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COLLEGE OF DEVELOPMENT STUDIES
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FARMERS' ADAPTATION STRATEGIES TO CLIMATE CHANGE ON AGRICULTURAL PRODUCTION: THE CASE OF NEGELLE ARSI WOREDA, WEST ARSI ZONE, OROMIA REGION

BY
KORICHO LETTA HAILE

A THESIS SUBMITTED TO CENTER FOR FOOD SECURITY STUDIES, COLLEGE OF DEVELOPMENT STUDIES, ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOOD SECURITY AND DEVELOPMENT STUDIES

OCTOBER 2020
ADDIS ABABA, ETHIOPIA

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Declaration

I, Koricho Letta, hereby declare that this thesis is my original research work and findings. It has not been submitted to any other University for any academic degree. Materials and information other than my own are duly acknowledged and a reference list has been attached. In presenting this thesis in partial fulfillment of the requirements for the degree of MSc in Food security and Development studies, I grant to Addis Ababa University the non-exclusive royalty free right to archive, reproduce, distribute, and display in any forms including electronic format, via any digital library mechanisms maintained by the University.

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Meskerem Teka (Advisor): Signature: ______________: date:_________________

Approval Sheet

As advisor, I certify that I have read and evaluated the thesis prepared by Koricho Letta entitled "*Farmers' Adaptation Strategies to Climate Change on Agricultural Production: the Case of Negelle Arsi Woreda, West Arsi Zone, Oromia, Ethiopia*" and recommend for open defense as fulfilling the requirement for the degree of Master of Science in Food Security and Development Studies.

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Advisors	**Signature**	**Date**

As members of the examining board of the thesis open defense, we certify that we have read and evaluated the thesis prepared by Koricho Letta "*Farmers' Adaptation Strategies to Climate Change in Agricultural Production: the case of Negelle Arsi Woreda, West Arsi Zone Oromia, Ethiopia*" and recommend that it is acceptable as a thesis required for the degree of Master of Science in Food Security and Development Studies.

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Abstract

Livelihoods of the rural communities depends on agricultural sector which is often affected by the variability and extremes of climate change. To capture the variation in Ethiopia's biophysical conditions (i.e., elevation, climate, terrain, soil type, vegetation, and fauna) the MoA has previously split the country into 32 Agro-Ecological Zones (AEZs). For assessment in this strategy, the AEZs have been clustered to create 14 Adaptation Planning Zones (APZs). This is in order to simplify the analysis while reflecting the diversity within Ethiopia's climate. The study area is one of the climate changes prone areas in the central rift valley of Ethiopia. Hence understanding of area specific and adaptation is crucial to develop and implement proper adaptation strategies that can reduce the adverse impact of climate change on crop and livestock sectors. This study investigated how the farming communities perceive climate change, its adverse impacts, adaptation mechanisms they practice and factors that hampers their decision to adapt appropriate strategies. Both primary and secondary data were used, and the primary data were collected through discussions, observation, and interviews. Moreover, annual temperature and precipitation data were obtained from the National Meteorological Agency (NMA) of Ethiopia for the period between 1983 and 2016. The study applied CV, SRA, a nonparametric Sen's slope estimator and Mann–Kendall's trend tests to detect the magnitude and statistical significance of climate variability. The Multinomial regression models with the help of software STATA version 13 were used to analyze the influence of the socioeconomic characteristics of sample households on the farmer's decision to choose climate change adaptation strategies. The result shows many of the farmers choose drought and disease resistant short season variety (75%), crop diversification (66%) and irrigation (47%) as adaptation strategies to the changing climate despite their actual adaptation practices in place. The result also indicated that crop failure, drought and shortages of water, pest and diseases, soil erosion and flooding are key climate change-related problems. To alter the negative impact of climate, farmers are mainly using drought resistant crops and livestock varieties, adjustment of planting dates, agroforestry and income sources diversification. The econometric model indicated that education, farmland, sex of household head, access to credit and market and extension services were the key factors determining farmers' adaptation practices in the study area. The study concludes that farmers' capacity to choose effective adaptation options depends on their affordability to buy farm inputs and get access to irrigation technologies. Thus, increasing their engagement on of farm activities that are less impacted by climate variability can be taken as best alternative way of adaptation mechanism. Segregation of detail adaptation strategies by subagroecologies is limitation of the study and it is recommended for further study.

Keywords: *Climate change, adaptation, strategies, variability, drought, resilience, diversification. Environment, food security.*

Table of Contents

List of Tables

List of Figures

Acronym

ADLI	Agricultural Development-Led Industrialization
AGP	Agricultural Growth Program
BoA	Bureau of Agriculture
CSA	Central Statistics Agency
DEM	Digital Elevation Model
EPA	Environment Protection Agency
FAO	Food and Agricultural Organization
FDRE	Federal Democratic Republic of Ethiopia
FEWSNet	Famine Early Warning System Network
FGD	Focus Group Discussion
FY	Fiscal Year
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
HRD	Humanitarian Requirement Document
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informant Interview
MDG	Millennium Development Goal
MK	Mann-Kendall
NGO	Non-Governmental Organization
MoFED	Ministry of Finance and Economic Development
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
NDRMC	National Disaster Risk Management Commission
NMA	National Metrological Agency
PSNP	Productive Safety Net Program
SDG	Sustainable Development Goals
SAM	Severely Acute Malnutrition
SRA	Standard Rainfall Anomaly
USAID	United States Agency for International Development
UNDP	United Nations Development Program
WMO	World Metrological Organization

CHAPTER ONE: INTRODUCTION

1.1. Background

Climate change or variability is the most pressing environmental challenge facing the world today (IAEA, 2015). The IPCC (2007) report showed that climate change is occurring in the form of temperature increases, changes in precipitation and sea-level rise, and the intensification of natural hazards, such as storms, floods, droughts, and landslides. Different reports further state that the average world temperature is expected to raise another 2.0°C to 7.0°C continuously from 2007 onwards. According to Porter et al., (2014), an average increase of 0.85°C in the global combined land and ocean surface temperatures was calculated for the period of 1880 to 2012. Increasing climatic variability may further complicate agricultural production and food security, and almost one-third of yield loss is related to climatic variability (Ray et al., 2015).

The perspective study of IFAD (2010) shows that developing countries are the most adversely affected by the negative effects of climate induced events because of their low level of adaptation. In addition, chronic poverty, lack of government funds and poor institutional interventions undermine coping and adaptive capacity to reduce food insecurity in these countries (Ziervogel and Ericksen 2010). Most areas of the African continent lack sufficient climate station data to draw conclusions about trends in annual rainfall, and poor climate change adaptation strategies (Ang et al., 2014). Accordingly, climate in the region has been experiencing unpredictable rainfall patterns, consequently, resulting to declining and uneven yield trends with significant effects on household (HH) food security. According to FAO (2006), agriculture contributes more than 30 percent to the Gross Domestic Product (GDP) in the different countries of sub-Saharan Africa (SSA) and occupies more than 70 percent of the active population. Accordingly, over 90 percent of the population in this region depends on rain-fed agriculture for food production.

In spite of mitigation and adaptation efforts implemented so far in different parts of African region, by different development partners in collaboration with the governments, human and natural systems have been unable to cope with the loss and damage linked to negative effects of climate change (UNFCC, 2013). In view of this, the recurrent humanitarian crises in many parts of Africa together with heightened climatic shocks resulting from climate change and increased geopolitical uncertainty are challenging and calls for an alternative perspective in recent years

(Frankenberger et al., 2012; Hoddinott, 2014). Accordingly, it has been suggested that "a focus on strengthening resilience can protect development gains and ensure people have the resources and capacities to better reduce, prevent, anticipate, absorb, and adapt to a range of shocks, stresses, risks and uncertainties" (Bahadur et al., 2015a, p. 2).

Therefore, resilience as a concept has been rapidly evolving and is now considered as a strategy, which applies to humanitarian and development approaches to resolve peoples' chronic vulnerability to recurrent shocks and stresses (Choularton, et al., 2015). Because of such climate variability and change, and the resulting shock incidences, Ethiopia is often labeled as highly vulnerable (World Bank, 2010; Conway & Schipper, 2011). It is a country, which highly suffers from risks associated with high rainfall variability (EPCC, 2015) and exposed to famine (Wassie & Fekadu, 2015). In terms of specific impacts, Ethiopia ranks 46th among countries of most at risk from climate change in 2019 (Eckstein, et al., 2019 p.29). On the other hand, a study by the World Bank (2010) projects that unless strong efforts to build resilience are put in place, climate change will cut Ethiopia's GDP growth up to 10% by 2045-between 0.5 and 2.5% each year (EPA, 2011). The impact of climate change and extremes are more pronounced in arid and semi-arid part of Ethiopia (IPCC, 2014). Estimates of the loss to the economy caused by current weather variability and related hazards have been presented. The largest impacts come from droughts with the cost to the economy being between 1%-4% of total GDP depending on the scale and duration of drought events (Ethiopia CRGE strategy, 2016).

Negelle Arsi *woreda* is among the most vulnerable part of Ethiopia. A study from Central Rift Valley of Ethiopia shows that climate change and variability is manifested through frequent droughts and floods, erratic rainfall and fluctuating mean temperature (Gizachew et al., 2014). The annual and seasonal rainfall variability for Negelle Arsi is between 50 and 80%. Average temperature has been increasing at a rate of 0.37 °C every ten years, and the maximum daily temperature has increased by a cumulative 1.5 °C since 1900 (Belay et al, 2013 cited in Belay et al., 2017). Hence, understanding the impact of climate change on crop and livestock production and farmers adaptation response is utmost important. Therefore, this study is intended to examine the impacts and adaptation responses of farming community in the agricultural sector in the face of changing climate in Negelle Arsi *Woreda*.

1.2. Statement of the Problem

Climate change is one of the greatest challenges of the 21st century that affect environmental, social, and economic aspect of human being (Chomitz et al., 2006). Disasters incidence by the phenomenon of climatic alteration have deep influence on agriculture Agossou et al., (2012). According to the IPCC (2014), it has been predicted that climate change will potentially affect all aspects of food security, including production of food, food accessibility and food usage and price stability if local temperature increases by 2°C or more above late 20th century levels.

Several studies have documented substantial evidence showing that climate is changing in Africa, including Ethiopia and will do so at an increasing rate in the future (Boko et al., 2007; Thomas, et al., 2007; Cooper et al., 2008; Conway & Schipper, 2011; Simane, et al., 2013; Eshetu et al., 2014). UNDP report stated that climate change generates various kinds of risks that would affect all sectors in Ethiopia (UNDP, 2011).

There is evidence that shows continued incidences of meteorological drought episodes resulting in human, crop and livestock losses, food insecurity and even famine to the Ethiopian population (e.g. EPCC, 2015; Savage, et al., 2015), particularly affecting the livelihoods of smallholder farmers (Amsalu &Alebachew, 2009; Alebachew & Amsalu, 2012; Bewket, et al., 2015; Savage et al., 2015). Specifically, with this changing climate, the country has experienced 47 major floods since 1900, which had killed close to 2000 people and affected 2.2 million (Deressa et al., 2010). Twelve extreme droughts were recorded between 1900 and 2010, which killed more than 400,000 people and affected over 54 million people Deressa et al., 2010). In terms of occurrence, many of the droughts and floods occurred since 1980 (World Bank, 2010). This is also expected to continue, as changes in temperature and perception are likely to increase the frequency of severe droughts and floods (Savage et al., 2015).

