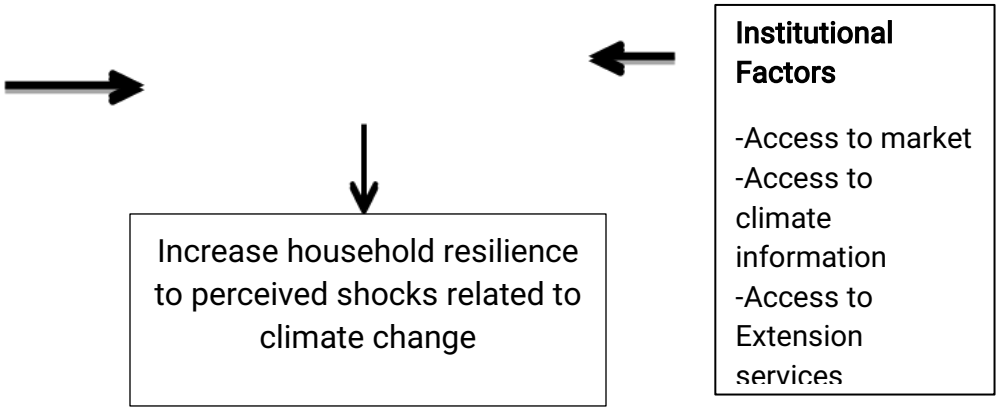


Figure 1 Conceptual framework designed for this study (2021)

Source:-Developed by author of study (2020)

CHAPTER THREE MATERIALS AND METHODS

3.1 Description of Study Area

The study area, Shebedino woreda is found in Sidama National Regional State (SNRS) in Ethiopia. The study area is defined by the geographic coordinates 6º45' and 7 º 00N(northern latitude) and 38 º15' and 38 º30'E(eastern longitude), which is located 27 km from Hawassa, and 302 km from Addis Ababa, the capital of Ethiopia. According to Ethiopian CSA report in 2012, the total population of the district was 269,529. Among them, 136,057 were males and 133,472 are females. The district consists of 35 kebeles comprising of 51,044 residential houses with an average household family size of 5. There are two types of agro ecology in study area: these are woina-dega and dega which constitutes 75 and 25% of area, respectively. The altitude of woina-dega and dega agro-ecology ranges from 1700-2070 and 2,230-2,460 m.a.sl, respectively. The district is

known for growing enset, chat, maize, barley, wheat, teff, Irish potato, sweet potato, banana, avocado and broad bean (CSA, 2012). The average annual rainfall is 900-1,100 mm and the average temperature of the Woreda is between 18-25 ^{o}C. (Bewket *et al.,* 2015).

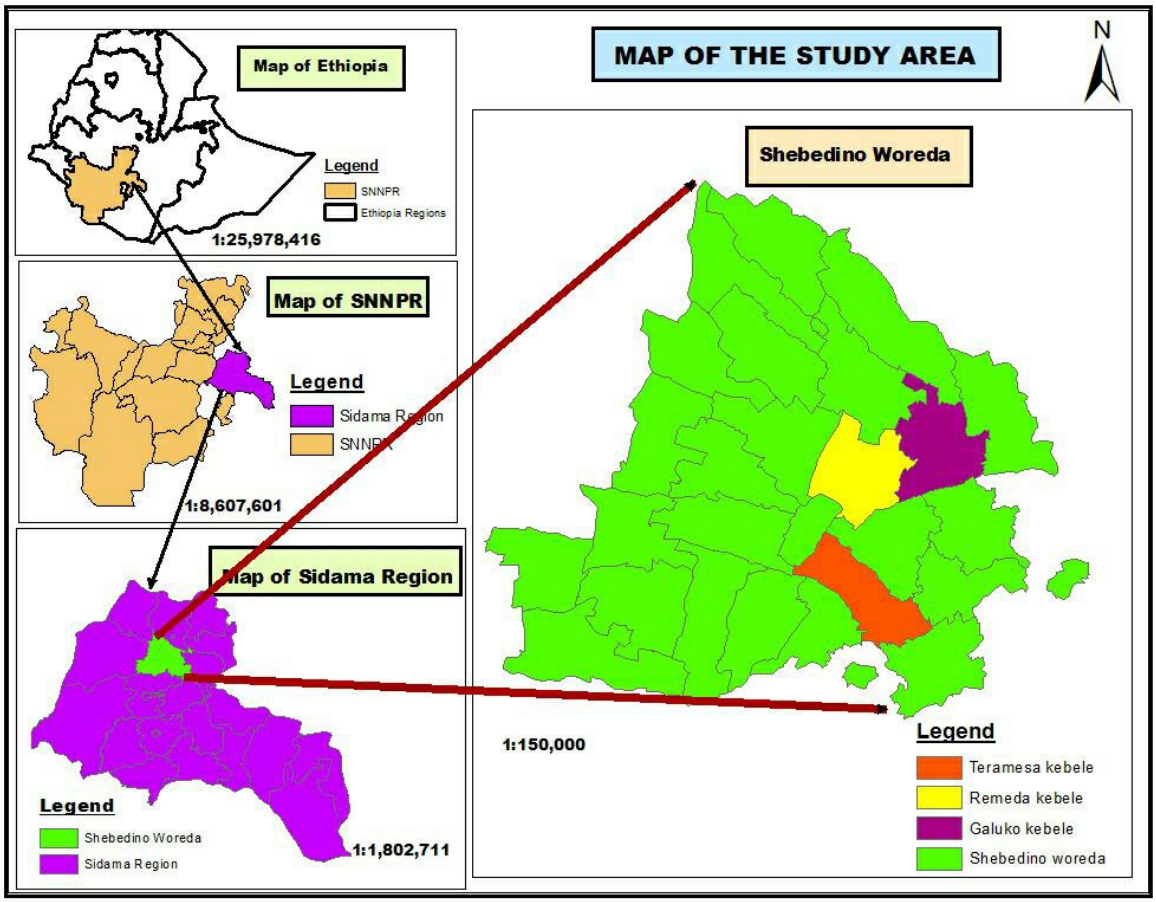


Figure 2 Location of study area

Source: Developed by Arc GIS(2021)

3.2 Research design

The study was carried out through a mixed research design which was carried-out by using qualitative and quantitative descriptions.

3.3. Study Population Sampling Technique and Sample Size

Study population

The target population of this study was comprised of all rural small farm households who are is susceptible to climate change impacts and those households who are not currently adapting to climatic shocks in selected Kebeles of Shebedino Woreda. According to the Shebedino Woreda Revenue Authority Branch Office, there are 623, 802 and 679 households in Teremesa, Remeda, and Galuko Kebeles respectively, making the study population of 2,104.

Sampling Procedure.

The study has employed stratified multi stage sampling technique to draw soundly representative sample. Accordingly, in the first stage, two strata containing agro-ecologicaly homogenous population namely: high land or Dega, and mid-highland or Woina Dega agro ecological strata were formed to select sample kebeles. It should be noted that Kolla climatic zone (agro ecology zone) do not exist in Shebedino Woreda(SWAO, 2020). In second stage, three kebeles out of which, one high land or Dega and two from, mid-highland or Woina Dega agro acro-ecological stratum respectively were selected by using simple random sampling proportional to sample size. The reason for selecting only one and/or two kebeles from each strata (agro ecology zone) was because of financial shortage and assuming since the selection

employs be probability sampling method, it was represent all kebeles in the area. .Finally in the third stage sample household were selected randomly by using systematic random sampling technique starting from the first household in household register of the respective kebeles book (the sampling frame of the study) and then considering the n^{th} households until the desired sample drown from each Kebele in proportion to total population.

Sample Size Determination

The study sample size of 145 respondent household heads was determined by using Yemane (1967) with 0.08 level of precision as shown below. The formula was chosen for its appropriateness in determining large sample size which in turn makes increases the representativeness of sample to the population under consideration. The sample sizes were then distributed to each kebles in proportion to the total population of respective kebeles (Table1).

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

Where: n=Sample size

N=Total population, in this case total households in all kebeles

e=Precision level

$$n = \frac{2104}{1 + 2104(0.08)^2} = 145$$

Table 1 sample household distribution by kebeles

Name of kebeles	Agro-climatic zone	Total HH(household)*	Sampled HH**

Teremesa	Semi low land or Woina-Dega	623	47
Remeda	Semi low land or Woina-Dega	802	55
Galuko	Dega	679	43
Total sampled HH		2104	145

Source: * Kebele administration, ** own computation in proportion to sample size *

3.4. Method of data collection

3.4.1. Data type and sources

In order to achieve the objective of the study and ensure the reliability and validity of collected data both primary and secondary data sources was employed. The primary data was generated from sampled households, focus group discussion members, from key informant's interviews. Secondary data was collected from different sources such as published and unpublished materials about subject matter, journals, reports prepared by different national as well as regional and woreda offices.

The study employed a combination of techniques as instrument of collecting the desired data. The data collection instruments include: household survey, focus group discussion and key informant interviews as described below.

Household survey

Household survey was used to collect primary data from respondent households. Semi-structured questions was prepared to collect data on major research issues such as, perception of farmers towards trend of changes in local climate for the past three decades, adaptation strategies of farmers in face of climate change and

key constraints they faced to adapt and also socio-economic and demographic characteristics of respondents and institutional accessibility are included in the questionnaire. The questionnaire was first prepared in English and later translated into the local language (Sidamigna), so that the respondents can easily understand the questions. The survey was conducted on 145 households and it was handled by two development agents (enumerators) of the respective three selected kebeles, after giving orientation and training by the researcher about the procedure and other related issues that need to be considered in the field survey.

Focus group discussion

The FGDs were composed of separate groups of elders, youth and women members with different age and sex groups, selected purposively since the research goal requires gaining different perceptions, verify opinion and attitudes from groups to help elaborate, clarify and counter-check ideas and experiences that are obtained through other methods. The focus group discussions for this study were held in each three selected/sampled Kebeles comprising 6–10 individuals per group. The sessions are moderated by the researcher using a semi-structured checklist including climate change parameters whether or not local community perceives climate change in the area, local indicators of climate change , effects of climate induced shocks on livelihoods , farmers' response to climate change, and what factors influenced farmers' adaptation decisions.

Key informant interview

The defining feature of key informants is that they are knowledgeable individuals

from the community including the agricultural staff, administrators from government offices, and NGOs who can provide information about the issue and local situations. Key informants were asked if they had experienced any change in their local climate with regards to increase in temperature, reduction in rainfall or other climatic changes in the last three decades. Other topics covered in the schedule include local indicators of the change in climate if farmers perceive any changes, choices of adaptation strategies and prospects for pursuing non-farm activities. Moreover, key informant interviews were conducted on three selected kebeles with an expert from Shebedino Woreda Agriculture and Rural Development office and Kebele Development Agents. These interviews are instrumental in providing critical information on the nature of climate-induced shocks and the effects it has resulted on agriculture and on other livelihood activities in the woreda.

3.5 Methods of data analysis

The gathered data was analyzed in terms of the study objectives already designed. The process of analysis was carried-out by using qualitative and quantitative descriptions. In this study, descriptive statistics and Econometric like multinomial logistic model was used. Simple descriptive statistics was used to analyze primary data sources of smallholder farmers (household survey), key informants, and focus group discussion participants and household demographic and other socio-economic variables.

Descriptive statistics such as mean, frequency and percentage was used to characterize farmer's perception on climate change indicator as well as various adaptation measures used by farmers, and barriers they face to adapt.

Excel sheets and Statistical Packages for Social Scientists (SPSS) version 20 were used for raw data entry and analyze descriptive results and STATA version 14.2 was used to analyze the data of econometric model (Multinomial logistic regression model (MNL)). Multinomial logistic regression model (MNL) was employed to analyze the factors influencing households' choice of climate change adaptation strategies in agriculture. We are aware that collecting and using only the most preferred adaptation option for each household risks underemphasizing the known importance to smallholder farmers of using multiple adaptation strategies (Dasgupta, 2014), but the approach has allowed a high level of specification of the relations between adaptation strategies and underlying socioeconomic variables. The model is specified as follows.

Let Y denote a random variable with values {1, 2…J} for a positive integer J and X set of variables (Deressa, 2011). In this study, Y is a dependent variable and represents the adaptation alternatives (strategies) from the set of adaptation measures, whereas the X represents the factors that influence choice of the adaptation strategies, and P1, P2…Pj as associated probabilities, such that P1 + P2 + … + Pj= 1. This tells as how a certain change in X affects the response probabilities P(y = j/x), j = 1, 2…J. Since the probabilities must sum to unity, P(y = j/x) is determined once the probabilities for j = 2…J are known.

$$P(y = 1/x) = 1 - (P2 + P3 + \cdots Pj) \quad \text{.....(1)}$$

In the MNL model, it is usual to designate one as the reference category. The probability of membership in other categories is then compared to the probability of membership

in the reference category. Consequently, for a dependent variable with j categories, this requires the calculation of j – 1 equations, one for each category relative to the reference category, to describe the relationship between the dependent variable and the independent variables. The choice of the reference category is arbitrary but should be theoretically motivated. The estimation of MNL model for this study it was conducted by normalizing one category which is named as "base category" or "reference estate." The adaptation measures are grouped into5 (five) because farmers used more than one strategy, and the base category is "No adaptation strategy." The theoretical explanation of the model is that in all cases, the estimated coefficient should be compared with the base group or reference category (Gujarati, 2004). Therefore, the choice of the reference category is based on empirical literature and theoretically motivated. The generalized form of probabilities for an outcome variable with j categories is:

$$\mathbf{P}_r = \left(y_i = j/_x\right) = pr_{ij} = \frac{\exp\,(x'\beta j)}{1 + \sum_{j=2}^{j} \exp(x'\beta j)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

j = 1, 2 . . . J for j > 1.

The parameter estimates of the MNL model only provide the direction of the effect of the independent variables on the dependent (response) variable; estimates represent neither the actual magnitude of change nor the probabilities. Differentiating Eq. (2) with respect to the explanatory variable provides the marginal effect of the Independent variables which give as

$$\frac{\partial pi}{\partial xk} = pj(\beta jk - \sum_{i=1}^{j=1} pj\beta jk) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Marginal effect of marginal probabilities is the function of probabilities and measures the expected change in Probabilities where particular adaptation choice is being made by a unit change of the independent variable from the mean (Greene,2000).

