Effect of Climate Variability and Change on Crop production and Adaptation Strategies of Farming Community in Aleta Wondo Woreda, Sidama Region, Ethiopia

MSc. THESIS

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EFFECTS OF CLIMATE VARIABILITY AND CHANGE ON CROP PRODUCTION AND ADAPTATION STRATEGY OF FARMING COMMUNITY IN ALETA WONDO WOREDA, SIDAMA REGION, ETHIOPIA

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A THESIS SUBMITTED TO THE FACULTY OF ENVIRONMENT, GENDER AND DEVELOPMENT STUDIES, COLLEGE OF AGRICULTURE, HAWASSA UNIVERSITY

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Climate Change and Sustainable Agriculture

APPROVAL SHEET

HAWASSA UNIVERSITY COLLEGE OF AGRICULTURE

This is to certify that the thesis entitled "**Effect of Climate Variability and Change on Selected Crop Production and Adaptation Strategies of Farming Community in AletaWondo Woreda woreda, Sidama, Ethiopia**" submitted in partial fulfilment of the requirements for the degree of masters of Science in Climate Change and Sustainable Agriculture, and has been carried out by Maru Konte, under our supervision. Therefore, we recommended that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Approved by Advisors:

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SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY EXAMINERS' APPROVAL SHEET-1

(Submission Sheet-2)

We, the undersigned, members of the Board of Examiners of the final open defense by Maru Konte have read and evaluated his thesis entitled "Effects of Climate Variability and change on Crop production and adaptation strategies of farming community in Aleta wondo Woreda, Sidama Region", examined the candidate.

This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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Name of Internal Examiner-I Signature Date

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Name of the External Examiner-II Signature Date

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SGS Approval Signature Date

DEDICATION

This thesis is heartily dedicated to my beloved girlfriend Misho (Shashaye), Melaku Mathewos, Muluken Melese and all my family for their moral support and encouragement during my work at Hawassa University.

DECLARATION

By my signature below, I declare and affirm that this thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation. 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 MARU KONTE BETA **Signature**__________

Place: College of Agriculture, Hawassa University, Hawassa

Date of Submission…………………………………………

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ABBREVIATIONS AND ACRONYMS

CSA	Central Statistical Agency
CV	Coefficient of Variation
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
ISS	Institute for Security Studies
MoA	Ministry of Agriculture
MEA	Millennium Ecosystem Assessment
MNL	Multinomial Logit model
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
MoWRNMA	Ministry of Water Resources and National Meteorological Agency
NMA	National Metrological Agency
NREPA	Natural Resources and Environmental Protection Agency
SD	Standard Deviation
SNNPR	Southern Nation Nationalities and Peoples' Region
SPI	Standardized Precipitation Index
UNEP	United Nation Environmental Program
VIF	Variance Inflation Factor
WMO	World Meteorological Organization

TABLE OF CONTENTS

Contents **Pages**

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

Effect of Climate Variability and Change on Crop Production and Adaptation Strategies of the Farming Community in Aleta Wondo Woreda, Sidama Region, Ethiopia

ABSTRACT

Climate change poses huge challenges to the global economy and to social development. Especially, Africa is highly vulnerable to the potential effects of climate change, while Ethiopia is often cited as one of the most vulnerable and with the least capacity to respond and adapt. The objective of this study was to investigate the effects of climate variability and change on crop production and adaptation strategies employed by the farmers in Aleta Wondo woreda. The study was based on a cross-sectional survey of 188 sample households. Primary data were collected by survey, interviews and focus group discussions, while, the secondary data were accessed from National Meteorological Agency and Woreda Agricultural offices. The collected data were analyzed using both descriptive and inferential statistics. Multinomial logit (MNL) model was used to identify factors influencing farmers' choice of adaptation strategies to the effects of climate change. The results showed that, 93.1% of respondents perceived decreasing trends of rainfall and 98.4% of the respondents reported temperature was increasing. However, according to the data obtained from NMA, the trend of RF was increasing by the rate of 2.035mm per annum. The effects of climate change were responsible to reduction of crop productivity, partial crop losses, increased pest incidence, and reduced production area. The highest correlation values of crop yield with the belg rainfall at ($p \leq 0.01$)) were observed. From the total households 25% of the sample households were practicing crop diversification as adaptation strategy in crop production. Adaptation strategies considered in the MNL model analysis for crop production were crop diversification, soil and water conservation, planting trees, using improved seeds, growing drought resistance crop varieties and changing planting date; Age, education, family size, of household, climate information, extension and credit services are factors that contribute different levels of adaptive capacity within the community. In conclusion the study indicated that small changes in rainfall patterns can result in significant effect on the livelihoods of the farming community. Therefore, the need to strengthen adaptation options, importance of resources and appropriate and timely information on future climate change so as to alert them to take appropriate averting actions are important.

Key words: Adaptation options, climate change, crop production, climate vulnerability

CHAPTER ONE

INTRODUCTION

1.1. Background and Justification

Climate change is predicted to have major adverse consequences for the world‘s ecosystems and societies. Although a global phenomenon, the severity of the adverse effects of climate change will differ significantly across regions, countries and socioeconomic groups. Poor countries will suffer more, with the poorest in the poor countries likely to suffer most. Africa is highly vulnerable to the potential effects of climate change and Ethiopia is often cited as one of the most vulnerable and with the least capacity to respond and adapt (Thornton, 2010).

Studies exposed that the world's climate has already changed and will change dramatically. The earth's climate has warmed on average by about 0.7^0C over the past 100 years with decades of the 1990s and 2000s being the warmest in the instrumental record (Watson, 2010). Analysis of historical climate data in Ethiopia show an increase in mean annual temperature by 1.3°C between 1960 and 2006, translating into an average rate of 0.28°C per decade. The annual minimum temperature increased by about 0.37°C every decade between 1951 and 2006 (McSweeney*et al.,* 2008). The IPCCs mid-range emission scenario results show that compared to the 1961-1990 average mean annual temperature across Ethiopia will increase between 0.9 and 1.1°C by the year 2030, and from 1.7 to 2.1°C by the year 2050. In contrast, precipitation remained fairly stable when averaged over the country (Schneider *et al.,* 2008). Similarly, no statistically significant trend in mean annual rainfall was observed in any season from 1960-2006 (NMA, 2006; McSweeney*et al.,* 2008). However, the spatial and temporal variability of precipitation is high, thus large-scale trends do not necessarily reflect local conditions. Projecting into the future, most global climate models indicate some increase in rainfall in both dry and wet seasons in Ethiopia (NMA, 2006).

Climate change poses huge challenges to the global economy and to social development. Its impacts will disproportionately affect sub-Saharan African countries such as Ethiopia because their economies are highly dependent on climate-sensitive activities such as rain-fed agriculture. It is that agriculture is the main livelihood of the majority of the population and is the basis of the national economy in Ethiopia. It contributes about 47% of the country's Gross Domestic Product (GDP) and more than 70 million people (85% of the Ethiopian population) depend on agriculture directly or indirectly for their livelihoods (Index Mundi, 2014). Therefore, any effect on agriculture will significantly affect the Ethiopian economy. It is predicted that changes in climate will lead to recurrent droughts and heavy rainfall in different parts of Ethiopia, reducing the amount of land that can be used for agriculture and decreasing crop productivity.

According to World Bank, (2006), current rainfall variability already costs the Ethiopian economy 38% of its growth potential. The major predicted impacts of climate change on Ethiopia's agriculture include frequent droughts and dry spells, shortened growing season, and increased incidence of pests and diseases (NMA, 2007). A study based on the Ricardian method predicts that a unit increase in temperature could result in reduction of the net revenue per hectare by 4484.91 birr in summer and 11733.93 birr in winter seasons (Deressa, 2007).

Annually, Ethiopia loses 2 to 6% of its annual production due to climate change (MoFED, 2010). Unless appropriate adaptation measures are put in place, the impacts of climate change will be manifested more in the loss of agricultural production, inundation and drying up of water resources and loss of biodiversity.

Understanding the nature of climate change effects, key vulnerabilities and indigenous adaptive responses at local levels, and the national institutional responses are important for developing appropriate adaptation strategies at community and farm levels (Mendelsohn and Kurukulasuriya, 2008). As the world adapts to its evolving climate, more global attention is now being focused on adaptation to the effects of climate change; therefore, it is important to assess how people are coping with the effects of climate change, how they could become more resilient to these effects and how people and communities can adapt to changes in climate (Malone, 2009).

Perception is not the only factor that influence farmers use of adaption measures; adaptation to climate change takes place in a dynamic social, economic, technological and biophysical context that varies over time, location, and sector. This complex mix of conditions determines the capacity of systems to adapt negative effect of climate change (Kates, 2000). Knowing determinants of the choice of climate change adaptation strategies is vital in developing intervention measures on those key determinants perceived to improve farmers' adaptive capacities (Jeffcott, 2013). There is, therefore, a need for a better understanding of farmer perceptions of long-term climatic changes, adaptation measures and factors influencing simultaneous choice of adaptation strategies (Temesgen, 2009).

Sidama's rural livelihoods are at risk due to several factors, an important one being climate change. Paradoxically, increased aridity and drought occur a mid-erratic rain and heavy flooding. For instance, in April 2013, heavy rainfall in the midland and highland areas caused localized flooding in Sidama (Seyoum, 2014). This has affected more than 3,500 people leading to livestock deaths, damaged houses and infrastructure, as well as damage to over 600 hectares of crops in Sidama and its surrounding areas (WFP, 2013). However, little study was conducted earlier on the climate change adaptation strategies of smallholder farmers in this study area using household-specific survey data. Therefore, this study was conducted to investigate the effects of climate variability and change on crop production, identify local level farmers' adaptation strategies and key factors that govern farmers' choice of adaptations option towards climate change.

1.2. Statement of the Problem

The issue of climate change vulnerability and adaptation strategies have drawn a great attention from policy makers and academicians for last decades. In view of that, a number of studies have been done at regional and country levels to estimate economic effects of climate change on Crop production and factors affecting adaptation strategies (Deressa *et al.,* 2008). Current climate change is already imposing a significant challenge to Ethiopia by affecting crop, water, energy supply, poverty reduction and sustainable development efforts, as well as by causing natural resource degradation and natural disasters (EPA, 2011).

The most pronounced problems are recurrent drought, floods, famine and lack of food security. High vulnerability to climatic risks is linked to dependence on climate-sensitive livelihoods, low economic development, low service coverage, underdeveloped water resources, inadequate road infrastructure, low adaptive capacity, and weak institutions. Dependence on undiversified livelihoods based on rain-fed agriculture means that production is sensitive to fluctuations in rainfall (Muluneh*et al.,* 2015).

Within the same framework, SNNPR region have been experiencing climate change. In the last decade, average annual minimum temperature of the SNNPR region had risen by 0.4^0c (NREPA, 2012) above the national 0.37^0c (MoWRNMA, 2007). This shows the seriousness of the problem in the region. Sidama is a typical case in this regard. Sidama’s smallholder farmers are heavily vulnerable to shocks, yet their perceptions and vulnerability are largely undocumented and least studied (Seyoum, 2014). Moreover, common to some other areas in Ethiopia (Kebede and Adane, 2011), Sidama has experienced food insecurity, diminishing water resources, erratic and torrential rainfall causing floods and inundation of crop fields near riverbanks and lakesides, flooding of crop fields, and the spread of malaria. In terms of climate change related research, current knowledge and understanding of vulnerability and adaptation by communities in Sidama is weak (Seyoum, 2014).

The most severely affected areas in the Region are semi-arid and dry areas, particularly quarter of Aleta wondo Woreda's kebeles are semi-arid. This area experienced higher temperature and receives less rainfall. As a result, the farmers in the Woreda are negatively affected by climatic changes, particularly by crop failures and have had to change their typical livelihood practices as well (Aklilu *et al.*, 2009). Therefore, the area have been subject to several interventions including the Safety Net programs whose results have yet to be proven from sustainable development point of view. Moreover, a combination of decreased rainfall and increasing temperatures, associated with climate change, has led to the desiccation of wells which are crucial sources of water for many peoples.

Despite a number of knowledge and information generated on effects of climate change and adaptation options on agricultural sector in Ethiopia, there is limited effort to review and synthesis the effects of climate change on crop and demonstrate the different adaptation strategies. In view of that, a number of studies have been done at regional and country levels to estimate economic effects of climate change on crop and factors affecting adaptation strategies. For instance, Yesuf *et al.* (2008); Molla (2008); Deressa and Hassan (2009) were some of the studies that deal with the effect of climate change on agriculture focusing on crop production and net farm revenue.
Similarly, most of the existing literatures on climate change in Ethiopia are focused on the estimation of impacts on crop production and net farm revenue. Moreover, vast majority of research works have targeted the perceptions of stakeholders and determinants of adaptation at country or regional scale. Studies like Deressa (2007); Deressa *et al.* (2008); Di Falco *et al.* (2011a) and Di Falco *et al.* (2011b) have assessed the impacts of climate change on agriculture and determinants of adaptation in case of Nile Basin region. However, studies like Tesso*et al*. (2012); Legesse *et al*. (2013); Tessema *et al*.

(2013) and Teka*et al. (*2012) have targeted the on assessment of farmers' perception and choice of adaptation options in different parts of Ethiopia. At country level, Gebreegziabher *et al*. (2011) have modeled the impacts of climate change on overall Ethiopian economy using a countrywide Computable General Equilibrium model.

Previous studies on the effect of climate change showed that Ethiopia is among the poor countries in Africa that is most vulnerable and likely to experience the worst of climate change effects (Deressa, 2007). Despite the seriousness of the problem, there are still a number of knowledge gaps that need to be addressed through research's on climate change and its associated effects on the various economic sectors, livelihood systems, communities and ecosystems of Ethiopia.

There have been few attempts to look into the economic effects of climate change in the context of Ethiopia. Although mixed crop-livestock farming is a dominant farming style, most of the studies on climate change, at least in the context of Ethiopia (Deressa and Hassan, 2009). Thus it would be more meaningful and realistic to fill the gap by investigating the economy-wide effects of climate change in a general equilibrium setting with a focus on the Ethiopian economy.

Likewise, most of the studies have captured the perception of farmers on the trend and variability of rainfall (Teka*et al.*, 2012). However, their studies have a gap in relating rainfall analysis with the local farmers' observation. Their study also focused only climatic variable i.e. rainfall and did not consider the effect of temperature. To our knowledge, there is also little, though growing evidence on the effectiveness of climate change adaptation strategies to ensure household food security. This is particularly important to inform policy makers in identifying most effective adaptation measure that could help reduce smallholders' vulnerability to climate induced shocks. They have partly dealt with the effectiveness of adaptation options, a step forward from climate change effects and determinants of adaptation strategies. But, their study treats different climate adaptation strategies as a package.

For this reason, the researcher has acknowledged the need for further study focusing on distinction of different adaptation strategies and the identification of the most effective ones in reducing risks pertaining to climatic shocks. The purpose of this study is; therefore, by considering above gaps it is increasingly important to identify effects of climate change on crop production, and key knowledge on adaptation strategies which could help to enhance understanding of policy makers for setting appropriate adaptation strategies at both national and farm-level.

1.3. Objectives of the Study

The general objective of the study was to analyze the effect of climate variability and change on crop production and adaptation strategies of farming community in Aleta Wondo Woreda

The specific objectives are:

i. To analyze the trends of temperature and rainfall pattern in the study area for the last three decades
ii. To examine the effects of climate variability and change on major crop production and composition
iii. To identify adaptation strategies employed by farmers in response to climate changes
iv. To investigate determinants of farmers' choice of adaptation strategies to climate change

1.4. Research Questions

- ✓ What is the historical trend of temperature and rain fall in the study area?
- ✓ What are the effects of climate change on crop production?

- ✓ What types of adaptation measures are practiced by farmers?
- ✓ Which factors influence farmer's choice of adaptation measures to climate change?

1.5. Significance of the Study

In response to climate change, adaptation initiatives are being pursued at different levels. In doing so, by broadening and extending our understanding of climate change, agricultural productivity and adaptation strategies in Ethiopia and enhancing informed decision making at various levels is important to poverty reduction and environmental sustainability. Particularly, this study would contribute to existing body of scientific knowledge through examining the empirical link among climate change, crop production and adaptation strategies. More importantly, it may give an insight into the identification of most effective climate change adaptation options which could help reduce vulnerability and ensure food security among households in rural areas of Aleta Wondo Woreda. Furthermore, it would generate important information policy maker on adaptation strategies to deal with climate change effect on crop. Finally, it would be supporting document for those who want to conduct further study in the area.

1.6. Scope of the Study

The scope of study was limited to Aleta Wendo Woreda of Sidama Region, to assess the level of climate variability and change on crop production and to assess the level of adaptation strategies of farming community towards changing climate.

1.7 Limitation of the Study

Shortage of time and budget made limitation for the further study of the effects of climate variability and change on crop production and adaptation strategies of farming community of the Aleta Wendo woreda. The study relied on the four selected kebeles only in Aleta Wendo Woreda, Sidama Region for practical reasons such as time and financial limitations and shortage of adequate secondary source of data was also another problem. This study was focus only on the effects of climate variability and change on crop production and adaptation strategies of farming community.

1.7 Organization of the Thesis

The document structured to five chapters. The first chapter describes the study problem and the objectives of the study. The second chapter presents the theoretical perspectives and empirical evidences related to the main themes of the Thesis. Chapter three discusses the methodological approach used to achieve the study objectives. Chapter four presents the key findings and discussions on the findings. Finally, chapter five presents conclusion and recommendation of the study.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Basic Concepts

Climate change: - Refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2014).

Effect: - Refer to effects, consequences or outcomes on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events (IPCC, 2014).

Adaptation: - The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities (IPCC, 2014).

2.2. Theoretical Framework

One of the theories reviewed in this study, utility maximization. Utility maximization argument is that it is a choice decision in which individual has a set of alternatives from which to choose (Chan, 2005). The level of utility from a specific choice is a latent variable known only to the decision maker (farmers) and observed through the choices made by the farmers denoted. In this way the farmers build a comprehensive inventory of risk aversion strategies based on political, cultural, economic, and environmental factors, and they identify impulsivity as an adaptive strategy in risky environments (Mwandosya*et al.,* 1998). In all cases the utility that the decision maker (i.e. crop farmer) gets from selecting a specific choice of climate change adaptation strategy is measured by a utility function U, which is a mathematical representation of the decision maker's (crop) system of preferences such that: $U(x_1)$ $U(x_2)$, where choice of climate change adaptation x_1 is preferred over choice x_2 or $Ux_1 = Ux_2$, where choice x_1 is indifferent from choice x_2 both choices are equally preferred (Wooldridge, 2002).

i. Vulnerability Assessment

In order to reduce vulnerability to future climate change, it is evident that adaptation to current climate variability (to reduce vulnerability to present-day climate extremes) is important. Thornton *et al.* (2006) go further, stating that adaptation is not an option but a necessity for many African countries. It is clear that, in terms of adaptation strategies, there is a distinction between the timescales of climate variability and climate change, with the former receiving the most priority in many African weather and climate centers. There is clearly a need to focus on the climate variability timescale, not least because it is likely that climate change will be partly manifested by a change in the frequency of extreme events currently experienced within present day climate variability (Thornton *et al.*, 2006).