Various study evidences showed that climate variability in combination with human threats have negative impacts on water resources and biodiversity in Ethiopian Central Rift Valley (CRV). According to Jansen et al (2007) as the maximum daily temperature has increased by 1.5^{0}Cover thirty-seven years, the potential evapo-transpiration has increased by 3 to 4 %, and the evaporation from the lakes also increased by 40 million m3 per year, which increases its salinity. In another way water resources over-exploited for irrigation, floriculture industry, soda abstraction,

fish farming, domestic use and recreation has adverse impacts on lake water qualities, levels, and river discharges (Gadissa, 2016). According to Gadissa (2016), since 2002, on an average Lake Ziway size has decreased by 0.5 meter per year; discharges by Bulbula River has decreased from 200 million m3 per year into less than 50 million m3 in 2003, then it reduced inflow to Lake Abyata which has caused a reduction into less than 60% of its original size. In addition, severe environmental degradation, mainly deforestation, over-grazing, soil erosion, waste disposal and sediment loads are the main threats of CRV Lakes. The Abyata-Shalla National Park, which is well known for its unique ecological characteristics of consisting over 400 bird species, is gravely degraded due to human induced threats in combination with climate change impacts (Raventós, 2010 and NCAP, 2007).
According to Belay et al. (2017) there is increasing incidence of seasonal flooding, crop yield reduction, occurrence of pests and diseases and extended drought because of climate variability in the Rift Valley areas. In case of extreme drought, the farmers migrated to the highland *kebeles* for some time. According to East Shewa Zone of Oromia Region Socio Economic Profile (2004), changes in the distribution and amount of rainfall have affected the agricultural system in Negelle Arsi as it receives lower rainfall and faces more frequent drought. Similarly, there is critical water shortage for both human and livestock in the low land *kebeles* of Negelle Arsi as the community travel more than 5 hours round trip to fetch water (Habitat Ethiopia Assessment (HFHE), 2018). HFHE (2018) baseline survey report shows that only 57% of the community members are accessible to water and only 7% are getting adequate safe water at 30-minute walking distance as per the national standard. Therefore, the community is also vulnerable to different water borne disease and food insecurity.

Other similar studies have attempted to analyze the impact of climate change and factors affecting the choice of adaptation methods in crop, livestock, and mixed crop livestock production systems at national level (Simane, 2011; Haileab, 2018; Bishaw et al., 2013; Bewket et al., 2015; EPCC, 2015; Savage et al., 2015; Wassie & Fekadu, 2015; Simane et al., 2016). Although informative, these studies lacked detail consideration of context-specific agro-ecological system requirements to reduce the vulnerability of smallholder mixed crop-livestock agriculture system, especially in the Rift -Valley of Ethiopia, in which Negelle Arsi is situated. This, would in turn, limit informed decision making on adaptation options in the study area.

Therefore, this study has examined the critical problems faced by households due to climate variability with special focus on crop and livestock production, assessed and analyzed existing adaptation practices and suggested the best strategic options that can build resilience of vulnerable community living in the area.

1.3 Objectives of the Study

1.3.1. General objective

The overall objective of this study is to investigate the impact of climate change on agriculture and key adaptation strategies practiced by farmers in Negelle Arsi *Woreda*.

1.3.2. Specific objectives

Specifically, this study aims to

1. analyze trends in and variability of temperature and rainfall of the study area over the last 34 years
2. describe the impact of climate change on crop and livestock production in the study area
3. identify adaptation strategies practiced by farmers to reduce the effect of climate variability on agricultural production in the study area,
4. define effective adaptation options from the existing practices in the study area
5. identify the factors determining farmers' adaptation practices in the study area

1.4 Research questions

1. How can climate change affect agriculture and food insecurity in the study area?
2. What are the major barriers of adaptation to climate change in the study area?
3. What are the common adaptation practices used by farmers to curb the effect of climate variability and to achieve food security at the household level in the study area?
4. Which adaptation practices used by the farmers at farm level are more effective?

1.5 Significance of the Study

The study aims at providing information on the impact of climate change on agricultural production and adaptation practices by the farmers to improve their food security status at Negelle Arsi

Woreda. The study will also benefit researchers and policy makers to identify which adaptation strategies and practices would be more effective and efficient to curb the impact of climate change for similar agro ecologies at the country level. In addition, since the outcome of the research emphasizes both on autonomous and planned adaptations that can increase the food production capacity of the farmers and any development actors operating in the areas can use these. The skills and experiences gathered from the local community in adapting themselves to the ever-changing climate can also be used by researchers and indeed contribute to existing science of climate change adaptation of similar contexts. The lessons from farmers' understanding and practices are further used to conduct new research in building on existing knowledge bases.

1.6 Data Validity and Reliability

The concept of 'validity' was applied to the research process. Hence, correct procedures have been applied to find answers to the research questions with an unbiased manner and drawn each conclusion to the best of the researcher ability and without introducing his own vested interest.

The good approach to get valid and reliable data depends on sources of data from which data is obtained. Key informants are relatively intellect individuals who understand the situation and the community properly. The tools translated into the local language and enumerators have taken detail orientation and conducted pretest of the tool before the actual data was gathered from randomly selected households. In addition, primary data was triangulated with each other as well as the secondary data readily available for the study area.

1.7. Scope of the Study

This study is conducted in West Arsi Zone confined with only rural smallholder farming households of Negelle Arsi *woreda*, which covers a sample of 3 out of 34 *kebeles.* Hence, did not take into consideration the communities living in the urban/towns. The focus of this study is on assessing the impact of climate change on agricultural production and productivity and adaptation strategies used by farmers in the study area.

1.8. Limitation of the Study

Despite climate change affects a wide range of sectors and all the four pillars of food security: availability, accessibility, utilization and stability, this study focused on climate change impacts on agricultural production (food availability). There are enormous coping strategies practiced by the rural community and this study focused on the major and commonly practiced adaptation strategies that enable the farmers to withstand food crises during extreme variability. The study sampled one kebele from each agro ecology (3 in total) and this might not precisely represent the entire 34 kebeles of the *woreda*. The time of primary and secondary data collection to complete the research works in its planned time frame was delayed due to COVID-19 and associated government travels and meetings restriction. Rainfall and temperature data analyzed using the mereological data and it is not agroecological based evidence.

1.9. Organization of the Study

This thesis comprises of five chapters. The first chapter, Chapter one, presents the introduction part (consists of background, statement of the problem, objectives of the study, research questions, significance of the study, scope and limitation of the study, data validity and reliability, and ethical consideration). In Chapter 2, review of related literature (consists the concept, empirical review, conceptual framework, and policies & strategies) is presented. Chapter three described the study area, methods and materials (comprises the description of the study area, sampling techniques, sample size, techniques of data collection, techniques of data analysis, and types of data & sources). Chapter four presents the results and discussions; and finally in Chapter five, the conclusions and recommendations of the study are presented.

CHAPTER TWO: REVIEW OF RELATED LITERATURE

2.1. Concepts and definitions

Climate: is the "average weather," which is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years" (World Meteorological Organization (WMO), 2016).

Climate change: According to FAO (2008) and Mugula (2013), climate change refers to progressive changes in the global system that result from anthropogenic heating of the planet due to continuous increases of the emissions of greenhouse gases, and the loss of the vegetation cover and other carbon reservoirs. It is a gradual change in climate norms, particularly the temperature and changes in the frequency, scope and severity of climate and time extremes. This can also be explained as a persisting change on the average and variability of climate variables such as temperature, rainfall, humidity, and soil moisture (Krishna, 2011; Mugula, 2013).

Climate variability: refers to variations in the current state of the climate and is a natural modification of the climate and therefore independent of human activity. Some examples of climate variability include the amount of rainfall received from year to year; extended droughts, floods, and conditions that result from periodic El Niño and La Niña events (Dimon, 2008).

2.2. Adaptation to climate change and variability

According to Isa (1995), cited in Nure (2019), adaptation is defined as the whole adjustment made or self-made within natural and human systems as a curative or preventive response to current or future climate stimuli or to their effects in order to reduce harm or take advantage of it at the right time. According to Ramsey et al. (2008), adaptation is an adjustment in ecological, social, and economic systems in response to real or expected climate stimuli and to their effects or impacts. Accordingly, adaptation is defined as a change of procedures, practices and structures that aims at limiting or eliminating the potential damages or to take advantage of the opportunities created by variability and climate change.

Moreover, adaption to climate change is the process through which people reduce the adverse effects of climate on their health and wellbeing, and take advantage of the opportunities that their climatic environment provides (Burton, 1992, cited in Smit et al., 2000). In the IPCC definitions and the analysis of Smith et al. (2000), adaptation is a response to (potential) environmental stimuli that affect given entities, subjects, or systems. Adaptations are processes within entities and systems, or adjustments made by human systems.

Adaptation approaches specifically refer only to human individuals and collective actors whereas a stimulus is a change in biophysical (meteorological) variables associated with climate change. In a very precise meaning, this must be distinguished from weather events. Stimuli can refer to changed values of statistical parameters such as average intensity, frequency, or higher statistical momenta (e.g. variance). Actions must be \`actual´ but stimuli may be potential or actual (Eisenack and Stecker, 2011).

2.2.1. Livelihood adaptation options for climate variability and change

Identification of livelihood adaptation option based on the context helps to focus on the effective approach to reduce the impact of climate on the life of farmers by ascertaining the appropriate spontaneous or planned strategy packages.

> *An adaptation option development refers to identification, synthesis, evaluation, and prioritization of viable adaptation options for managing drought risks by employing criteria, prioritization of tools and stakeholder engagement. The purpose of this component is to synthesize all the adaptation practices that can direct adaptation action. This process generally includes four major generic tasks, as presented in the figure below. These are: (i) synthesis of local, introduced, and improved adaptation options (ii) identification and formulating adaptation options based on the constraints and opportunities (iii) selecting and prioritizing adaptation options and (iv) formulating an adaptation option menu. The steps match well within the overall adaptation policy framework proposed for the country (Asian Disaster Preparedness Center (ADPC), 2006). See Figure 2.1 below*

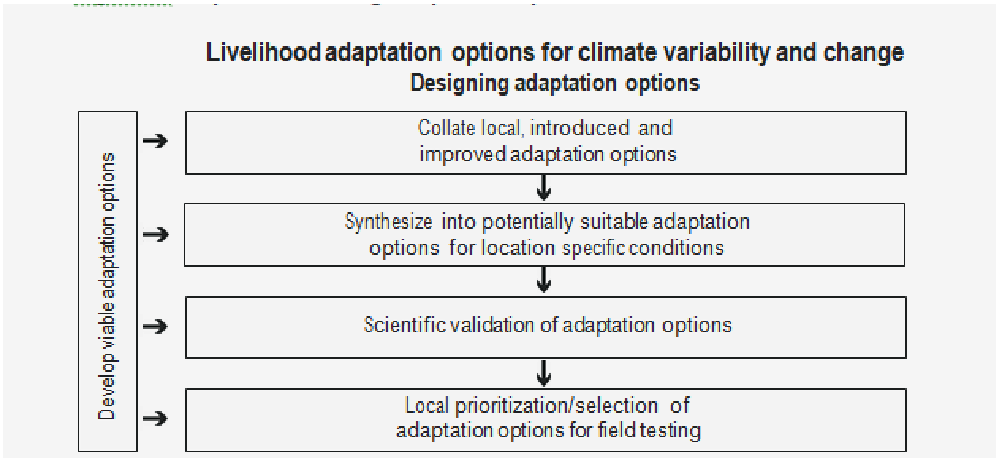

Figure 2.1 Designing of livelihood adaptation option

Source: FAO 2006

2.2.2 Types of adaptations to climate change

Adaptation can be classified either as planned adaptation or as autonomous adaptation. In the last 10 years or so, interest in adaptation has grown in developing countries for reasons to reduce vulnerability, increase resilience and to attain food security for ever growing population (IIEP-WP-2010-27).

a) Autonomous Adaptation

Adaptation that does not constitute a conscious response to climate stimuli, but is triggered by ecological changes in natural systems and by market or welfare changes in human systems is referred to as spontaneous or autonomous adaptation (IPCC, 2001)

b) Planned adaptation

According to Washington (2010), planned adaptation is the result of a deliberate policy decision based on awareness that conditions have changed or are about to change and the action is re-quired to return to maintain or to achieve a desired state. Based on timing, it is divided into two:

- Anticipatory adaptation- adaptation that takes place before impacts of climate changes is observed. It also referred to as proactive adaptation.