Before running the model, it is useful to look into account the problem of multicollinearity among the independent variables. Variance Inflation Factor (VIF) will be used to test the degree of multicolinearity among continuous and dummy variables. Thus, a measure of multicolinearity associated with variance of inflation factor is defined as: -

$$VIF(X_i) = (1 - R_i^2)^{-1} \quad \ldots\ldots (4)$$

Where R^2 is the multiple correlation coefficients between explanatory variables.The larger the value of R^2, the higher the value of VIF (Xi), causing multi collinearity in the variable (Xi). Therefore, in current study, only those variables, whose coefficients are statistically significant at less than or equal to 10% probability levels was discussed.

3.5.1. Definition of Variables and Working hypothesis

Dependent Variable

The dependent variable for this study is households' choice decision on climate change adaptation options used by the farmers'. The alternative climate change adaptation strategies include crop diversification, herd (livestock) diversification drought tolerant crop varieties and livestock species, soil and water conservation,

engaging in off farm and non-farm activities, and using irrigation.

Independent variable

Independent variables are variables that determine whether a household recognizes climate change and take some mechanism used to adapt the impact of climate change on agriculture. Based on the review of literature on adaptation studies, a range of household socioeconomic and demographic characteristics and institutional factors that describe local conditions was hypothesized to influence farmers' adaptation choice in the study area. The expected effects of each of these variables are presented in Table 2 and discussed as follows.

Age of the household head: This indicates the age of the household head in years and can also be used as a proxy for farming experience of the household head. Adaptation to climate change is developed from experience accumulated over time (Mutekwa, 2009). Moreover, Deressa *et al.* (2009) and Tesso *et al.* (2012) also indicated that age of the household has a positive and significant effect on adopting climate change adaptation options. Experienced farmers are more likely to use one or more climate change adaptation strategies (Maddison, 2006). Thus, in this study, age was expected to affect climate change adaptation options positively.

Sex of the household head: It has been argued that male-headed households in Ethiopia have access to information, agricultural inputs, institutions and other attributes. Accordingly, they have a significant and positive influence on adoption of climate change adaptation strategies (Deressa *et al.,* 2009; Legesse *et al.,* 2013). In contrast, Nhemachena and Hassan (2007) noted that female-headed households

are more likely to adopt climate change adaptation methods. This study was followed the former argument which indicated that male headed households are more likely to use adaptation methods as they have more access to resources and information.

Education: Education refers to the literacy level of household head in years of formal schooling. Adaptation to climate change is a response for understanding the issue and its long term risks and opportunities embedded. The positive and significant effect of education on adopting climate change adaptation methods is observed in Ethiopia (Deressa *et al.,* 2008, 2009; Tesso *et al.,* 2012). Maddison (2006) noted experienced farmers are more likely to perceive climate change, but educated farmers are more likely to respond by making at least one adaptation option. Therefore, education was hypothesized to have a positive influence on the farmers' decision to adopt one or more climate change adaptation options.

Farm size: It refers to the total farmland size owned by a farmer measured in hectares. The ownership of fixed agricultural assets (land) increases the share of own farm income in total household income, and reduces the need for undertaking wage employment off-farm and nonfarm sectors. The findings of Taddesse (2011) and Tessema *et al*. (2013) also showed that farmers with large farm size have adopted one or a combination of climate change adaptation options as compared to the farmers with small land holdings. Thus, farm size was hypothesized to increase adaptation to climate change.

Farming experience: It is a continuous variable; it refers to the number of years that

the farmer engaged in farming activity and is expected to influence household adaptation strategy positively. As farmers got more experience in farming, the probability of increasing production and hence farm income would be higher.

Extension service and information on climate: This represents access to information required to make decision on adaptation to climate change. The provision of agricultural extension service and agriculturally relevant climate information enhances farmers' awareness of climate change and knowledge on adaptation measures. Research findings in Ethiopia also showed that access to extension and climate information have a positive and significant effect on adaptation to climate change (Deressa *et al.,* 2009; Tesso *et al.,* 2012; Legesse *et al.,* 2013; Tessema *et al.,* 2013). Maddison (2006) also reported that farmers who get extension advice are likely to adopt climate change. Hence, access to extension and climate information was hypothesized to have a positive relation with the household's adoption decision on climate change adaptation options.

Credit access: credit access refers to the households' opportunity to get credit service from formal and/or informal institutions. Availability of credit eases the cash constraints and allows farmers purchase inputs such as fertilizer, improved crop varieties and irrigation facilities. Studies dealing with adoption of agricultural technologies showed that there is a positive relationship between the level of adoption and the availability of credit (Deressa *et al.,* 2009; Ishaya and Adaje, 2008; Tesso *et al.,* 2012). It is hypothesized that there was a positive relationship between access to credit and climate change adaptation.

Annual income: this is an annual income of household obtains from outside of farming, off farm and non-farming activities. For example besides farm income, off farm income, trade, remittance and governmental employer are among others. Such income makes the farmers to respond impacts of climate change easily. Therefore the expected sign of this variable is positive for the farmers‟ who are used adaptation method to climate change and it is a continuous variable. This variable also measure in Ethiopian Birr.

Distance from input and output market: -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.

Livestock holding: Diversification of herd species compositions, keeping other species such as camels, sheep and goats along with cattle, is also increasingly being practiced in response to changing environmental conditions (Homann *et al.,* 2008; Zander 2011).It is the total number of livestock holding of the farmer measured in tropical livestock unit (TLU). Livestock is considered as another asset which is a security against crop failure. Livestock is generally considered to be an asset that could be used either in the production process or be exchanged for cash or other productive assets. Deressa *et al.* (2009) and Taddesse (2011) also showed

positive influence of livestock ownership on adoption of climate change adaptation options. Therefore, it was hypothesized that the herd diversifications of the household to affect climate change adaptation options positively.

Table 2: Variable description of the study

Independent variable	Nature/Description	Expected design
Age	Continuous(years)	±
Sex	Dummy takes the value of 1 if male and 0, otherwise.	±
Education	Continuous(years)	+
Farm size	Continuous (hectare)	+
Farming experience	Continuous (years)	
Access to Extension service	Dummy takes the value of 1 if yes and 0otherwise	+
Access to climate information	Dummy takes the value of 1 if yes and 0otherwise	+
Family size	Continuous(Number)	±
Accesses to credit service	Dummy takes the value of 1 if yes and 0otherwise	+
Distance from input and output market	Continuous variable measured in km	-
Livestock holding	Continuous(Tropical Livestock Unit)	+

CHAPTER FOUR: RESULTS AND DISCUSIONS

4.1 Socio-economic Characteristics of Respondents

Respondents' age distribution

Form the total respondents , about 34.9% were between the age of 40 and 49 years while 27.3%, 18.7%, 15.8% and 2.9% were between 50 – 59 years, 30 – 39 years, above 60 years and 20 – 29 years, respectively (Table3). The mean age of the respondents was 47.53 years. This result corroborates the findings of (Deressa *et al.,* 2009; Legesse *et al.,* 2013; Nhemachena and Hassan (2007), they indicated that farmers in the Amhara, and Tigray Regions, Rift valley of Ethiopia and Niger Delta region of Nigeria were on the average aged above 45 years. The implication of this finding is that respondents were old enough to have noticed recent changes in the climate and are in their high productive stage and have ability to synthesize and utilize information that can boost agricultural production.

Education status of household

This finding shows that the majority (46.3%) of the respondents have attended secondary school .The others i-e 35.9 and 15.7 educated primary school, and followed no education. The remaining 3% of the respondents had certificate and above. The mean (M) number of years spent in acquiring formal education was 11.00 years. The level of education acquisition has an implication in the utilization or adoption of information on agriculture. Idrisa, Ogunbameru, Ibrahim and Bawa (2012) noted that education plays an important role in creating awareness in farming communities because educated people are better equipped to source

information. With regards to climate change information, Deressa *et al.* (2008) revealed that formal education increases climate change awareness and the likelihood of adaptation.

Estimated annual income

On estimated annual income, a greater proportion (40%) of the studied farmers noted that their estimated annual income was above 10,000 ETB (Table3).

Table 3: Percentage distribution of respondents by socio-economic characteristics

Socioeconomic characteristics	**Total (%)**	**Mean(M)**	**Standard deviation(S.D)**
Age (Years)			
20-29	2.8		
30-39	18.7		
40-49	34.9	47.53 years	10.78
50-59	27.3		
60 years and above	15.7		
Sex			
Male	78.25		
Female	21.75		
Educational Qualification			
Illiterate	15.7		
Primary level	35.9		
Secondary school	46.3		
Certificate and above	3		
Years spent in school		11.00 Years	4.28

Family size(Person)			
1-5	33.7		
5-10	59.2	7 Persons	
11 and Above	7.1		
Number of years lived in the community			
1-20	34.4		
21-40	38.5	39.14	27.13
41-60	24.1		
Above 60	3.0		
Land size(Ha)			
<1	15.6		
1-2	70.3	1.02	0.59
2.1 and above	14.1		

Table3: continued

Livestock ownership (TLU)	**Percentage**	**Mean(M)**	**Standard deviation(S.D)**
<2	9.5		
2-5	48.2	5.8	2.61
6-9	33.4		
10 and above	7.9		
Farming experience(years)			

Less than 10 year	8.4		
11-20	13.7	14.04	9.03
21 – 30	38.5		
31-40	32.3		
>41	7.1		
Estimate of annual income			
<4000 ETB	26.3		
5000-10000	33.7	9,205 ETB	3,501.24
>10000	40		
Type of farm			
Crop farm	14.29		
Livestock farm	2.71		
Both	83		

Source: Household survey (2021)

Access to Credit

Acquisition of credit is main practice of the respondents to recuperate from adverse circumstances due to uneven climatic conditions. Attaining credit increases their ability and flexibility to change production strategies in response to the forecasted climate conditions. Availability of credit eases the cash constraints and allows them to buy inputs such as fertilizer, improved crop varieties, and irrigation facilities. Easily access to credit helps the farmers to purchase the required inputs that may influence the extent of adoption of the farmers and adaptation towards adverse effect of climate change. The credit acquisition patterns of the respondents are

given in (Table 4). The data reveals that majority of the respondents (59.3%) had acquired credit; out of which 50 per cent had obtained credit from cooperative society, whereas, 29.06 per cent of them had obtained credit from bank as well as other source.

The respondents exploited credit for various purposes, in which majority of the respondents (42.7%) obtained credit as crop loan followed by 35.17 and 22.06 per cent of them were obtained credit for farm implements and other purposes, respectively. In line with this study, access to credit easies the financial constraints faced by farmers. When having an access to credits farmers will be in a position to finance adoption of new technologies such as oxen, improved crop variety seeds and fertilizer. Findings by Gbetibouo (2009) and Deressa *et al.* (2009) show that access to credit significantly influences the farmer to adapt to climate change and increase resilience.

Table 4: Responses of credit acquisition pattern of the respondents

Particulars		**Frequency ***	**Percentage***
Do you used/borrowed a credit?			
	No	69	47.5
	Yes	86	59.3
Source of credit(n=86)	Co-operative society	43	50
	Bank +Cooperative	18	20.9

	Bank + other source	25	29.06
Purpose of credit	Crop loan	62	42.7
	Farm implement	51	35.17
	Other purpose	32	22.06

*Multiple responses possible.

Source: Household survey (2021)

Contact with extension personnel

Regarding to acquiring extension services, the respondents were asked about their contact with six enlisted personnel (rural agriculture extension officer, agricultural development officer, subject matter specialist, Non-Governmental Organizations, and Input dealers) and compiled results are given in Table 5. Majority of the respondents replied that they were supervised by extension personnel twice a month (50%), whereas, 31.1 and 18.9% per cent of them were supervised weekly and once a year, respectively. Many studies have confirmed that having better access to extension services increases the probability of adopting different adaptation measures (Aymone, 2009; Temesgen *et al.*, 2009). Farmers with better extension services access are more likely to be aware of changing climatic conditions and expected to have good knowledge about different types of adaptation measures in order to reduce climate change impact or to exploit the advantages.

Table 5: Access to extension service and extent of contact (n=145)

Contact with extension personnel		Frequency(*)	Percentage*
Did you supervised by extension agent?			
	No	55	37.9
	Yes	90	62.06
Extent of supervision	Weekly	28	31.1
	Twice a month	45	50
	Once a year	17	18.9

*Multiple responses possible.

Source: Household survey (2021)

Distance from input and output market

Input and output market is the place where buying of agriculture inputs and selling of agriculture produces are taken place among large number of buyers and sellers. Distance to market is taken as variable in accordance with availability of agriculture inputs. Distance to market is directly correlated with availability of agriculture inputs, lesser the distance means easier they get. Table 6 shows the distribution of respondents according to their distance to market for seasonal farm inputs. It can be observed that 42.7 per cent of the respondents were getting farm inputs from the market within 3 to 5 km of distance followed by 23.4 per cent of them were getting inputs within 2km. Nearly 14 per cent of the respondents had input markets within 6 up to 8 km, whereas, about 7.5 per cent of them said that they had market

input within village for agriculture inputs. Similar findings were reported by Maddison (2006) and Arya (2010).

Table 6: Distribution of respondents according to their distance to market for seasonal farm inputs

Distance from input and output market	Frequency	Percentage
Within village	11	7.5
Up to 2 km	34	23.4
3 km to 5 km	62	42.7
6 km to 8 km	20	13.7
More than 8 km	8	5.5

Source: Household survey (2021)

Access to weather forecast

Timely and accurate information related to weather forecast is very important for the farmers in present scenario of changing climatic conditions. It is needful that the weather forecasts often should correct, so that the farmers can make agricultural decisions based on the weather forecasts. The respondents were asked about sources for weather forecast information and results are depicted in (Table 7). The summation of scores obtained by respondents for frequency of use and utility of information sources were considered to determine the extent of utilization of information sources. It is apparent from Table 7 that majority (33.1 %) of the respondents were having medium level of utilization of information sources for collecting weather information followed by 28.3 per cent of them had reported high level of utilization. The information sources were utilized nil by very little (11.03%) number of respondents to collect weather information. Information on climate

change impact also increases the likelihood of using different crop varieties as an adaptation measure. Having access to farmer-to-farmer extension increases the likelihood of using different crop varieties and planting trees (Temesgen *et al.*, 2008).