Lessons can be learnt on how the most vulnerable (usually the rural poor) currently adapt to this variability, and these lessons can then be used to assist in further adaptation to future climate change (Kandlinkar and Risbey, 2000). Although climate variability and climate change are often seen as separate issues, it is recognised that the two can be bridged, with adaptation to the immediate impacts of climate variability being vital in preparing for the longer term impacts of climate change (Daze *et al.*, 2009). In this way, successful management of shorter term climate variability provides a win–win outcome, by reducing vulnerability both now and in the future. At the same time, however, it is acknowledged that it would be shortsighted to only focus on short-term adaptive capacity, such as immediate responses to climate shocks and uncoordinated or isolated adaptation projects (Kandlinkar and Risbey,2000). Based on the fact the study utilized random utility theory of vulnerability assessment based on the notion that a farmer derives utility from choosing an adaptation strategy which best meet the challenges.

ii. Impact Assessment

Climate change impact assessment mentions studies and investigations designed to find out what the effects of climate change at the moment and in the future on human activities and the natural world are (Burton *et al.*, 1998). Hence climate change impact assessment usually goes together with present assessment of adaptation options and promotes future possible adaptation strategies for response to a changing climate. One of the approaches used to assessment of the effect of climate change on crop statistical approaches. Statistical approaches to climate change impacts can capture different modes of adaptation, depending on the methodology used. Consequently, the approaches give a chance to famers to choose available adaptation option.

So, farmer plays a role of the decision maker that must decide how much each of the many available climate change adaptation strategies to use so as to secure the highest possible level of total utility subject to his or her available income, prices, and other factors. In addition, famers can intrinsically account for a wide range of mechanisms that can influence yields and population in a changing climate. It provides an excellent option because it allows one to investigate the individual input variables that are capable of influencing crop yields and population while maintaining all other variables constant. For this reason, this approach has been largely used to assess climate change impacts in many regions of the world.

2.3. Trends of Climate Change

i. Global climate change trend

Climate is changing more rapidly than ever before. The evidence comes from direct measurements of rising surface air temperatures, ocean temperatures and from phenomena such as increase in sea levels, retreating glaciers, and changes to physical and biological systems. Since the early 1990s the Intergovernmental Panel for Climate Change (IPCC) has provided evidence of accelerated global warming and climate change. The latest IPCC's Fifth Assessment Report presents new evidence of climate change (IPCC, 2013).

The global average temperature showed a warming of 0.78 (0.72 to 0.85°C) over the period of 1850 to 2012, and current predictions for the end of the 21st century is that global average temperature increase will be between 1.5 - 2°C (IPCC, 2013). Evidence of changes in rainfall at global scales is complex because of large regional differences, gaps in spatial coverage and lack of long term data. Climate predictions indicate that the contrast in rainfall between wet and dry regions and between wet and dry seasons will increase (IPCC, 2013) even though the projections of rainfall are uncertain for the West African region because of uncertainty in the quantification of potential vegetation-climate links.

The trend in rainfall globally is that it is increased variance. Wet areas are becoming wetter, and dry and arid areas are becoming drier (UNEP, 2007). Based on observed changes since the beginning of the twentieth century, Donat*et al.* (2013) found more areas of the globe with significant increasing trends in extreme precipitation amounts than decreasing trends. Recent reviews have considered an impending global water crisis in the context of continued population growth and predicted climate changes. According to (IPCC, 2007) the significantly increases in rainfall have been observed in the eastern parts of North and South America, in northern Europe and in northern and central Asia, whiles a decrease and drying has been observed in the Sahel.

ii. Continental climate change trend

In Africa, temperatures have increased in the same way as in the rest of the world the last 100 years (EPA, 2011). Analysis for the time period 1901-1995 indicates that the African continent is now warmer than it was 100 years ago (Rosell, 2010). Most climate models predict that the Sahel region will be drier in the 21st century than it has been earlier (UNEP, 2006). Even slight increases in rainfall are unlikely to reverse the situation since a warmer climate means that evapo-transpiration will be more intense, and worsening the already arid conditions (UNEP, 2006). In Africa global warming is likely to be even larger than the global annual mean warming and this across the whole continent and across all seasons (IPCC, 2013).

iii. National climate change trend

Like much of Africa, Ethiopia has become warmer over the past century and human induced climate change will bring further warming over the next century at unprecedented rates (EPA, 2011). Over the last decades, Ethiopia has experienced climatic changes. Average temperature has increased markedly, with 0.2 - 0.28°C per decade over the last 40-50 years (Eshetu*et al.*, 2014). Temperature rise is different per region and season. It has been most extreme in already dry and hot areas of the country, most notably in the north and east, and in the July September season (McSweeney*et al.*, 2008). Simultaneously, the number of cold days and cold nights has decreased by 6 and 11% respectively (McSweeney*et al.*, 2008). Data analyzed in selected stations indicated that temperature has been increasing by 0.37^{0}C every ten years (Kefyalew and Tegegn, 2012). Climate change projection also indicated that the mean annual temperature in Ethiopia expected to increase from 0.9 to 1.1°C by 2030, 1.7 to 2.1°C by 2050 and 2.7 to 3.4°C by 2080 (Kefyalew and Tegegn, 2012). While all models foresee warming, they contradict each other as to where the largest increase will happen: in the west and north, in northwest, northeast and central areas, or in the south-central part (USGS *et al.*, 2012).

Different climate models present roughly similar projections concerning temperature change, but different ones for precipitation. Mean annual rainfall shows large spatial and temporal variation. Same authors also indicated that, rainfall variability is increasing (and predictability is decreasing) in Oromia and Tigray, while total average rainfall is declining in these regions (Aragie, 2009). Another report found that for some southern, south-western and south-eastern regions, Belg and Kiremt rainfall have decreased by 15-20% between 1975 and 2010(Eshetu*et al.,* 2014).

2.4. Effect of Climate Variability and Change on Agriculture Production

Agriculture is an economic activity that is highly dependent upon weather and climate in order to produce the food and fiber necessary to sustain humanity. It is not surprising, that crop is deemed to be an economic activity that is vulnerable to the risks associated with climate variability and change. It involves natural processes that frequently require fixed proportions of nutrients, temperatures, precipitation, and other conditions (Vuren*et al.,* 2009). Agriculture represents less than 2% of GDP in high-income countries, and 2.9% for the world as a whole. It is more important for low-income countries, contributing largely to the GDP (Seo and Mendelsohn, 2006).

Climate change affects crop in a number of ways; including through changes in average temperatures; rainfall and extremes with an important impact on soil erosion (i.e. floods, drought, etc.): changes in pests and diseases, changes in atmospheric carbon dioxide, changes in the nutritional quality of some foods, changes in growing season, and changes in sea level (World Bank, 2008). Crop yields show a strong correlation with temperature change and with the duration of heat or cold waves, and differ based on plant maturity stages during extreme weather events (Hoffmann, 2013). In an indirect way, a change in temperature and moisture levels may lead to a change in the absorption rate of fertilizers and other minerals, which determine crop productivity. In short, the rise in temperature along with the reduction in rainfall reduces agricultural productivity if both are beyond the threshold that is suitable for crop production (Tirado and Cotter, 2010).

In most of African countries, there is a strong association between GDP growth and climate variables like rainfall. This resulted largely due to lack of economic diversification and strong dependence on the agricultural sector (Pane, 2009). The crux of the matter is that, in Africa, this association is a direct reflection of the very high dependence of agricultural production on climate variables. In Ethiopia, such a relationship is very striking. Agricultural output is highly pronounced even by changes in a single climate variable, i.e., rainfall (PANE, 2009). The same is true for the country's GDP as it heavily relies on agriculture (World Bank, 2006).

Rain failure, floods and drought and other changes in the country`s natural and environmental system due to climate change threaten the performance of the economy as a whole and are the main cause of severe malnutrition and loss of livelihoods for households particularly in marginal and less productive lands in the country (PANE, 2009). This effect is attributed to the fact that those changes can seriously depress crop production in the country. This clearly demonstrates that economic growth in general and households` welfare in particular are entwined and therefore livelihoods are still significantly influenced by changes in rainfall and other climate variables (World Bank, 2006).

Specifically to Ethiopia, climate change affects crop production through shortening of maturity period and then decreasing crop yield, depressing the quality and quantity of forage crops, changing distribution of diseases, changing decomposition rate, contracting pastoral zones, expansion of tropical dry forests and the disappearance of lower montane wet forests, expansion of desertification, etc (NMA, 2007).

The history of climate extremes, especially drought, is not a new phenomenon in Ethiopia. The most drought prone and affected areas of the country are in the northern, eastern and southern parts. Total failure or shortage of rainfall is often cited as the major cause for the recurring droughts and harvest failures. For instance, Ethiopia has suffered from periodical extreme climate events, manifested in the form of frequent drought in 1965, 1974, 1983, 1984, 1987, 1990, 1991, 1999, 2000, 2002, and 2011 (Orindi*et al.*, 2006).

The farmers living in Ethiopia's semi-arid and arid lowlands have less diversified assets and are heavily reliant on rain-fed agriculture, along with their crop, particularly are vulnerable to climate change (MacDonald and Simo, 2011). It is estimated that the 1984-85 climate induced drought reduced Ethiopia's agricultural production by 21%, which led to a 9.7% of all in the GDP (IPCC, 2007). Bezabih*et al.* (2014) also point out that climate variability and change in Ethiopia has significant impact on the yields of different crops.

Climate changes also affects harvests in dry land areas because of delays in onset and early cessation of rains that force farmers to miss the optimum planting time. As a result, farmers fail to plant long-season crops (Dry land Crops Research Strategy 2002). According to MoA and NRMRD (1998) due to low water holding capacity of the soil in the semi-arid areas, the length of the two growing periods are generally short, ranging from 1-60 days (December February season) and 60-120 days (March-May season) days. For instance, the poor performance of rains during these seasons in April and May 2002 significantly affected planting and early growth development of the long cycle crops of maize (DPPC 2003).

A decrease in length of growing season could result, for example, in alteration of planting dates determining lower yields of traditionally planting crops, which may not fully mature (Linderholm, 2006). Bearing in mind that in many areas with alternating wet and dry seasons, the annual rainfall is less than the amount of the water that a crop well supplied with water would transpire during the growing season (Ayanlade*et al*., 2010) hence affect the entire crop growing cycle. This meant that the group is highly vulnerable based on weather fluctuations and climate variability playing a significant role in crop growth and yield. Literature notes that occurrence of abnormal weather episodes during any growing season or during critical development stages may hamper growth processes resulting in yield reduction (Anyamba and Tucker, 2001). For example, in semi-arid rainfed agriculture the onset of the rainy season often determines the length of the growing period and thereby suitable combination of crops (Mugalavai*et al.*, 2008).

2.4.1. Effects on crop production

Crop production will be depressed by increased climate variability and increased intensity and frequency of extreme weather events such as drought and floods (IPCC, 2007; Zenebe and Alemu, 2011). Its negative impact is much higher in areas where rain-fed agriculture dominates. For instance, frequent droughts not only reduce water supplies but also increase the amount of water needed for evapo-transpiration by plant (IPCC, 2007). Climate change affects crop production in several ways. These include effects of increased temperatures, changes in soil water balance, changes in length of growing period increased soil erosion and land degradation due to increased rainfall intensities, increased incidence of floods in flood-prone areas, and increased incidence and expansion of crop pests, diseases and weeds mainly associated with increasing temperatures (IPCC, 2007).

Climate change can also lead to a shift in agro-ecological zones as a result of altered water balances and local climatic conditions, rendering existing technologies less relevant. Across the study sites, crop production is highly vulnerable to climate change through all of above ways, creating high annual variability in crop production (David *et al.*, 2007). Seasonal rainfall variability is critically important, as it determines such variables as: the effective onset of the crop season, the timing length and severity of dry spells during the growing season and the effective end of the season (IPCC, 2014). The productivity of crops is determined by crop development, photosynthesis and growth (Doltra*et al*., 2012). These determinants are affected by abiotic factor such as temperature, solar radiation, the length of the growing season as well as supply of water and nutrients which are influenced by climate change (Doltra*et al*., 2012).

Ethiopian agriculture is heavily dependent on natural rainfall, with irrigation agriculture accounting for less than 1% of the country's total cultivated land. Thus, the amount and temporal distribution of rainfall and other climatic factors during the growing season are critical to crop yields and can induce food shortages and famine (CSA, 2008). During drought and delay in the onset of rain land becomes dry and difficult to plough, forage deficit leads to weakness and oxen mortality (engine of subsistent cultivation), and lack of precipitation hinders seed cultivation and germination of cultivated seeds. Even weeks delay in the onset of rain was found to have significant difference on the harvest and has deprivation of households' livelihood (Abate, 2009).

At the national scale, the link between drought and crop production is widely known. Such a problem is further exacerbated by the social, economic and ecological situations (Dawit&Habtamu, 2011). Declining Belg rains as projected by one study (although contradicted by others), could have significant effects on both crop production and livestock rearing due to their important role in Ethiopian food production (Regassa*et al.,* 2010). Thus, declines in seasonal rainfall total and extended dry spells are more critical and determinant of crop growth and final yield. This is because; unusual rainfall amounts and distributions usually lead poor harvest and complete crop failures at the end of the season (Tesfaye and Assefa, 2010).

2.4.2 Effects of increased temperature

Temperature often determines the potential length of the growing seasons for different crops, and generally has a strong effect on the timing of the development processes and on the efficiency with which solar radiation is used to make plant biomass (Olesen*et al*., 2011). Increasing temperatures resulted in reduction in crop yields by affecting a range of physiological, biochemical and molecular processes. Sensitivity to supra optimum temperatures and mechanisms of tolerance depend on the severity, timing and duration of heat stress together with the developmental stage of the plant (Olesen*et al.*, 2011).The most significant factors related with yield lessening under heat stress are increased sterility, shortened life cycle, reduced light interception and the perturbation of carbon assimilation processes (photosynthesis, transpiration, and respiration) (Mersha*et al*., 2005).

Recent increases in climate variability may have affected crop yields. Changes in short term temperature extremes can be critical, especially if they coincide with key stages of development. Only a few days of extreme temperature at the flowering stage of many crops can drastically reduce yield. Most food crops are sensitive to direct effects of high temperatures, decreased precipitation, and flooding (Porter and Semenov, 2005). For example, extreme events may lower long-term yields by directly damaging crops at specific developmental stages, such as temperature thresholds during flowering). This is as result of increased evapotranspiration and accompanying soil water deficits (Bals*et al*., 2008).

2.4.3 Effects of rainfall variability

Climate changes remote from production areas may also be critical. Irrigated agricultural land comprises less than one-fifth of all cropped area but produces between 40-45% of the world's food (FAO, 2008) and water for irrigation is often extracted from rivers which depend upon distant climatic conditions. With no change in precipitation (or radiation), slight warming (+1°C) might reduce average yields by about 5-4%; and a 2°C warming might reduce average yields by about 10-7%. A combination of increased temperatures (+2°C) and reduced precipitation could lower average yields by over a 15% (Olesen and Bindi, 2002). It is expected that, the temperate regions could become wetter and dry areas in the tropics could become drier (FAO, 2008).

According to Parry *et al*. (2007) Sub Saharan Africa is an experienced decreased precipitation which is about 20%. Since Sub Saharan Africa depends on rain fed agriculture and other deformations of the rainfall patter would limit crop productions and this would bring untold, physical and socio-economic hardships for the farmers. Thus, considerations of the potential impacts of climate change on agriculture should be based not only on the mean values of expected climatic parameters but also on the probability, frequency and severity of possible extreme events (Rosenzweig*et al.*, 2001). Climate change has posed complex challenges to Ethiopian agriculture through increased frequency of drought events as well as unpredictable rains that fall in a shorter but more intense incident (Cesar and Ekbom, 2013). Study conducted by Tittonell and Giller (2013) who have reported even in low and irregular rainfall conditions, the low fertility of the soils is often considered much more a limiting factor than water. Similarly, farmers can suffer production losses as a result of the insufficient and erratic precipitation during the rainy season (Lichtenstein, 2014).

2.5. Adaptation Strategies Employed by Farmers

Increasing climate change is impacting on agricultural livelihoods since resource-poor farmers are unable to cope with multiple stressors or adapt to climate-related risks. To reduce the impact and enhance food security, adaptation measures are urgently required. In order to identify and implement appropriate adaptation strategies at local level, it is important to understand the nature of climate change impact, key vulnerabilities and indigenous adaptation practices. What might work in one place or within one socioeconomic group may not be feasible elsewhere. The reason for this might be among other different agro-ecological zones, different climate and different assumption for adaptation. Sustainable land management measures are among the important approaches that households can use to adapt to climate change and vulnerability. Therefore, there is a need to adapt adaptations to fit each case and circumstance (Smith *et al.,* 2003).

Local communities in an Ethiopian use a range of strategies to cope with climate variability and adapt to climate change. These include crop diversification, mixing crop production with pastoralism, tree planting, off-farm activities, diversify income, soil and water conservation, selling of assets, sowing drought tolerant, suitable or improved seed varieties, food aid or food appeal, irrigation, temporary migration, changing planting dates, selling home made products, intercropping, collection of wild food, change dietary preferences, access to appropriate technology, use of inter-household transfers and loans, Increase petty commodity production, grain storage, mortgaging of land and etc(Brandshaw et al., 2004 and Orindi and Eriksen, 2005).

2.6. Determinants of Adaptation Strategies

Adaptation to climate change had challenging factors as identified by researchers. There are many factors hampering farmer's adaptation possibilities. Despite having perceived changes in rainfall and temperature, a large percentage of Ethiopian farmers have not made any adjustments to their farming practices (Deressa*et al.,* 2008). This might be due to many reasons such as:-shortage of cultivated land, poor potential for irrigation, financial constraints, lack of improper policy, size of productive labor, lack of extension service, education status of household, lack of farm inputs, lack of access to weather forecasts, access to credit were the most important barrier to climate change adaptation (Yibekal*et al.,* 2013).

The IPCC (2013) has emphasized that Africa is characterized by a low adaptive capacity. 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.

2.7. Conceptual framework

Currently climate change is a serious global issue; it is manifested through different process, such as increase in temperature, rise in sea level, variability on rain fall etc. and it has adverse effect on human being directly or indirectly. Therefore, to minimize the adverse effect of climate change taking adaptation measure is an important option. But, in order to take different adaptation measures, first farmers have to perceive the change on local climate and identifying the factors that hinder and facilitate adaptation practices is crucial because, they have influence on the implementation of adaptation measures to climate change effects.