Reactive adaptation- is adaptation that takes place after the impact of climate change has been observed.

Frankhauser et al. (1999) discussed the linkage between autonomous and planned adaptation. According to him, planned adaptation is either being substitutes or complements. If autonomous adaptation increases the marginal benefit of planned adaptation and vice versa, they are considered complements. Planned and autonomous adaptations emerged as important subjects in the adaptation literature (Agrawal, 2018). On the one hand, in some literature emphasizes the value of planned adaptation intervention and questions the extent to which society can realistically relay autonomous adaptation process alone. Especially as more intense climate change induced problem can be expected to occur in the future (Estering et al., 2007 cited in Agrawal, 2018), there is still a debate between the two approaches. Some analyses claim that autonomous adaptation is inefficient and suggest focusing on planned adaptation instead (Eisenach, 2009 as cited by Agrawal, 2018). The vulnerable people have engaged in autonomous adaptations and such practices are often uncoordinated and aided by national development agencies or by international development organizations (Christoplos et al., 2009 p 3).

2.3. Impacts of climate change and variability on food security

Climate change undermines crop production; resulting to large risks on food insecurity globally (IPCC, 2014). According to Howden and White (2009), climate change and climate variability compel limitations to crop growth and it affects the choice of crop species and cultivars including farm management decisions. Livestock production will also be negatively impacted by climatic change (due to diseases, water availability, etc.); especially in arid and semiarid regions (Table 2.1). In addition, climate change will affect the nutritional content of livestock products, which are one of the suppliers of global calories, proteins, and essential micronutrients (Rojas-Downing et al., 2017). Agricultural adaptation to climate change is a complex, multidimensional, and multi-scale process that takes on several forms (Bryant et al., 2000). Bryant et al. (2000) identify four main components of adaptation: (1) the characteristics of the stress, (2) the characteristics of the system, including the cultural, economic, political, institutional and biophysical environment, (3) multiple scales, and (4) adaptive responses.

The first component, characteristics of the stress, refers to the stimulus to which actors and systems respond. These include climate signals (climate change and variability) as well as other drivers such as economic conditions, population growth, and government policies. Some argue that adaptation to short-term climate variability may facilitate adaptation to long-term climate changes (Burton, 1997). However, some adaptations taken in response to short-term climate variability, which could be classified as coping responses, may not be well suited for or could increase vulnerability to long-term climate change (Ziervogel et al., 2008). Such ‘‘mal-adaptations’’ may serve short-term goals but come with future costs to society (Smithers and Smit, 1997). Thus, there is the need to anticipate long-term changes and make the appropriate adjustments in addition to coping with current climate conditions. This strategic adaptation should involve government intervention to promote and guide adaptation of the agricultural system (Smithers and Smit, 1997).

The second component, system characteristics, of adaptation refers the conditions of the agricultural system including its sensitivity, resilience, vulnerability, adaptive capacity, and other factors influencing its response to stressors (Smithers and Smit, 1997; Bryant et al., 2000). Other factors include the socioeconomic, cultural, political, and institutional characteristics, which can either facilitate or hinder the adaptation process. The third component refers to the multiple scales at which adaptation occurs. Climate impacts, adaptive capacity, and adaptation responses differ across multiple scales from the plot and farm levels to the country and international levels. Therefore, analyzing the adaptive capacity of a system and appropriate adaptation responses should consider the scale of analysis (Vincent, 2007).

The nature of the response depends the fourth component, the adaptive responses. It refers to the degree of exposure to and nature of the stress, the properties of the system exposed to stress, and the scale and magnitude of the event (Smithers and Smit, 1997). Burton (1997) argues that willingness to adapt to climate change and variability depends on experience, time horizon, and the risk tolerance of individual decision-makers.

Table 2.1 climate change related impact on agriculture (2015)

No	Climate stresses	Key impacts (stylized)
1	High mean temperature	Shifting agro-ecological zones
2	Days with a max temperature above 35˚C	Heat stress for some crops
3	Days with a max temperature above 40˚C	Leads to heat stress on people and livestock
4	Lower mean rainfall	Shifts in agro-ecological zones; plus, drought impacts
5	Higher mean rainfall	Landslides, damage to crops and livestock
6	Large scale floods	Damage to crops, livestock, infrastructure and people
7	Flash floods	Local damages to crops, livestock, infrastructure and people
8	High 1-hour rainfall intensity	Soil erosion and landslides, some local damages to crops
9	Heavy hail events	Crop damage at certain times in the growing season
10	Rainfall distribution (variability) within season	Significant impact on some crops
11	10-day dry spells	Significant impact on some crops
12	Seasonal droughts	Significant impact on most crops
13	Consecutive seasonal droughts	Significant impact on livelihoods and economic growth
14	Later onset of rainfall season	Shortens growing period - impacts on crops, fodder
15	Earlier end date of the rainfall season	Shortens growing period - impacts on crops, fodder
16	Decreased predictability of the rainfall season	Less reliable forecasts affect some enterprises
17	Increased uncertainty in rainfall distributions	Increases risk, important for some enterprises
18	Increases in cloudiness and humidity	Reduces radiation, increases thermal stress for people

Source: 2015-08 Sectoral climate change strategy for Ethiopia

2.4. Empirical Literature Reviews

Empirical evidence suggests that the most common farm-level adaptation strategies to climate change are changing crop varieties, irrigation, planting trees, crop and livestock diversification, soil conservation, early and late planting, increasing plant spacing, using clay soil, and adjusting the level and timing of fertilizer application (Kurukulasuriya and Mendelsohn, 2008a, Molua, 2009, Nhemachena and Hassan, 2007). FAO (2008) stresses the importance of addressing impacts and responses across sectors and scales and of establishing institutional mechanisms for scaling-up adaptation measures.

Analysis by Ray (2019) showed that climate change has already affected crop yields around the world. There were variations between locations and among crops, but when all these different results were totaled, it was found global rice yields reduced by 0.3% and wheat yields by 0.9% on average each year. In some Corn Belt states, such as Indiana and Illinois, climate change is shaving up to 8% off of annual corn yields.

Ethiopia is highly experiencing the effects of climate change and the direct effects such as an increase in average temperature or a change in rainfall patterns (FDRE 2011). Over the last decades, the temperature in Ethiopia increased at about 0.2°c per decade. The increase in minimum temperatures is more pronounced with roughly 0.4°c per decade (Marius Keller, 2006). According to ACCRA (2011), the mean annual temperature in Ethiopia has increased by between 0.5 and 1.3 ºc. On the other hand, as shown in the projection data, Ethiopia's mean temperature will be 3.5 ºc in 2100 (UNDP, 2012). Consequently, the tropical and seasonally dry regions is likely to have negative impacts, particularly for cereal crops. Warming of more than 3ºC is expected to have negative effects on production in all regions (IPCC, 2007). However highest yields in C3 crops are obtained around a mean daily temperature of 15 ºc and in C4 crops around 30 ºc (Sinha S., et [1]al. 2006). Whereas the temperature optima for vegetative growth and the reproductive

[1] *C3, C4 and CAM are the three different processes that plants use to fix carbon during the process of* photosynthesis. *Fixing carbon is the way plants remove the carbon from atmospheric carbon dioxide and turn it into organic molecules like carbohydrates. The C3 pathway gets its name from the first molecule produced in the cycle (a 3-carbon molecule) called 3-phosphoglyceric acid. The carbon fixation pathways used by C4 and CAM plants have added steps to help concentrate and reduce the loss of carbon during the process. Some common C3 plant species are spinach, peanuts, cotton, wheat, rice, barley and most trees and grasses.*

phases are often different although an increase of temperature beyond a mean of 22ºC causes sterility in rice resulting in reduced grain yield, though it has no effect on photosynthesis. In wheat, an increase in mean temperature above 16 ºC results in a decrease in grain weight and a poor yield. A higher temperature significantly reduces tillering, which is essential to building shoot population (Sinha S. et al., 2006).

Moreover, livestock production is likely to be adversely affected by climate change, competition for land and water, and food security at a time when it is most needed (Thornton, 2010). A study conducted in Yabelo, Borana Zone in Southern Ethiopia indicated that households have experienced a severe reduction in their assets, with an average reduction of 80% in livestock holdings from their peak holdings over the past ten years mainly by climate change (Stark et al., 2011). Additional study indicated that the decline in the number of livestock species namely cattle, goats, sheep and donkey kept by pastoralists of Moyale and Dillo areas was remarkable in which most of the animals were reported to have died during severe droughts, which occurred in 2005 and 2008 (Zelalem et al., 2009).

2.5 Conceptual framework

Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels (FAO, 2008). In the conceptual framework presented in Figure 2.2, it is indicated that climate variability is often resulted in disease outbreak, complete crops failure, poor seed/grain quality and yields.

In addition, the conceptual framework clearly indicates how climate variability commonly understood as independent variables; erratic rainfall, prolonged drought and rise in temperature negatively affect agricultural production. These are climate factors, which resulted in various adaptation practices, that the farmers use to reduce their impacts contribute to production and yield of crop and livestock productions (dependent variables) to achieve food security. The adaptation capacity of the farmers is mainly influenced by explanatory variables like demographic, technological, institutional, and infrastructural development of the study area.

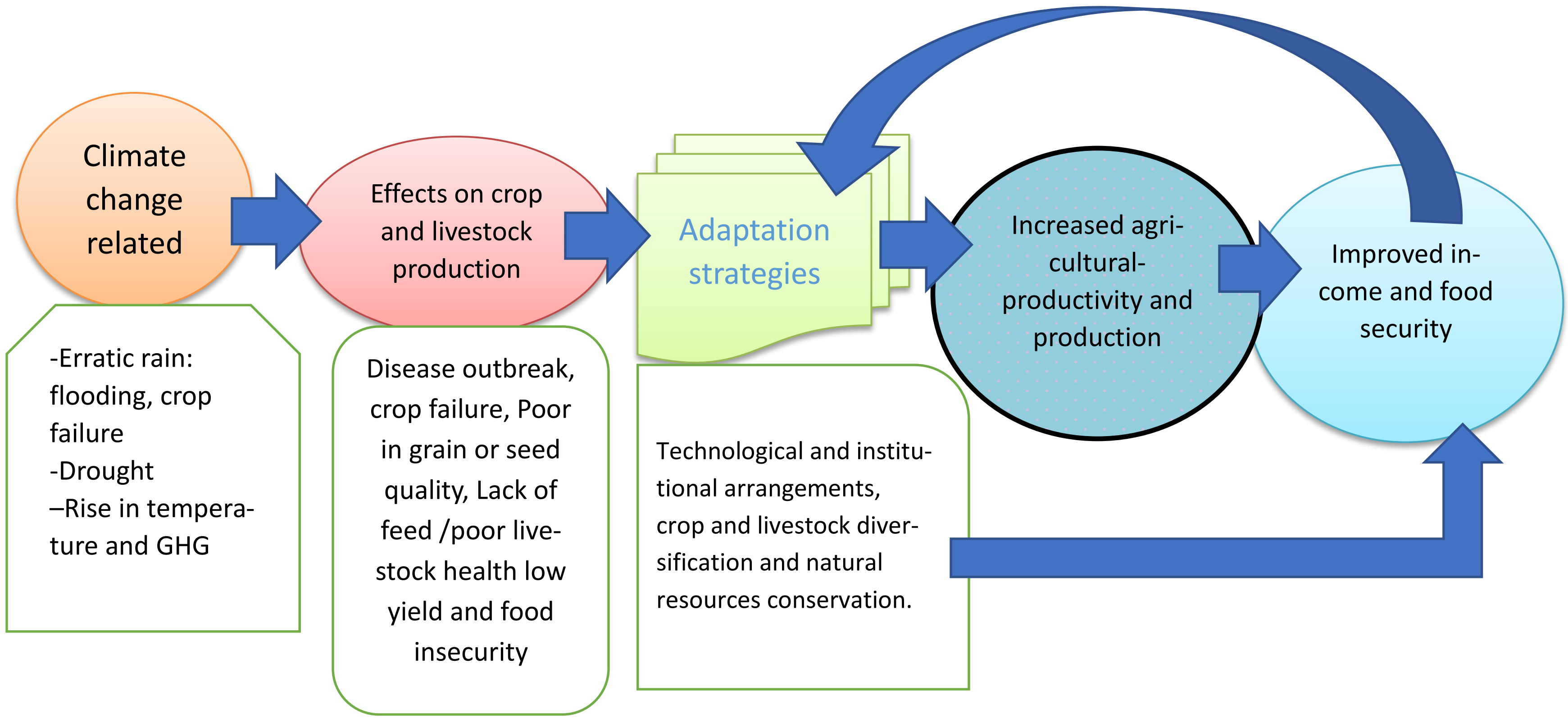

Fig 2.2 conceptual framework

Source: own constructed

CHAPTER THREE: DESCRIPTION OF THE STUDY AREA AND RESEARCH METHODS

3.1. Description of the Study Area

The research area is located in West Arsi Zone of Oromia Region, in Negelle Arsi *woreda* (Figure 3.1) where the majority (89%) of the population settled in rural area. The woreda is bordered with East Shoa Zone in the Northeast direction, with Shashemene *Woreda* in the South direction and with Shalla Woreda in the Southwest direction. Negelle Arsi Woreda capital, Negelle Town is located at 250 km South of the national capital city of Ethiopia, Addis Ababa. Geographically, it is located between 7°17′N and 7°66′N, and between 38°43′E and 38°81′E.