Table 7: Extent of utilization of weather forecast information (n=145)

Extent of utilization	Frequency	Percentage
Nil	16	11.03
Low(1-12 score)	30	20.68
Medium (13-24 score)	58	33.1
High (More than 24 score)	41	28.3

Source: Computed from household survey, 2021

4.2 Perception of Farmers about Climate Change

The finding reminded that the farmers in Woina-Dega and Dega agro-ecological zones noticed there is the existence of climate change (Figure3). About 84.02 and 78.31% out of studied farmers in Woina-Dega and Dega indicated the change in climate.

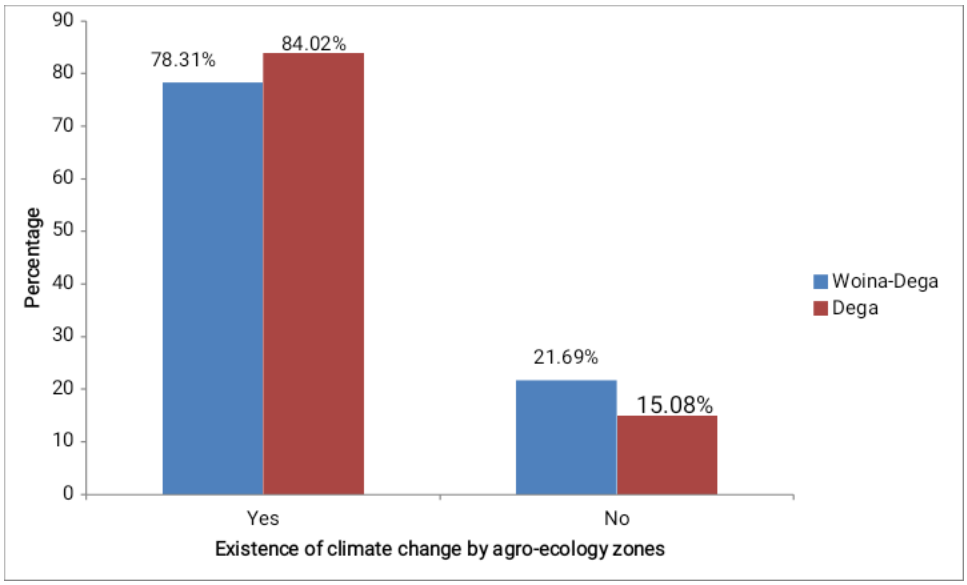


Figure 3 Perceived response of farmers on climate change in Shebedino Woreda

Source:-Household survey (2021)

The result for rainfall (Table8) shows a similar pattern across the two agro-ecological zones. Majority of the farmers in the two agro-ecological zones; Woina-Dega (80.25%), and Dega (76%) said that rainfall had decreased over the years. Also, 6.24% and 11% of the farmers perceived increase in rainfall for Woina-Dega and Dega, respectively. Also, 33.18% of the farmers in the Woina-Dega, and Dega (14.2%) said that there had been change in the timing of rains. Moreover, about 45.12 and 30.12% of Woina-Dega and Dega farmers noticed uneven distribution of rainfall, respectively, while only 7.4 and 13.1% of the respondents in the Woina-Dega, and Dega said no change in rainfall.

Results (Table 8) indicate that significant number of farmers in the two agro-ecological zones; Woina-dega (77.13%), and Dega (70%) said that temperature has increased over the 30 years. By contrast, 18.72%, and 10.3% of farmers in Dega, and

Woina Dega respectively said that temperature has decreased. Also about 46.5 and 30.13 Farmers in Dega, and Woina Dega agro-ecological zones known temperature change has altered. Findings also indicated that heat from high temperature which can destroy field crops and animals as reminded by farmers in Woina-dega(51%) and Dega (40.3%) agro-ecological zones, respectively.

Furthermore farmers had continued to indicate that due to climate change: extended dry season lead to drought (18.1 and 9.2%), dry spell frequency increased (39 and 17.1%), increase in pests and disease infestation as a result of high humidity (29.15 and 26.4%), heavy wind which can affect the field crop (22.3 and 29.1%), drying of rivers and streams(14 and 21.5%), and distortion and destruction of wildlife ecosystems(11 and 16.2%) as a result of deforestation in both Woina-dega and Dega agro-ecological zones. From the above it suggests that the farmers are perceptive to climate change which is a basic precondition for adaptation.

Table8: Perception of climate change by agro-ecological zones (% of respondents)

Climatic variability and change	**Midland land(Woina-Dega):N=102***	**Highland(Dega): N=43***
	(%)	**(%)**
Rainfall		
Increased rainfall	6.24	11.0
Decreased rainfall	80.25	76
Change in timing of rains	33.18	14.2
Uneven distribution of rainfall	45.12	30.6
No changes in rainfall	7.4	13.1
Change in frequency of floods	20.5	32.3
Temperature	**%**	**%**
Increased temperature	77.13	70.0
Decreased temperature	10.3	18.72
Altered temperature change	30.13	46.5
Heat from high temperature which can destroy field crops and animals	51.0	40.3
Others	**%**	**%**
Shift of season	19.2	30.1
Prolonged dry season that can lead to drought	18.1	9.2

Dry spell frequency increased	39.0	17.1
Prevalence of pests and disease infestation	29.15	26.4
Heavy wind which can affect the field crop	22.3	29.1
Decrease in pouring potential of rivers and streams	14.0	21.5
Distortion and destruction of wildlife ecosystems as a result of deforestation	11.0	16.2

NB:* *Implies multiple responses are possible by each HHs on different attributes of climate change indicator*.

Source: Household survey result (2021)

More over regarding climate change the focus group discussion highlighted that:

"The temperature and the climate got hotter over the years. The outside temperature has increased. Until we come inside our home it is very unfavorable. It used to be very cool and comfortable in the past, it is totally incomparable with now. Now there is high temperature. The temperature has increased and the rain is rare on this time.

The farmers perceived the increasing temperature as uncomfortable to their livelihood, but they also understood the impact of high temperature on their yields and mentioned that it composed a physical stress to their crops and animals:

The temperature is not only a problem for people but also for the animals. The animals have to live in the house as well because they cannot control the temperature change. And there is not enough grass, so they need to live in the

home where there is shade.

Now the rainfall it is very low compared to the past, so this year is special (because the rain started earlier). By April 02 many of the farmers have already planted maize, when in the recent past years we used to wait until May 15 to plant maize, because the rain would start then. The rain has started early this year, like in the old days. People are surprised because the wet season has started early this year. It has not been the case in the short past.

In years where the rain had started late the yield would be less due to water stress in the early stages of the crop. In years where the rainy season had stopped early the crops would not grow fully and therefore similarly result in a lower yield: If the rain comes late it is very dangerous and it exposes us to poverty and also drought. If the rain season comes on time all the farmers will plant on time, harvest on time and do all the things on time. So it is very good for the rain to come in time.

Interestingly, many of the farmers explained that this year was special compared to the recent years, since the rain had started very early this year. They therefore hoped that this meant a shift back to the precipitation pattern they knew from the old days:

"In the old days the climate used to be very farmable and comfortable. The wet season used to be very long. This year we are getting a good start of the wet season, the same like in old days, but in the previous years the weather and climate was very bad.

Compared to the last three or five years this year is better and the wet season is coming earlier, that is good for the crops. In the past three or five years there hasn't been this kind of weather."

This is in agreement with the household perception regarding increased temperature and decreased rainfall reported in Ethiopia and other countries (Addisu *et al.,* 2016**;** Weldegebriel and Prowse, 2017; Tadesse *et al.,* 2017; Deressa *et al.,* 2011). In our case, the proportion of farmers who perceived increasing temperature and decreasing rainfall is slightly different compared to studies in Ethiopia and other countries, being influenced by factors affecting their level of perception in general and the type of meteorological data (station vs. gridded data) and climate data availability (longer vs. shorter time period) in particular.

4.3. Climate Change Impact on Farming and Related Activities

The finding verified that climate change has harmed farming activities negatively in Shebedino woreda (Table9). The majority of farmers in Woina-Dega and Dega agro-ecologies indicated that climate change has resulted in reduction of livestock productivity (63.5 and 50.4%), low crop productivity (55 and 42.2%), less pasture/grass for livestock (52.43 and 55.1%) and crop failure (45.2 and 47.56%). Furthermore the farmers from their farming and life experience indicated that due to climate change: competition for fertile land (43 and 39.45%), increasing scarcity of natural resources (change in forest and biodiversity) (37.5 and 19.2%), abandonment of traditional activities (34.2 and 20.3%), loss of income (32.3 and 54.05%), change in water availability for crop and livestock (30.15 and 17.25%), and

increase rural-urban migration (29.2 and 44.34%).

Similarly, Tesso *et al.* (2012) documented perceived impacts of climate change among AEZs in North Shewa, Ethiopia. Hence, farmers' perception of the climate-induced impacts over years is indicative of Ethiopia's vulnerability to climate change and variability. Thus, studies recognized that Ethiopia suffers from problems associated with high rainfall variability (Degefu *et al.,* 2017). Specifically, Amsalu and Adem (2009) show that climate change has both direct and indirect impacts on the occurrence and spread of pests and diseases. The impacts of climate change on smallholder agriculture are likely to intensify in future years, as climate models project rising temperatures, more erratic rainfall, and a potential increase in the intensity and/or frequency of extreme weather events (Magrin *et al.,*2007; Imbach *et al.,* 2017). Moreover, extracts from qualitative information supports the changes in the climate parameters and the corresponding impacts over the last two decades as follows:

"Before 2000s, the area was very green and we had adequate pasture for the cattle. Now, there is no grass for grazing, and there is a movement in search of grass. Since 2000s, we have witnessed a decrease in rainfall and an increase in temperature warming. The rivers have decreased flow potential, and the vegetation cover has been declining. Where there is irrigation, production of crops is good." (Focus Group Discussion in midland (woina-dega) AEZ, December 2020).The key informant interview as verifies that there were also agro ecology based differences in the percent of farmers reporting different climate change impacts and the

severity of these impacts.

In line with this (IPCC, 2014, Megersa *et al.*, 2014; Ogalleh *et al.,* 2012; UNFPA *et al.*, 2011 and WFP, (2012) indicated that climate change impact on production affects intra and inter-household social networks and arrangements, which are vital forms of food security practices (Article 4). These includes high temperatures are often associated with drought while increase in temperature is expected to reduce crop yields and increase levels of food insecurity. Similarly the traditional animal sharing is affected due to a climate change impact on livestock production. Moreover, the farmer's participation in social activities is affected because of climate change impacts on production and incomes. A study shows that climate change affects health, food security, employment, incomes and livelihoods, education, housing, poverty and mobility–either directly or indirectly.

Table9 Farmer's response of climate change impact on farming activities based on agro-ecological-zones in study area

Climate change impacts	Respondents who experienced the impacts of CC (NHH=145) in %	
	Mid-land(Woina-Dega):N=102	Highland(Dega): N=43
Crop failure	45.2	47.56
Crop productivity decreased	55.1	42.2
Reduction of livestock productivity	63.5	50.4
less pasture/grass for livestock	52.43	55.1
Change in water availability for crop and livestock	30.15	17.25
Competition for fertile land	43	39.45
Abandonment of traditional activities	34.2	20.3
Increasing scarcity of natural resources(change in forest and biodiversity)	37.5	19.2
Loss of income	32.3	54.05
Increase rural-urban	29.2	44.34

migration

*Note * that 100 percent was not put underneath since all respondents perceived the impacts of CC in different extents.*

Source: Analyzed from household survey (2021)

4.4 Adaptation Strategies Used By Smallholder Farmers

The analysis of adaptation strategies in response to climate change made by respondents across the agro-ecological zones were revealed in Table 10. Households reported that they have used more than one type of adaptation strategies. This implies that a single strategy is not adequate in adapting to the impact of climate change as combination of several strategies is likely to be more effective than a single strategy. Results showed that the major adaptation method adopted by farmers across the agro-ecological zones was using drought tolerant crop varieties/livestock species. This was observed to have the highest percentage in both agro-ecological zones, that is, Woina-Dega (70.1%), and Dega (61.4%). Similarly, change in livestock variety (herd diversification) (49.25 and 57.3%), crop diversification (42.03 and 25.1%), agroforestry as farming system which comprises: crop, livestock production and tree planting(41.2 and 36.45%), implementing soil and water conservation (40.15 and 33.2%) ,engaging in off-farm and non-farm activities(34.4 and 37.3%) , using irrigation (29.4 and 4.5%) and changed land-use practices such as crop rotation, and shifting cultivation (19.3 and 10.1%) were also the important adaptation strategies used by farmers in these agro-ecological zones of Woina-Dega, and Dega.

The result reveals that among these adaptation strategies used by farmers such as

using drought tolerant crop varieties/livestock species, crop diversification, agroforestry, implementing soil and water conservation and irrigation were widely practiced in Woina-Dega than Dega. However, adaptation strategies such as herd diversification, engaging in off and non-farm activities were more pronounced and/ or used by farmers in Dega agro-ecology in Shebedino woreda.