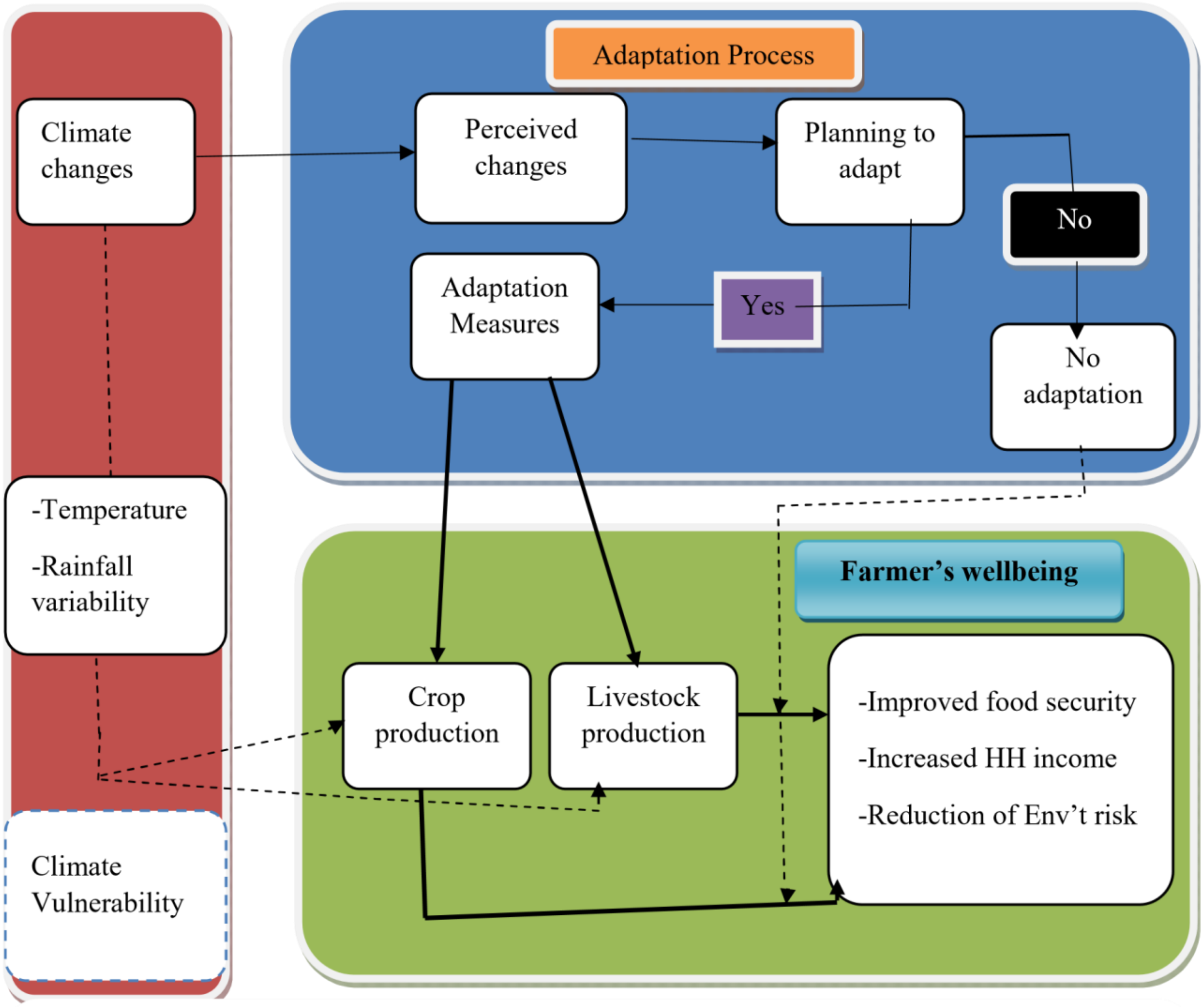

Figure 1: Conceptual framework of the study

Key: ….. Showing negative effect ⟶ showing positive effect

Source: Adapted from Bewkwt (2010)

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the Study Area

Aleta wondo woreda is among the 36 Woredas of Sidama Regional State of Ethiopia located between 6° 15′ N and 6° 45′ N latitude and between 38° 15′ N and 38° 45′ longitudes (CSA, 2008/09). The altitude of the woreda ranges between 1700 to 2500m.a.s.l. It is located at a distance of 333 km south east of Addis Ababa and at about 67 km from Hawassa, which is the capital city of the region. The district has 640 km^2 area of land with an estimated population of 188976, of whom 96,640 are men and 92,336 women (CSA, 2007). Annual rainfall in the area ranges from 900 to 1400 mm. whereas; mean minimum and maximum temperature is between15°c and 29°c (Woreda report, 2020). The district has 27 kebeles with three agro ecologies namely highland ‘Dega’ (12%), moist ‘Weyina Dega’ (71%) and Dry ‘Weyina Dega’ (17%). Aleta wondo woreda is bordered on the south by Dara woreda, on the west by Chuko, on the north by Dale and Wonsho, on the east by Bursa and on the south east by Hula.

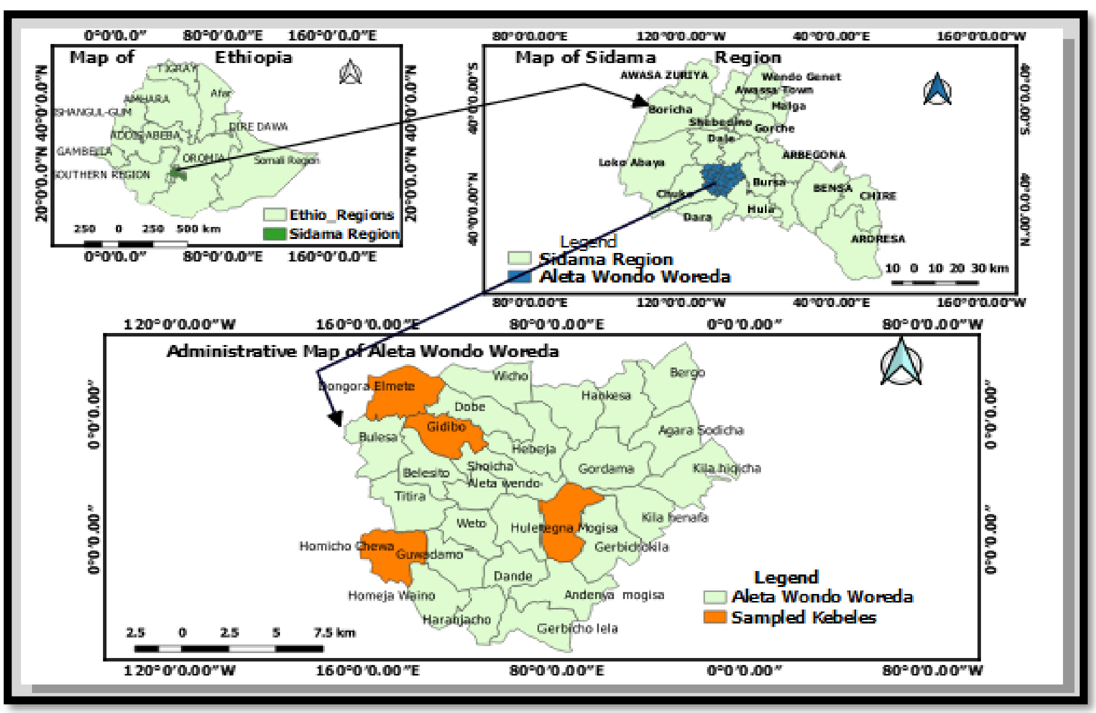

Figure 2. Map of the Aleta Wondo Woreda.

Agricultural system and livelihood of the community

In Aleta Wondo woreda Mixed type of farming is the main source of income. The majory types of crops grown include maize, haricot bean, wheat, root crops (sweet potato,and enset) and cash crops as coffeee, chat and fruit trees. Coffee, enset and ftuit trees are perennial crops in the area and the productivity and production depends on the availability of the required amount of rain in addition to other required inputs. In this woreda in addition to the failure of the rainfall, population pressure was cited as a major contributing factor in the current food shortage problem.

The mean annual minimum and maximum temperatures of the area ranged from 15 to 29^{0}C. The rainfall of the woreda lies between1001-1400mm per annum which is characterized by erratic distribution (SNNPR, 2010). The rainy season of the woreda is divided into two major cropping seasons i.e. *Belg* and *kiremt.* The *belg* season starts in February and ends in May, while the *kiremt* season is from June up to mid-September.

Agriculture is the main source of livelihood, and the major crops grown in the Woreda are: - perennial crops such as coffee and enset; cereal mainly maize; root crop including sweet potato and pulse crop (haricot bean). The farmers in this woreda practice mixed farming system which includes growing of different crops and raring livestock. The major agriculture and food security related challenges of the district includes degradation of natural resources, frequent droughts, severe flooding and increasing population (Bewket*et al.*, 2015).

3.2. Research Approach

In the current study both quantitative and qualitative approach was employed. Employing both quantitative and qualitative approach is more useful to understand the complex factors that make households vulnerable and their strategy which requires a detail understanding of everyday lives and processes involved. It also, helps to assess the effects of intervention mechanisms on the lives of the poor. To this end, the study employed more of qualitative and some quantitative research approaches.

3.3. Research Design

The study also utilized cross-sectional survey research design which helps to gather information of a particular population at a distinct time. Therefore this study helps to obtain information on the effects of climate change on crop production and adaptation strategies.

3.4. Data Type and Sources

Both primary and secondary data sources were used. The primary data focused on effects of climate change on crop production, adaptation strategies and determinant factors that influence farmers' choice of adaptation strategies and were collected through questionnaires directly from sample households, focus group discussions and key informants. Secondary data related to monthly rainfall and temperature records (1983-2017) were obtained from the National Meteorological Agency (NMA) of Ethiopia while crop yields were obtained from Woreda Agriculture and Natural Resource Management Office, for the years concerned.

3.5. Sampling Procedure

Household survey: - The selection of study area was done based on spatial difference, which links to the fact that vulnerability and effects of climate change and hence adaptation strategies vary from place to place. Accordingly, Aleta Wondo *Woreda* was selected purposively due to its vulnerability to climate change effects. Then four *Kebeles* in the woreda: (Homacho Chawa, Dongora, Gidiwo and Mogisa) were selected randomly out of the 27 *kebeles in the woreda*. Sample households were then selected using systematic random sampling technique. Simplified formula provided by Yamane, (1967) was used to determine the required sample size at 95% Confidence level and 7% level of precision as indicated:

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

Where: n is sample size, N is total population (total households of selected kebeles) and e is precision level

$$n = \frac{2258}{1 + 2258(0.07)^2} = 188$$

$$ni = n\frac{\mathrm{Ni}}{\mathrm{N}}$$

Where ni is assigned sample size for each kebeles, n is total sample size, Ni is the household size of single kebele and N is total household size.

Table 1: Sample household size allocation

No	Name of Kebelles	Household size			Sample size		
		Male hh	Female hh	Total	Male hh	Female hh	Total
1	H/Chawa	682	21	702	56	2	58
2	Dongora	468	52	428	33	4	37
3	Gidiwo	500	72	572	43	5	48
4	Mogisa(ii)	370	89	556	38	7	45
	Total	**2024**	**234**	**2258**	**170**	**18**	**188**

Source: Woreda Demographic and socioeconomic Information center

3.6 Data Collection Methods or Techniques

Household Survey Questionnaires: Semi-structured questionnaires were also prepared and the sample households were interviewed about the effect of climate change on crop production and their adaptation strategies. The questionnaires were pre-tested among seven randomly selected households from non-sampled kebeles, before data collection was carried out through face-to-face interview with farmers.

Key informant interviews (KII) interviews were also carried out with a total of 14 key informants including 4 development agents (one from each kebele), 8 elder informants (two from each kebele) and 2 woreda crop office experts.

Focus group discussions (FGDs) were held with both female and male farmers' representatives of different: age groups; education level and wealth status which were selected from each sampled kebeles. Local, relative wealth status ranking method was used to identify wealth groups; which declares that, a household is poor or rich in the context of the community in the village. A total of 8 focus group discussions were conducted consisting two FGDs in each kebele; with six participants in each focus group discussion.

3.7 Methods of Data Analysis

Both descriptive and inferential statistics were used to analyze the collected data. For the descriptive part; tables, percentages, frequency, charts, means and indices were used. Index analysis was used for ranking effects of climate change on crop production according to the method suggested by Kosgey (2004). The ranking was expressed as an Index which is the sum of (4 times first order + 3 times second order + 2 times third order + 1 times fourth order) given for an individual variable divided by the sum of (4 times first order +3 times second order + 2 times third order + 1 times fourth order) for all variables.

The qualitative data from the open-ended questions of the questionnaire, key informant's interviews and focus group discussions were discussed through qualitative description. To analyze data type of adaptation measures and its determinants multinomial logit model (MNL) was used. Long term of rainfall and temperature trends were analyzed by linear trend analysis. The rainfall data was also analyzed by Standard Precipitation index (SPI) and Coefficient of Variation. SPI is used to quantify the precipitation deficit for multiple timescales given as:

SPI= $\frac{X-\bar{X}}{SD}$ Where; SPI is Standardized Precipitation Index, X is discrete precipitation data, $\bar{X}$ is mean and SD= Standard deviation.

SPI is drought index which is a powerful, flexible and simple to calculate. In addition, it is just as effective in analyzing wet periods as it is in analyzing dry periods. It indicates the moisture level from extremely wet (SPI ≥ 2) to extremely dry (SPI ≤ -2).

Table 2: SPI value to define drought intensities

SPI value	**Moisture level**
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Source: McKee *et al.* (1993)

Intra-seasonal and annual rainfall Variabilities were analyzed using the coefficient of variation (CV). According to Hare (1983), CV (%) values are classified as follows: < 20% as less variable, 20- 30% as moderately variable, and > 30% as highly variable.

CV= $\frac{SD}{\bar{X}} \times 100$ Where CV is Coefficient of Variation; SD is Standard deviation and $\bar{X}$ is mean

Man-Kendall test is a technique based on the Kendall tau statistics has been introduced to test for randomness against trend in climatologically time series (Zhang *et al.*, 2001). Therefore, Mann-Kendall trend test was applied to detect the presence of trends in the precipitation and temperature records for Aleta Wondo districts. The test statistic for the Mann-Kendall test is

Given as:

$$s = \frac{\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \operatorname{sgn}(Y_j - Y_i}{\sigma_s} \qquad \sigma_s = \sqrt{\frac{N(N-1)(2N+5) - \sum_{i=1}^{n} t_i i(i-1)(2i+5)}{18}}$$

Where N is the number of data, Yj and Yi are the data values in two consecutive periods; ti is the number of ties, i.e. equal values, of extent i and N is the number of tied groups. The function sign (Y_j-Y_i) =1 if Y_j- Y_i>0; sign (Y_j- Y_i) =0 if Y=0 and sign (Y_j- Y_i) = -1 if Y_j- Y_i<0. Therefore, excel sheets and Statistical Packages for Social Scientists (SPSS, version 20 was used to analyze the data and present the findings.

The multiple regressions and correlation analysis were used analyzed relation between rainfalls, temperature, and crop yield population.

The multiple regression models is expressed as: $Y=\alpha+\beta_1X_1+\beta_2X_2+\beta_kX_k+e$ Where *Y* is the value of the dependent variable,α is the intercept, *β1, β2..., βk,* are regression coefficient variable,*β* is represents the amount of change in *Y* for one unit change in the corresponding *x* value when the other *x* values are held constant; *x1*, *x2*,... *xn,* are the independent variables and *e* is the error of estimate or residuals of the regression.

Multinomial Logit Model

In order to achieve the objective, the study employed multinomial logit model. This model makes it possible to analyze factors influencing households' choices of adaptation strategies in the context of multiple choices. The decision of whether to use any adaptation option or not could fall under the general framework of utility maximization (Komba and Muchapondwa, 2016). Following Greene (2000) suppose for the i^{th} respondent faced with *j* choices, we

Specify the utility choice *j* as: $U_{ij} = Z_{ij}\beta + \varepsilon_{ij}$

If the respondent makes choice *j* in particular, then we assume that *Uij* is the maximum among the *j* utilities. So the statistical model is derived by the probability that choice *j* is made, which is: $Prob(U_{ij} > U_{ik})$ for all other $K = j$ Where; Uij is the utility to the i^{th} respondent from adaptation strategy j, U_{ik} the utility to the i^{th} respondent from adaptation strategy k.

If the household maximizes its utility defined over income realizations, then the household's choice is simply an optimal allocation of its asset endowment to choose adaptation strategy that maximizes its utility (Brown *et al.*, 2006). Thus, the i^{th} household's decision can, therefore, be modeled as maximizing the expected utility by choosing the j^{th} adaptation strategy among *J* discrete adaptation strategies, i.e., $\max_j = E(Uij) = f_j(xi) + \varepsilon_{ij}; j = 0 \ldots J$

In general, for an outcome variable with *J* categories, let the j^{th} adaptation strategy that the i^{th} household chooses to maximize its utility could take the value 1 if the i^{th} household chooses j^{th}

With the requirement that $\sum = 1$ for any *i*, where P_{ij} = probability representing the *i*th respondent's chance of falling into category *j; X* = predictors of response probabilities. *Bj* = Covariate effects specific to j^{th} response category with the first category as the reference. Appropriate normalization that removes indeterminacy in the model is to assume that $\beta 1 = 0$ (this arises because probabilities sum to 1, so only *J* parameter vectors are needed to determine the *J* + 1 probability (Greene, 2003), so that $\exp(X_i\beta_1) = 1$

Where; y = A polytomous outcome variable with categories coded from 0… J. Note: The probability of $P_{i1}$is derived from the constraint that the J probabilities sum to 1. That is, P_i1= 1 ∑... The estimated coefficients of multinomial logit model provide only the direction of effect of independent variables on dependent variables, but estimate neither represents the actual magnitude of change nor probabilities (Tizale, 2007).The marginal effects measure the expected change in the probability of a particular choice being made with respect to a unit change in an independent variable (Greene, 2000). Therefore, it is important to look into account the problem of multicollinearity among the independent variables before running the model (Gujarati, 1995).Variance inflation factor test was used to test the multicollinearity for continuous independent variables. The test statistic for the Variance inflation factor test is given as: **VIF=1 /1-Ri²**. Where, VIF is variance inflation factor; Ri^2 is the adjusted square of the multiple correlation coefficients that result when one independent variable (X_i) is regressed against all others. If an approximately linear relation exists among the explanatory variables then this will result, in large value of Ri^2 in at least one of the test regressions. By default, value of VIF greater than 10% is assumed to indicate model multicollinearity problem (Gujarati, 1995). The model was fitted using STATA version 14.2 to generate the parameter estimates and marginal effects. Specifically, to analyze smallholder farmers' adaptation strategies to climate change in Aleta Wondo Woreda, the cross sectional data collected through questionnaire was used.

Table 3: Variables of the study

Independent Variables	Nature
Age of household head	Continuous

Sex of household head	Dummy
Educational level of household head	Categorical
Family size of household head	Continuous
Farm size of household head	Continuous
Access to climate information	Dummy
Access to credit service	Dummy
Extension service	Dummy
Access to market	Continuous

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Background of the Respondents

4.1.1 Household characteristics

The effect of household characteristics including gender, age, educational level and family size on choice of response to climate change (Table 4). Out of the 188 sampled household 90.43%) were maleheaded; while only 9.57% were female-headed households. The age of household ranges from 25 to 62 years, while the family size of household ranges from 2 to 13 members, with mean of 8 persons per household. Moreover, education level of household ranging from 1 to 12 grade of schooling.