The total population of the Woreda is 246,110 of which 125,516 are female and 120,594 are male (Zonal Health Office report 2017/18). According to the information from the district administration office, Negelle Arsi has a total of 34 rural kebeles out of which four are small rural towns. The topography of the district ranges from mountainous to rugged terrain and has low land, mid and highland agro-ecological characteristics (Table 3.1). The land is slightly undulating especially in the highlands and almost flat in the lowlands. Some parts of the highlands in the *Woreda* are covered by natural forest. There are also bushy vegetation and shrub in the mid altitude areas (Negelle Arsi Agriculture office report, 2017). . There are three rift-valley lakes in the Woreda namely, Langano, Shalla and Abijata. Even though, the district is rich in rift valley lakes, both human and livestock do not utilize most of them for consumption. Recently, Lake Abiyata is drying rapidly because of climate change and low precipitation and environmental degradation in the area.

Agro Eco	**# of Kebeles**	**% total**
Highland	12	35%
Midland	10	29%
Lowoland	12	35%
total	34	100%

The source of income for most of the community living in rural areas is farming mainly crop and livestock, which is usually affected by drought. Maize, wheat, food barley, teff, haricot bean, potato and other vegetable and fruits are the major crops grown in the study woreda (Negelle Agriculture office report, 2011). Maize is one of the major food crops grown in terms of coverage of cultivated crops affected by climate change due to low rainfall variability and incidence of diseases like American Ball Worm (ABW) in the midland and lowland areas resulted in low yield and quality. On the other hand, Irish potato is highly affected by bacterial wilt in mid and highland agro-ecology of the study areas both during the short and summer production seasons. Livestock disease, low coverage of grazing lands and feed shortages are key constraints of livestock sector.

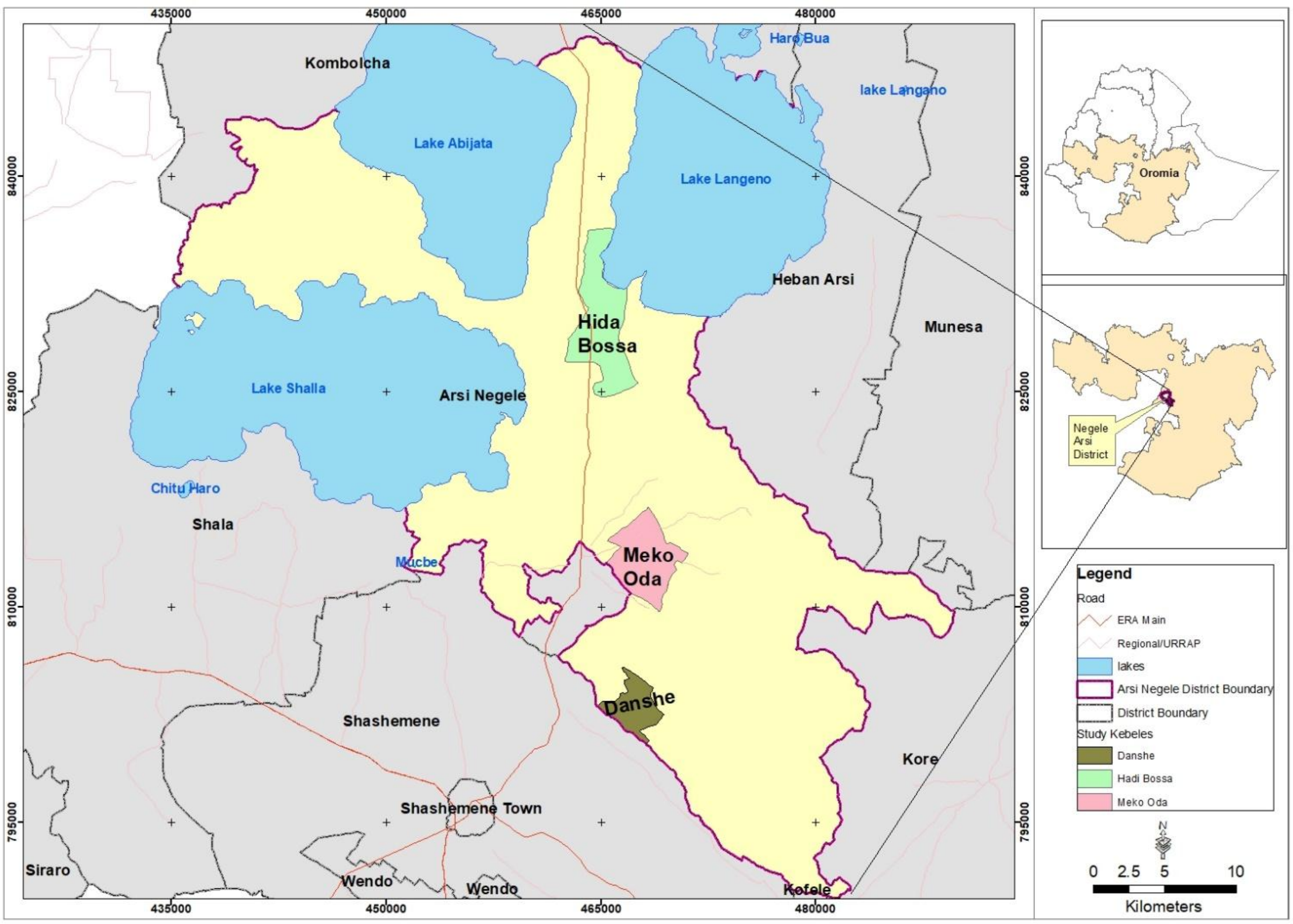

Figure 3.1: Map of the study area
Source: Own constructed

Land use and land cover: In the period 1986-2016, agriculture and settlement areas have increased by 250% and 618%, respectively in the Woreda whereas, forests and woodlands have decreased by 72% and 84%, correspondingly (Mekonnen et al, 2018). The results show that vegetation dynamics vary both spatially and temporally against precipitation and temperature due to climate variability.

Climate: the temperature of the area ranges between 10 and 25 °C, while annual rainfall varies between 500 and 1200 mm. The area has four distinct seasons including the dry season (December to February), the short rainy season (March to May), the main rainy season (June to August), and the autumn season (September to November) (Socioeconomic Profile of East Shewa Zone, 2004 as cited by Belay et al., 2017). Annual mean temperature of the District showed increasing and the total annual rainfall showed variation over the years from 1983-2014 with the peak in 2004 (1,486.5 mm) and sharp drop in 2013 (206 mm) (Zegeye, 2018).

The trends of climate change and variability in the study area showed gradual change. Erratic rainfall, frequent rain delay, heavy and un-seasonal rainfall, drought, and seasonal variations are indicators of climate change. The pattern of temperature, rainfall, and high wind caused the reduction of agricultural production and productivity, shortage of water, drying of shrubs and other vegetation, which affect the livelihood of the community.

3.2 Research methods

3.2.1. Research design and approach

The study is based on a retrospective cross-sectional study design that followed a qualitative and quantitative mixed approach. The retrospective cross-sectional design was appropriate for the study as the previous 34 years meteorological data was used to investigate how climatic factors were changing over time and what impacts were observed on agricultural production as per information from the farmers. Both quantitative and qualitative data were used for this study to triangulate the reliability of information from different sources. Quantitative data were collected through household surveys. The qualitative data were directly collected through focus group discussions, key informant interviews and field observations.

3.2.2. Data types and sources

Both primary and secondary data were collected from different sources of information. Primary data were collected through a household surveys, key informant interviews and focus group discussions. Household surveys were conducted with farmers living in three different agro-climatic areas in the *woreda*. The sample households were asked how climate variability affected their livelihood bases; natural resources, cropping and livestock sectors' production and productivity.

Women and men headed with different levels of education and wealth were included in the interview to compare whether climate change had affected them differently or not. In addition, data related to perception and experiences of the trend of rainfall and temperature, impact of climate change on crop and livestock production, adaptation options and actual adaptation implemented were also collected through surveys. Furthermore, data related to factors affecting farmers adaptation or barriers to adaptations, and the temporary coping mechanism they are using in responding to extreme events were collected through key informant interviews and focus group discussions. Perceived trends in rainfall and temperature was triangulated with meteorological data analyses.

3.2.3. Sampling and sample size determination

The study applied multistage (three stage) sampling technique. At the first stage, Arsi Negelle *Woreda* was purposely selected since it was the researcher's development project intervention area with resilience building WASH project. In the second stage, Kebeles in the woreda were stratified based on their agro-ecological zones (high land, midland and lowland), and three representative sample *kebeles* from the total of 34 rural *kebeles* were selected. This is due to the fact that farmers residing in different agro-ecology may face different or similar underlying causes of vulnerability to climate change in achieving food security for their households. Besides, this approach helped to confirm representation stratum of the total population and results in more reliable and detailed information. In the third stage, sample households from each stratum were selected using systematic random sampling from the list of households living in the study *kebeles* and village. The sample size for the households' survey was determined using the rule $N \geq 50 + 8m$ (Samuel,1991) in order to assure that the econometric model could be estimated with sufficient degrees of freedom, where N = sample size, and m = number of explanatory variables. Consequently, a total of 131 sample households were selected and interviewed: 44 from Danshe (high altitude Kebele), 42 from M/Oda (mid-altitude Kebele), and 45 from Hadha Bosso (low altitude kebele). The number of sampled households depend on the proportion of total households in the sample kebeles of the study *woreda*.