Few of the maize farmers report no changes in agricultural practice across the two agro-ecological zones; woina-Dega (3.3%), and Dega (2.1%). This implies that every respondent across the agro-ecological zones have made at least one adaptation. These adaptation strategies have been widely in use in Ethiopia for a long period of time in response to historic climate change (Legesse *et al.,* 2013; Deressa *et al.,* 2009; Tessema *et al.,* 2013). But it is not required to link all of these strategies directly to reduce climate change impacts (Ayal and Leal, 2017). For instance, the aim of adoption of new crop varieties might be to increase production and household income. The subject of adaptations and adaptive capacity of farmers is subject to various debates. For example, acknowledging that different regions and areas exhibit varying degrees of temporal variability (Di Falco *et al.,* 2011), means that different areas may require different appropriate adaptations be fitting the locals. Orlove *et al.,* 2010; Eignenauer (2004) argues that scientists and planners often place emphasis on the extrapolation from one set of coping and adaptation practices, rather than taking lessons from the variability and diversity of farmers' coping and adaptation practices. Policies and development oriented programs stand to succeed in enhancing adaptive capacity of the vulnerable farmers if they support and implement adaptation strategies that are currently being practiced by

farmers (Kotir, 2011). The local knowledge of woina-dega and Dega farmers in Shebedino woreda is fundamental to enhancing the adaptive capacities of these vulnerable farmers, who show differences in preferences for adapting. Ideas seen in the context of existing practices of farmers can be easily accepted and embraced by farmers. Since farmers use their perceptions to make decisions on coping and adapting, through local knowledge, policy makers can understand what smallholders perceive and adapt to, before they design policies on how best to prepare and respond to climatic variability. Adaptation policies that integrate farmers' knowledge will improve smallholders' agriculture through promotion of farmer friendly adaptations.

Table10 Farmer's adaptation to climate change by agro-ecological zones (% of respondents)

Adaptation strategies	**Percentage of respondents who used various adaptation measures against CC (NHH=145)**	
	Midland(Woina-Dega):N=102*	**Highland(Dega): N=43***
Change land use practices	19.3	10.1
Implementing soil and water conservation	40.15	33.2

Change in livestock variety(Livestock diversification)	49.25	57.3
Use of drought tolerant crop varieties and livestock species	70.1	61.4
Crop diversification	42.03	25.1
Using irrigation	29.4	4.5
Agroforestry	41.2	36.45
Engaging in off-farm and non-farm activities	34.4	37.3
No adaptation strategy used	3.3	2.1

NB:* implicates multiple responses are possible

Source: Household survey (2021)

The results in Table11 show that although diverse climate change adaptation strategies exist in the area, the farmers were not practicing them to their full potential due to constraints. The major constraint was the low adoption of farm technology. About 17% of the respondents reported a low adoption of improved farm technology as the major constraint to adaptation to climate change (Table11). This was followed by shortage of labor, lack of access to information through mass media, shortage of farm implements, and financial constraints, respectively. Lack of sufficient money hindered farmers from getting the necessary agricultural inputs. Also the farmers did not have sufficient family labor and were not able to employ

laborers. Shortage of farmland has been associated with the limited capacity of farmer to intensify their agricultural production.

Table11 Farmers' primary constraints to adapting to the changing climate

List of constraints	Respondents in %(n=145)
Lack of accurate climate forecasting information	9
Shortage of necessary farm inputs	13
Poor potential for irrigation	11
Shortage of labor implement for adaptation	14
Inadequate contact with extension personnel	5
Shortage of necessary farm inputs	13
Shortage of farm land	7
Low adoption of farm technology	17
Shortage of income	11

Source: Survey result (2021)

4.5 Determinants of Farmers' Choices of Adaptation Strategies to Climate Change

A MNL model was employed to estimate the determinants of farmers' choices of adaptation practices to reduce the impact of climate change. In this analysis, "change land use practices" was used as base category. The likelihood ratio

statistics indicated by the Chi-square test were found to be significant (Table 12). Then the model was tested for the validity of the independence of irrelevant alternatives using assumptions by Hausman specification test procedure. The use of the MNL model specification was found to be appropriate, and model has been used previously by different studies to estimate the determinants of climate change adaptation options by smallholder farmers (Deressa *et al.,* 2009; Hassan and Nhemachena, 2008; Di-Falco, 2011; Negash, 2011). The problem of multicolinearity among the explanatory variables was tested using variance inflection factor and Contingency Coefficient for continuous and dummy explanatory variables, respectively. In both cases, no problem of multicolinearity was detected. Hence, the parameter estimates of the MNL model were used to provide the direction of the effect of the independent variables on the dependent (response) variable, whereas estimates represent neither the actual magnitude of change nor the probabilities (Table12). The marginal effects of marginal probabilities are a function of probabilities and measures expected to change within the probabilities. Particularly, adaptation choices are made by changing the independent variable from the mean (Greene, 2000). In the following section, only the variables that were statistically significant at less than or equal to 10% probability levels are interpreted and discussed (Table12).

Table12: Multinomial logit marginal results of factors affecting farmers' adaptation decisions to climate change

EXP.Variables	Crpdivn	Herdivn	Drtclvs	Swc	Enoffnfm	Usirr
	Marginal Coeff.	Marginal Coeff.	Marginal Coeff.	Marginal Coeff.	Marginal Coeff.	Marginal Coeff.
Sex	-.046	.024	.127**	-.118*	.046	-.146**
Age	.002	.0017	-.0025*	.0028*	-.0002	-.0013
Education	.0005	.005	-.013	-.008	.019*	.011
Familysize	.003	.003	-.031***	.005	-.011	.018*
Farmsize	.053*	-.144	.029	-.144	-.018	-.046
Livestock	-.0372**	.0373***	.0009	.022	.0012	.026
Extension	.688*	.180***	-.141	.247	-.060	-.094
Credit	-.129*	.056	.087	.078	.035	.216**
FAREXP	.0013	.004	.001	-.004	-.001	-.001
CCIN	-.013	-.062	.045	.148**	-.045	.030
Market	.011	-.057*	.006	-.022	.034	.0008
Anninc	-.030	.053	-.076	.030	-.033	.084
		Number of obs = 145				

LR chi2(72)	=	379.68
Prob > chi2	=	0.0000
Log likelihood = -88.615864		
Pseudo R^2	=	0.6818

NB: Asterisks*, **, and *** notifies significant at 10, 5 and 1% probability level

Crpdivn: Crop diversification

Herdivn: Herd (livestock) diversification

Drtclvs : Drought tolerant crop varieties and livestock species

Swc: Soil and water conservation

Enoffnfm: Engaging in off farm and non-farm activities

Usirr: Using irrigation

CCIN:Climate Change Information

Source: MNL model result computed by STATA 14.2

The outcome of marginal MNL model result (Table 12) revealed that sex, education level of the household head, family size, farming experience, age, land size, livestock ownership, acquisition of credit service , extension visit, climate change information, distance from market, and knowledge of adaptation options are significantly determined farmers' adaptation decision to experienced impacts of climate change. Each of the significant variables elaborated above were discussed as follows:

Sex of the household head: Based on the result of the MNL model, sex of the household head has a significant and negative influence on the use of irrigation and

the use of SWC practice as an adaptation strategy. However the sex of the household head affects use drought tolerant crop varieties and livestock species positively. This means that being female than male in the household head decreases the probability of using irrigation and soil and water conservation by 14.6 and 11.8% at 5 and 10% significant level. It implies that female headed households are less likely to use irrigation and SWC practice than male headed households while male headed households are more likely to use drought tolerant crop varieties and livestock species than female headed households to adapt to climate change due to males were enriching long-term farming experience. The FGD members also indicated that irrigation practices are commonly undertaken near home that females are more readily responsible by investing their labor. The other reason is the labour demanding nature of SWC practices and male are usually involved in laborious activities as compared to females. In addition, female headed households have limited access to inputs and institutions as a result of traditional social barriers. Males are highly engaged in farm activities than females and have better farm experience and information in the study area. The result is supported by Temesgen *et al.* (2009) that found male headed households adopt SWC practices more readily than female headed households. Male headed households were 9% more likely to conserve soil. However, it is contrary to Nhemachena and Hassan (2007) which found that female-headed households are more likely to take up SWC practices than male-headed households. It is also contrary to Temesgen *et al.* (2009) and Abrham *et al.* (2017) which noted that males are more likely to plant trees to adapt climate change.

Age: The age of the household head was found to have an inverse relationship with drought tolerant crop varieties and livestock species strategy. The finding(Table12) indicates that the more aged farmers decreases the probability of farmers use of using drought tolerant crop varieties and livestock species strategy by 0.25% at 10% significant level. Thus, the farmers with more productive age groups are more interested in drought tolerant crop varieties and livestock species strategy than the youngsters and older ones. Contrary to this if the age of farmers increased by one year the probability of using soil and water conservation increased by 0.28% at 10% significant level. Since farming as any other professions need to accumulate farming experience including adoption of improved technology, skill and physical capability, it is decisive in determining the right cropping portfolio. The knowledge, the skills as well as the physical capability of farmers are likely to increase as their age increases. However, this tends to decrease after a certain age level. Moreover, older farmers may be more interested in following traditional methods that are familiar to them rather than adapting new practices (Acquah, 2011; Quayum & Ali, 2012).

The educational level of household head was found to have positive and significant relation with the engaging in off farm and non-farm activities as adaptation strategies. This result showed that education increases the awareness of farmers about the consequence of climate change on productivity and the benefit of engaging in off farm and non-farm activities to reduce the impact of climate change. This finding is in line with the investigation of Deressa *et al.* (2008), Uddin *et al.* (2014) and Zuluaga *et al.* (2015)

Family size:-The model result (Table12) showed that family size has negative and significant impact on the likelihood of using drought tolerant crop varieties and livestock species as adaptation strategy to reduce the negative impact of climate change. The increase in family size by 1(one) the probability of using drought tolerant crop varieties and livestock species decreased by 3.1% at 1% significance level. The possible reason for the inverse relationship between family size and using drought tolerant crop varieties and livestock species is that increase in family size would increase expenditure for home consumption and creates financial constraints for other inputs such as improved/drought tolerant crop varieties and livestock species. This finding is in line with the investigation of Tazeze *et al.* (2012) and Zuluaga *et al.* (2015).

Landholding size: Landholding size significantly and positively affected use of crop diversification in response to climate change. The bigger the landholding, the more likely the farmer is to adopt crop diversification by 5.3% at 10 significant level. The possible reason is that farmers who have bigger farm size have an option to divide their farm into different enterprises. According to the focus group discussions, they reach at a consensus that farmers who have a very limited land size could not use crop diversification. It is mostly because they produce consumption goods on the farm they have. In addition, the farm of some households with small landholding may have higher probability of not better suited for use of crop diversification. This finding agrees with the result found by Nhemachena and Hassan (2007) that noted an increase in landholding increases the likelihood of using crop diversification in response to climate change. The result is contrary to Legesse *et al.* (2013) that

revealed large landholding size decreases the use of irrigation while it is similar with the same author regarding the positive effect of landholding size on the use of agro-forestry in response to climate change.

Livestock ownership: Ownership of livestock is also statistically significant and negatively

associated with crop diversification, but positively and significantly affects herd/livestock diversification. Farmers who have large number of livestock in tropical livestock unit are less likely to respond to climate change using crop diversification as an adaptation strategy. The possible conviction is that since farmers use traditional way of livestock husbandry system, it competes for land, time and labor with crop production. Cattles are also likely to destroy terraces and soil bends. In addition, ownership of large livestock implies the farmer is affluent and has alternative source of income so that he or she would give less attention for crop production. Therefore, he or she participated less in crop diversification and diversifies more herd/livestock. This result is contrary to the work of Abrham *et al*. (2017) which revealed that owning large number of livestock in tropical unit increase farmers‟ likelihood of using SWC practices.

Access to credit: The MNL model of marginal result (Table12) revealed that farmer‟s access to credit has statistically significant negative effect on using of crop diversification and positive effect of using irrigation. The result showed that having access to credit decreases and increases the propensity of farmers to use crop diversification and using irrigation by 12.9% and 21.6% at 10 and 5%

significance level as adaptation strategies in response to climate change. This is due to the fact that access to affordable credit mitigates the financial limitation of the farmer and increases their ability to meet transaction costs associated with the various adaptation options they might want to take than merely crop diversification. It enables farmers to change their management practices in response to changing climatic factors and to buy fertilizers, seedlings, drought tolerant varieties, irrigation technologies like water pumps and other inputs to smoothening production and reduce the negative impact of climate change.This result is contrary supported by Gadédjisso-Tossou (2015) that found farmers who have access to credit are more likely to adopt crop diversification. It is also consistent with the work of Nhemachena and Hassan (2007) that strongly advocated the positive effect of access to credit on the probability of adopting irrigation, SWC practices, adjusting planting date, and using different crop variety in response to climate change by strengthening their financial capacity. Besides, it is in line with Temesgen *et al.* (2009) that confirmed access to credit increases the probability of using irrigation, SWC practices, and adjusting planting date in response to climate change.

Extension visit: Extension visit was found to be statistically significant and positively related to crop diversification and herd diversification. This implied that having access to extension visit increases the probability of crop diversification and herd diversification by 68.8 and 18% at 10 and 5% significant level. Conceivably, the reason is that extension visit helps farmers to get informed about contemporary climate related issues and plays a crucial role in improving farmers‟ knowledge about best adaptation practices to the change in climate. Hence, it enables farmers

to make decision based on substantial information. More specifically, it informs farmers when to sow and what variety to use in response to climate change. In line with this finding, the study by Temesgen *et al.* (2009) showed that extension service increases the chance of using crop diversification and herd diversification in response to climate change. In addition, Abid *et al.* (2015), Gebru *et al.* (2015) and Aemro *et al.* (2012) also confirmed that extension visit enhances the likelihood of using improved variety.

Access to climate information: Access to climate information significantly and positively affected using of soil and water conservation. Those farmers who have information on climate change the probability of using soil and water conservation increases by 14.8% at 5% significance level. Farmers who have access to climate related information from different media like radio and television have a higher probability of using soil and water conservation as an adaptation strategy in response to climate change. Most likely, the reason is that access to climate information permits to perceive the change and choose appropriate strategies in response to climate change. Climate information notifies the situation of the existing climatic conditions to enable the farmers to use alternative adaptation strategies like drought tolerant variety and irrigation. The result is found to be the same with Gadédjisso-Tossou (2015) and Temesgen et al. (2009) which asserted that access to climate information increases the likelihood of using short season and improved variety in response to climate change. It is also supported by Gebru *et al.* (2015) that confirmed access to climate information increases the use of soil and water conservation. From the focus group discussion, extension personel is the

major source from which farmers obtain climate related information.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusions

This study dealt with analysis of small holder farmers' adaptation to climate change in Shebedino Woreda of Sidama national regional state. Cross-sectional survey data collected from 145 respondents. To answer the questions of what is the level of perception of farmers and the major adaptation strategies to climate change and their determining factors.