Table 4: Demographic characteristics of respondents

Characteristics	**Frequency**	**Percentage (%)**
Sex of respondents		
Male	170	90.4
Female	18	9.6
Marital status		
Married	176	93.6
Single	8	4.3
Widowed	4	2.1
Family size		
01-Feb	5	2.7
03-May	17	9
06-Sep	107	56.9
Oct-13	59	31.4

Age category		
18-25	14	7.4
26-35	43	22.9
36-45	48	25.5
46-58	67	35.6
59-62	16	8.5
Educational status		
Cannot read and write	106	56.4
Primary(1-4)	45	23.93
Secondary(5-8)	19	10.1
High school(9-12)	11	5.85
College	7	3.72

Source: Interview based questionnaire results of the selected respondents, 2020.

4.1.2. Asset of the household heads

Land is the ever known to exist resource as the most limiting factor for agricultural production in Ethiopia, in general and the study area in particular. The result revealed that per capita land size is small and landholding of the interviewed farmer's falls between 0.125 and 3.5 hectares and the average landholding was 0.98 hectare per household.

4.1.3. Institutional Factors

Farmers' access to agricultural service, credit service, climate information and markets showed that most of the surveyed households had access to agricultural extension services. Agricultural extension systems in the study area offer a multitude of activities such as training, organizing demonstration trials. These activities might have a direct effect on creating awareness of the households on new agricultural technologies and environmental developments, which later affect perception and decision making of the farmers. The availability of credit for resource poor farmers is quite important to finance agricultural technologies and management options that enable them to increase farm investment. Among the surveyed respondents 32.3% had access to credit service; whereas 67.7% have not access.

Reliable information about seasonal forecast of the weather condition and climate variability is necessary to understand the climatic condition and to take some measures to adverse effects. This implied the importance of climate information as a driving force to enhance the tendency of farmers' perception. In the study area, there were no formal sources that deliver weather information. Most farmers obtained climate related information from local meetings, radio and development agents. The result indicated that, regardless of the source, majority of the sampled households have access to climate information.

Table 5: Sampled households access to institutional information

Variables	Response	Frequency	Percentage
Access to extension services	*No*	*68*	36.2
	Yes	*120*	63.8
Access to credit services	*No*	*127*	67.6
	Yes	*61*	32.4
Access to climate information	No	66	35.1
	Yes	122	64.9

4.2. State of Local Climate

4.2.1 Rainfall

The annual rainfall of the study area range between 301.5mm in 2016 (the driest year) to 1410 mm in 2017 (the wettest year) (Figure 3). This clearly demonstrates that there is high variability of rainfall across the years. The results of linear trend for the period of the study (1983-2019) showed that the amount of annual rainfall increased by 2.035mm per year over the past three decades. The mean annual rainfall of those years is about 908mm with SD value of 223mm.

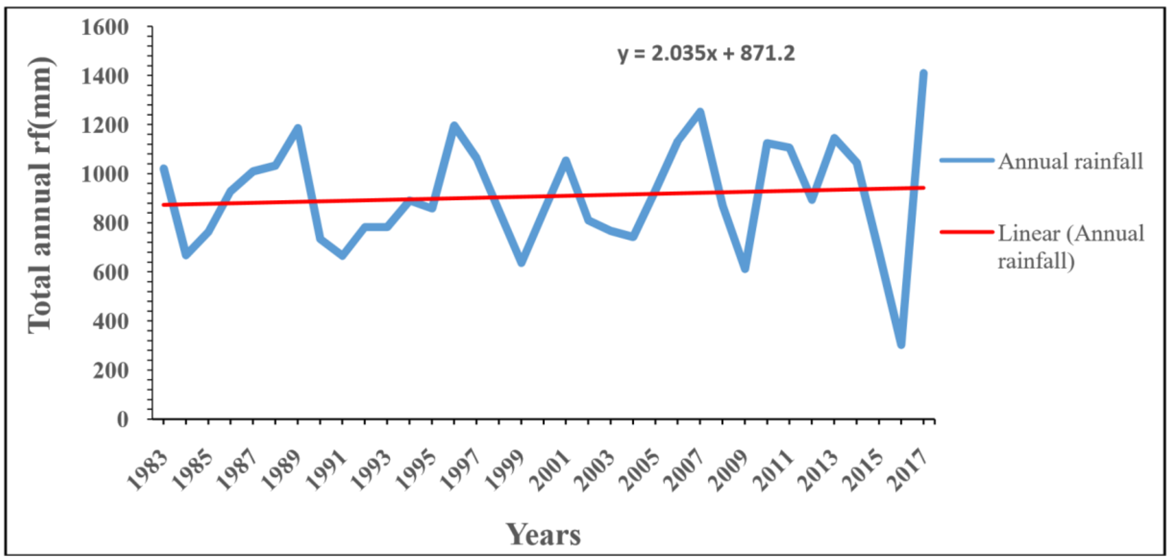

Figure 3: Annual rainfall trend in study area

i. Seasonal rainfall variability trends

Analyses for the seasonal rainfall revealed that growing season rainfall of study area generally exhibits high inter and intra-seasonal variability. Among thirty- five years (1983-2017) the *belg* and *kiremt* season rainfall 16 and 18 years were below average respectively (Figure 4). The *kiremt* season has a rainfall varying from 81.6mm to 510mm. The mean rainfall of *kiremt* season was 309.2mm; with SD value of 121.2mm; whereas *belg* season rainfall has varied from 114.7mm to 569.8mm. It has 346.64mm mean and SD value of 114.88mm. Moreover, the *kiremt* rainy season rainfall has showed increasing trend, its amount increased by about 2.29mm per year over the past three decades; whereas *belg* rainy season rainfall has decreasing by about 3.27mm per year over the past three decades (figure 4). The increasing trend of *kiremt* rainy season rainfall could be the main cause for increasing of annual rainfall.

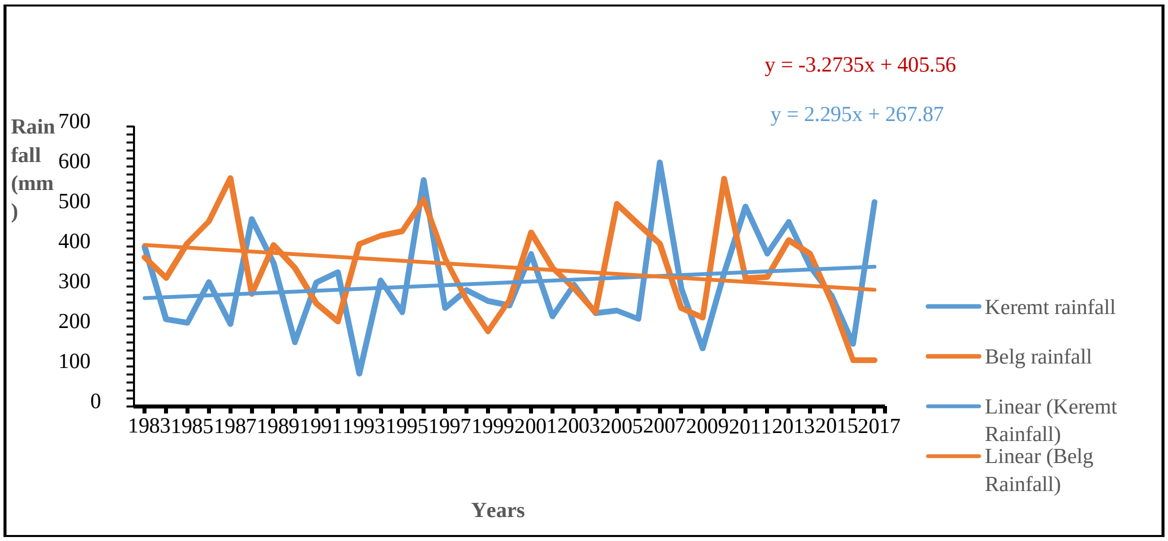

Figure 4: Kiremt and belg rainfall trends in study area, 2020.

This result is in agreement with previous report on rainfall trend (NMA, 2009), indicated that rains have decreased during the *belg* rainy season in the east and southeast with the largest percent reductions. Moreover, rainfall decrease during the short rainy season has been typical for some parts of Ethiopia during the last decade (Nater, 2010). Declines in belg rains may impact long cycle crop production with crippling consequences for agricultural production. In much of Ethiopia, similar to the Sahelian countries to its west, rainfall from June to September contributes the majority of the annual total, and is crucial to Ethiopia's water resource and agriculture operations (Korecha and Barnston, 2007).

The coefficient of variation in this study revealed that the annual rainfall was moderately variable with CV value of 24.47% while both *kiremt* and *belg* rainfall were highly variable with (CV value of 39.19% and 33.14%) respectively. This means annual rainfall is less variable as compare to *kiremt* and *belg* rainfalls. Moreover, when compare the belg and kiremt season rainfall; the degree of variation in amount of rainfall was higher for *kiremt* than *belg* season.

ii. Standard Precipitation Index (SPI) analysis

SPI is drought index which is a powerful, flexible and simple to calculate. In addition, it is just as effective in analyzing wet periods/cycles as it is in analyzing dry periods/cycles (*McKee et al*., 1993). The SPI is based on the probability of precipitation for any time scale. The probability of observed precipitation is then transformed into an index. It is being used in research or operational mode in more than 70 countries (WMO, 2012). According to (McKee *et al.*, 1993), the appearance of drought is happening every time when SPI is negative and its intensity comes to -1.0 or lower. The positive values in the SPI indicate greater than mean precipitation while negative values indicate less than mean precipitation. Moreover, droughts are classified as severe and extreme drought if the SPI value is-1.5 to -1.99 and -2 and less respectively.

Based on that criterion of WMO, the STUDY area has experienced significant number of drought years in the period between 1983 and 2017. The results revealed that, 1 annual extreme; 2 belg extreme and 1 kiremt severe droughts occurred in the stated period.

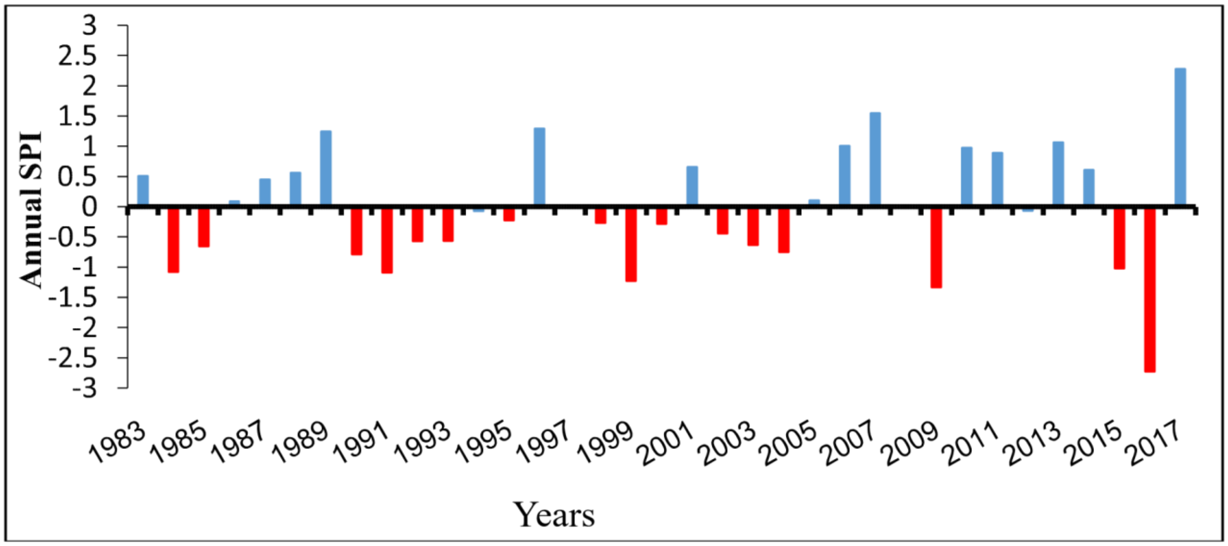

Figure 5: Annual standardized precipitation index in study area, 2020.

The *belg* extreme drought also occurred in the 2016 and 2017 years with equal SPI values (2.01). However, 2017 was the wettest year among recorded period of the study (figure 5). Since the amount of *kiremt* rainfall much higher than belg rainfall. Because the total amount of *kiremt* rainfall is the main cause for increasing or decreasing in total amount annual rainfall. Kiremt severe drought has been observed in the year 1993 with SPI value of -1.87 (Figure 6). However, farmers expressed that they had experienced severe droughts in 2016 that resulted in losses of crop. Especially, Enset and traditional ponds were dried.

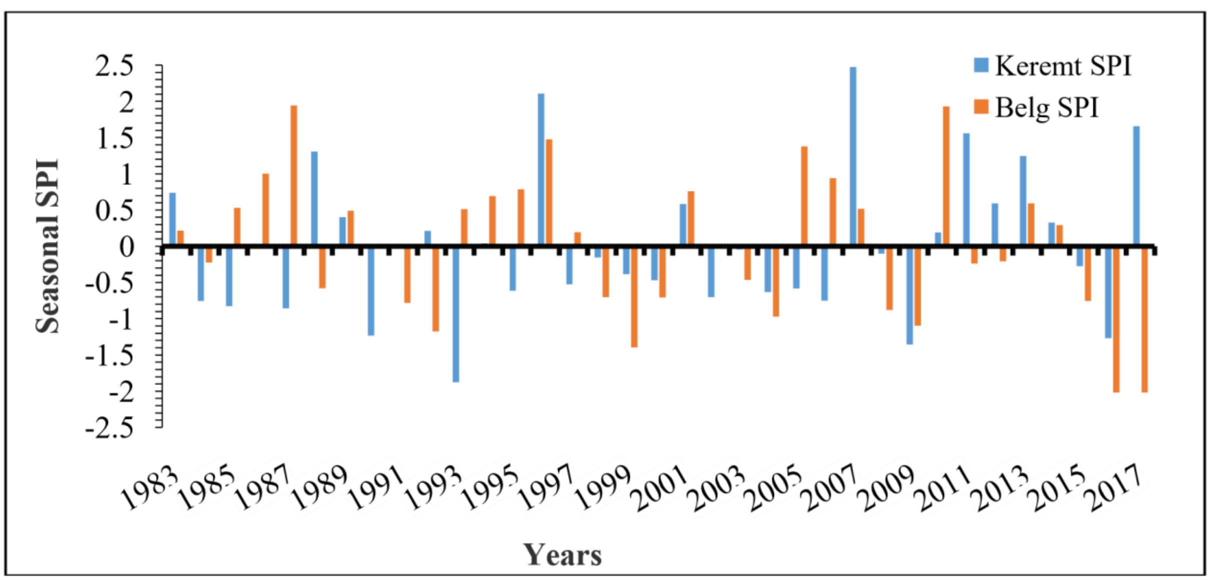

Figure 6: Seasonal standardized precipitation index in study area

In central rift valley of Ethiopia, droughts occur due to either failure of the main (kiremnt) rains or both the short and the main rains. Short season rainfall of Aleta Wondo woreda showed decreasing trend despite reduction of the short rainy season alone may not result in drought, if the long rainy season resume timely. Climate risk quantified in terms of drought frequency revealed that the district experienced four droughts in thirty-five years. The risk of heavy crop losses and animals deaths during recurrent severe droughts associated with rainfall variability presents one of the most serious threats to crop and livestock production. It is obvious, that, drought phenomenon enhanced vulnerability for the subsistence farming sector. Respondents also stated that, drought devastates affected not only crop and livestock production, but the entire balance of their livelihood system.

4.2.2 Temperature

Temperature is one of the climate elements that determine weather condition as well as climate of an area. It is recorded as maximum and minimum daily, monthly and annual temperatures. Monthly maximum and minimum temperatures in the current study revealed that, March is the warmest month for the study area; whereas July is the coldest month (Appendix III). *Bega* season is the warmest season of the study area; whereas the coldest season is kiremt season. The warmest year was 2009 (31.78^0C); while the coldest year was 2017(28.1^0C). Therefore, average annual maximum temperature of Aleta Wondo *woreda* ranges between 28.1^0C to 31.78^0C (Figure7). The maximum temperature of the *woreda* also increased by about 0.017^0C annually over the past three decades.

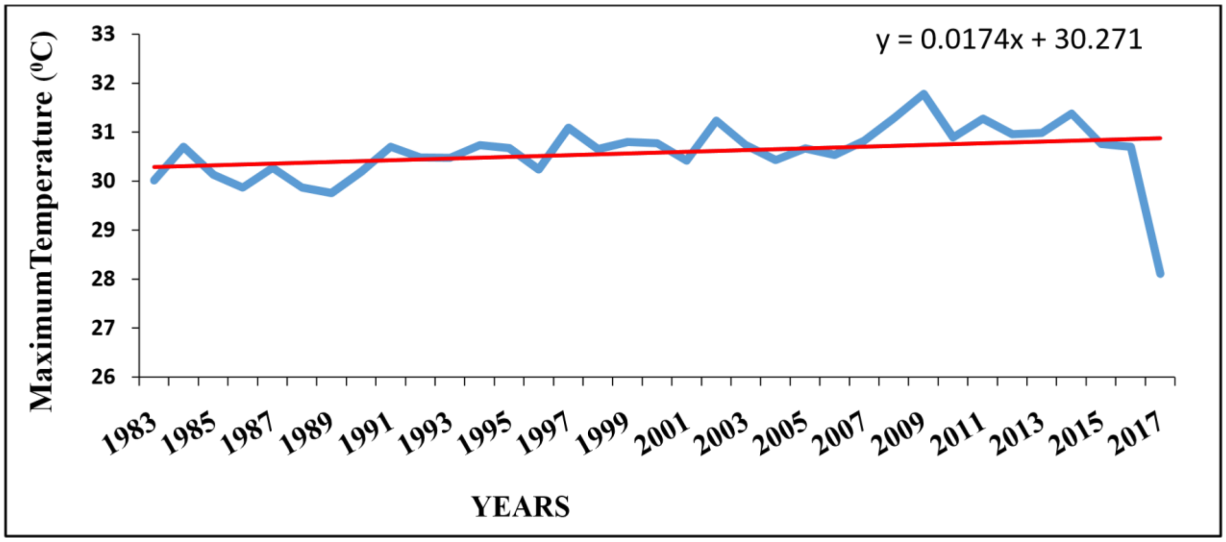

Figure 7: Trends of annual maximum temperature

The average annual minimum temperature ranges between 16.8^{0}C to 18.5^{0}C (Fig: 8). accordingly, the lowest value was recorded in year 1996; whereas the highest was in 2009 year. Moreover, the average minimum temperature was increased by 0.034^{0}C annually over the past thirty-five years.