Table 3.2: Sample study kebeles

Kebele name (and agro-ecology)	Total number of households	Number of sampled household heads	Male household heads (%)	Female household Heads (%)
Danshe (Highland)	500	44	89	11
M/Oda (Midland)	530	42	79	21
Hadha Bosso (Lowland)	570	45	82	18
Total households	1600	131		

3.2.4. Data collection instruments

Household surveys, Focus Group Discussions (FGDs), Key Informant Interviews (KIIs) and field observations were used to collect the primary data whereas surveys, reports and plans of the government sector offices and humanitarian non-governmental development organizations were used as the secondary data collection.

a) Household Surveys

The survey was administered with 131 sample farming households by using a structured and semi structured questionnaires after obtaining the consent of the respondents as stipulated in a research ethics. Hence, data related to demography, socioeconomic, biophysical, farming practices and productivity were collected from the primary sources. Scientific principles and guidelines during questionnaire designing, data collection, data filling, encoding, data entry and processing were applied to maintain the quality of data. The questionnaire was completed by direct interviewing of the heads of farm households by enumerators. Enumerators were provided with intensive orientations on data collection procedures and ethics. Pilot study was also undertaken for pre-testing the questionnaire to determine the time needed to complete the questionnaire per household. The questionnaires were edited in the light of the results of the pilot study before actual data gathering was started. Computer-based data cleaning carried to check for the completeness, consistency and accuracy of data and to identify errors that occurred during data collection or coding process.

b) Key Informant Interviews (KIIs)

Interviews were organized with knowledgeable people from the community, including the Development Agents (DAs), *Woreda* experts of agriculture and rural development, Kebele leaders, extension workers and NGOs operating in the areas. Selected individuals are familiar with the agro-ecological conditions of the district and had access to updated information on weather, climate change impact, adaptation strategies and constraints. In-depth interviews was focused on organizing formal interview with the aim of facilitating open interface between the key informant and the researcher through inviting key figures in the respective institutions relevant for the issue under discussion to participate in open dialogue forum. The KIIs was done face-to-face.

c) **Focus Group Discussions (FGDs)**

Different segments of the community members were selected for FGD in the sample *kebeles* from women, men and youth and the impact of climate on agricultural production, existing coping and adaptive strategies were thoroughly discussed. They were selected using purposive sampling method from different villages or *gotts* of the sample *kebeles* based on their knowledge and experience of local agricultural activities of their community in the study *woreda*. Hence, nine FGDs comprising 5–8 individuals per group, were conducted with different age and sex groups in the sampled kebeles. During the discussion, information on climate change parameters in the area, the resultant impact, farmers' response, and adaptation practices were collected. The researcher moderated the discussions using a checklist. Group discussants were respectfully requested for their consent before starting the discussion and praised for their time and the information they provided in the end of the discussion. Ethical consideration was earnestly considered to ensure the protection, integrity, namelessness, and other human elements of the informants.

d) **Field Observations (Transect Walk)**

The researcher has conducted a transect walk in agro-ecological scenario of the study area and observed biophysical and socio-economic condition at the household as well as the farmland levels. These include Settlement patterns, vegetation grown and trends of deforestations, topography and lands, which are exposed to soil erosion and sliding. Unless continuous efforts of integrated biological and physical conservation measures are taken, the land productivity and carrying capacity will be questionable especially in the lowland and midland *kebeles*.

e) Secondary Data Sources

Rigorous desk review of published and unpublished literatures such as books, journals, articles, reports and e-resources were reviewed and augmented the primary data. Government documents from regional and federal sectors, UN agency and NGOs, Central Statistical Agency (CSA), National Metrological Agency (NMA) and Environmental Protection Agency were also reviewed and considered in the results and discussion as well.

3.2.5. Method of Data Analyses

A. Descriptive analyses

Demographic and socioeconomic data of study area were summarized and presented using descriptive statistics such as frequency, percentage, graphs, figures, and tables. These tests mainly employed to know whether the difference is statistically significant or not for quantitative household data. For the analysis, both Microsoft Excel and STATA version 13 were used.

B. Temperature and rainfall analysis

Different techniques have been employed for the analysis of rainfall and temperature, largely fall into variability and trend analysis. Annual and seasonal rainfall variability has been computed using standard deviation, coefficient of variation (CV) and Standardized Precipitation Anomaly.

Likewise, annual and seasonal temperature variability has been computed using CV. It is calculated to evaluate the variability of the rainfall and temperature. A higher value of CV is the indicator of larger variability, and vice versa. CV can be calculated as:

$$\mathrm{CV} = \frac{\sigma}{\mu} * 100$$

Where CV is the coefficient of variation; σ is standard deviation and μ is the mean precipitation. According to Hare (2003) and NMSA (1996), CV is used to classify the degree of variability of rainfall events as less than 20 is less variable, CV between 20 and 30 is moderately variable, and CV greater than 30 is highly variable. Standard Rainfall Anomaly (SRA) was calculated as:

$$\mathrm{SRA} = \mathrm{Pt} - \mathrm{Pm}/\sigma$$

Where, Pt is annual (rainfall) in year t, Pm is long-term mean annual (rainfall) over the period of observation and σ is standard deviation of rainfall.

Moreover, the study employed Agnew and Chappell's (1999) drought severity assessment method. This method provides a more elaborate classification of drought magnitudes. The model differentiated drought severity into four scales: extreme drought (SRA < -1.65), severe drought (-1.28 > S > -1.65), moderate drought (-0.84 > S > -1.28), mild drought (0.0 > S > -0.84), normal (0.84 > SRA > 0.0), moderately wet (1.28 > SRA > 0.84), very wet (1.65 > SRA > 1.28) and extremely wet (SRA > 1.65).

Furthermore, Mann-Kendall (MK) was used to detect the trend of rainfall and temperature with Sen's slope estimator (test Pettitt's test was used to test the degree of homogeneity of the data). Trend analysis has been carried out on annual bases, as well as for *Belg* and *Kiremt* seasons. The Mann-Kendall test as described by Mann (1945), Kendall (1975) and Yue et al. (2002) was used to detect trends. The significance level of the slope was estimated using Sen's method, which computes both the slope (the linear rate of change) and intercept. The magnitude of the trend is predicted by Theil (1950) and Sen (1968) slope estimator methods. A positive value of β indicates an increasing trend while a negative value of β indicates a decreasing trend.

C. **Econometric analyses**

Farmers' adaptation practices to climate change was analyzed using a multi-nominal logit (MNL) model. The approach was given analyses to the farmers' strategies regarding crop- and livestock-based adaptation and what factors restraints farmers to be food insecure in a sustainable manner. Households were associated with their most preferred option from a given set of adaptation strategies to meet their food security. Other alternative of adaptations was also collected not to underemphasizing the known importance to smallholder farmers of using multiple adaptation strategies. Hence, the study analyzed a high level of specification of the relations between adaptation strategies and underlying socioeconomic variables. The model used to interpret main socio-economic factors affecting adaptation practices against climate variability and its implication to food security in the study area. Hence, the parameter estimates of the MNL model were used to provide the direction of the effect of the independent variables on the dependent (response) variable. The use of the MNL model specification was found to be appropriate, and model has been used previously by different studies to estimate the determinants of climate change adaptation options by smallholder farmers (Belay et al., 2017, Deressa et al., 2009, Nhemachena and Hassan, 2008). Therefore, the multinomial logit model is appropriate to the model of climate change adaptation practice of smallholder farmers in this study. Hence, following Greene (2003), the Multinomial logit model for the adaptation choice was computed.

Description of variables

Dependent Variable of the model: The dependent variable for multinomial logit analysis were different climate change adaptation strategies with multiples of options at least one or two employed by the study area farmers.

Independent variables: Based on literature review and researcher's personal experience, households' demographic, socioeconomic and institutional factors which were expected to affect adaptation strategies and practices were presented with their operationalization.

Sex of the household head (SEX): It is represented with male coded as 1, and 0 if otherwise. Therefore, it is a dummy variable and expected that sex of the household head may have positive or negative relation to climate change adaptation in agricultural production. Deressa *et al.* (2008) showed that male headed households could be more likely to have access to technologies and climate change information than female-headed households.

Age of the household head (AGE): Age is a continuous variable measured in years. It is assumed that there is a negative relation between age of the household head and climate change adaptation. Older age household heads could be less likely to implement climate change adaptation strategies (Muzamhindo et al. 2015; Berhe et al., 2017).

Education (EDU): Education helps to increase farmer's ability to obtain, understand, process, information relevant to the climate change adaption strategies. Education was thus expected to increase the probability of adapting to climate variability.

Farm size (FARMSZ): refers to arable land and it is a continuous variable measured in hectares. Large land sizes allow farmers to diversify their crop and livestock options and help spread the risks of loss associated with changes in climate (Farid et al., 2015).

Farming system (FARMSY): represents household engaged in crop, livestock, or both (mixed) farming or off farm activities. It is an increasingly important livelihood strategy in rural households and a categorical variable which indicate the number of households engaged in crop production, livestock rearing, and mixed farming. Practicing multiple farming systems related to better adaptation practices of households to climate change.

Access to agricultural credit (ACESSCRDT): the accessibility of a household to credit services increase the probability of adapting CC strategies and practices. Access to credit is taken as a dummy variable; if the respondent has access to credit, they will be coded with a numeric value 1, and 0 if otherwise they could not get access to the service.

Access to extension service (EXTEN): this is a dummy variable which depends on the frequency of contacts by extension agent. Such services are an essential source of information and technical backup for improvement of agriculture production and productivity as well as adaptation practices to climate change. It also allows farmers to get understanding and access to agricultural technology to leverage production and productivity. Therefore, it was hypothesized that there is a positive relationship between access of credit and adaptation practices to climate variability.

Table 3.3. Summary of description of study variables

Variable	Descriptions	Variable type	Measurement	Expecting sign
Sex	Sex of Household head	Dummy	1 if Male, 0 if Female	+ve or _ve
Age	Age of household head	Continues	Years	+ve or -ve
HHSZ	Total number of family members in the household	Continuous	Adult equivalent	+ve or -ve
Edu	Educational background off hh head	Dummy	0 if Illiterate or 1 otherwise	+ve or -ve
Farm size	Farmland size (hectare)	Continuous	Hectare	+ve or -ve
Farm income	Average annual income of household in etb	Continuous	birr	+ve or -ve
Market access	Households access to market	Dummy	1 if Yes, 0 if Otherwise	+ve or -ve
Credit Access	Households access to credit services	Dummy	1 if yes, 0 otherwise	+ve or -ve
Extension services	Households' access to extension services	Dummy	1 if yes, 0 other wise	+ve or _ve

CHAPTER FOUR: RESULTS AND DISCUSSIONS

This chapter deals with the analysis of the survey data and interpretation of the results of study, and it is divided into six sub-sections. The first sub-section presents the socio-economic and demographic characteristics of respondents. The second sub-section presents the trends in and variability of temperature and rainfall over the last 34 years. The third sub-section describes farmers' perception on weather and climate factors. The fourth sub-section identifies the adaptation strategies practiced by farmers. The fifth subsection describes the effective adaptation options from the existing practices practiced by farmers in the study area, and finally section six identifies the factors determining farmers adaptation practices.

4.1. Socioeconomic and demographic characteristics of respondents

Understanding the demographic and socioeconomic characteristics of respondents (farming community) plays a significant role to draw a conclusion on how they perceive and respond to the changing climate, and how it affects their day to day activities. The empirical data at local level like this study helps to evaluate the difference between the literate and the illiterate, male-headed households and female headed households, old and young in perceiving the indicators of climate variability and its impact on different sector like livestock and crop production sector. Figure 4.1 presents the distribution of the study households by sex across the three agro-ecological zone. About 83% (109) respondents and 17% (22) of respondents were male-headed and female-headed households respectively. Agro ecologically, Midland (7%), lowland (6%) and highland (4%) women headed household have taken part in the survey. In addition, 30%, 28% and 25% of male headed households from highland, lowland and midland participated in the survey, respectively.

The summary of some demographic and socio-economic data for the surveyed households are presented in Table 4.1. Regarding the age of the study households, about 51% of the respondents' age fall between 20 and 40, 36% falls between 41 and 60 and near to 13 % above 60 years with an average range of 47 years. About 87% of farmers are within the active working-age group and have relatively long years of farming experience to notice environmental changes. 93% of the respondents are married and the proportion of widows, single and divorced are 3.82, 2.29 and 0.76, respectively.