Descriptive statistics was used to analyze farmers‟ perception to climate change and adaptation strategies, and multinomial logistic regression of econometric model was used to analyze factors affecting farmers use of adaptation strategies to climate change.

It was found in the investigation that smallholder farmers' in the study area were

able to

recognize there was change in state of climate in their locality for over long period of years. The finding elaborated to conclude existence of climate change in Shebedino woreda was decrease in amount of rainfall, increasing temperature, extended dry season lead to drought, increased dry spell frequency, pests and disease infestation as a result of high humidity, heavy wind which can affect the field crop, decreasing pouring potential of rivers and streams, and distortion and destruction of wildlife ecosystems as a result of deforestation in both Woina-dega and Dega agro-ecological zones. Smallholder farmers in both landscapes (agro ecology) were exposed to different types of climatic stresses, with some farmers being most affected by droughts and others struggling with the impacts of excessive rainfall or floods. This change in state of climate has resulted in reduction of livestock productivity, low crop productivity, less pasture/grass for livestock and crop failure for the farmers of Woina-dega and Dega agroecological zones. Furthermore the farmers from their farming and life experience indicated that due to climate change: competition for fertile land, increasing scarcity of natural resources (change in forest and biodiversity), abandonment of traditional activities, loss of income, change in water availability for crop and livestock, and increase rural-urban migration. The findings deducts that the existence of climate change and its effects felt differently in both agro-ecological zones of Shebedino woreda because the natural and social systems of different geographical areas are heterogeneous, local knowledge can be a critical ingredient to solving local problems because it is time specific, area specific and culturally acceptable.

The smallholder farmers are trying to adapt the perceived impacts of climate change through the use of drought tolerant crop varieties/livestock species, change in livestock variety (herd diversification),change in crop diversity ,agroforestry, implementing soil and water conservation, engaging in off-farm and non-farm activities, using irrigation and changed land-use practices such as crop rotation, and shifting cultivation were the important adaptation strategies used by farmers in Woina-Dega, and Dega agro-ecological zones of Shebedino woreda. The study concluded that smallholder farmers perceived climate change to be happening and reported climate change impacts, farmers varied in the impacts they experienced, their use of adaptation strategies, and their adaptation needs.

The finding of this study concluded that farmers' capacity to choose effective adaptation options is influenced by sex, age, family size, farm size, livestock holding, access to credit support, extension service, and information related to climate change were critical factors to be take into account in order to enhance adaptation capacity of the small holder farmers of Shebedino woreda in Sidama region.

5.2 Recommendation

Based on the finding of the study, the following intervention measures are recommended so as to enhance resilience and adaptive capacity of the smallholder farmers. These measures include;

- In order to solve the problem of climate change at first building resilience among the smallholder farmers in collaborating with local government by fostering climate resilient green economy followed by individual contact method through

trained extension agents, and campaign of local weather forecast information and how to use modern agricultural technologies is imperative to increase and/or enhance adaptive capacity of the farmers.

- There is a need to encourage local farmers to get engaged in non-farm jobs and various occupations which may be under taken low capital such as bee keeping, poultry and other off farm activates other than agriculture is worthwhile to resilience.

- The local and federal government should preferably enhance adaptation amongst others through giving education, training on improved technology adoption, and infrastructure facilities. They should also invest more in investigation of new suitable seed varieties and distribute this to farmers. Investigation in a drought warning system would also be positive, and if such a system are put in place in the future this would be

  very valuable for the farmers. Thus, endure adaptation strategies that are accessible for smallholder farmers and fit their agro ecological and socioeconomic contexts that affect adaptation practice.

- Inorder to minimize the effects of climate change, agricultural extension services, up to date climatic information, training of improved farm technology adoption, subsidize inputs and infrastructural building should be enhanced to sensitize farmers about climate change thus improving their perception and adaptation strategies.

- The present investigation was confined to three kebeles of Shebedino woreda. The study needs to be replicated in large sample covering all the major potential areas in the woreda it may provide a clear direction for future strategies and for development planning and adaptation management programs in different ecological zones so that the inference drawn can be generalized to a greater extent.

References

Abebe Tadege (2007). Climate change National Adaptation Program of Action (NAPA) of Ethiopia. Addis Ababa, Ethiopia.

Abid, M., Scheffran, J., Schneider, U. A., and Ashfaq, M. 2015. Farmers' perceptions of and adaptation strategies to climate change and their determinants: The case of Punjab province, Pakistan. *Earth System Dynamics*, 6(1): 225-243.

Abrham Belay, Recha, J. W., Teshale Woldeamanuel, and Morton, J. F. 2017. Smallholder farmers‟ adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture and Food Security*, 6(1): 1-13.

Acquah, H. D. (2011). Farmers' perception and adaptation to climate change: A willingness to pay analysis. *Journal of Sustainable Development in Africa*, 13 (5), 150–161.

Aemro Tazeze, Jemma Haji and Mengistu Ketema, 2012. Climate change adaptation strategies of smallholder farmers: The case of Babilie District, East Harerghe Zone of Oromia Regional State of Ethiopia. *Journal of Economics and Sustainable Development*, 3(14): 1-12.

AFP, (2007). Climate Change and Africa. *8th Meeting of African Partnership Forum*, Berlin, Germany, 22-23 May, 2007.

AGRA (Alliance for a Green Revolution in Africa) (2014) Africa agriculture status report (2014) Climate change and smallholder agriculture in sub-Saharan Africa. Nairobi,

Kenya.

Aklilu Amsalu and Dereje Gebremichel, (2010). Ethiopian Environment Review, Volume1,

Aymone, G., 2009. Understanding farmers' perceptions and adaptation to climate change and variability: The case of the Limpopo basin, South Africa. IFPRI Discussion paper 00849, *International Food Policy Research Institute*. Washington DC.

Amsalu and A. Adem (2009).Assessment of Climate Change-Induced Hazards, Impacts and Responses in the Southern Lowlands of Ethiopia, Forum for Social Studies (FSS), Washington, DC, USA, http://hdl.handle.net/123456789/3075.

Aragie, E.A. (2013): Climate change, growth, and poverty in Ethiopia.Working paper no.3. http://mercury.ethz.ch/serviceengine/Files/ISN/165446/ipublicationdocument_singledocu
ment/ad43f694-2a16-458f-bc13-3375b47f622a/en/ccaps+working+paper+no.+3.pdf.

Araya, A. and Stroosnijder, L. 2010. Assessing drought risk and irrigation need in Northern Ethiopia, URL: *http://www.sciencedirect.com*.

Ayana S, Beyene S, NebilSh, Sertse S and Tefera T (2011). Agriculture Sector Programme of Plan on Adaptation to Climate Change, Technical working group, Addis Ababa.

Backstrand, K. and Lovbrand, E.: Climate governance beyond 2012: Competing discourses of green governmentality, ecological modernization and civil environmentalism. In Pettenger, D.M., ed.: The Social Construction of Climate Change: Power, Knowledge, Norms, Discourses. Ashgate, Farnham, pp. 123-148, 2007,

Bassett, T., and C. Fogelman. 2013. "Déjà Vu or Something New? The Adaptation Concept in the Climate Change Literature." Geoforum 48: 42-53.

http://dx.doi.org/10.1016/j. geoforum.2013.04.010

Belaineh Legesse, Yared Ayele and Woldeamlak Bewket, 2013. Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, west Hararghe, Ethiopia. *Asian Journal of Empirical Research* 3(3):251-265.

Belay, A., J. W. Recha, T. Woldeamanuel, and J. F. Morton. 2017. "Smallholder Farmers' Adaptation to Climate Change and Determinants of Their Adaptation Decisions in the Central Rift Valley of Ethiopia." Agriculture and Food Security 6: 24.

Bewkwt Amdu (2010). Analysis of farmers' perception and adaptation to climate change and
variability: the case of Choke Mountain, east Gojjam. MA thesis, submitted to graduate
studies of Addis Ababa University, unpublished.

Bewket, W.Radony M. and Mungaic. (2015). Agricultural adaptation and institution responses to climate change and variability in Ethiopia working paper no.106.

BewkwtAmdu (2010). Analysis of farmers' perception and adaptation to climate change and variability: the case of Choke Mountain, east Gojjam. MA thesis, submitted to graduate studies of Addis Ababa University, unpublished.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., and Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants, J. Environ. Manage, 114, 26–35.

CCAFS. (2009). Provisional Medium Term Plan: 2010-2012 Challenge Program on Climate Change, Agriculture and Food Security (CCAFS). Frederiksberg, Denmark.

Cohn, A. S., P. Newton, J. D. B. Gil, L. Kuhl, L. Samberg, V. Ricciardi, J. R. Manly, and S. Northro.2017."Smallholder Agriculture and Climate Change." *Annual Review of Environment and Resources* 42: 347–75.

CSA (Centeral Statistical Authority). (2007). Central Statistical Authority population estimates in Ethiopia, Addis Ababa.

Degefu, D. P. Rowell, and W. Bewket (2017). "Teleconnections between Ethiopian rainfall variability and global SSTs: observations and methods for model evaluation," Meteorology and Atmospheric Physics, vol. 129, no. 2, pp. 173–186. View at Publisher · View at Google Scholar · View at Scopus.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T. & Yesuf, M. (2008). *Analysis of the ` determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia*. Washington, DC: International Food Policy Research Institute.

Deressa, T, T, Hassan, R, M, Ringler, C, Alemu, T, and M, Yesuf, (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia, URL:https://vpn.uia.no/+CSCO+ch756767633A2F2F6A6A6A2E66707672617072 7176657270672E70627A++/science.

Deressa, (2010), Factors affecting the choices of coping strategies for climate extremes: the case of Farmer's in the Nile Basin of Ethiopia,

Deressa TT, Hassan RM, and Ringler C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. J Agric Sci. 2011; 149(01):23–31.

Dereasse Demisse(2018). Impact of Climate Change on Livestock Production. Shebedino Woreda of Sidama Region in Ethiopia.

Diggs, D. M. (1991). Drought experience and perception of climatic change among Great Plains farmers. Great Plains Research, 114-132.

Di Falco S, Veronesi M, Yesuf M. 2011. Does adaptation to climate change provide food security micro perspective from Ethiopia? Am J Agric Econ. 2011;93(3):825–44.

Dorward, A., Fan, S., Kydd J., Lofgren, H., Morrison J., Poulton, C., Rao, N., Smith, L., Tchale, H., Thorat, S., Urey, I. and Wobst, P. (2004) 'Institutions and economic policies for pro-poor agricultural growth', IFPRI Discussion paper, DSG 15.

D. Y. Ayal and W. Leal Filho, 2017. "Farmers' perceptions of climate variability and its adverse impacts on crop and livestock production in Ethiopia," *Journal of Arid Environments*, vol. 140, pp. 20–28, 2017.View at: Publisher Site | Google Scholar

SWEWR(Shebedino Woreda Early Warning Report).2019. Annual Assessment Report,Shebedino, Sidama Region of Ethiopia.

Egbule, C. L. (2010). Indigenous and emerging adaptive agricultural technologies to climate
change in the Niger Delta region of Nigeria. (Unpublished M. Sc Thesis). University
of Nigeria, Nsukka, Enugu state, Nigeria.

Eignenauer, J.D. *Summary of Seeing Like a State*; Yale: Bakersfield, CA, USA, 2004

Elasha, B. 2006. Background paper for Vulnerability and Adaptation in Africa: The African Workshop on Adaptation Implementation of Decision1/CP.10 of the UNFCC Convention/Accra/Ghana.

EPCC. 2015. First Assessment Report, Working Group II Agriculture and Food Security, Published by the Ethiopian Academy of Sciences

Eriksson, M., 2006.Climate Change and its Implications for Human Health in the Himalaya. Sustainable Mountain Development in the Greater Himalayan Region, 50.

FAO (Food and Agriculture Organization)(2008). Climate change adaptation and mitigation in the food and Agriculture Sector. Food and Agriculture Organization of the United Nations, Rome, Italy. 58

FAO. (2009). Climate Change in Africa: The Threat to Agriculture. Retrieved from

ftp://ftp.fao.org/docrep/fao/012/ak915e/ak915e00.pdf.Accessed on 25/12/2012 .

FDRE (Federal Democratic Republic of Ethiopia). 2015. *Ethiopia's Climate Resilient Green*
Economy Climate Resilience Strategy Agriculture and Forestry. Addis Ababa: Ministry of Agriculture and Rural Development.

Fosu-Mensah, B. Y., Vlek, P. L., andMacCarthy, D. S. 2012. Farmers‟ perception and adaptation to climate change: A case study of Sekyedumase district in Ghana. Environment, Development and Sustainability, 14(4): 495-505.

Füssel, H. M. (2007). Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. Sustainability science, 2(2): 265-275.

Gadédjisso-Tossou, A. 2015. Understanding Farmers‟ Perceptions of and Adaptations to
Climate Change and Variability: The Case of the Maritime, Plateau and Savannah Regions of Togo. *Agricultural Sciences*, 6(12): 1441-1454.

Gebru Hadgu, Kindie Tesfaye, Girma Mamo and Belay Kassa. 2015. Farmers‟ climate change
adaptation options and their determinants in Tigray Region, Northern Ethiopia. *African*
Journal of Agricultural Research, 10(9): 956-964.

Greene WH. Econometric analysis. 4th ed. New York: Prentice Hall International Inc; 2000.

G. Tadesse, M. Bekele, and B. Tesfaye, 2017. "Farmers' perceptions and adaptation strategies to climate change and variability the case of Kacha bira Woreda, Kembata tembaro zone, southern nations, Nationalities and peoples Ethiopia," Journal of Environmental and Earth Science, vol. 7, no. 3, pp. 52–61. View at Google Scholar

Homann, S., Rischkowsky, B., Steinbach, J., Kirk, M., and Mathias, E., 2008. Towards endogenous livestock development: Borana pastoralists´ responses to environmental and
institutional changes. Human Ecology 36, 503–520.

Gujarati D. Basic econometrics. 4th ed. New York: McGraw Hill; 2004.