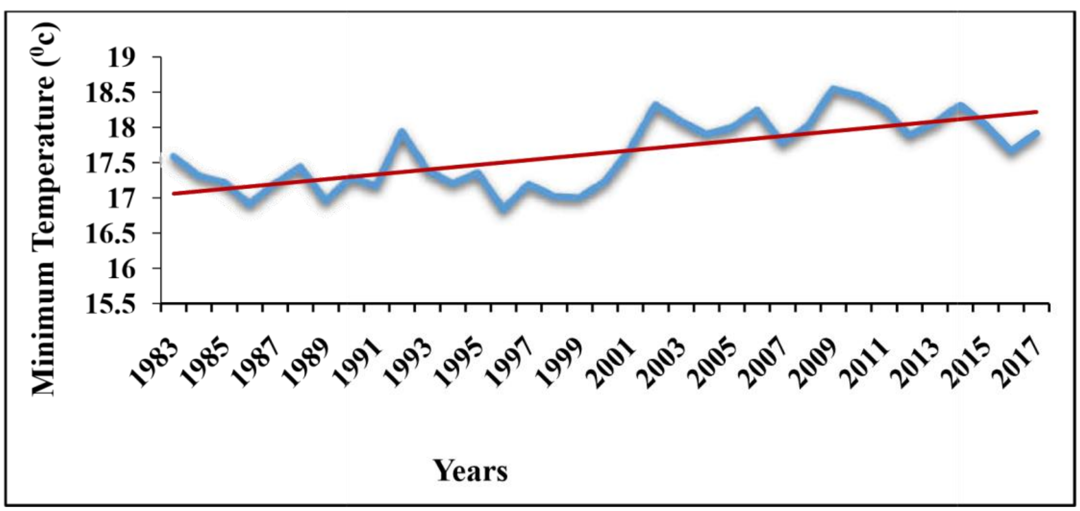

Figure 8: Trends of annual minimum temperature

In general, the average yearly maximum temperature of the study *woreda* was 30.58^{0}C whereas the minimum 17.6^{0}C over the past three decades (Appendix III). This result is in agreement with previous report on annual temperature trend, in Ethiopia in which the average annual minimum and maximum temperatures over the country have been increasing by 0.25^{0}C and 0.10^{0}C respectively per decade (NMA 2007). Furthermore, (NREPA, 2012) reported that the average temperature of the SNNPR region had risen by 0.4^{0}c in the last decade; thus, temperature ranges of the study area have been found to be above the national 0.37°c (NMA, 2007).

The Mann-Kendall non parametric trend test was also applied to evaluate the relationship of time series with annual kiremt and belg rainfalls as well as maximum and minimum temperatures of the *woreda*. Accordingly, an increasing trend was observed in both maximum and minimum temperatures whereas no trend for precipitation (Table7).

Table 6: Mann-Kendall test of significance

Variables	Mann-Kendall's tau	Significance level
Annual rainfall	0.109	0.363
Kiremt rainfall	0.102	0.394
Belg rainfall	-0.181	0.128
Maximum temperature	0.431*	0.0003
Minimum temperature	0.433*	0.0003

The result is in conformity with the earlier studies by Cheung *et al.* (2008) and Viste *et al.* (2012) which indicated a non-significant trend of annual and seasonal rainfall totals in northern Ethiopia. Similarly, no statistically significant trend in mean annual rainfall was observed in any season from 1960-2006 (NMA, 2006; McSweeney*et al.*, 2008). However, the spatial and temporal variability of precipitation is high, thus large-scale trends do not necessarily reflect local conditions. Similar to the result of the present study Meze-Hausken (2004) and Deressa etal. (2009) reported that, although most farmers noticed changes in the amount and occurrence of rainfall in their locality yet the observed climate data did not indicate a significant trend in Northern Ethiopia.

4.2.2. Farmers perceptions to climate change in study area

Perception of farmers on trends of seasonal and annual rainfall, temperature and its distribution showed that more than 91% of the farmers had perceived a decreasing trend of annual, *kiremt* and *belg* rainfall (Table 8). The perception of farmers on *belg* rainfall has been supported with observed meteorological data of the stations (Figure 4).

In this regard, perception of farmers on decrease in amounts of *belg* rainfall agreed with the observed data. However, observed meteorological data of the area showed an increasing trend of annual and *kiremt* rainfall, which is in contrary with perception of farmers (Figure 3 and 4), respectively.

The farmers in the study area perceived that rainfall characteristic such as start of rainy season, end rainy season and length of growing period had changed. It has been indicated that about 94.8 and 97.4% of the farmers perceived increasing late start of rainy season and early end rainy season, respectively and consequently, 98% believed decreased in length of growing season. Moreover, about 98.4% of respondents had perceived increased level of temperatures, while only 1.6% claimed that hadn’t observed any changes.

Table 7: Farmers perceptions on the trends of rainfall and temperature in Aleta Wondo woreda

Variables	Increased (%)	Decreased (%)	No change (%)
Annual rainfall	3.2	93.1	3.7
Kiremt rainfall	5.4	94.4	3.2
Belg rainfall	7.4	92.6	-
Late onset of rainfall	94.8	-	5.2

Early cessation of rainfall	97.4	2.6	-
Length of growing season	-	98	2
Temperature	98.4	-	1.6

Source: Field survey report, 2020

As mentioned earlier, perception of farmers' on trends of annual and *kiremt* rainfall did not agree with observed meteorological data of the area. This might be due to fact that; farmers' reflection focuses more on the variability of climate which could be further limited by several factors including educational background of the farmers. Hence, acknowledging the local community's perception on climate change, however, for the analysis of the climate change effects, the metrological data reflects about the long-term state of climate variables as compared to farmers view. This result is in agreement with previous study on rainfall trend in Ethiopia (Cheung *et al.,* 2008). These indicated that the farmers were not able to differentiate between consistent changes in climate and yearly rainfall fluctuations. Mertz *et al.* (2009) have demonstrated however a good match between perceptions of the local people and empirical trends in long-term climate data.

The *belg* rainfall in the study area has been found to be more erratic and less in amount as compared to the *kiremt* rainfall, while the trend was decreasing and supported farmers' perception (fig.4). Regarding temperature, most of the interviewed farmers perceived long-term changes in temperature. The analysis which shows that, farmers' perceptions of increasing temperature is also in accordance with the statistical record of temperature data.

Majority of the respondents perceived a shift in start of rainy season and end rainy season (Table 7). The respondents who noted changes in the onset and cessation of rainy season reported that as it cause subsequent reduction in length of growing period. More ever both too early and too late cessation could affect yields, since rainfall early stop leads to fewer crop yields and late stop damages the harvest. This unfavorable rainfall conditions have aggravated food insecurity leaving significant proportion of sampled farm households vulnerable to risks pertaining to weather variability and climatic change. This agrees with the finding of Belaineh*et al.* (2012) which shows awareness of farmers increased temperature, changes timing of rains and frequent drought than it was before in central Tigray and Western Hararghe of Ethiopia.

Furthermore the farmers clearly reported that the amount rainfall was decreasing progressively every year since 1970s and resulted in drought conditions. The great majority (94%) of farmers indicated that, the changes which occurred in their environment are related to severe drought. In view of that 89.4% of respondents mentioned the occurrence of recurrent drought (1971/2; 1984/5; 1999; 2000/01; 2008/09 and 2015/2016) during the last thirty years. Out of these droughts, they singled out three (1971/72; 1984/5 and 2015/2016) the hardest and worst droughts. In support of this, Seleshi and Zanke (2004) noted that during the major drought years of 1972/3, 1984 and 2001 covered the whole of Ethiopia and the well-known drought period that occurred from 1978 to 1986 years.

The findings from the focus group discussions and in-depth interviews well recognized the existence of drought and the frequency increased from decade to decade, from every ten years, to every five years and two years. They further declared that there was a time when heavy rain resulted in excessive flooding which devastated vegetation and land degradation, leaching to crop losses in the years 1996; 2006; 2008; 2009; 2010; and 2012.

4.3. Effect of Climate Variability and Change on Crop

There is a significant relation between climate and crop production in terms of the timing, variability, and quantity of seasonal and annual rainfall in Ethiopia. As a result, farmers during unexpected break in rainfall in early growing season may be able to recover and resume production despite the loss of some of their crops. Majule*et al*. (2008) has also reported similar results. Moreover, the results from key informants and focus group discussion were corroborated with the survey.

In this study the respondents reported a number of observed effects of climate change on the agriculture and environments. They argued that, climate change contributed to decline in water availability, soil erosion, soil degradation, and thereby exerting significant influence on agriculture and environment.

Effects of climate change on crop was also the most frequently mentioned problems by the respondents. Respondents explained that climate change had its effect on their crop production activities through various ways. The climatic changes that result from increased temperature and changes in rainfall patterns usually brings irregular rainfall distribution within the different crop phenology. Occurrence of rainfall within the harvesting time also causes grain shattering, interference in harvesting operations and pre-harvest seed germination. Changes in rainfall can also affect soil erosion rates and soil moisture content both of which are important factors which could influence growth and yields.

A total of 85.2% respondents of this study reported planting time was changed in which growing seasons became shorter than before. Other effects of climate variability include changes in the opportunities to grow other crop types or varieties. In this study about 79.4% of respondents reported as they have switched to cultivation of fewer crops out of diverse types of crops they were previously cultivating as a consequence of declining and erratic rainfall distribution (Table 10). Replacement of wheat and barley over time by maize and sorghum owing to early maturity, late planting and lower total water consumption has been observed in the research area. As repeatedly indicated by respondents change in crop type or varieties is resulted from repeated occurrence of climate events, most of crop didn't maintain productivity due to this shock so, they in forced to withdrawal of those crops out of production; whereas some other respondents reported that they made changes in the farming practices by shifting to cultivation of crops and crop varieties that are drought tolerant and higher yields.

The study also identified that 81% of sample respondents' perceived decline of in annual crop production per year associated with drought and delay in onset of rain in which the land becomes dry and difficult to plough by oxen which are already weakened by feed shortage. Likewise, fairly large 78.3% of respondents stated a decreasing in trend of crops yield per hectare. From the fact, owing to it being a stable food crop of farmers at the area, crops yields became below farmers' family food requirement. Moreover, the study revealed that 82.5% of the respondents had believed an increases seeding rate per hectare in recent periods than before. This shows that, the greater use of seed rate is attributed to recover damaged crops due to lack of precipitation which hinders germination of cultivated seeds.

Table 8: Respondents' perception on trends of crop production and productivity

Variables	Increased (%)	Decreased (%)	No change (%)
Planting time and growing season	85.2	11.6	3.2
Change in crop varieties	79.4	6.9	13.8
Production per year	8.4	81	10.6
Yield obtained per hectare	9	78.3	12.7
Seed use per hectare	82.5	7.4	10.1

Source: Field survey, 2020

Respondents claimed that, shortening of growing season was associated with temperature increase and precipitation deficit, hence crop dries earlier with smaller grains. The main effects of climate change on crop production leads to changes in regular crop planting period, length of growing season, and shifts in crop species or cultivars (Mahoo*et al.*, 2013). Length of growing season variations is a useful climatic indicator and has several important climatologically applications (Robeson, 2002). Changes in rainfall patterns, coupled which shifts in thermal regimes, influence local seasonal and annual water balances and in affect distribution of periods during which temperature and moisture conditions permit agricultural crop production (Herrero*et al.*, 2010).

The respondents also emphasized that, the weather became drier as compared to the beginning of the 1970s. Normally, the rainy season begins in January, but starting from year in 2008 it started to be delayed consistently leading to crop yield reduction. Similarly, Parry *et al*. (2004) found that climate change is likely to lead to declining crop yields. However, yields of lowland crop were impacted most by the increasing aridity in the area following the rising temperatures and unpredictable rains leading to frequent droughts. Respondents in study area also claimed that, the rain is becoming less reliable

Especially at the time of flowering of maize causing reduced rainfall, changes in onset and increasing temperature as major constraints for yield failures. During the focus group discussion, participants also reported shortening of the rainy seasons since rains start later than they used to do in the past. In addition, they indicated changes in rainfall amount, frequency and distributions. The problems have become more severe since the last five years leading to increased water scarcity and losses of resources. Fertilizers purchase with high prices. They expressed that enset is the only crop that survives drought without which life couldn’t continue in Aleta Wondo although its productivity has been decreasing from time to time.

In addition, short duration excessive rains, hailstorms, flooding and water logging have caused considerable damaged to their crop production. The respondents also ranked the major effects of climate change on crop production as reduced crop productivity, reduced yield, partially crop loss, increased crop pest, and reduced seeding area and total crop loss (Table 9).

Table 9: Major effects of climate change on crop production ranked by respondents

Variables	(N=188) 1	2	3	4	Index Mean
Reduced crop productivity	60	59	51	37	0.294
Reduced yields	54	52	62	47	0.287
Partial crop loss	47	47	35	46	0.235
Increased diseases and pests	31	21	20	25	0.134
Reduced seeding area	19	8	13	21	0.078
Total crop loss	9	1	7	12	0.035

Source: Field survey, (2020).

The respondents prioritized the identified effects according to their degree of effect. This result also affirms they study done by Temesgen *et al.,* (2008) which indicated that, crop yield declined by 32.8% as result of drought. Similarly study done by Quinlan *et al.,* (2015) indicates that, farming in Ethiopia is a high-risk endeavor. Nearly 40% of Sidama farmers report losing half or more of their crops in recent years due to drought, leading to large deficits in per capita caloric production.

Rainfall variability, incidence drought and soil erosion were found to be the major challenges for crop production in the central rift valley of Ethiopia. Resulting in high risk of drought and intra-seasonal dry spells, leading to low crop yields and sometimes total crop failure (Kim *et al.,* 2014). This means the number of rainy days during the growing period is as important, if not more, as that of the seasonal total (Woldeamlak, 2011). This is because unusual rainfall amounts and distributions usually lead to poor harvest and/or completes crop failures at the end of the season (Tesfaye and Assefa, 2010). Also, the results corroborate with Lichtenstein *(*2014) who noted that farmers can suffer production losses as a result of the insufficient and erratic precipitation during the rainy season.

The climatic changes that result from increased atmospheric CO_2 concentrations will undoubtedly influence the geographic range of insect pests and disease. An increase in atmospheric CO_2 is just as likely to increase the growth rate of weed species (Rosenzweig and Hillel 1995). In this study outbreak of crop insect pests and disease are commonly mentioned problem of crop production by the respondents. They declared that increased spread of existing insect and disease pests such as African army worm, beetles, potatoes blight disease and maize dry disease, with the most recent one being American ball worm, head smut and leaf blights. This is associated with rising temperature which tends to lengthen the breeding season thereby increasing the reproduction rate and raises the number of insects attacking crops. As respondents, African armyworm is rated as high importance in severe armyworm occurs in severity leading to complete crop losses.

Moreover, beetles have also caused damaged to maize and sweet potatoes; while potatoes blight disease has caused considerable damaged on sweet potatoes production only. Thus, an increasing proportion of unfilled grains (smaller and lighter) and sometimes total crop failure. This may be associated with the warming temperature or drought on resistance of crops to specific diseases and also increased pathogenicity of organisms by mutation-induced resulted from environmental stress (Gregory *et al*., 2009). Discussions with key informants also showed that, previous years only four months were dry, and thus the rainy season was enough food crops as compared with the current condition.

i. Relationship between climatic variables and crop yield

A correlation analysis between different crop yields and climatic variables showed that, *belg* rainfall ($r = 0.69$), ($r = 0.67$), and ($r =0.96$) had positive moderate and strong correlation with maize, sweet potatoes and teff respectively (Table 12). The *kiremt* minimum temperature ($r = -0.57$) had negative moderate correlation with maize yields. On other hand, *belg* maximum temperature ($r = 0.092$) had a positive correlation with coffee Climate change effects on coffee are unclear. It has been suggested that higher temperatures adversely affect yields in current coffee areas, especially in the south, because coffee plants require temperatures below 22°C. Moreover, coffee yields may be adversely affected by the coffee berry borer, which requires high temperatures (Eshetu*et al.*, 2014).

Table 10: Correlation coefficients between crop production and climatic variables

Variables	Maize	Teff	Coffee	Sweet potatoes
Belg rainfall	.69*	.96*	-.83	.309
Kiremt rainfall	.102	.40	.377	-94
BelgT.minimum	-.33	-.06	-.921	-.004
BelgT.maximum	-.49	-.56	.092**	.100
KiremtT.minimum	-.57*	-.34	.035	.121
KiremtT.	-.370	-.466	-.073	.233

Source: Woreda Agriculture and Natural Resource Office, 2020

ii. The regression results for crop yield

Computed values for coefficient of multiple determinations (R^2) for crops (maize, teff, coffee, and sweet potatoes) are (0.928), (0.891), (0.916), and (0.886). This means that time series is responsible for (92.8%), (89.1%), (91.6%), and (88.6%) of the variations in yields of crop (maize, teff, coffee, and sweet potatoes) for the past 10 years in the study area respectively (Table 11). This means, more than 50% of total variance of crop yields is explained jointly by *belg* and *kiremt* rainfalls as well as *belg* mean maximum temperatures. This showed that, among the climate variable included in the study, belg rainfall had significantly affect maize, and teff yields indicating that yields of maize, and teff along with *belg* rainfall. Whereas the *belg* mean maximum temperature has a negative effect on yields of coffee; meaning that there was higher yield of coffee under years with lower seasonal *belg* mean maximum temperature.

Table 11: The regression results of different crops with time (2008-2017)

Model	Unstandardized Coefficients β	Std. Error	Standardized Coefficients Beta	R^2	Adjusted R^2	t-value	Sig.
Maize (Constant)	864.9	14319				-5.8	.000
Belg Rf	.93	81.304	.963	.928	.92	6.6	.000**
Teff (Constant)	964.9	1451.4				2.5	.044
Belg Rf	.043	80.304	.961	.891	.88	4	.003**
Coffee (Constant)	101.5	296.9				-3.4	.009
Belg T.max	-.561	4672.2	9.29	.916	.91	4.8	.001**
Kiremt Rf	.031	4548.6	-8.33	.951	.94	1.8	.013*
Sweet P (Constant)	112.7	6236.6				5	.001
Kiremt Rf	-.0561	64.49	.941	.886	.87	2.3	.047*
Haricot(Constant)	332.7	1426.9				5.1	.001
Belg Rf	.701	27.3	.741	.55	.499	-1.6	.051*

*Note: **, * Significant at 0.01 and 0.05 level*

Source: Own analysis report, 2020.

Whereas, the remaining (7.2%), (10.9%), (8.4%), and (11.4%) of the variation in (maize, teff, coffee, and sweet potatoes) yields is explained by other climatic and non-climatic factors. Further, statistical t-test analysis indicates that, among the rainfall characteristics, only *belg* rainfall significantly influenced maize and teff yields positively at ($p \leq 0.01$) and ($p \leq 0.01$) respectively. On other hand, *kiremt* rainfall significantly influenced coffee and sweet potatoes yields negatively at ($p \leq 0.07$). Moreover, *belg* mean maximum temperature significantly influenced coffee yield negatively. Likewise study done by Lemi (2005) found in three provinces of Ethiopia showed that yield variability in Ethiopia agriculture can be partly explained by rainfall.

4.4. Adaptation Strategies Employed by Farmers

Farmers in the study area are using soil and water conservation techniques and planting tree as adaptation strategies to climate change effects. Similarly, Legesse *et al*., (2013) noted that crop diversification along with soil and water conservation and water harvesting practices were commonly used as climate change adaptation strategies in eastern Ethiopia.

Table: 12. Adaptation strategies employed by sampled households of the study area.

Adaptation strategies for crop production	Number of sampled households used these strategies	Percentage of sampled households
Soil and water conservation	175	93%
Planting trees	160	85%
Crop diversification	88	46.8%
Changing planting date	82	43.6%
Using improved seeds	79	42
Growing drought resistance crop varieties	51	27.12%
Small scale irrigation	23	12.23%

In general, about 93% of respondents employed at least one adaptation strategy in response to climate change, while the remaining 7% of the sampled households did not use any mechanism at all.