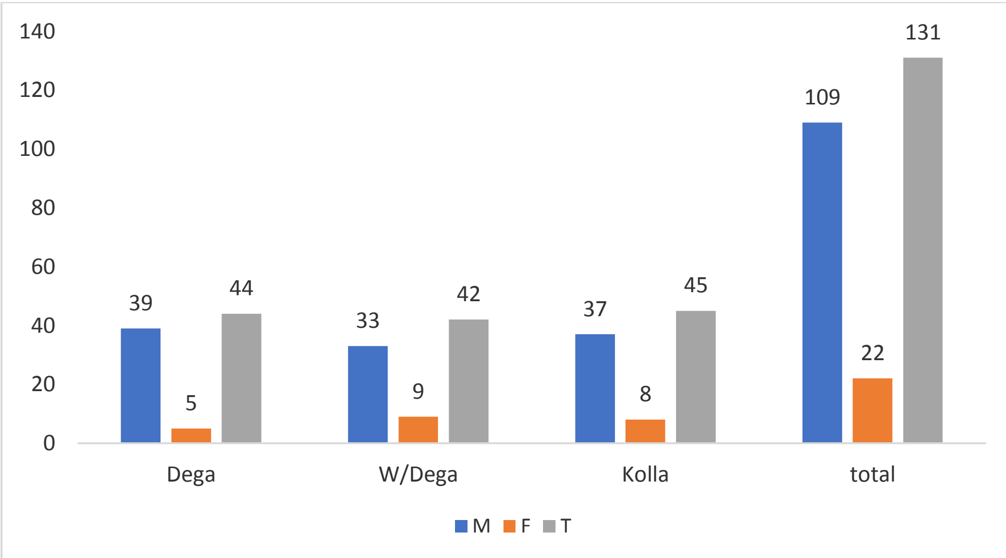

Figure 4.1: Study area by AEZ and sex
Source: (Researcher Construction)

As shown in Table 4.1, about 46% of respondents were illiterate who have not attended any formal education whereas 54% of them attend formal and informal education which is literate. In the meantime, these have implications on the perception of climate change, on the adoption of coping and adaptation strategies to climate variability and change. This is due to getting better education (higher level of education) is more likely to provide a better understanding of climate change impacts and the strategies that should be taken to mitigate them. The average family size of the surveyed household was 7.2 which is greater than the national average (5) with minimum of 2 and 13 members, respectively. Large family size of the household has a positive impact on farmer's decision to choose adaptation options by involving on varies adaptation practices/options.

In addition, the result shows that the average land holding size was 1.8 hectare (Table 4.1). The amount of farmer's land size has a positive impact on climate change adaptation option. As farm size of the household increase, it gives an opportunity to implement various adaptation options like crop diversification, agroforestry and mixed farming system. Average per person per annual income of surveyed households were 40, 709.2 ETB. The landholding size and per-person annual income reflects the living standards of a given society, which is sign of impoverishment (Ayal et al, 2017).

Table 4.1 Respondents' socio-economic and demographic characteristics

Description	**Category**	**M**	**F**	**Total**	**Percent**
Age	20-40	56	11	67	51.15
	41-60	38	9	47	35.87
	above 60	15	2	17	12.98
Marital status	married	105	17	122	93.13
	Single	3	0	3	2.29
	Divorce	0	1	1	0.76
	Widow	1	4	5	3.82
Educational status	Illiterate	45	15	60	45.8
	1-8	45	5	50	38.2
	9-12	16	2	18	13.7
	Diploma & above	3	0	3	2.3
Farm experience	Less than 10 years	24	2	26	19.85
	10-25 year	66	14	80	61.07
	More than 25 years	19	6	25	19.08
Average family size			7.2		
Average annual household income (ET birr)			40709.2		
Average age of respondents			47		
Average landholding size (hectare)			1.8		

Sources: Field data collected September 2020.

4.2. Trends in temperature and rainfall variability over the last 34 years

The descriptive statistics on annual and seasonal rainfall is presented in Table 4.2. The result shows that the mean annual rainfall of the study area during the study period was 649 mm with 115 mm standard deviation and 17.7 CV. The minimum and maximum ever recorded rainfalls were 429 mm (in 2015- the driest year) and 867.4 mm (in 2001-the wettest), respectively.

Table 4.2 Annual and seasonal rainfall, mean, standard deviation and coefficient of variation

Station	Annual (total)			Main rain season (***Kiremt***)			Short/***Belg*** rain season		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Negele	649.00	115.14	17.74	404.47	85.18	21.06	178.48	79.97	44.81

SD = standard deviation, CV = coefficient of variation

Source: Authors construction from NMSA data

Kiremt is the major rainy season in the study area which contributes about 62.3% of the total rainfall. The short rainy season which lasts from March-May (*Belg*) also contributes a substantial amount of rainfall, 27% of the total. The study revealed that the mean *Kiremt* rainfall (June–September) in the study area from 1983 to 2016 was 404.4 mm and 178.5 mm for *Belg* season (Table 4.2). Though the declining trends of *Belg* and annual rainfall is not statistically significant (Table 4.2), the coefficient of variation (CV) was 21.06% for *Kiremt* and 44.8% for *Belg* season, which implies high rainfall variability during the *Belg* season than *Kiremt*. The result agrees with the findings of previous studies (Aklilu, 2006, Viste et al., 2013, Alemayehu & Woldeamlak, 2017), where more variability in *Belg* rainfall than the *Kiremt* rainfall in most parts of Ethiopia.

The amount of annual rainfall had decreased by 28.3 mm per 34 years, 8.3 mm per decade and 0.83 mm per year. For *Belg* season rainfall had decreased by 23.8 mm per 34 years, 7 mm per decade and 0.7 mm per year. However, *Kiremt* rainfall had increased by 10.2 mm in 34 years, 3 mm per decade and 0.3 mm per year (see Sen's slope in Table 4.3).

Table 4.3: Trends of annual and seasonal rainfall (1983-2016)

Station	**Annual rainfall**		***Kiremt* rainfall**		***Belg*/short rainfall**	
	ZMK	Sen's Slope (mm/year)	ZMK	Sen's Slope (mm/year)	ZMK	Sen's Slope (mm/year)
Negelle	-0.30	-0.83	0.71	0.3	-0.74	-0.7

Source: Authors construction from NMSA data.

According to World Bank (2010) Ethiopia has faced many droughts and floods since 1980s. According to the report the country has face more than 47 floods that killed more than 2000 people since 1990. In addition, more than 16 drought events have been occurred from 1980s to 2004 (IDA, 2006). The recent FAO (2016) report shows that the 2015/16 El Nino induced drought causes more than 10.2 million people in need of emergency food aid. The result of Standardized Rainfall Anomaly (SRA) revealed that drought has occurred at different levels of severity in the study period during annual, Kiremt and Belg seasons. For instance, 2015, 2011, and 2009 were the driest years based on annual calculations. The drought that occurred in 2015, 2011 and 2009 were extreme that the standardized rainfall anomaly values were -1.91, -1.67 and -1.72, respectively (Figure 4.2). But 1996 and 2010 were the wettest years with anomaly values of 1.96 and 1.63, respectively.

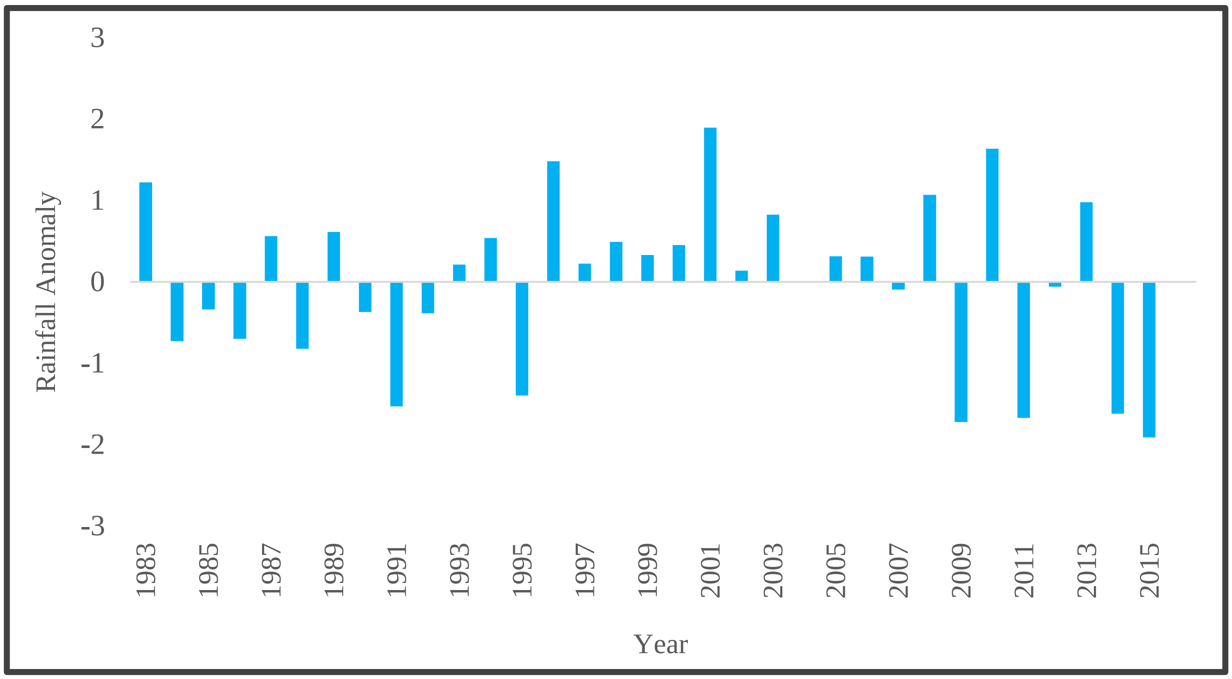

Figure 4.2. Rainfall anomaly of Negelle Arsi (1983-2016)

The wettest *Kiremt* season were 1994 (1.79), 2008 (1.8) and 2012 (1.9), whereas the wettest *Belg* season were 2001 (1.76), 1987 (2.75) and 2016 (2) (Figure 4.3). The findings of this study is in agreement with the previous studies by Viste et al. (2013) and Suryabhagavan 2017) that reported 2009, 2011 and 2015 were the driest years in most parts of Ethiopia including the study area. According to Asfaw et al. (2018), these drought years were either coinciding or follow El Nino events shortly.

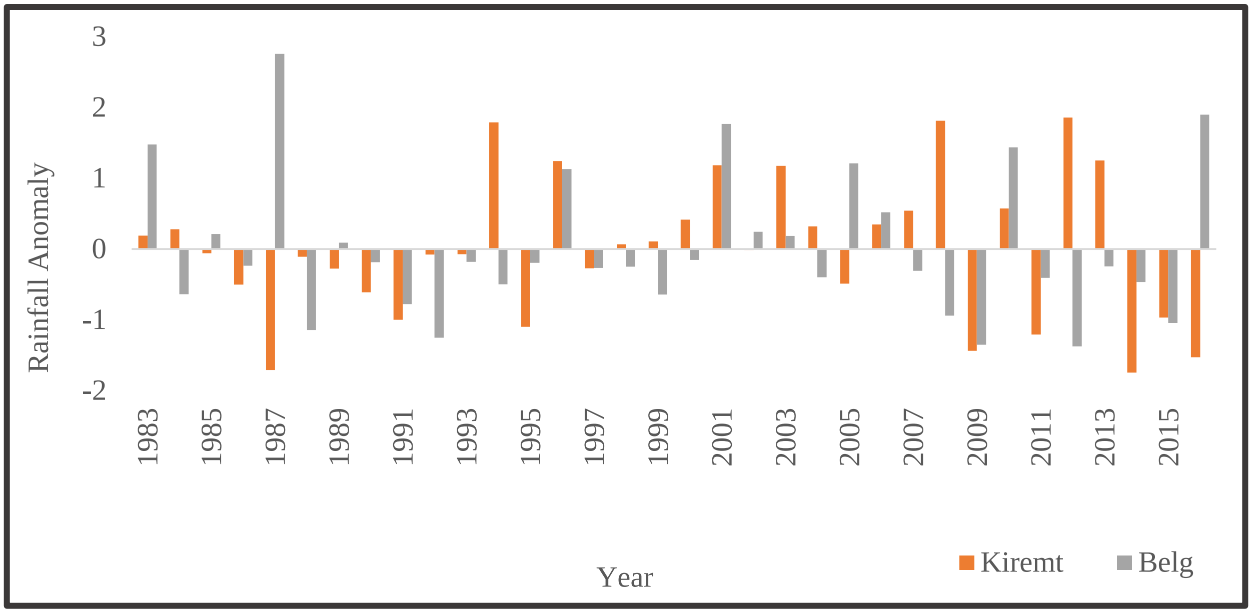

Figure 4.3 Rainfall anomalies of *Belg* and summer for Negelle Arsi Woreda

Table 4.4 presents the frequency of drought events that occurred in the study area based on standardized rainfall index during 1983-2016. As a result, about 3 (8.82%), 3 (8. 8%) and 8 (23.5%) were observed as extreme, severe and mild drought in annual rainfall anomaly. On the other hand, 2 (5.9%), 2 (5.9%), 4 (11.8%) and 10 (29.4%) extreme, severe, moderate, and mild drought events respectively were observed during *Kiremt* season. During Belg season, 2 (5.9%) severe, 4 (11.8%) moderate and 16 (47%) mild droughts were occurred. (see fig. under annex 2). The result of this study supports previous studies by Asfaw et al. (2018), Temam et al. (2019) and Esayas et al. (2019) reported drought frequency increased in recent decades.