IFAD (International Fund for Agricultural Development) (2013) The adaptation advantage: the economic benefits of preparing small-scale farmers for climate change. Rome: IFAD. [Online]. Available at: http://www.ifad.org/climate/ resources/adaptation_farmers.pdf (Accessed: 26 February 2014).

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability: Regional Aspects. Cambridge University Press.

IPCC, (2007) .Climate Change Impacts Adaptation and Vulnerability, Inter governmental Panel on Climate Change.

IPCC (Intergovernmental Panel for Climate Change). 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaption. New York: Cambridge University Press.

IPCC. (2001). Climate Change 2001: Impacts, Adaptation Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: UNEP/WMO.

Imbach P, Beardsley M, Bouroncle C, Medellín C, Läderach P, Hidalgo H, Alfaro E, Van Etten J, Allan R, Hemming D, Stone R, Hannah L, Donatti CI(2017). Climate change, ecosystems and smallholder agriculture: an introduction to the special issue. Climate Change. 2017. https://doi.org/10.1007/s10584-017-1920-5.

Jeffcott J. (2013). *Adaptation to climate change and variability in eastern Ethiopia*.Haromaya University, Ethiopia, American Journal of Greenhouse Gas 3(1), pp. 2568-5252.

Jotzo F., P. J. Burke, P. J. Wood, A. Macintosh, and D. I. Stern (2012) Decomposing the 2010 global carbon dioxide emissions rebound, Nature Climate Change 2(4): 213-214.

Juana J., Z. Kahaka and F. Okurut (2013). Farmers' Perceptions and Adaptations to Climate Change in Sub-Sahara Africa: A Synthesis of Empirical Studies and Implications for Public Policy in African Agriculture. *Journal of Agricultural Science; Vol. 5(4):121-135*.

Keffyalew G. (2011). Ethiopia: A country confronted by climate change, population growth, poor agriculture & bad governance. Special report to FAO/WFP crop and food security assessment mission to Ethiopia.

Kichamu, E. A., Ziro, J. S., Palaniappan, G., & Ross, H. (2018). Climate change perceptions and adaptations of smallholder farmers in Eastern Kenya. *Environmental Development and Sustainability*, 20, 2663–2680. DOI: https://doi.org/10.1007/s10668-017-0010-1

Kirton JJ, Cooper AF, Lisk F, Besada H (2014) Moving health sovereignty in Africa: Disease, governance, climate change. Ashgate Publishing Limited, Farnham, England .

Lautze et al., (2003); NMS, 2007).Lautze S., Aklilu Y., Raven-Roberts A., Young H., Kebede G. and Learning J. 2003. Risk and Vulnerability in Ethiopia: Learning from the Past, responding to the Present, preparing for the future. Report for the U.S. Agency for International Development. Addis Ababa, Ethiopia.

Kotir, J.H.2011. Climate change and variability in Sub-Saharan Africa: A review of current and future trends and impacts on agriculture and food security. *Environ. Dev. Sustain.* **2011**, *13*, 587–605.

Legesse, B., Ayele, Y. & Bewket, W. (2013). Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, west Hararghe, Ethiopia. *Asian Journal of Empirical Research*, 3 (3), 251–265.

Maddison, D. (2006). The perception and adaptation to climate change in Africa CEEPA. Discussion paper No. 10. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria.

Mahmud Yesuf, Temesgen Tadesse, Ringler C., Falco D. and Kohlin G. (2008). *The impact of climate change and adaptation on food production in low-income countries: Evidence from the Nile Basin, Ethiopia, EDRI*.

Magrin G, Gay García C, Cruz Choque D, Giménez JC, Moreno AR, Nagy GJ, Nobre C, Villamizar A. Latin America. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Climate change 2007: impacts, adaptation and vulnerability, contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University Press; 2007. p. 581–615.

Megersa, B., Andre, M., Ayana, A., and Zarate, A. 2014. The role of livestock diversification in ensuring household food security under a changing climate in Borana, Ethiopia. Food Security, 6, 15-28.

Melissa, M. Rojas-Downing, A., Nejadhashemi, A., Harrigan, T., and Woznicki, S. (2017). Climate change and livestock: Impact, Adaptation and mitigation. *Regional Environmental Change*, *16:* 145-163.

Mideksa, T. K., and S. Kallbekken, 2010: The impact of climate change on the electricity market: A review. Energy Policy, 38, 3579–3585, doi:10.1016/j.enpol.2010.02.035.

Ministry of Finance and Economic Development, (MoFED) (2010) Survey of the Ethiopian economy. Addis Ababa, Ethiopia.

MoA (Ministry of Agriculture), 2012. Agriculture sector Programme of plan on Adaptation on

climate Change. Addis Abba.

NAPA, (2007). Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia, Addis Ababa, June, 2007.

Nega Debela, Mohammed, C., Bridle, K., Corkrey, R., and McNeil, D. 2015. Perception of climate change and its impact by smallholders in pastoral/agropastoral

systems of Borana, South Ethiopia. SpringerPlus, 4(1): 236.

Negash, M. 2011. Analysing the determinants of farmers' preference for adaptation strategies to climate change: evidence from north Shoa zone of Amhara region, Ethiopia. Doctoral dissertation.

Newton, A.C., S.N. Johnson, and P.J. Gregory, 2010. Implications of climate change for diseases, crop yields and food security. A paper presented in BGRI 2010 Technical Workshop, 30-31- May 2010, St Petersburg, Russia.

Nhemachena, C. & Hassan, R. (2007). Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper No. 714,International Food Policy Research Institute, Washington, DC.

Ngigi, S.N., 2009. Climate change adaptation strategies: Water resources management options for smallholder farming systems in sub-Saharan Africa. Columbia University: New York.

NMA, (2007), NMA (National Meteorological Agency). 2007. Climate Change National Adaptation Program of Action (NAPA) of Ethiopia. NMS, Addis Ababa, Ethiopia.

NMA. 2001. NMA (National Meteorological Agency). 2001. Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC). Addis Ababa, Ethiopia.Paper.No.72.

Orlove, B.; Roncoli, C.; Kabugo, M.; Majugu, A(2010). Indigenous climate knowledge in southern Uganda: The multiple components of a dynamic regional system. *Climatic Change* 2010, *100*, 243–265.

Oxfam International. 2011. Briefing on the Horn of Africa Drought: Climate Change and Future
Impacts on Food Security. Availableat http://www.oxfam.org/sites/www.oxfam.org/files/
briefing-horn of Africa drought climate change-food security-020811.pdf.

PANE, (Poverty Action Network of civil society organizations in Ethiopia). (2009). "The Impact of Climate Change on Millennium Development Goals (MDGs) and Plan

for Accelerated and Sustained Development to End Poverty (PASDEP) implementation in Ethiopia, Addis Ababa

Quayum, M. A. & Ali, A. M. (2012). Adoption and diffusion of power tillers in Bangladesh. *Bangladesh Journal of Agricultural Research*, 37 (2), 307–325

Ramirez-Villegas, J. and Thornton, P.K. 2015. Climate change impacts on African crop production. CCAFS Working Paper No. 119. Copenhagen, Denmark: CGIAR Research
Program on Climate Change, Agriculture and Food Security (CCAFS)

S. Addisu, G. Fissha, B. Gediff, and Y. Asmelash, 2016. "Perception and adaptation models of climate change by the rural people of lake Tana Sub-Basin, Ethiopia," Environmental Systems Research, vol. 5, no. 1, pp. 1–10.View at Publisher · View at Google Scholar

Salami, A., Kamara A. B. and Brixiova, Z. (2010) 'Smallholder agriculture in East Africa: trends, constraints and opportunities.' African Development Bank. Working Paper No. 105.

Skambraks, A. 2014. Smallholder Farmers' Adaptation to Climate Change in Zenzelima, Ethiopia: A Case Study of Female and Male Farmers Perception of and Ability to Adapt
to Climate Change in Zenzelima, Ethiopia. University of Natural Resources and Life
Sciences Vienna Department of Sustainable Agricultural Systems; Division of Organic
Agriculture European Master in Organic Agriculture and Food systems.Submitted to the
Graduate Studies of Haramaya University, Haramaya, Ethiopia.

Stern, N. (2006). The Stern Review: The Economics of Climate Change.

Storck, H., Berihanu Adnew, Bezabih Emana, and Shimelis WoldeHawariat. 1991.

Farming
system and farm management practices of smallholders in Harareghe highlands.Farming
systems and resource economics in the tropics, vol. 11, Wirtschafts- Verlagvauk, Kiel,
Germany.

Sowunmi, F.A. and J. Kintola (2009). Effect of climatic variability on maize production in Nigeria. *Research Journal of Environmental and Earth Sciences,* 2 (1): 19-30.

Taddesse T., 2011. Farmers' perception and adaptation mechanisms to climate change and variability: the case of La'ilay Maichewworeda, central Tigray, Ethiopia. An MSc Thesis Presented to the School of Graduate Studies of Haramaya University.

Tazeze, A., Haji, J. & Ketema, M. (2012). Climate change adaptation strategies of smallholder farmers: The case of Babilie district, East Harerghe zone of Oromia regional state of Ethiopia. *Journal of Economics and Sustainable Development*, 3 (14), 1–12.

Tesso, B. Emana, and M. Ketema, (2012). "A time series analysis of climate variability and its impacts on food production in North Shewa zone in Ethiopia," African Crop Science Journal, vol. 20, no. 2, pp. 261–274. View at Google Scholar

Temesgen, T. D., Hassen., R. M., and Ringler, C, (2009); Assessing House hold vulnerability to
climate change . The Case of farmers in the Nile basin of Ethiopia. IFPRD, Discussion

Temesgen Tadesse, Hassan R., Ringler C., Tekie Alemu and Mahmud Yesuf (2008).
Analysis of the determinants of farmers' choice of adaptation methods and perceptions of
climate change in the Nile Basin of Ethiopia. IFPRI Discussion Papers No. 798.Paper.
0935.

Temesgen G, (2009). A study on the perception and adaptation to climate change: The case of farmers in the Nile Basin of Ethiopia. Centre for Environmental Economics and Policy for Africa (CEEPA), University of Pretoria, South Africa.

Temesgen G, Wondie M., Daniel H. and Abeba N. (2014) Climate Change Adaptation and Mitigation Measures in Ethiopia, Vol.4, No.15, 2014.

Tessema, Y.A., C.S Aweke, G.S Endris, 2013. Understanding the process of adaptation to climate change by small-holder farmers: the case of east Hararghe Zone, Ethiopia. *Agricultural and Food Economics, available* at http://www.agrifoodecon.com/content/1/1/13 , Accessed on 10 Nov, 2013.

Thornton, P.K, Boone, R.B. and Ramirez-Villegas, J. 2015. Climate change impacts on livestock. CCAFS Working Paper No. 120. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Uddin, M. N., Bokelmann, W. & Entsminger, J. S. (2014). Factors Affecting Farmers' Adaptation Strategies to Environmental Degradation and Climate Change Effects: A Farm Level Study in Bangladesh. *Climate*, 2 (4), 223–241.

UNEP, (2006). Climate change and variability in the Sahel region: impacts and adaptation strategies in the agricultural sector.

UNFPA et al. 2011. The social dimensions of climate change. Discussion draft. Copenhagen, Bonn and Cancun.

UNEP. 2012. Africa without Ice and Snow, UNEP Global Environmental Alert Service (GEAS),
Taking the Pulse of the planet; connecting science with policy. Available at www.unep.org/geas.

United Nations Framework Convention on Climate Change. Historic Paris Agreement on Climate Change. 195 Nations Set Path to Keep Temperature Rise Well Below 2 Degrees Celsius. Available online: http://newsroom.unfccc.int/unfccc-newsroom/finale-cop21/ (accessed on 29 March 2016).

WFP. 2012. Climate impact on food security and nutrition. A review of existing knowledge. World Food Program.

WFP (World Food Programme) (2013) 'Ethiopia: food security outlook update', Available online: http://reliefweb.int/sites/reliefweb.int/files/resources/Ethiopia . %20Food%20Security%20Outlook%20Update%20May%202013.pdf (Accessed: 10 May 2014)

WMO, (2003) .Our Future Climate. Geneva, Switzerland. World.

World Meteorological Organization (WMO) 2016, 'Climate and Weather definitions' Available at: https://www.wmo.int/. Accessed on May 20, 2016.

World Bank, (2008). Climate Change Adaptation and Mitigation in Development Programmes: APracticalGuide.http://siteresources.worldbank.org/EXTEEI/Resources/ DCCToolkitCRAlores.pdf (access on 01 August, 2011).

World Vision. Worst Natural Disasters of 2015. Available online: http://www.worldvision.org/newsstories-videos/natural-disasters-2015 . (accessed on 29 March 2016).

Yemane Taro. 1967. Statistics. An introductory analysis, 2nd edition. New York. Harper and Row.

Yesuf M., Di Falco. S., Deressa, T., Ringler. C., & Kohlin. G. (2008). *The Impact of Climate Change and Adaptation on Food Production in Low-Income Countries: Evidence from the Nile Basin, Ethiopia, EDRI*.

Yibekal Tessema, ChanyalewAweke and GetachewEndris (2013).*Understanding the process of adaptation to climate change by small-holder farmers: the case of east hararghe zone, Ethiopia*.Agricultural and Food Economics, 1(13).

Yohannes G/medhin. (2003). Ethiopia in view of the National Adaptation Program of Action. National Meteorological Services Agency, Addis Ababa, Ethiopia.

Y. A. Tessema, C. S. Aweke, and G. S. Endris, 2013. "Understanding the process of

adaptation to climate change by small-holder farmers: the case of east Hararghe zone, Ethiopia," *Agricultural and Food Economics*, vol. 1, no. 1, pp. 1–17, 2013.

Zander, K.K., 2011. Attitudes of livestock keepers to breeding strategies: threats and opportunities for on-farm conservation of the Borana cattle breed. Journal of Agricultural Science 3, 3–12.