4.5. Determinants of Adaptation Strategies

Multinomial Logit and regression models were employed to determine the factor that influences farmers' choice of adaptation method as well as identifying different adaptation strategies of the farmers in response to climate change. For this purpose, 9 independent variables were used. Besides, the existence of multicollinearity problem was checked using Variance Inflating Factor (VIF) and correlation matrix methods prior to running the final regression analysis.

i. Estimated results of the multinomial logit model

The results of MNL model show how factors influence farmers' choice of adaptation measures in the study area. The MNL adaptation model with these restructuring choices was run and showed some significant levels of the parameter's estimates. (Appendix I) represented the results of parameter estimated of the multinomial logit Regression model. The likelihood ratio statistics as indicated by chi^2 statistics (LR chi-square (60) =140.18 are highly significant Prob> chi^2= 0.0000), suggesting the model has a strong independent power. In all cases, the estimated coefficients should be compared with the base category of no adaptation.

The maximum likelihood method was employed to estimate the relative importance of predictor variables on the farmers' decision to choose adaptation strategies. The parameter estimates of the multinomial logit model estimates neither actual size of change nor the probabilities, but it gives only the direction of the effect of independent variables on the dependent variable. We can compute the magnitude of effect by using STATA command Mfx2 after multinomial logit regression and it gives marginal effect or elasticity.

Table 12: Marginal effects from the multinomial logit climate change adaptation in crop farm

Independent Variable	crop diversification	SWC	Tree Planting	Change planting date	Using Improved seeds	Drought resistance crop
Sex	.4065	.0828	.07096	.0884	-.0384	-.5561
Age	-.0306	.00025	.0691*	.0105	.00095	-.0294
Education	.0542	.0308	.01373	.0062	-.0079	.01099
Family size	.009	.1355*	-.0132	-.00063	-.0308	-.0232
Land size	.0161	-.0286	.0348	.0073	.00042	.00974
Extension	.1744	.0435	-.0288	.0561	.30476	-.56923
Credit	.145**	.0927	-.0745	-.06313	-.0378	.0783*
Information	-.034	-.01601	.0053	.2194*	-.0292	.0007
Market access	.0027	-.0166	.03246	-.023	.00403	-.0252

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

Source: Analysis based on survey data, 2020.

ii. Interpretation of significance from the marginal effect result in crop production

Age of household: is one of a significant explanatory variable in which the results of this study have shown that a one-year increase in age of the household head increases the probability of farmers' uses of planting trees as adaptation strategy by 6.91% at ($p \leq 0.01$) holding other variable constant (Table 12). This means that the likelihood of taking up climate adoption measures was higher among elderly farmers. Thus, age of the household head can be used to capture farming experience, since age might often mean better experience, access to information, and knowledge. However, among other things poor could have negative consequence and thus age and experience might give both positive and negative outcomes (Deressa*et al.*, 2008).

Family Size: - family size also has significant and positive effect on adaptation strategies to climate change. A one person increases in the family size, the probability of farmers to build rain water-harvesting as well as soil and water conservation adaptation strategies increase by 2.9% at ($p \leq 0.01$), keeping other variables constant. It is argued that a size of family is a driver for the adoption and implementation of any given adaptation practice, since the number of people living in a family influence the labor as an input for farm production, especially demanding manual farm labor, like in the adoption of soil and water conservation. This result is consistent with the argument of Croppenstedt *et al.,* (2003) who assumed that large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks, especially during peak seasons. Hassan and Nhemachena (2007) also found the same results.

Access to climate information: - is also one of a significant explanatory variable. Even though service on climate information delivery is not formal, access to information from different sources had positive influence on the probability of adaptation options to climate change. Getting information about seasonal forecasts and climate trends increases, the probability of changing planting date as adaptation by 21.9% at ($p \leq 0.01$), holding other variables constant. This result confirms the finding of Mulatu (2013) who showed that, increase in access to climate information increases farmers' likelihood to prefer change in planting date as climate change adaptation options.

Access to credit service: - in this study access to credit increased access the probability of growing drought resistance crop variety and crop diversification as adaptation strategies by 7.81% and 14.5% at ($p \leq 0.01$) and ($p \leq 0.05$), keeping other variables constant. The probable reason for the positive relationship between access to credit service and growing drought resistance crop variety and crop diversification as adaptation strategies could be due to the fact that, differences among crop varieties in resistance to climatic stress and disease risks enable farmers to hedge against risks and ensure survival under the looming climate change. In this line other studies also revealed that, an increase in credit access significantly enhanced farmers' choice of climate change adaptation strategies (Tizale, 2007 and Tesso*et al*., 2012). Moreover, the positive correlation has been observed between adaption to climate change and the availability of credit (Gbetibouo, 2009 and Deressa *et al.*, 2009).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

In this study area, almost all of the respondents were aware of the change in the level of precipitation and temperature, and reported a reduction in seasonal and annual rainfall amounts, delayed onset and early cessation of rainfall, and steady increase in temperature. However, meteorological recorded data of *kiremt* season and annual rainfall of 35 years period in the areas showed in contrary of the most farmers' perception and indicate an increasing trend. This lack of agreement between farmers' perception and Meteorological data is due to the fact that farmers assess rainfall in relation to the needs of particular growing seasons. And also, they were more of reflection of the variability of climate and further limited by several factors among which educational background of the farmers is one. Majority of the respondents perceived increment in temperature over the last twenty years. Indicators of climate change have been observed in the study area includes: drought, flood, as well as rainfall variability.

Farmers in the study area have encountered adverse climate change effects on crop and natural resources. For instance, decline in water availability, soil erosion, soil degradation, and thereby exerting significant influence on environment. For crop production, climate change has reported to have caused negative effects due to increased temperatures, negative changes in soil water balances, reduction in length of growing seasons, increased soil erosion, increased incidence of floods in flood-prone areas, and increased incidence and expansion of crop diseases and pests.

Moreover, farmers' reported crop farming is more vulnerable to the effect of climate effect than livestock production. Further, farmers' used different adaptation strategies in response to climate change effects such as diversification, soil and water conservation, planting trees, using improved seeds, growing drought resistance crop varieties and changing planting date are used by the farmers' for the effect of climate change on crop production.

The result from the multinomial logit analysis showed that age, family size, access to climate information and credit service have a significant influence on farmers' choice of adaptation strategies in response to climate change. For instance, age of household as positive effect on the probability of farmers to use of planting trees. Moreover, family size of the household has positively influence on the probability of farmers to use rain water harvesting and soil and water conservation adaptation strategies. An increasing in family size of the household, increase the probability of farmers to use build rain water-harvesting and soil and water conservation adaptation strategy. An increase in farm size of the household, increase the probability of farmers use rain water-harvesting adaptation strategies.

5.2. Recommendations

Based on the findings of this study, the following recommendations were forwarded to reduce the effects of climate change on crop production and to enhance adaptive capacity.

- ✓ All the stakeholders should formulate effective and efficient planned and anticipatory adaptation strategy, which is depend on indigenous practices of the community. Therefore, before planning and implementing any interventions, a proper assessment of locally available adaptation options and coping strategies should be considered in order to insure its sustainability.

- ✓ An effort that improves farmers' awareness on better production techniques, climate change and access to financial system, which enhance capacity to adopt climate resilience adaptation options, are important policy measures that should be considered.
- ✓ In addition, addressing the climate related problems calls for the Regional and District government as well as NGOs working on this issue to first tackle the barriers to climate change adaptation in the study areas

REFERENCES

Abate FeyissaSenbeta. 2009. Climate Change Impact on Livelihood, Vulnerability and Coping Mechanisms; a Case Study of West-Arsi Zone. Thesis Submitted to Lund University Master's Program in Environmental Studies and Sustainability Science, Lund University, Sweden.

Abraham Belay. 2013. Analysis of climate variability and its economic impact on agricultural crops: the case of ArsiNegele district, central rift valley of Ethiopia.

Afar National Regional State (ANRS). 2010. Programme of Plan on Adaptation to Climate Change.

Aklilu A, Alebachew, A. 2009. Assessment of climate change-induced hazards, impacts and responses in the southern lowlands of Ethiopia. Forum for Social Studies, Addis Ababa, Ethiopia.

Anley, Y., Bogale, A., and Haile-Gabriel, A. 2007. Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in dedo district, Western Ethiopia, Land Degradation and Development. 183, 289-302.

Anyamba, A. and Tucker, C.J. 2001. NDVI anomaly patterns over Africa during the 1997/ 98 ENSO warm event. *International Journal of Remote Sensing*, 22(10): 1847–1859.

Aragie, E. 2009. The Empirics of Growth, Poverty and Inequality in Sub-Saharan Africa. Ethiopian Economic Policy Research Institute Working Paper No. 1/2009.

AregaDemelash. 2003. Improved production technology and efficiency of small holder farmers in Ethiopia: Extended Parametric and non-parametric approaches to production efficiency.

Ayanlade, A., Odekunle, T.O. and Orimoogunje, O.O.I. 2010. Impacts of Climate Variability on Tuber Crops in Guinea Savanna Parts of Nigeria: A GIS Approach. *Journal of Geography and Geology*, 2(1):27 -35.

Bals, C., Harmeling, S. and Windfuhr, M. 2008. Climate change, food security and the right to adequate food. DiakonieKatastrophenhilfe, Brotfuer die Welt and Germany.

Bewket W, Radeny M, and Mungai C. 2015. Agricultural Adaptation and Institutional Responses to Climate Change Vulnerability in Ethiopia. CCAFS Working Paper no. 106. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

BewkwtAmdu. 2010. Analysis of farmers' perception and adaptation to climate change and variability: the case of Choke Mountain, east Gojjam.

Bezabih M., DiFalco S., and Mekonnen A. 2014. On the Impact of Weather Variability and Climate Change on Agriculture, Evidence from Ethiopia. Published by Sida, Environment for Development and Resource for the Future.

Bradshaw B., H. Dolan, and B. Smit. 2004. Farm-level adaptation to climatic variability and change: Crop diversification in the Canadian prairies. *Climatic Change* 67: 119–141.

Brown D, Stephens E, Ouma J, Murithi F, Barrett CB. Livelihood strategies in the rural Kenyan highlands. Afr J AgricResour Econ. 2006. 1(1):21–36.

Bryan, B. A. 2013. Incentives, land use, and ecosystem services: Synthesizing complex linkages. *Environmental Science and Policy*, 27:124–134

Burton, I. J.B. Smith, S. Lenhart. 1998. Adaptation to Climate Change: Theory and Assessment' in Feenstra, J.F., I. Burton, J.B. Smith, R.S.J. Tol (eds.) *Handbook onMethods for Climate Change Impact Assessment and Adaptation Strategies*, Version 2.0, UNEP/RIVM: Nairobi.

Care International. Midterm Evaluation Report. 16 may, 2016. Care International. Assessing Resilience Outcomes for GRAD Households and GRAD Cost Extension Scenario reports for review by CARE Ethiopia senior management.

César. E, and Ekbom, A. 2013). Ethiopia Environmental and Climate Change policy Ethiopia.

Proceedings from national work shop held in Adama, Ethiopia, 5-6.

Chan YH. 2005. Basic statistics for doctors, multinomial logistic regression. Singapore Med J.46.

Cheung, W.H., Senay, G.B., Singh, A. 2008. Trends and spatial distribution of annual and seasonal rainfall in Ethiopia. Int. J. Clim. 28, 1723–1734.

Croppenstedt, Demeke, M .and Meschi, M.M. 2003. Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. Review of Development Economics.7

CSA (Central Statistics Authority). 2008. FDRE CSA Agricultural sample survey: report on area and production of Belg season crops for Private peasant holding, Addis Ababa.

David, S., Thomas G., Twyman C., Osbahr H., and B., Hewitson. 2007. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. Climatic Change, 83: 301-322.

Dawit and Habtamu. 2011. Climate change adaptations and induced farming livelihoods. DCG Report No.64.

Dazé, A., Ambrose, K. and Ehrhart, C. 2009. *Climate Vulnerability and Capacity AnalysisHandbook*. CARE International.

Dercon, Stefan and Ruth Vergas Hill. 2009. Growth from Agriculture in Ethiopia, Identifying Key Constraints, and Paper prepared as part of a study on Agriculture and Growth in Ethiopia, DFID

Deressa T, Hassan R.M, Ringler C. 2010. Perception and adaptation to climate change: The case of farmers in the Nile Basin of Ethiopia, Journal of Agricultural science.

Deressa, T. 2007. Measuring the economic impact of climate change on Ethiopian agriculture:

Ricardian approach," CEEPA Discussion Paper No. 25. Centre for Environmental Economics and Policy in Africa,

University of Pretoria.

Deressa, T., Hassan, R. 2009. Economic impact of climate change on crop production in Ethiopia: evidence from cross-section measures. *Journal of African Economies, 18, 529–554.*

Deressa. T., Hassan. R. M., Ringler. C., Alemu. T., &Yesuf. M. 2008. Analysis if the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin in Ethiopia. IFPRI Discussion Paper No: 798, Washington D.C., 2008.

Desta, Z.H. 2004. Feed scarcity and livestock mortality in enset farming systems in the Bale highlands of southern Ethiopia. Outlook on agriculture, v. 33(4), p.277-280, 11 ref. ISSN

Di Falco S., Veronesi M., and Yesuf M. 2011a. Does Adaptation to Climate Change Provide Food Security? A Micro-perspective from Ethiopia. American Journal of Agricultural Economics Advance Access published March 7

Di Falco S., Yesuf M., Kohlin G. and Ringler C. 2012b. Estimating the Impact of Climate Change on Agriculture in Low-Income Countries: Household Level Evidence from the Nile Basin, Ethiopia. Environ Resource Econ (2012) 52:457–47

Diao. X., and A.N. Pratt. 2007. Growth Options and Poverty Reduction in Ethiopia: An Economy wide Model Analysis. *Food Policy* 32(2):205-228.

Doltra. J., Lægdsmand. M., and Olesen. J.E. 2012. Impacts of projected climate change on productivity and nitrogen leaching of crop rotations in arable and pig farming systems in Denmark. *Journal of Agricultural Science,* 152:75–92.

DPPC (Disaster Prevention and Preparedness Commission), 2003. Update of emergency assistance requirements&implementationoptionsfor2003.(*Available*from41http://www.dppc.gov.et/down loadable/reports/appeal/2003/Appeal_2003_Update_%20August.pdf).

EPA-(Environmental Protection Agency)(n.a.). EPA's Endangerment finding, *URL:http://www.epa.gov/climatechange/endangerment/downloads/Endangerment Finding Climate Change Facts.pdf*

Eshetu, Z.; Simane, B.; Tebeje, G.; Negatu, W.; Amsalu, A.; Berhanu, A.; Bird, N.; Welham, B.; Canales Trujillo. N. 2014. Climate finance in Ethiopia. Extension and Rural Development University of Pretoria, South Africa.

FAO. 2008. Intro. Soaring food prices: Facts, perspectives, impacts and actions required. Background paper prepared for the High Level Conference on World Food Security: The challenges of climate change and bioenergy, Rome, June 3 5, 2008

Funk C, Rowland J, Eilerts G, Kebebe E, Biru N, White L and Galu G. 2012. A climate trend analysis of Ethiopia. Climate change adaptation series. U.S. Geological Survey. Famine Early Warning Systems Network-Informing (FEWSNET). Fact sheet 3053. 6p

Gbetibouo, G. A. 2009. Understating Farmers' Perceptions and Adaptation to Climate Change and Variability: The Case of the Limpopo Basin. IFPRI, Discussion Paper Washington, D.C.

Gebreegziabher Z., Stage J., Mekonnen A. and Alemu A. 2011. Climate Change and the Ethiopian Economy: A Computable General Equilibrium Analysis. Environment for Development Discussion Paper Series, EfD DP 11-09

Getachew, H and Tesfaye, K. 2015. Analysis of Risks in Crop Production due to Climate Change I the Central Rift Valley o Ethiopia. African Journal of Agricultural Research.Vol 10(16).

Gizachew, L., and Shimelis, A. 2014. Analysis and mapping of climate change risk and vulnerability in Central Rift Valley of Ethiopia, African Crop Science Journal 22(s4): 807-18.

GoE. 2011. Ethiopia's Vision for a Climate Resilient Green Economy. Environmental Protection Authority, Government of Ethiopia, Addis Ababa, Ethiopia.

Green H. 2000. Econometric analysis, 4th ed. Prentice Hall, Upper Saddle River, New Jersey.

Greene W. Econometric analysis, vol. 4. New York: Macmillan Publishing Company; 2003

Gregory PJ, Johnson SN, Newton AC, Ingram JSI. 2009. Integrating pests and pathogens into the climate change/food security debate. J Exp Bot 60:2827-2838

Gujarati, D.N. 1995. Basic Econometrics. Third Edition. McGraw-Hill, Inc., New York.534p.

Hameso, S. 2014. Perception about climate change in Sidama zone, Ethiopia. In: Leal Filho,W., Alves, F., Caeiro, S., Azeiteiro, U.(eds) International perspectives on climate change. Climate change management. Springer, Cham.

Hare, F.K. 1983. Climate and Desertification. Revised analysis (WMO-UNDP) WCP-44 pp5-20. Geneva, Switzerland. In central high lands of Ethiopia PhD thesis. Department of Agricultural

Hassan R. and Nhemachena, C. 2007/8. Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. African Journal of Agricultural and Resource Economics. 2 (1), pp. 83–104.

Hoffmann, U. 2013. Section B: Agriculture: a key driver and a major victim of global warming, in:

Lead Article, in: Chapter 1, in Hoffmann 2013, pp: 3-5.

Houghton, J.T. 2001. Climate Change: The Scientific Basis. Contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, UK.

ICRA. 1999. Livelihood and drought coping strategies of farm households in the Central Rift Valley, Ethiopia: Challenges for agricultural research. 1999. Prepared by AdmassuHabtamu, Alfred Daka, Etagengnhu G., Lundall Magnuson Elize, Mulhall Abigail, and Mutsaers Arthur, Working document series 76. Netherlands

Index Mundi. 2014. Ethiopia Economy Profile. Index Mundi. [Cited 21JUNE 2014].

IPCC. 2007. *Summary for Policymakers. In: Climate Change 2007: Impacts,Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

IPCC. 2013. Summary for Policymakers. In: T.F. Stocker et al. (Editors), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report

IPCC. 2014. Technical summary in: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the FifthAssessment Report. Cambridge University Press, Cambridge and United Kingdom.

ISS (Institute for Security Studies), the impact of climate change in Africa. DebayTadesse, ISS Paper 220, November, 2010.

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

Kandlinkar M, Risbey J. 2000. Agricultural impacts of climate change: if adaptation is the answer, what is the question? ClimateChange; 45:529–39.

Kassie B. T., Rötter R. P., Hengsdijk H., Asseng S., Van Ittersum M. K., Kahiluoto H. and Van Keulen, H. 2012. Climate variability and change in the Central Rift Valley of Ethiopia: challenges for rain-fed crop production. Climate Change and Agriculture Research Paper.

Journal of Agricultural Science Page 1 of 17. Cambridge University press 2013.

Kates W. 2000. *Cautionary tales: adaptation and the global poor*. Climatic Change, 45(1), 5-17.

Kebede, D. and Adane, H. 2011. Climate change adaptations and induced farming livelihoods', DCG Report No. 64 October.