Table 4.4. Drought frequencies for Negelle Arsi Woreda during the study period (1983-2016)

Drought Category	SRA Ranges	Annual		*Kiremt*		*Belg*	
		N	%	*N*	%	*N*	%
Extreme drought	< -1.65	3	8.82	2	5.88	0	0.00
Severe drought	1.28 to -1.65	3	8.82	2	5.88	2	5.88
Moderate	0.84 to -1.28	0	0.00	4	11.76	4	11.76
Mild drought	0 to -0.84	8	23.53	10	29.41	16	47.06
Normal	0 to 0.84	14	41.18	9	26.47	5	14.71
Moderately wet	0.84 to 1.28	3	8.82	4	11.76	2	5.88
Very Wet	1.28 to 1.65	2	5.88	0	0.00	2	5.88
Extremely Wet	> 1.65	1	2.94	3	8.82	3	8.82

Table 4.5 portrayed the seasonal and annual temperature (minimum, maximum and mean) characteristics for annual, *Belg* and Kiremt seasons. The long term annual mean temperature in the study area is 18.9 ^{0}C with 0.6 standard deviation and 3% CV. The long term annual mean minimum and maximum temperatures of Kiremt season are 12.9 ^{0}C and 24.5 ^{0}C with 6% and 2.3 % CV, respectively. For the *Belg*, the minimum temperature is 12.8 ^{0}C with 0.9 SD and 7.2% CV, and the maximum temperature is 27.4 ^{0}C with 07. SD and 2.7% CV. The result indicated that CV in *Belg* season is higher than that of *Kiremt* and annual temperature which implies more inter-annual variability of *Belg* temperature than *Kiremt* and annual temperature.

Table 4.5 Annual and seasonal temperature (Maximum, minimum and mean), standard deviation and coefficient of variation, 1983-2016.

Station	**Temp**	**Annual**			***Kiremt***			***Belg***		
		LTM	SD	CV	LTM	SD	CV	LTM	SD	CV
Negele	MAX	26.0	0.4	1.6	24.5	0.6	2.3	27.4	0.7	2.7
	MIN	11.7	0.9	8.0	12.9	0.8	6.1	12.8	0.9	7.2
	AVE	18.9	0.6	3.0	18.7	0.5	2.7	20.1	0.7	3.3

SD = standard deviation, CV = coefficient of variation.

Source: Authors construction from NMSA data.

Trends of annual minimum, maximum and mean temperature and Mann-Kendall test (ZMK) results for Negele Arsi station are presented in Table 4.6 The result revealed that minimum, maximum and mean temperature of Negele Arsi have been increasing significantly from 1983 to 2016. Annual maximum mean temperature has been increasing by 0.68 degree Celsius, 0.25 degree Celsius per decade and 0.02 degree Celsius per year. The annual minimum mean temperature has increased by 2.5 degree Celsius, 0.7 degree Celsius per decade and 0.07 degree Celsius per year. Furthermore, annual average temperature has increased by 1.56 degree Celsius per 34 years, 0.156 degree Celsius per decade and 0.04 degree Celsius per year from 1983-2016. And the trends are statistically significant for maximum ($P < 0.01$) and mean and minimum ($P < 0.001$). On seasonal basis, the *Kiremt* maximum, mean and minimum temperature have been increasing by 0.60, 1.22, and 1.84 degree Celsius respectively for the last 34 years or 0.17, 0.35, and 0.54 per decade from 1983-2016 respectively and 0.017, 0.035 and 0.054 degree Celsius per year respectively and are statistically significant (Table 4.6). The *Belg* maximum temperature has increased by 1.04, 0.3 and 0.03 degree Celsius per 34 years, decade, and year respectively. The

Belg mean and minimum temperature have been increasing by 1.46 and 1.87 degree Celsius respectively for the last 34 years or 0.42 and 0.55 per decade from 1983-2016 respectively and are statistically significant.

Station	Temp	Annual		Kiremt		Belg	
		ZMK	Sen's Slope	ZMK	Sen's Slope	ZMK	Sen's Slope
Negele	MAX	2.85**	0.02	2.3*	0.02	2.3*	0.03
	MIN	5.23***	0.08	4.2**	0.06	3.8***	0.07
	AVE	5.16***	0.05	4.3***	0.04	4.1***	0.04

Note: *, **, *** statistically significant at 0.05, 0.01 and 0.001 alpha levels.

Source: Authors construction from NMSA data.

4.3. Farmers perception on climate variability

4.3.1. Farmers perception on rainfall variability and trend

Table 4.7 reveals that most of the farmers perceived the declining trend of rainfall from time to time in their localities. About 74% of the respondents perceived that rainfall was declining, while only 11.5% of them perceived increasing trends in rainfall. In addition, the majority of farmers well realized the late onset and early cessation of rainfall becoming a major challenge with increased intensity and decreased trends of rainfall amount, and the number of untimely excess rainy days on the other side in the study area. For instance, about 94% and 90.8% of respondents confirm unpredictable onset and cessation of rainfall, respectively. From this results we can conclude that majority of the farmers in the study area perceived a decrease in the level of rainfall.

Table 4.7 Farmers perception on rainfall variability

Perception of Rainfall Variability Indicators	No of respondents (N=131)			
	Have perceive		have not perceive	
	N	*%*	*N*	*%*
Little rainfall (rainfall amount decreases)	116	88.5	15	11.5
Increase in rainfall amount	97	74	34	26
Decrease in rainy days	105	80.2	26	19.8
Increased in the intensity of rainfall	122	93	9	7
The onset of rainfall become more unpredictable	123	94	8	6
The cessation of rainfall become more unpredictable	119	90.8	12	9.2
Drought occurrence frequency increase	120	91.6	11	8.4
Flood after rain	125	95.4	6	4.6

The information obtained from FGDs and key informants confirmed that the main rainy season and *Belg* season rain are starting later and ending earlier. As stated by participants, farmers perceived that they have lost *Belg* rains and this was supported by meteorological data which indicate a declining trend of *Belg* and annual rainfall in Negele Arsi area for the period 1983-2016. This result is also supported by previous studies on perceptions on climate variability and change that covered different parts of Ethiopia (Gebrehiwot and van der Veen 2013, Alemayehu & Bewket, 2017, Ayal et al., 2017).

4.3.2. Perception on temperature variability and trend

An increase in temperature is among the manifestations of global climate change (Asfaw et al., 2018). The result obtained from surveyed households show that the majority of farming community perceived the increasing trend of temperature (91.6%), while 8.4% did not. About 49.6% and 84.7% of farmers perceived the increasing in hot days and warm nights from time to time in their localities (Table 4.8). The perception of farmers on the increasing of temperature match with the meteorological records of temperature trends presented in section 4.2. When perceptions are compared to the meteorological records of temperature data of Negele Arsi, both sources confirmed increasing trend in annual mean, maximum and minimum temperature.

Table 4.8: Farmers' perceptions of temperature variability indicators

Perception of Temperature Variability Indicators	No of respondents (N=131)			
	Noticed		Not noticed	
	N	*%*	*N*	*%*
Temperature increases	120	91.6	11	8.4
Decrease in temperature	12	9.2	119	90.8
No of hot days increase	65	49.6	66	50.4
Number of warm nights increased	111	84.7	20	15.3
No change in temperature	23	17.6	118	82.4

Source: From authors' field survey, 2020.

Similarly, the information obtained from FGDs and Key informant interviews revealed the increasing trend of temperature, hot days and warm nights in their localities. In addition, farmers' perception is consistent with scientific claims about the increasing trend of temperature in Ethiopia (Woldeamlak, 2012; Asfaw et al., 2018; Ayal & Filho, 2017).

4.4. Impacts of climate change on agricultural production

There is different climate related problems, which could impact the farming community in their usual livelihood. The study area is mainly rain fed that agricultural production significantly altered by drought. About 86% of respondent farmers reported the occurrence of frequent drought as major impacts associated with climate change affecting their livelihoods (Figure 4.4) In the low land parts of the study area, particularly, in Hadha Bosso kebele flooding is a frequently mentioned impact of climate change and variability (28% of respondents confirmed). About 71% of respondents reported the occurrence of animal and crop pests and disease. Furthermore, 70% and 68% of respondents perceived soil erosion and water shortage as the major impacts of climate variability and change in the study area.

In this study, respondents were asked to identify the impacts of climate variability and change in their locality. Based on their response the major problems induced by climate variability and change in the study area is shown in the following Figure 4.4. The impact of climate change is reflected in crop failure due to insufficient rainfall amount and distribution and associated diseases incidences during production and harvesting period. Accordingly, about 60% of respondents witnessed that climate change and variability induced crop failure in the study area. Death of livestock is also a climate variability and change induced problem indicated by 31% of the respondents.