Zegeye H (2018) Climate change in Ethiopia: impacts, mitigation and adaptation. Int J Res Environ Stud 5(1):18–35

Zhai, F. and J. Zhuang (2009). Agricultural impact of climate change: A general equilibrium analysis with special reference to Southeast Asia. ADBI Working Paper 131. Tokyo: Asian Development Bank Institute. http://www.adbi.org/workingpaper/2009/02/23/2887 .

Ziervogel, G., Cartwright, A., Tas, A., Adejuwon, J., Zermoglio, F., Shale, M., and Smith, B. (2008). Climatechange and adaptation in African agriculture. Stockholm EnvironmentInstitute, Sweden.

Zuluaga, V., Labarta, R. & Läderach, P. (2015). Climate Change Adaptation: The Case of the Coffee Sector in Nicaragua. International Center of Tropical Agriculture (CIAT), Selected Paper prepared for presentation at the Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, CA, July 26–28.

Z. B. Weldegebriel and M. Prowse, 2017. "Climate variability and livelihood diversification in northern Ethiopia: a case study of Lasta and Beyeda districts," Geographical Journal, vol. 183, no. 1, pp. 84–96. View at Publisher · View at Google Scholar · View at Scopus

Biographical Sketch

The author was born in 1992, in Bensa woreda , Sidama region. He attended his primary school at Wochabo and secondary school at Kebena Gata comprehensive high school.The he joined the Hawassa University of Wondogenet College in 2010 and graduated with BSc degree in General Forestry. He has been working in Bensa Woreda as an expert of Agroforestry for the past seven years. He rejoined Hawassa University, College of Agriculture in 2018 to pursue his Masters of Science in Climate Change and Sustainable Agriculture. Currently he is student at Hawassa University.

Appendices

HAWASSA UNIVERSITY

SCHOOL OF GRADUATE STUDIES COLLEGE OF AGRIICULTURE

FUCALITY OF ENVIRONMENT, GENDER AND DEVELOPMENT STUDIES

QUESTIONNAIRE FOR HOUSEHOLD HEADS

My name is Degefu Dafursa, MSc student at Hawassa University, College of Agriculture. I am conducting a research concerning smallholder farmers' perceptions and adaptation strategies to climate change: the case of Shebedino Woreda, Sidama National Regional State. Hence, your opinion and perception will help me in this regard. Dear Respondents: The main objective of this questionnaire is to understand farmer's perspectives on climate change impacts on the area, small holder farmer's adaptation measures and determine factors that influence farmer's choice of adaptation in response to climate change in your area. This type of local level study is important for planners as well as decision makers at different level. Therefore, the information that you provide is believed to help the concerned bodies in understanding Vulnerability and adaptation strategies on climate change.

Hence, taking the above objectives into consideration, you are kindly asked to provide the appropriate answer for the following questions.

General Information

Kebele: _____

Respondent's Name: _____

Date of Interview: _____

Enumerator's Name: _____

Socio economic characteristics of households

1.1 Sex of household head (1) Male (0) Female

1.2 Age of household head in years_____

1.3 Number of family in household_____

1.4 Education level of household head, a) illiterate, b) primary education, c) secondary education, d) certificate

1.5 Primary activity of household members: 1= livestock production, 2 = crop production, 3= mixed farming, 4 informal trade, 5= formal employment, 6= others specify

1.6 Farming experience in years__

1.7. How much your farm size is if you have any?
a) < 0.5 ha, b) 0.5-1 ha, c) 1-2 ha, d) 2- 3 ha, e) > 4 ha

1.8 Major crops grown and production trends (bags) by the household per acre per year per crop for the good and bad years? The crops listed above are ones that will be explained in the table below. 2019/2020?

Crop type	Total harvested (qa)	Amount of land Cultivated(Acres)	Production per year (Bags/quintal)	
			Good year	Bad year
Haricot bean				
Maize				
Coffee				
Vegetables				
Fruits				
Enset*/produc*				

ts				
Chat				
Potato				
Sweet potato				
Teff				
Others				

1.8.1 How can you evaluate your household's crop production and incomes before 20 years?

1. No change 2. Decreasing 3. Increasing

1.8.2 Do you mainly produce for either cash or subsistence? And do you have any specific cash crop or do you sell the surplus that you produced for your own use?
A. Subsistence [ ], B. Cash [ ], C. Selling the surplus [ ]
Why?……
……
……

Livestock Production

1.9 Do you own livestock? 1 = yes, 0 = no. If yes, why do you keep livestock?
……
…….

19.1 If no, why don't own livestock?.....
.....
.....

Livestock asset holding

Mark 'X' on the type and number of livestock you owned

Livestock type	**Livestock number**	**How many are**		
		Juveniles	**Sub adults**	**Adults**
Cows				
Calves				
Heifers				
Oxen				

Bull calves				
Sheep				
Goat				
Poultry				
Horses				
Donkeys				
Mules				

Trend of livestock herd number since 1990 E.C, Mark “X”

Types of animal	Trend of livestock numbers, mark ‘X’ under the column		
	Increase	No change	Decrease
Cows			
Calves			
Heifers			
Oxen			
Bull calves			
Sheep			
Goat			
Poultry			
Horses			
Donkeys			
Mules			

1.9.2 What problems are you facing in livestock production?

Problem	**Severity (1 = very severe, 2 = moderately severe, 3 = not severe)**
Diseases	
Low yields	
Poor market access	
Low market prices	
Poor breeds	
Feed shortage,	

Land shortage,	
Grazing lands conflict	
Drought	
Others specify	

INSTITUTIONAL SUPPORT

1. Do you have a credit access? 1. Yes 0. No

2. Did you look for credit last two season? 1. Yes 0. No

3. If no, why? 1. Self-sufficient 2. Credit service unavailable 3. Credit requires collateral which

I can't provide 4. Others_____

4. If yes to Q. 1, did you receive any credit in your surrounding? 1. Yes 0. No

5. Have you ever taken credit to use it to adapt to climate change 1. Yes 0. No.

6. If yes in Q 5, for what adaptation mechanism?

a. To buy food for the family and the livestock

b. To buy resistant crop varieties and livestock species

b. To conserve water and soil

c. To buy irrigation equipment's

d. To be engaged in alternative income activities

e. Other, specify_____

7. Have you ever got extension service? 1. Yes 0. No

8. If yes to Q 7, on average how many times you have contacted the extension workers within the year (2019/20)?_____

9. Have you ever been advised by any development agent about the impact of climate change and means of adaptation strategies? 1. Yes 0. No

10. If your response is yes for Q 7, on average how often the extension agent visits you or

you visit him? _____

11. Have you received training on adaptation mechanisms to climate change? 1. Yes 0. No

12. If yes in Q11, on which adaptation mechanism?_____

13. If yes in Q10, do you think the training was helpful for your practical problem? 1. Yes 2. No

14. If No to Q11, why?_____

15. How far you should travel to get the nearest market center to sell your products and buy the

necessary items?_____ km.

16. Have you ever used the traditional information exchange methods to communicate and

share experience in your community? 1. Yes 0. No

17. If yes to Q 16, identify frequently used methods in the community._____

18. Have you ever got any information about forecasted weather condition? 1. Yes 0. No

19. If yes in Q 18, what was your source of information?

a. Listen from radio/mass media b. Owen experience c. Listen from other farmers

d. Training and Workshop e. Extension Agent f. Others specify_____

20. Do you think that governmental and non-governmental agencies are aware about climate

change problems and gave enough considerations? 1. Yes 0. No

21. If your response yes to Q20, How does they support you?

a. Provision of climate related information

b. Financial support (Credit,)

c. Provision of training on adaptation strategies

d. Provision of climate friendly technologies

e. Community mobilization on soil and water conservation

f. Others (specify)_____

7. If no to Q.1, why?

1. Not needed credit 2. Lack of access to credit 3. Interest rate is very high

4. Fear of credit 5. Bureaucracy of paper work 6. Others,

Climate change trends and perceptions

2.1 Have you experienced change in climate in your area? 1= Yes, 0= No.

2.2 What indicators are there to show that there is climate change occurring in this area?

Climate change events	Yes	No
Too much rainfall		
Little rainfall		
Late rainfall onset		
Early rainfall cessation		
Late rainfall cessation		
Drought		
Floods		
Early rainfall onset		
Hailstorms		
New diseases: be it crop or livestock (example??)		
New pests (example???)		
Others specify		

The effect of climate variability and change

1. Tell me about your experiences of the effects of climate variability and change

(Probe: make sure that the interviewee discusses how the change affected their livelihoods/crop and livestock production)

2. What are the biggest climate-related hazards you faced?

3. How are these hazards likely to change over time as a result of climate change?

4. How do you withstand the effects of climate variability and change?

ADAPTATION STRATEGY TO CLIMATE CHANGE

1.Have you ever used any adaptation strategy to resist climate change? 1. Yes 0. No
2. If yes for Q1, Which adaptation strategy you used to resist the climate change?
a. Adjusting planting date, d. Irrigation
b. Changing crop varieties and livestock species e. Crop diversification
c. Water and soil conservation practice, f. engaging in alternative income activities
g. Others specify _____
3. If no adaptation method used, why?_____
4. Identify any precautionary measures you have taken to overcome the side effect of climate
change?
a. Sell of food grain b. Livestock and its product sale c. Mobility d. Saving money
e. Others (specify)_____

5. How have the adaptation strategies to climate change and variability influenced the agricultural production at your farm?

……
……

6. Did the adaptation strategies to climate change and variability help you to attain food security? If yes or no, how?

……
……

Questionnaire for focus group discussion (FGD)

1. Statistical information on land use and farming system/ cropping pattern, and household size

2. What is the agro-ecology of your peasant association (village)? Explain the present weather (environmental) condition in your locality. Local names and percentage share of each (if more than one type),

Is there any form of climate change in your kebele? What is your observation on the climatic (temperature and rainfall) condition in your area? Over the past 20 years by each type

4. Are the temperature and rainfall distribution and intensity changing? If yes how?

5. What are the main climatic shocks (hazards) affecting livelihood in your locality? In the order of priority

6. Who is more vulnerable to the impacts? Why? By the type of hazard and impact

7. Explain years of extreme climate condition that affect your income in your locality (drought, flood, storm etc...).
8. What are the major local coping mechanisms (adaptation strategies) used to reduce the
adverse impacts? Rank (simple or pair-wise) and determine their effectiveness
9. Identify any indigenous crop cultivar, which is now out of production due to climatic change and variability? By type of climate scenario?
10. Identify any newly appeared crop infestation and diseases in your locality.
11. What is the institutional effort made to reduce future impacts?
12. What do you recommend to be done so as to reduce the adverse effects of climate change?

Key informant interviews

1. Are you originally from this *kebele*?
2. In your opinion what is climate change?
3. How would you describe the climate condition over the last three years?
4. Have you seen any long-term changes of temperature and rainfall for the last 20 years? If you say yes, how do you detect, and what is the reason to change?
5. Have you ever faced any climate related impact in your life time? Yes / No If yes, what type of climatic effect?
6. If your answer for Q4 is yes, did it affect your livestock or/and crop?
7. What extent that has been affected you and/or your family and, how did you adapt the situation?
8. Have you seen any disease or pest cases on animal and agriculture production? Over the last 32 years? Yes /No if your answer is yes what the causes were? (Explain)
9. Have you seen changes in the vegetation/forest cover over the last 20 or more years? (Please explain)
10. What are the general strategies that are undertaken and will be taken to adapt the impact of climate adapt on agriculture activities?
11. What are the main challenges/ difficulty to adapt climate change in your locality?
12. What do you recommend to be done to fight towards climate change?

Thank you!

Appendix 1 Parameter estimates of multinial logit model for climate change adaptation decision

. mlogit AdPr sex age education familysize farmsize livestock extension credit FAREXP CCIN market Anninc

Iteration 0: log likelihood = -278.45432

Iteration 1: log likelihood = -124.54076

Iteration 2: log likelihood = -110.38469

Iteration 3: log likelihood = -94.917946

Iteration 4: log likelihood = -90.939366

Iteration 5: log likelihood = -89.479797

Iteration 6: log likelihood = -88.880073

Iteration 7: log likelihood = -88.633355

Iteration 8: log likelihood = -88.618503

Iteration 9: log likelihood = -88.616481

Iteration 10: log likelihood = -88.616008

Iteration 11: log likelihood = -88.615892

Iteration 12: log likelihood = -88.615869

Iteration 13: log likelihood = -88.615864

Multinomial logistic regression Number of obs = 145

LR chi2(72) = 379.68

Prob > chi2 = 0.0000

Log likelihood = -88.615864 Pseudo R2 = 0.6818

AdPr	Coef. Std. Err.	z	P>z	[95% Conf.	Interval]
Change_ land_ use practices	(base outcome)				
Crop_diversification					
Sex	-7.620123 4.288192	-1.78	0.076	-16.02482	.7845779
Age	.1603494 .1330033	1.21	0.228	-.1003323	.4210312
Education	1.098932 .809552	1.36	0.175	-.4877611	2.685624
Familysize	1.107806 .6137052	1.81	0.071	-.0950337	2.310646
Farmsize	-13.67118 11.44581	-1.19	0.232	-36.10457	8.7622
Livestock	1.965069 1.477204	1.33	0.183	-.9301973	4.860335
Extension	66.77358 3261.138	0.02	0.984	-6324.94	6458.487

Credit	20.62501 1190.14	0.02	0.986	-2312.007	2353.257
FAREXP	-.0610473 .1524407	-0.40	0.689	-.3598256	.237731
CCIN	5.722601 4.324597	1.32	0.186	-2.753453	14.19865
Market	-.6278841 1.631813	-0.38	0.700	-3.826179	2.570411
Anninc	.1361944 2.520837	0.05	0.957	-4.804555	5.076943
_cons	-27.27118 2930.535	-0.01	0.993	-5771.015	5716.472
Herd_Livestock__diversification					
Sex	-5.859292 3.932733	-1.49	0.136	-13.56731	1.848724
Age	.1558796 .1240185	1.26	0.209	-.0871922	.3989514
Education	.9309518 .7372356	1.26	0.207	-.5140034	2.375907
Familysize	.8586571 .5204475	1.65	0.099	-.1614011	1.878715
Farmsize	-15.43662 11.40886	-1.35	0.176	-37.79758	6.924341
Livestock	2.919449 1.373999	2.12	0.034	.2264599	5.612437
Extension	47.38079 1430.742	0.03	0.974	-2756.822	2851.584
Credit	19.45199 1190.14	0.02	0.987	-2313.179	2352.083
FAREXP	-.0596079 .1358016	-0.44	0.661	-.3257742	.2065584
CCIN	4.816257 4.09321	1.18	0.239	-3.206286	12.8388
Market	-1.787896 1.535883	-1.16	0.244	-4.798172	1.22238
Anninc	1.692569 2.139474	0.79	0.429	-2.500723	5.885861
_cons	-7.508727 4.715229	-1.59	0.111	-16.75041	1.732952
Using_drought_torerant_crop_live					
Sex	-5.389153 4.309332	-1.25	0.211	-13.83529	3.056982
Age	.0578799	0.44	0.660	-.2000757	.3158356