Kim, J., Waliser, D.E., Mattmann, C.A., Goodale, C.E., Hart, A.F., Zimdars, P.A., Crichton, D. J., Jones, C., Nikulin, G., Hewitson, B., Jack, C., Lennard, C., Favre, A. 2014. Evaluation of the CORDEX-Africa multi-RCM hind cast: systematic model errors. Clim. Dyn. 42, 1189–1202.

Komba C, Muchapondwa E. Adaptation to climate change by smallholder farmers in Tanzania. Economic Research Southern Africa (ERSA) Working paper No 299, 2012. *http://econra.org/home/index.php?optioncomdocman&task. . Accessed 14 December, 2016.*

Korecha, D and A. Barnston. 2007. Predictability of June-September Rainfall in Ethiopia. *Monthly Weather Review* 135(2): 628–650.

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 J Empir Res. 3(3):251–65.

Lemi, A .2005. Rainfall probability and agricultural yield in Ethiopia, Eastern Africa social science review, volume 21, number 1, pp.57-9.

Lichtenstein, D. 2014. The Effects of the Rainy Season on Farmers. Online:

http://www.ehow.com/info_799661_effectsrainyseasonfarmers.html

Linderholm, H.W. 2006. Growing season changes in the last century. Agriculture for Meteorology, 137, 1.14

AletaWondoworeda Agriculture Development Office AletaWondo. 2019. The Annual Report of agriculture production. AletaWondo, Ethiopia.

Mahoo, H., Radeny, M., Kenyan, J., Cramer, L. (ends). 2013. Climate change vulnerability and risk assessment of agriculture and food security in Ethiopia: which way forward? CCAFS working paper 59. Copenhagen, Denmark (online: www.ccafs.cgiar.org).

Majule, A.E. 2008. Climate change and variability impacts on agriculture and water resource and implications for livelihoods in selected basins. Institute of Resource Assessment (IRA), University of Dares Salaam. Dares Salaam, Tanzania.

Malone, EL. 2009. Vulnerability and Resilience in the Face of Climate Change: Current Research and Needs for Population Information. PNWD-4087. Richland, WA: Batelle.

Markos. K. G. 2017. Contribution of livelihood diversification to climate change adaptation in Sidama zone, southern Ethiopia. Mac Thesis, Hawassa University, un published.

McCarthy, J., Canziani, O.F., Leary, N.A., Dokken, D.J. & White, C. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the third assessment report of the IPCC. Cambridge: Cambridge University Press.

McKee, T.B., N.J. Doeskin and J. Kleist. 1993. The relationship of drought frequency and duration to time scale. In: *Proceedings of the Eighth Conference on Applied Climatology*, Anaheim, California, 17–22 January 1993. Boston, American Meteorological Society, 179–184.

McSweeney, C. New, M. Lizcano, G. 2008. UNDP Climate Change Country Profiles: Ethiopia. *http://ncsp.undp.org/sites/default/files/Ethiopia.oxford.report.pdf*.

MEA. 2005. Ecosystems and Human Well-Being: Our Human Planet. Summary for Decision

Makers. The Millennium Ecosystem Assessment, online at http://www.millenniumassessment.org

Mendelsohn, R Dinar A. & Deflect, A, 2008. Climate Change Impacts on African Agriculture Yale University

Mersha E, Boken KV. Agricultural drought in Ethiopia. In: Boken KV, Cracknell AP, Heathcote LR (eds), Monitoring and predicting agricultural drought: a global study. 2005. Oxford University Press, p 227.

Mertz, O., Mbow, C., Reenberg, A. and Diouf, A. 2009. Farmers' perceptions of climate change and Agricultural adaptation strategies in rural Sahel. Environmental Management, 43: 804-816.

Meze-Hausken, E. 2004. Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. Climate Research, 27(1), 19-31.

Ministry of Water Resources and National Meteorological Agency (MoWRNMA). 2007. Climate Change National Adaptation Programed of Action of Ethiopia, Addis Ababa.

MoA and NRMRD] Ministry of Agriculture and Natural Resource Management and

Regulatory Department. 1998. Agro-ecological zones of Ethiopia. Addis Ababa, Ethiopia

Molla, M. 2008. Climate Change and Crop Agriculture in Nile Basin of Ethiopia: Measuring Impacts and Adaptation Options, Master thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Mugalavai, E.M., Emmanuel, C., Kipkorir, E.C., Raes, D. and Rao, M.S. 2008. Analysis of rainfall onset, cessation and length of growing season for western Kenya. Agric. Forest Meteorol. 148.

Mulatu N. 2013. Analysing the Determinants of Farmers' Preference for Adaptation Strategies to Climate Change: Evidence from North Shoa Zone of Amhara Region. Addis Ababa

University, Ethiopia.

Muluneh, A., Biazin, B., Stroosnijder, L., Bewket, W. and Keesstra, S.D. (2015). Impact of predicted changes in rainfall and atmospheric carbon dioxide on maize and wheat yields in the Central Rift Valley of Ethiopia. Regional Environmental Change 15: 1105-1119

Mwandosya. M. J., Nyenzi B. S., and Luhanga. M. L. 1998. *The Assessment of Vulnerabilityand Adaptation to Climate Change Impacts in Tanzania*. Dares Salaam. Centre for Energy, Environment, Science and Technology (CEEST).

Nater, T. 2010. *UNCCD* News, Climate Change and adaptation in Ethiopia,

National Meteorology Agency (NMA). 2006. Agro-Meteorology bulletin, Addis Ababa Ethiopia.

Ndambiri F. N., Chikaire, J., Echetama, J. A., Ihenacho, R. A., Umunnakwe P. C. and Utazi, C. O. 2013. Agricultural insurance: A strategic tool for climate change adaptation in the agricultural sector. *Net Journal of Agricultural Science*, 1(1): 1-9.

Negash, M. 2013. Determinants of farmers' preference for adaptation strategies to climate change: evidence from north shoa zone of Amhara region Ethiopia, MPRA Paper No. 48753.

Nhemachena C. & Hassan R. 2007. Micro-level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper. 00714, Environment and Production

Nhemachena, C., Hassan, R. and Kurukulasuriya, P. 2010. Measuring the Economic Impact of Climate Change on African Agricultural Production Systems, *ClimateChange Economics*, Vol. 1, No. 1 33–55.

NMA (National Meteorological Agency). 2006. National Adaptation Programed of Action of Ethiopia (NAPA). National Meteorological Agency, Addis Ababa.

NMA (National Meteorology Agency). 2009. Seasonal Agro meteorological Bulletin. Belg 2009.Volume 19 No. 15

NMA. 2007. Climate change National Adaptation Program of Action (NAPA) of Ethiopia. Ministry of Water Resources, Addis Ababa. Northern Ghana', Africa Portal Backgrounder No 48.

NREPA (Natural Resources and Environmental Protection Agency).2012. SNNPR's climate change adaptation plan – Draft Document [Amharic] Hawassa: SNNPR, NREPA.

Olesen, JE. And Bindi, M. 2002. 'Consequences of climate change for European agricultural productivity, land use and policy.' *European Journal of Agronomy*, 16:239–262.

Olesen, JE.,Trnka, M., Kersebaum, CK., Skjelvag.F. 2011. 'Impacts and adaptation of European crop production systems to climate change.' *European Journal of Agronomy*, 34:96-112.

ONRS (Oromia National Regional State). 2011. Program of Plan on Adaptation to Climate Change.

Orindi A. and Eriksen S. 2005. Mainstreaming adaptation to climate change in the development process in Uganda. Eco. Policy Series15. Nairobi, Kenya: African Centre for Technology.

Orindi V, Ochieng A., Otiende B, Bhadwal S, Anantram K, Nair S, Kumar V, Kelkar U. 2006. Mapping climate vulnerability and poverty in Africa

PANE. 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, Ethiopia.

Parry, M.L., Canziani, O.F., Palutikof, J.P., van deer Linden, P.J., and Hanson, C (Eds.). 2007. Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the III Assessment Report of the IPCC. *Cambridge University Press, Cambridge, United Kingdom*.

Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M. and Fischer, G. 2004. Effects of climate change on global food production under SRES climate and socioeconomic scenarios. *Global Environmental Change*, 14, 53-67.

Pingali, P. 2012. Green Revolution: Impacts, limits, and the path ahead. *ProcNational Academy of Science*, USA. 109:12302 –12308.

Porter, J.R., Semenov, M.A. 2005. Crop responses to climatic variation. Philosophical Transactions of the Royal Society B360 (1463), 2021–2035.

Quinlan, Robert J., Marsha B. Quinlan, Samuel JiloDira, Mark Caudell, AmaloSooge, and Awoke AmzyeAssoma. 2015. Vulnerability and resilience of Sidamaenset and maize farms in Southwestern Ethiopia. Journal of Ethno biology 35(2):314–336.

Raventós, J. 2010. Evidence for the Spatial Segregation hypothesis: A test with nine-year Survivorship Data in a Mediterranean Shrub land. Ecological Society of America. Volume 91.

Regassa, S.; Givey, C.; Castillo, G.E.; McGrath, J.; Pfeifer, K. (2010): The rain doesn't come on time anymore: Poverty, vulnerability, and climate variability in Ethiopia. Oxfam International. Robeson, S.M. 2002. Increasing growing-season length in Illinois during the 20th century. *Climatic Change*, 52, 219–238.

Rosell, S. 2010. Regional perspective on rainfall change and variability in the central high lands of Ethiopia1978 – 2007.

Seyoum Hameso. 2015. Perceptions, vulnerability and adaptation to climate change in Ethiopia: the case of smallholder farmers in Sidama Zone; A thesis submitted to University of East London for the degree of ''Doctor of Philosophy''

Shapiro, B.I., Gebre, G., Desta, S., Regassa, A., Nigussie, K., Aboset, G. and Mechal, H.

2015. *Ethiopia livestock master plan.* ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Smith J., Klein B. and Richard J. 2003. Climate change, adaptive capacity and development, Imperial College Press.

Smith, B., McNabb, D. &Smithers, J., 1996. Agricultural adaptation to climatic variation. Climate change 43, 7-29.

Sørhaug, AK. 2011. Climate Change Impacts and Adaptations among Ethiopian Farmers Case studies of HagereSelam, Tigray, and Kofele, Oromia. University of Agder. Unpublished.

Speranza CI. 2010. Resilient adaptation to Climate Change in Africa. Studies German Development Institute, Bonn

Teka, K., A. Van Rompaey, J. Poesen, Y. Weekday, J. Dickers.2012. Impact of climate change on smallholder farming: A case of eastern Tigray, northern Ethiopia. African Crop Science Journal. 20 (2– 347)

TemesgenTadesse, 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.

TemesgenTadesse. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia.Global environ. Climate change.

Tesfaye. K. and Assefa. M. 2010. Climate change, climate variability and adaptation in Ethiopia. Journal of Agriculture and Development, 1: 43-70.

Tessema, Y.A., C.S Aweke, G.S Indris. 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*

Tesso, G., B. Amana, M. Ketema. 2012. Econometric analysis of local level perception, adaptation and coping strategies to climate change induced shocks in North Shea, Ethiopia. *International Research Journal of Agricultural Science and Soil Science*, 2(8): 347-363.

Thornton, P. K. 2010. Livestock Production: Recent Trends, Future Prospects. CGIAR/ESSP Program on Climate Change, Agriculture and Food Security (CCAFS), International Livestock Research Institute (ILRS) 365, 2853-2867.

Thornton, P., M. Herero, A. Freeman, O. Mwai, E. Rege, P. Jones and J. McDermott., 2007. Vulnerability, climate change and Livestock-Research opportunities and challenges for poverty alleviation. SAT e Journal, 4(1): 1-23.

Thornton, P.K., Jones, P.G., Alagarswamy, G., Andresen, J. 2009. Spatial variation of crop yield response to climate change in East Africa. Glob Environ Chang 19:54–65. Addis Abeba University, Ethiopia.

Tirado R. and Cotter J. 2010. Ecological USAID and FEWS NET (2012): A Climate Trend Analysis of Ethiopia. *Fact Sheet 2012-3053.http://pubs.usgs.gov/fs/2012/3053/FS12*

Tittonell, P., Giller, K.E. 2013. When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. Field Crops Res. 143, 76–90.

Tizale C. The dynamics of soil degradation and incentives for optimal management in Central Highlands of Ethiopia. South Africa: University of Pretoria. 2007.

UNEP. 2006-07. Climate Change and Variability in the Sahel Region: Impacts and Adaptation StrategiesintheAgriculturalSector,URL:http://www.unep.org/Themes/Freshwater/Documents.

USGS, USAID and FEWS NET. 2012. A Climate Trend Analysis of Ethiopia. *Fact Sheet 20123053. http://pubs.usgs.gov/fs/2012/3053/FS12-3053_ethiopia.pdf*.

Viste, E., Drib Korecha and Sager Sort berg. 2013. Recent drought and precipitation tendencies in Ethiopia. Theoretical Apple Climate (2013) Springer-Vela, 112 (DOI 10.1007/s00704- 012.

Vuren DPV.Ochola WO., Gampietro. M., and Ginze H. 2009. Outlook on agricultural change and its drivers. In: McIntyre BD, Wakhungu J, Watson RT (Ed.). Agriculture at a Crossroads.

Watson. B. 2010. Climate change: An environmental, development and security issue. Livestock and global climate change international conference proceedings, Tunisia, 20 May 2008, 6-7.

WFP (World Food Programme). 2013. Ethiopia: food security outlook update, A*vailable online: http://reliefweb.int/sites/reliefweb.int/files/resources/Ethiopia%20Food%20Security%20Outlook%20Update%20May%202013.pdf.*

WMO. 2012. Drought monitoring and early warning. Weather-climate-water; Standardized Precipitation Index User Guide. WMO-NO. 1090.

Woldeamlak Dawit. 2011. Agricultural adaptation to climate change: farmer responses to experienced climate variability in Ethiopia. *http://www.slu.se*

Wooldridge, J. M. 2002. *Econometric analysis of cross section and panel data.* Cambridge, Mass.: MIT Press.

World Bank .2006. Managing Water Resources to Maximize Sustainable Growth: A World Bank Water Resources Assistance Strategy for Ethiopia.

World Bank. 2003. Africa rainfall and temperature evaluation Farming: Drought-resistant Agriculture. Greenpeace Research Laboratories, University of Exeter, United Kingdom.

World Bank. 2007. World Development Indicators. The World Bank Washington, DC.

World Bank. 2008. World Bank data on agricultural value added as a share of GDP in 2008.

Yamane, Taro. 1967. Statistics. An Introductory Analysis, 2nd Ed., New York: Harper and Row.

Yesuf, M., Falcon, D. S., Deressa, T., Ringler, C., &Kohlin, G. 2008. The Impact of Climate Change and Adaptation on Food Production in Low-Income Countries. Ethiopia Development Research Institute. International Food Policy Research Institute. Discussion Paper No: 828.

YibekalTessema, ChanyalewAweke and Getachew Indris (2013*)*. Understanding the process of adaptation to climate change by small-holder farmers: the case of east hararghe zone, Ethiopia.

Yirga, Chilot. 2007. The dynamics of soil degradation and incentives for optimal management

ZenebeMeseret and Alemu. 2011. Crop-livestock Inter-linkages and Climate Change Ethiopia

Zhang,X., Harvey, KD. Hogg, WD.andYuzyk, TR. 2001.*Trends in Canadian streamflow. WaterResources Research 37:987-998.*

APPENDICES

Appendix-I: Estimated results of the multinomial logit model; Crop production

Table 1: Parameter estimates of the multinomial logit climate change adaptation model f Crop farming

Explanatory Variables	Diversifying crops		Soil and water conservation		planting trees		changing planting date		improved seeds		Drought resistance crop	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Sex	2.3406***	0.096	1.973	0.205	2.349	0.127	2.132	0.196		0.559	-11.4858	0.990
Age	.1846	0.625	.3279	0.431	1.2846*	0.004	.5148	0.250	.359	0.459	-.409286	0.487
Education	1.827**	0.011	1.932**	0.010	1.799**	0.019	1.73**	0.025	1.42***	0.067	1.84855**	0.023
Family size	1.227**	0.010	2.493*	0.000	1.016***	0.095	1.18**	0.037	.6505	0.279	.649386	0.328
Farm size	.6458**	0.049	.3234	0.402	.0405**	0.014	.715***	0.080	.575	0.205	.7872804	0.118
TLU	.7808**	0.030	.50801	0.205	.2472	0.570	.39542	0.35	.252	0.548	.7804269	0.119
Extension	-2.045	0.893	.2157	0.886	-.2589	0.874	.5399	0.725		0.000	-13.3691	0.987
Credit	2.69**	0.036	2.998**	0.033	.9559	0.573	1.278	0.456	1.292	0.393	3.9382*	0.005
Information	2.03**	0.034	2.06***	0.053	2.368**	0.032	4.908*	0.000	1.754	0.127	2.1749***	0.073
Market	-.393	0.445	-.5489	0.342	.04733	0.939	-.654	0.284		0.607	-.9762	0.180

Base category = No adaptation; Number of observations = 188; LR chi2 (60) = 261.36; Log likelihood = -213.94936; Prob> chi2= 0.0000; Pseudo R2 = 0.3792

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

Appendix-II: Metrological data

I. Monthly minimum and maximum temperature (1983-2017)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	Max	31.6	31.9	33.8	31.9	29.1	28.4	27.4	27.6	29.1	29.1	29.7	30.6
	Min	15.9	17.1	19.1	18	18.6	18	17.6	17.7	18.4	18.1	16.5	16
1984	Max	31.8	33.8	34.3	32.1	29.1	28	28.1	29	29.7	30.7	31.4	30.4
	Min	14.8	16.6	18	18	18.3	18.6	18.7	17.8	18.2	16.2	17	15.5
1985	Max	32	32.5	33.1	30.1	29.1	27.9	26.8	27.6	29.5	30.7	30.9	31.4
	Min	16.4	15.9	17.7	17.7	17.6	18	18.1	17.4	17.8	17.5	16.9	15.6
1986	Max	32.1	32.4	32.8	30.1	28.1	26.6	27.4	28.3	28.8	29.5	31.5	30.8
	Min	15	16.1	16.6	17.3	17.4	18.4	17.9	17.7	17.4	16.7	16.5	15.9
1987	Max	31.9	32.8	32.1	30.6	28.6	27.4	28.6	29.3	30.2	29.9	30.6	31.3
	Min	15.6	16.5	18.2	17.5	18.2	17.2	18	18.1	17.8	17.5	16.3	15.5
1988	Max	32.2	32.8	33.7	31.2	28.7	28	26.4	27	28.2	29.1	30.2	30.9
	Min	16.6	17.3	17.8	18.5	18.3	18.6	18	17.9	17.8	17.5	15.8	15.1
1989	Max	31.3	31.5	32.1	30	29.3	28.3	27.1	28.7	29.3	29.2	30.1	30.2
	Min	15.7	15.3	17.2	17.8	17.3	17.9	17.7	17.5	17.7	16.9	16	16.5
1990	Max	31.6	30.8	30.7	30.7	29.8	28.9	28.1	28.1	30.5	30.8	31.5	30.8
	Min	15.7	17.4	17.4	18	18.4	18.1	17.8	18.1	17.7	17	16.6	15.2
1991	Max	31.3	31.6	31.6	31.1	30.2	29.2	27.5	28.9	30.9	31.3	32.5	32.3
	Min	16.4	16.9	17.4	17	18	18.7	17.9	18.2	17.8	16.3	16.3	15.1
1992	Max	33	32.7	33.3	32.1	30.4	29.3	28.8	27.9	29.2	28.9	30.2	30
	Min	16.5	18.5	19.3	18.4	18.5	18.8	18.3	18.2	18.3	17.8	16.5	16.1
1993	Max	30.2	29.9	32.1	31	28.9	27.8	29.3	29.6	30.6	30.8	32.2	33.3
	Min	16.9	16.6	16.3	18	18.5	18.7	18.1	17.9	17.9	17.7	16.5	15.6
1994	Max	33.9	34	33.2	31.5	29.1	28.2	27.7	27.7	30.7	31.2	30.4	31.2
	Min	15.5	16.2	17.8	17.9	18.6	18.5	18.1	17.9	18.4	16.8	16.3	14.4
1995	Max	33.2	33.1	32.3	30.3	30	29.3	28.2	28.9	29.9	30.3	30.8	31.8
	Min	15.4	17	17.8	18	18.4	18.2	17.9	18.2	17.8	17.5	16.1	15.9
1996	Max	31.9	32.8	32.2	31.2	28.9	28	28.1	28.1	28.8	30.1	31.1	31.7
	Min	16.2	16.4	16.8	16.9	17.6	18	17.7	17.8	17.4	16.5	15.6	15.1
1997	Max	32.9	34.3	35.2	30.5	29.6	29.9	28.8	30.7	32.3	30.8	28.9	29.2
	Min	16.9	15.4	17.4	17.9	17.8	18.1	17.7	17.5	17.8	17.1	17	15.7
1998	Max	31	31.8	32.4	32.6	30.3	30.1	28.5	28.2	30.2	29.6	31.1	32.1
	Min	15.9	17.2	17	17.7	18.4	17.4	17.6	18	17.6	17.8	15.7	13.9
1999	Max	32.7	34.5	31.4	31.7	30.5	30	27.5	29.3	30.2	29.1	30.8	31.9
	Min	15.9	15.9	17.8	17.2	17.7	18.1	17.8	17.5	17.7	17.7	15.4	15.3
2000	Max	33.3	34.7	34.8	32.2	28.8	28.5	28.3	27.9	30.5	29.1	30.1	31.1
	Min	15.2	15.6	17.8	17.9	17.9	17.9	18.2	18.3	18.1	17.9	16.3	15.6
2001	Max	31.1	32.9	32.5	31	29.5	27.9	28.6	28.7	30.5	29.9	30.4	32
	Min	16.6	16.6	18.4	18.6	18.6	18.1	18.3	17.9	18.2	18.1	16.7	16.1
2002	Max	31.5	33.9	32.3	31.6	29.8	29.7	30.1	29.8	31	31.1	32.8	31.2
	Min	17.2	17.3	18.9	18.7	19.2	19	19.1	18.7	18.5	18.1	17.2	17.9
2003	Max	31.2	34.3	34.1	31.7	29.3	28.7	27.7	27.3	30.4	31.6	31.8	30.7
	Min	16.7	18	19	18.9	18.8	18.8	18.3	18.2	18.6	18	17.8	15.9
2004	Max	31.7	32.2	34	30.2	30	29.3	29.1	28.9	30.4	30	29.8	29.6
	Min	17.4	17.3	18.2	18.8	18.9	18.9	18.5	18.8	18.5	17.7	17.6	14.2
2005	Max	31.6	33.7	32.6	32.5	28.3	28.6	28	29.4	29.6	30.2	31	32.5
	Min	16.8	18.1	19.2	19.3	18.8	18.9	18.1	18.4	18.1	18	16.9	15.3

2006	Max	33.9	33.7	31.6	30.1	29.9	29.4	28.8	28.6	30.3	30.5	29.8	29.8
	Min	18.4	19	18.4	18.5	18.5	18.4	18.2	17.9	18.4	18.2	17.3	17.7
2007	Max	31.3	33.2	34	32.4	30.4	27.8	29	28	29.4	30.7	31.3	32.4
	Min	17.4	18.1	18.4	17.8	19.4	18.8	18	18.2	18.2	17.1	16.7	15.2
2008	Max	33.6	33.8	34.9	32.4	31.2	29.6	28.4	29.7	30.4	29.8	29.8	31.8
	Min	16.6	17	18.4	18.3	18.8	19	18.6	18.7	19	18.2	16.8	16.7
2009	Max	32.7	33.6	35	31.9	30.5	30.5	30.2	30.7	31.7	31.2	32.2	31.2
	Min	16.9	17.8	19.1	19	18.7	18.7	18.5	19.2	19.3	18.9	17.7	18.7
2010	Max	32.3	32.9	31.8	31	29.4	29.3	28.6	28.7	30	31.4	32.7	32.6
	Min	17.9	19.2	19	19.1	19.4	18.9	18.5	18.3	18.5	18.3	17.7	16.6
2011	Max	33.6	34.7	34.6	34.6	30.7	28.4	29	28.8	30	31.1	29.6	30.2
	Min	17.8	17	19.4	19.6	19.4	19.3	18.7	18.6	18.5	17.7	17.8	15.4
2012	Max	33.2	34.5	34.8	31.1	29.8	28.2	28.2	29	29.4	30.6	30.7	32
	Min	15.8	16.9	18.4	18.5	18.7	19	18.3	18.5	18.1	17.7	17.5	17.2
2013	Max	32.9	35.2	33.1	30.9	30.1	29.4	28.9	29.4	30.9	30.5	28.9	31.6
	Min	16.7	18.2	19.1	18.5	18.9	19.6	18.4	18.3	18.4	17.9	16.8	15.9
2014	Max	33.6	33.3	33.6	32.7	31.1	29.7	29.3	30.2	29.9	30.2	31.2	31.8
	Min	17.7	18.5	19.3	18.6	19	19	19	18.9	18.6	18.1	17.1	16
2015	Max	31.7	32.4	34.2	32.3	29.4	28.4	28.2	28	30.4	30.8	31.5	31.8
	Min	15	16.7	18.3	19.9	19.2	18.2	19.3	18.9	19	18.6	17.6	15.7
2016	Max	33.2	33.5	33.8	31.6	28.9	28.7	28	29.4	30.2	31	28.9	31.2
	Min	16.5	16	18.6	17.8	17.3	18.6	18	18.3	18.2	17.2	18.3	17.2
2017	Max	31.2	30.5	29.2	28.8	26.9	27.9	26.9	26.4	26.2	25.7	27.4	30.2
	Min	17.5	18.2	19	18.7	18.8	18.2	17.5	17.5	18.2	17	15.5	18.9

II. Monthly Total Rainfall (1983-2017)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	5.2	32.3	36.7	149.5	153.1	89.2	69.5	153.1	86.7	146.7	83.8	15.6
1984	0	4.6	30	164.8	121.2	58.1	33.7	29.7	95.8	70.3	30.1	29.4
1985	20.7	2.4	72.7	166.8	165.4	74.8	67.1	20.9	45.9	60.1	58.7	6.7
1986	0	37.6	70.5	176.7	177.2	131	46.1	90.6	42	63.3	54.1	38.8
1987	17.9	14.2	155.7	168.4	245.7	19.6	15.4	55.8	114.2	136.7	50.7	14.4
1988	6.1	26.2	43.6	151.3	85.3	48.6	153.1	139.2	126.6	169.6	67.6	15.4
1989	34.1	44.2	94	178.7	130.2	102	121.5	57.2	77.3	126.4	83.4	136.6
1990	4.7	126.7	122.7	81	141	35.1	23.3	48.7	52.4	44.8	26.7	25
1991	23.5	40	109.1	28.1	119.3	63.8	65.5	76.6	103.1	24.7	5.4	6
1992	8.4	0	20.8	133.6	57.1	44.1	84.5	84.4	121.6	166	25.4	35.5
1993	82	138.7	15.3	165.6	224.4	57.5	0	24.1	0	56.3	18.7	0
1994	0	5.3	58.6	162.2	205.4	76.1	85.5	103.6	48.5	61.6	73.3	10.9
1995	0	28.6	79.1	217.4	140.5	52.5	62.7	35.2	84.4	94.9	43.2	19
1996	17.4	5.3	112.7	247.9	155.6	161	102.5	193.6	107.3	54.6	31.7	6
1997	3.4	0	20	217.7	131.1	60	86.2	65.4	34	216.9	166.6	61.1
1998	58.2	41.7	48.9	117.6	99.5	69.4	79	112.1	29.8	169.3	22.6	0.4
1999	10.2	0	85	62.2	39.2	52.8	95.9	67.3	46.7	144.6	15.1	16.1
2000	0	0	10.1	93.9	161.5	56.6	82.3	74.6	38.6	212.1	86.5	27.8

2001	27.5	15.1	130.5	150.5	152.9	80.6	130.5	98.8	70.1	139	49.6	8.6
2002	32.5	16.9	179.4	133.4	32.1	69.4	45	63.9	45.9	66.9	19.9	104.1
2003	10.5	6.7	33.6	163.2	96.7	56.1	79.5	145.6	22.4	44.6	52.3	55.1
2004	43.9	27.1	13.1	164.2	57.7	41.7	29.9	78.8	81.9	53.2	102	47.7
2005	16.4	8	107.3	150.1	247.7	45.1	84.4	20.6	88.5	132	31.1	0
2006	13.8	45.8	155.3	174.5	125.1	60.1	40.6	111.9	5.2	170	103.5	126.6
2007	67.9	22.9	72.9	132.4	200.5	163.1	105.1	185.1	155.4	98.6	48.5	0
2008	7.8	5.6	35.8	114.6	94.9	34.7	97.2	79	85.7	202.6	112.4	0
2009	0	11.9	15.3	90.8	114.6	44.4	18.4	28.6	53.5	153.3	35.1	45.6
2010	34.9	70.8	191	183.2	194.1	108.9	55.1	92.3	75.8	91.9	8.7	18
2011	0	11.9	31.8	49.2	238.3	145.6	115.5	124.7	112.4	66.6	210.3	0
2012	0	0	10.6	211.1	101.1	48.8	112.1	112.5	107.6	90.8	68.1	30.2
2013	17.7	12.6	75.6	181.3	157.9	71.3	98.8	129.1	161	157.5	77.8	3.9
2014	6.2	45.9	104.8	72.2	203.2	61.8	64.7	136.6	85.5	176.2	86.8	0
2015	14.3	6.7	70.9	87.8	101.2	40.8	97.1	65.7	72.5	92.4	31.7	0
2016	0	0	13.8	48.5	52.4	32.6	16.4	101.4	5.1	22.8	7.7	0.8
2017	0	63.6	63.6	112.4	203.4	48.8	150	127	184.2	255.2	206.9	0

Source: National Metrological Agency, Ethiopia 2020)

Appendix-III: Primary data Collection Instruments

I. SURVEY QUESTIONNAIRES

Date: ___________ Kebele: ________Name of Interviewer______________

Part I: Demographic and Socio-economic Characteristics

1. Sex of household head: a) Male b) Female
2. Age of the household head (in years) …………
3. Education level of the household head……………………
4. How many family members do you have?

a) Number of children below 15 years…… c) Number of elders above 64 years………
b) Number of household members aged between 15-64 years…….

5. For how long have you practiced as a farmer? ....
6. Do you have farm land? a) Yes b) No
7. If your answer for Q.no.6 is 'yes' how much is the total size of your land? In hectares………
8. Which of these farming systems did you practice?

a) Crop production b) Livestock rearing c) Mixed farming d) Others, specify

9. Would you please provide the following information about your crop production experience in your area over the past twenty years?

Year	Type of crop	Est area allocated (ha)	Est yield Kg/ ha	Yield trend (increasing, decreasing & constants)
Before 1990 E.C	1.			
	2.			
	3.			
	4.			
1991-2000 E.C	1.			
	2.			
	3.			
	4.			
2001 E.C–Recent	1.			
	2.			
	3.			
	4.			

10. What you produce to the market?
11. How far is the market where you sell your agricultural products and buy inputs from your home? Distance in (Km)…………
12. Do you have access to any credits when you face shortage of money to undertake your usual farming activities? a) Yes b) No
13. Do you have access to crop extension services? a) Yes b) No
14. If your answer for Q.no.13 is 'yes' how many visit(s) in the cropping season and/or years?
15. Do you have access to climate related information? a) Yes b) No
16. Have you ever got any kind of formal training about the impacts of climate change and how it can be cope up? a) Yes b) No
17. Any improvement in agronomic practices and or yield after the extension service is provided?

PART II: Household perception on variability and climate change

18. Is there climate change in your locality? a) Yes b) No c) I do not know
19. If your answer for Q.no.18 is 'yes' which local indicators do you use to evaluate the change of local climate in your locality?
a) Increased drought and flood frequency b) Dry up of water resources c) Prevalence of new crop and animal disease d) Decline of agriculture yields e) Decline of soil productivity f) Change in timing of rain g) other, specify
20. What was the trend of temperature for the past two decades to date?
a) Increased b) Decreased c) Fluctuating d) No change
21. Please specify the pattern of the change in rainfall you have noticed
a) Highly variable b) Less variable c) No change
22. Is start of growing seasons rainfall changed than normal?
a) Starting early than normal b) Starting late than normal c) No change
23. What was the amount of rainfall during main growing seasons?
a) Increased b) Decreased c) Fluctuating d) No change
24. Is duration of rainy season changed than normal?
a) Long rains than normal b) Short rains than normal c) No change
25. How do you describe the frequency of drought incidence compared to before twenty years?
a) Increased b) Decreased c) No change
26. Have you affected by flood so far? a) Yes b) No c) I do not know

27. If your answer for Q.no.26 is ‘yes, how do you describe its frequency after the last twenty years?
a) Increased b) Decreased c) No change

28. Dear respondent, please fill the following if you are experienced with it and rank in the order of their importance in your local area. (*Rank 1 for the most important, 2 to the next and so on).*

			Measurements		
No	**Indicators**	Rank	Duration	Intensity	Frequency
1	Too little rainfall				
2	Off-seasonal rainfall				
3	Heavy rainfall				
4	Early rain				
5	Delayed rain				
6	Wurch				
7	High temperature				
8	Strong winds				
9	If other, specify				

PART III: A. EFFECT OF CLIMATE CHANGE ON AGRICULTURE

29. Did you observed a climate change effect on crop production system? A/ yes, B/ no
30If your answer for Q.no 29 is yes how it affects? ______________________________________

31. Have you changed crop type due to climate change? A/ yes, B/ no
32. If your answer in Q.no 31 is yes which crop went out and which crop come in to the system?
----
33. Which agriculture system do you think, more susceptible to the effect of climate change?
a) crop farming b) livestock production c) I don’t know
34. If your answer for Q.no.33 is crop farming; what do you think as a reason? ....

B. **EFFECT OF CLIMATE CHANGE ON CROP PRODUCTION**

35. How do you describe crop diversity after twenty years?
36. Have you changed crop type since you started farming? a) Yes b) No c) I do not know
37. If you have changed, what is the reason for? a) To use drought resistant varieties b) To use improved seed varieties c) To use early maturing varieties d) other, specify
38. What was observed changes in crop disease over the last twenty years?
a) New diseases have emerged b) Increased spread of existing diseases c) Decreased in
Disease spread d) No significant change e) other, specify
39. If you have observed any change on disease of crop, what do you think the cause?
a) Change in rainfall pattern b) Change in temperature c) Wurch, frosts and ice

40. Which crop type and variety, do you think more resistant to climate extreme events?
41. Identify the following climate change related effects on crop in the last two decades

No	Climate change related effects	Rank
1	Crops are partially failing	
2	Crops are totally failing	
3	Production per hectare is decreasing	
4	Decrease of long cycle crops	
5	Increased problem of seasonal flooding	
6	Crop disease and weeds are increasing	
7	If others, specify	

42. How do you describe water availability after twenty years?
a) Increased b) Decreased c) No observable change
43. If your answer for Q.no.42 is decreasing, what are the factors for?
a) Flood b) Drought c) Use of irrigation d) If others
44. Describe if there were any water sources dried up totally in your locality, if there what the reason were for? ....
45. Which specific weather variable is changing? A/ temperature, B/ rainfall, C/ radiation intensity, D/ wind, E/ A&B
46. The level of climate change on crop yield is increasing or decreasing?
47. How much yield reduced and because of which specific variable?

PART IV. ADAPTATION STRATEGIES FOR CLIMATE CHANGE
48. Which of the following adaptation strategies you used to minimize the effects of climate change in crop farming?

No	Adaptation strategies for crops production	Put "✓" mark for your choice
1	Crop diversification	
2	Soil and water conservations	
3	Planting trees	
4	Small scale irrigation	
5	Changing planting date	
6	Using improved seeds	
7	Growing drought resistance crop verities	
8	No adaptation	

49. Have you ever got any technical support from the Government to implementing adaptation to climate change? a) Yes b) No
50. If yes to'49', what kind of technical support do you got to reduce the effects of climate Change and improve your production system? ……………………………………
51. If no. to'49', what kind of support would you want to gate from? ....

THANK YOU!

II. **Checklists for focus group discussions (FGDs)**

- Explain any form of climate change you have noticed in your locality?
- Describe the situation of flood, drought, high temperature, too little rainfall, and frost over the last twenty years. (frequency and effects it pose on agriculture)
- Which farming system, do you think more vulnerable to the adverse effects of climate change?
- What is your future plan in increasing crop productivity under changing climate?
- Which adaptation strategies have you used to reduce the effects of climate changes?
- What are the main challenges that hinder your adaptation strategies?
- What kind of support do you want to undertake adaptation strategies?

III. **Interview guides for key informants**

*Kebele*______________________________________

Name_______________________________________

Profession/position____________________________

- Is there any change in the state of the climate in your locality? Please explain trends of temperature and rainfall over the past three decades?
- Did you perceived changes in the local climate motivate changes in the farming practices? If Yes, Explain perceived changes in crop farming.
- Describe status of water availability for both human and livestock use. (previous and current water sources and availability)
- Describe status of crop yield over the twenty years (variety of crop species increased and decreased in number, quality and quantity of crop productivity), if you observed any changes, what do you think the reason?
- How do you adopt the effects of climate change on your crop production?
- What do you suggest to be done to reduce the effects of climate change further?

BIOGRAPHICAL SKETCH

The author was born on 24th July, 1992 G.C in Homacho-Chawa *kebele*, Aleta Wondo woreda, Sidama Region his Father Konte Beta and Mother Bekelech Yote. He attended his primary education at Wondo andegna dereja School. After completion of elementary school at Wondo andegna dereja he attended high school class at Wondo Secondary School from 2007-2009 G.C and Preparatory in Aleta Wondo Preparatory school from 2010-2011 G.C. After passing the Higher Education Entrance Certificate examination (HEECE), he joined Haramaya University in 2012 and graduated with a BSc degree in Environmental Science in 2014. Soon after graduation he was employed by Aleta Wondo Woreda Agriculture office at the position of food security and disaster risk management officer. He served for three years and joined the School of Graduate Studies at Hawassa University in October 2018 to pursue his MSc. study majoring in the field of Climate Change and Sustainable Agriculture.