	.1316124				
Education	.9518018 .8021824	1.19	0.235	-.6204468	2.52405
Familysize	1.476684 .6203863	2.38	0.017	.2607495	2.692619
Farmsize	-14.36592 11.46575	-1.25	0.210	-36.83837	8.106538
Livestock	2.855255 1.413329	2.02	0.043	.0851808	5.62533
Extension	49.96227 1430.743	0.03	0.972	-2754.242	2854.167
Credit	26.50134 1190.139	0.02	0.982	-2306.128	2359.13
FAREXP	-.0857273 .1512073	-0.57	0.571	-.3820881	.2106335
CCIN	7.111622 4.333675	1.64	0.101	-1.382226	15.60547
Market	-.5739359 1.626484	-0.35	0.724	-3.761786	2.613914
Anninc	-.217705 2.538034	-0.09	0.932	-5.19216	4.75675
_cons	-14.12459 6.714849	-2.10	0.035	-27.28545	-.963724 8
Soil_and_water_conservation					
Sex	-6.955349 3.895365	-1.79	0.074	-14.59012	.6794271
Age	.1629467 .1243004	1.31	0.190	-.0806775	.406571
Education	.7343141 .7332636	1.00	0.317	-.7028562	2.171484
Familysize	.8602819 .509247	1.69	0.091	-.1378239	1.858388
Farmsize	-15.2381 11.40792	-1.34	0.182	-37.59722	7.121015
Livestock	2.789257 1.373534	2.03	0.042	.0971795	5.481334
Extension	45.52421 1430.742	0.03	0.975	-2758.679	2849.728
Credit	19.10275 1190.139	0.02	0.987	-2313.528	2351.733
FAREXP	-.1335651 .1383087	-0.97	0.334	-.4046452	.1375149
CCIN	6.669072 4.030872	1.65	0.098	-1.231291	14.56943

Market	-1.565424 1.535028	-1.02	0.308	-4.574023	1.443175
Anninc	1.59286 2.098362	0.76	0.448	-2.519853	5.705574
_cons	-5.550494 4.503274	-1.23	0.218	-14.37675	3.275762
Engaging_in_off_farm_and_non_far					
Sex	-4.989934 4.823712	-1.03	0.301	-14.44424	4.464367
Age	.1030407 .1325623	0.78	0.437	-.1567766	.3628579
Education	1.828297 .852837	2.14	0.032	.1567674	3.499827
Familysize	.480359 .7242129	0.66	0.507	-.9390723	1.89979
Farmsize	-15.33229 11.6077	-1.32	0.187	-38.08296	7.418379
Livestock	2.831186 1.423977	1.99	0.047	.0402422	5.62213
Extension	46.93562 1430.743	0.03	0.974	-2757.269	2851.14
Credit	24.27024 1190.141	0.02	0.984	-2308.363	2356.903
FAREXP	-.1653682 .1626536	-1.02	0.309	-.4841635	.153427
CCIN	4.120711 4.364482	0.94	0.345	-4.433517	12.67494
Market	.4197136 1.871589	0.22	0.823	-3.248534	4.087961
Anninc	-.1861619 2.857455	-0.07	0.948	-5.786671	5.414347
_cons	-13.07329 8.244346	-1.59	0.113	-29.23191	3.085332
using_irrigation_schemes					
Sex	-8.271594 4.291592	-1.93	0.054	-16.68296	.1397731
Age	.0719078 .1315488	0.55	0.585	-.1859231	.3297387
Education	1.28761 .7947257	1.62	0.105	-.2700237	2.845244
Familysize	.8778977 .6269333	1.40	0.161	-.350869	2.106664
Farmsize	-15.27307 11.50604	-1.33	0.184	-37.8245	7.27836

Livestock	3.136614 1.420225	2.21	0.027	.3530233	5.920205
Extension	50.3326 1430.743	0.04	0.972	-2753.872	2854.537
Credit	27.94812 1190.14	0.02	0.981	-2304.683	2360.579
FAREXP	-.1142375 .1530906	-0.75	0.456	-.4142896	.1858147
CCIN	6.762495 4.329019	1.56	0.118	-1.722227	15.24722
Market	-.5402173 1.623107	-0.33	0.739	-3.721448	2.641014
Anninc	1.475216 2.48518	0.59	0.553	-3.395647	6.346079
_cons	-12.37228 6.870478	-1.80	0.072	-25.83817	1.09361

Source: Computed by STATA 14.2 from Household Survey (2021)

Appendix 2 Marginal effect due to independent variables

. margins,dydx(*)

Average marginal effects Number of obs = 145

Model VCE : OIM

dy/dx w.r.t. : sex age education familysize farmsize livestock extension credit FAREXP CCIN market Anninc

1._predict : Pr(AdPr== Change_ land _use practices), predict(pr outcome(1))

2._predict : Pr(AdPr==Crop_diversification), predict(pr outcome(2))

3._predict : Pr(AdPr==Herd_Livestock__diversification), predict(pr outcome(3))

4._predict : Pr(AdPr==Using_drought_torerant_crop_live), predict(pr outcome(4))

5._predict : Pr(AdPr==Soil_and_water_conservation), predict(pr outcome(5))

6._predict : Pr(AdPr==Engaging_in_off_farm_and_non_far), predict(pr outcome(6))

7._predict : Pr(AdPr==using_irrigation_schemes), predict(pr outcome(7))

	Delta-method				
dy/dx	Std. Err.	z	P>z	[95% Conf.	Interval]

Sex						
_predict						
1	.1131604	.0616867	0.83	0.167	-.0077433	.2340642
2	-.046941	.0561073	-0.84	0.403	-.1569092	.0630272
3	.0247242	.0773878	0.32	0.749	-.126953	.1764014
4	.1275805	.0625303	2.04	0.041	.0050233	.2501377
5	-.1189474	.0694399	-1.71	0.087	-.2550471	.0171523
6	.0468241	.0694349	0.67	0.500	-.0892658	.182914
7	-.1464009	.0646287	-2.27	0.023	-.2730708	-.0197309
Age						
_predict						
1	-.0027522	.0021071	-1.31	0.191	-.0068819	.0013776
2	.0022015	.0015399	1.43	0.153	-.0008166	.0052196
3	.0017336	.0015832	1.10	0.274	-.0013694	.0048366
4	-.0025191	.0013337	-1.89	0.059	-.0051332	.000095
5	.0028642	.0016302	1.76	0.079	-.000331	.0060594
6	-.0002236	.0010835	-0.21	0.837	-.0023472	.0019001
7	-.0013045	.0014645	-0.89	0.373	-.0041748	.0015658
Education						
_predict						
1	-.0152325	.0123837	-1.23	0.219	-.0395041	.009039
2	.0005708	.0116971	0.05	0.961	-.0223551	.0234967
3	.0059228	.0121386	0.49	0.626	-.0178684	.0297139

4	-.0134506	.0121079	-1.11	0.267	-.0371816	.0102804
5	-.0086792	.0128553	-0.68	0.500	-.033875	.0165167
6	.0195487	.0101047	1.93	0.053	-.0002561	.0393535
7	.01132	.0119813	0.94	0.345	-.0121629	.034803
Familysize_predict						
1	-.0150568	.0077518	-1.94	0.052	-.03025	.0001364
2	.0037671	.0100327	0.38	0.707	-.0158966	.0234307
3	.0035025	.012986	0.27	0.787	-.0219497	.0289546
4	-.0318806	.0095048	3.35	0.001	-.0132516	.0505097
5	.0054894	.0115064	0.48	0.633	-.0170627	.0280416
6	-.0110358	.0116935	-0.94	0.345	-.0339545	.011883
7	.0185471	.0107554	1.72	0.085	.0396272	.0425331
Farmsize_predict						
1	.2702339	.1867402	1.45	0.148	-.0957702	.6362379
2	.0532766	.031132	1.71	0.087	-.0077409	.1142941
3	-.1441586	.1194788	-1.21	0.228	-.3783327	.0900154
4	.029611	.0569201	0.52	0.603	-.0819503	.1411723
5	-.1445306	.1456753	-0.99	0.321	-.4300489	.1409876
6	-.0181189	.0553469	-0.33	0.743	-.1265968	.090359
7	-.0463132	.073616	-0.63	0.529	-.190599	.0979729

		7			3	
Livestock _predict						
1	-.0502288	.0196788	-2.55	0.011	-.0887985	-.0116592
2	-.0372478	.0186234	-2.00	0.045	-.0737491	-.0007465
3	.0373133	.0131251	2.84	0.004	.0115885	.0630381
4	.0009975	.0139643	0.07	0.943	-.026372	.028367
5	.0217984	.0138884	1.57	0.117	-.0054224	.0490192
6	.0012079	.008412	0.14	0.886	-.0152793	.0176951
7	.0261595	.0163554	1.60	0.110	-.0058964	.0582154
Extension _predict						
1	-.8191889	25.25244	-0.03	0.974	-50.31306	48.67468
2	.6884415	111.6999	3.21	0.095	218.2393	419.6161
3	.1800394	35.00014	2.01	0.006	68.41897	108.77905
4	-.1417914	31.38292	-0.00	0.996	-61.65119	61.36761
5	.247156	16.11024	0.02	0.988	-31.32833	31.82264
6	-.0603899	8.492084	-0.01	0.994	-16.70457	16.58379
7	-.0942666	29.69207	-0.00	0.997	-58.28966	58.10113
Credit _predict						
1	-.3456166	21.0063	-0.02	0.987	-41.5172	40.82597
2	-.1296764	.0689433	-1.88	0.060	-.2648027	.0054499

3	.0569592	8.549728	0.01	0.995	-16.7002	16.81412
4	.0874888	.3069157	0.29	0.776	-.5140549	.6890326
5	.078561	11.25761	0.01	0.994	-21.98595	22.14308
6	.0355618	.8492358	0.04	0.967	-1.62891	1.700033
7	.2167222	.1072222	2.02	0.043	.0065705	.4268738
FAREXP_predict						
1	.001836	.0024113	0.76	0.446	-.00289	.006562
2	.0013031	.0022335	0.58	0.560	-.0030745	.0056807
3	.0036136	.0029674	1.22	0.223	-.0022025	.0094296
4	.0010057	.0023338	0.43	0.667	-.0035684	.0055798
5	-.0047604	.0031323	-1.52	0.129	-.0108996	.0013789
6	-.0018474	.0021269	-0.87	0.385	-.0060162	.0023213
7	-.0011506	.0027618	-0.42	0.677	-.0065636	.0042623
CCIN_predict						
1	-.1027016	.0655686	-1.57	0.117	-.2312136	.0258104
2	-.013277	.050853	-0.26	0.794	-.1129471	.086393
3	-.0628217	.0598986	-1.05	0.294	-.1802209	.0545775
4	.0453169	.0759248	0.60	0.551	-.1034929	.1941268
5	.1483202	.0597719	2.48	0.013	.0311695	.265471
6	-.0453263	.0367794	-1.23	0.218	-.1174127	.0267601

7	.0304895	.0791196	0.39	0.700	-.1245819	.185561
Market_predict						
1	.0275191	.0259937	1.06	0.290	-.0234277	.0784659
2	.0115599	.0177651	0.65	0.515	-.023259	.0463789
3	-.057829	.0297349	-1.94	0.052	-.1161083	.0004503
4	.0061104	.0185604	0.33	0.742	-.0302672	.0424881
5	-.0229774	.0283327	-0.81	0.417	-.0785084	.0325536
6	.0347276	.0281301	1.23	0.217	-.0204064	.0898615
7	.0008893	.0209566	0.04	0.966	-.0401848	.0419634
Anninc_predict						
1	-.0271057	.03601	-1.75	0.052	-.097684	.0434726
2	-.0309628	.0427976	-0.72	0.469	-.1148445	.052919
3	.0532931	.0546622	0.97	0.330	-.0538428	.160429
4	-.0761885	.0522439	-1.46	0.145	-.1785847	.0262078
5	.0303166	.0518654	0.58	0.559	-.0713376	.1319709
6	-.0338099	.0464351	-0.73	0.467	-.1248211	.0572012
7	.0844572	.0514272	1.64	0.101	-.0163384	.1852527
.						

Appendix 3 Contigency variables of dummy variables

```
. correlate sex extension credit CCIN
(obs=145)
```

	sex	extens~n	credit	CCIN
sex	1.0000			
extension	-0.0723	1.0000		
credit	0.0495	0.4070	1.0000	
CCIN	-0.1487	0.3307	0.4016	1.0000

Appendix 4 Variance of inflation factors for continuous variables

```
. estat vif
```

Variable	VIF	1/VIF
farmsize	1.10	0.906817
education	1.06	0.940973
FAREXP	1.06	0.946804
age	1.05	0.953014
Anninc	1.05	0.954056
familysize	1.04	0.965190
livestock	1.03	0.967724
market	1.02	0.980374
Mean VIF	1.05	

Appendix 5 Livestock Category &Tropical unit (TLU)

Livestock category	TLU-equivalent
Calf	0.25
Weaned calf	0.34
Heifer or Bull	0.75
Cows or Oxen	1.00
Donkey (young)	0.35
Donkey (adult)	0.70
Sheep or Goat (adult)	0.13

Sheep or Goat (young)	0.06
Horse or Mule	1.10
Chicken	0.013

Source: Storck et al. (1991)