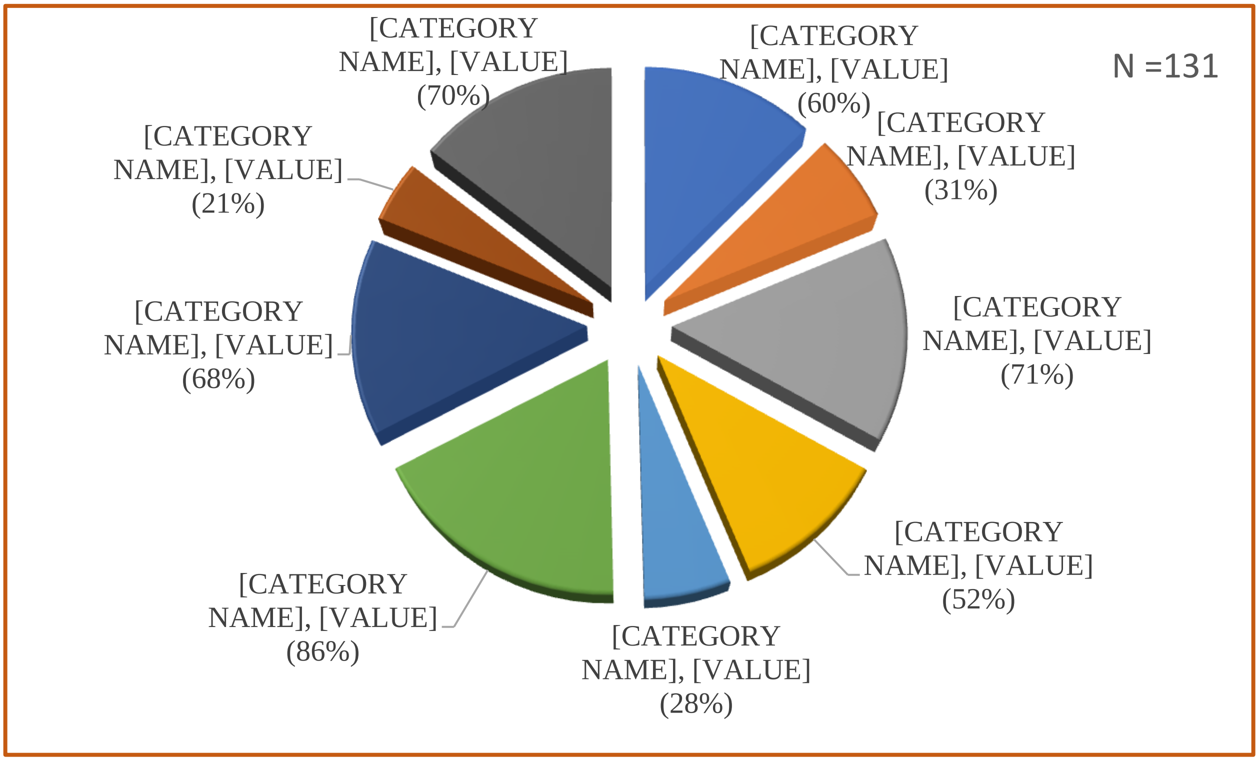

Figure 4.4 Degree of impact of climate change as perceived by the respondent farmers

4.5. Climate change adaptation mechanisms implemented by farmers

Farmers have their own adaptation strategies against climate change and variability to sustain their lives and livelihood. Figure 4.5 illustrates the actual adaptation strategies practiced by the respondent farmers in the study area. Among these adaptation strategies, almost 29% of sample households used drought resistant crop varieties as the primary adaptation strategy followed by changing of planting date (24%). On the other side, only 2% of the respondents used destocking and stall feeding adaptation strategy. Construction of physical/biological soil and water conservation was perceived by the farmers (10%) as one of the most important adaptation strategies practiced particularly in lowland and midland areas. The finding of this study agrees with the finding of previous study conducted by Belay et al. (2017) of smallholder farmers' adaptation strategy to climate change.

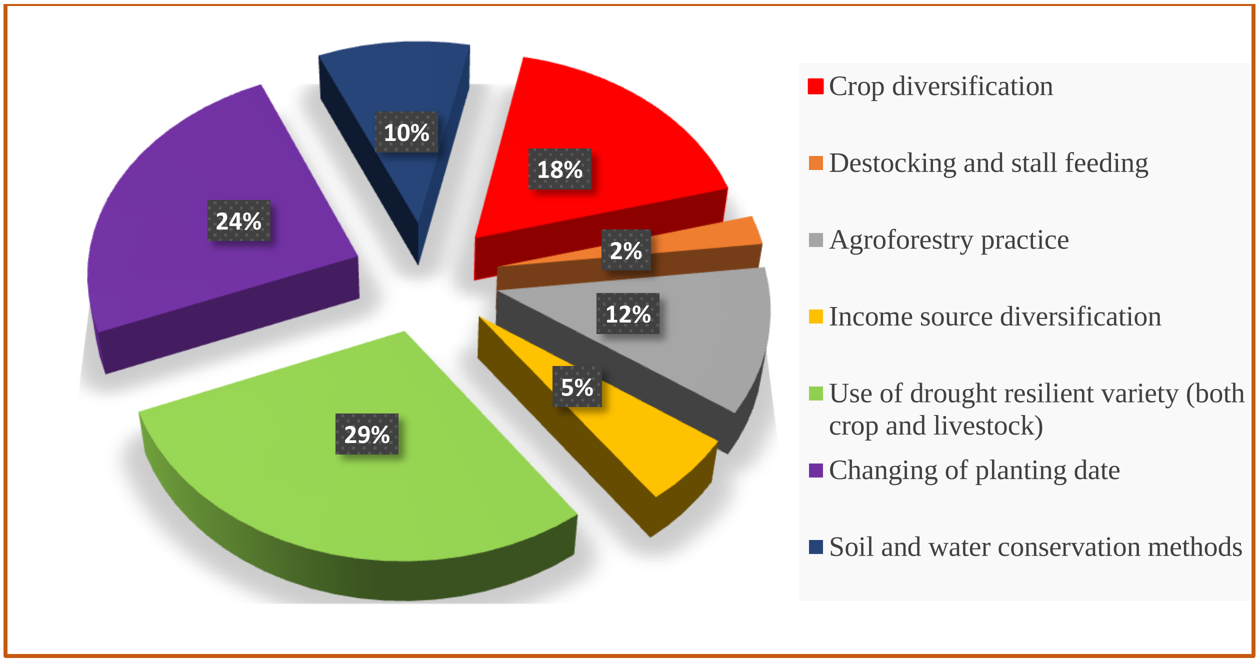

Figure 4.5 Adaptation strategies implemented by farmers

Information from key informants indicate, farmers in the study area were practicing both reactive and planned adaptation mechanism in response to the changing climate that affect the production and productivity of agricultural production. Most of the adaptation strategies practiced in the study area are government agriculture sector initiatives of the extension program to boost the sector productivity and production in crop and livestock sector. Back yard vegetables like carrot, beet roots, cabbages, avocado, guava, coffee and lemons production were observed by the re-searcher during household visits in study District. Cultivation of drought tolerant crops such as Enset (Ensete ventricosum) as a source of food for human being and livestock feed was observed as one of the adaptation strategies in the mid and highland agro-ecology in the study Woreda. Fruit and fodder tree planting, soil and water conservation practices, and using crop residues as livestock feed were also commonly used adaptation mechanism. The widely preferred potato varieties in the mid and high altitude kebeles are Jalane and Gudane whereas composite maize (Katumani, Hawassa and Melkassa1) are the most preferred variety used by the lowland farmers. Maize (Limu) variety is mostly preferred in the low and midland for it is resistant to rust and insect pests however they are not adequately available during high time of need by the farmers.

4.5.1. Coping strategies during extreme climate change events

The study also revealed the key ongoing coping strategies practiced by the household during extreme and severe drought events. These strategies are experienced through selling their livestock 84% (110), grain reserve 92% (121), reduced meal frequency 51% (67), borrow food items and money 31% (40) emergency food aid and productive safety net 41% (54). One or more seasonal coping mechanism as the strategy against the adverse impact of climate change is used by the farmers and some copying mechanism varies based on AEZ. For instance, emergency food aid and productive safety net program mainly targeted poor farmers living in the low and midland agro-ecological zones. Other coping mechanisms such as sell of livestock, reduced meal frequency and amount of food and grain stock are experienced across all agro-ecological zones.

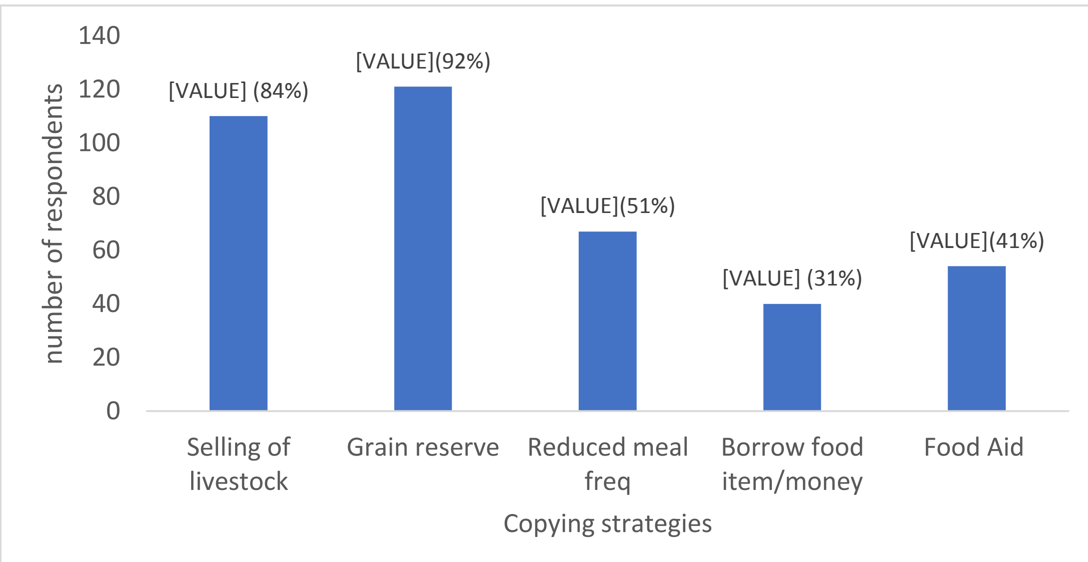

Figure 4.6 Copying strategies of farmers during short term stress

Source: (Author Construction)

4.5.2. Adaptation strategy options to climate change

Assessment of the choice of farmer's adaptation with sample households indicate that 98 respondents (75%) prefer to use short season and disease resistant crop variety as their first option and 62 respondents (48%) choose irrigation for adapting to the changing climate even though they were not using irrigation due to limited access to irrigable farm land. There are farmers' highly benefitting from irrigation by producing three times a year.

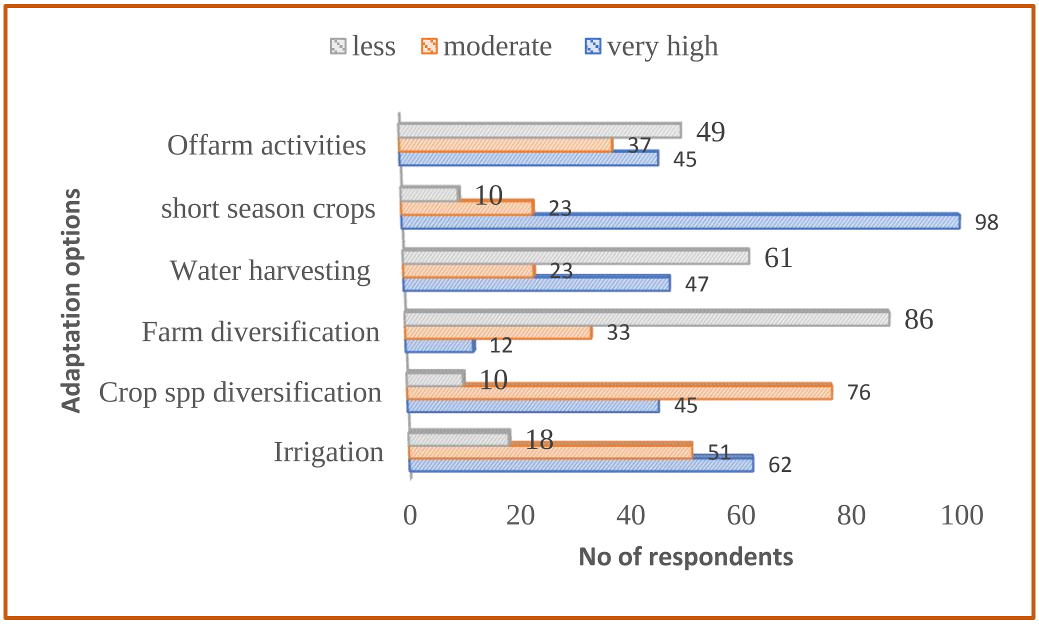

Figure 4.7 Adaptation choices of farmers to the changing climate and rainfall

Source: (Author Construction)

Crop species diversification and agroforestry practices were also another choice of farmer's interest in their planned adaptation strategy. 47 (35.9) respondents have shown very high interest in water harvesting through ditch, private and communal ponds for backyard crops and livestock consumption during the extreme and severe drought season. 82 (63%) of the respondents have shown very high and moderate interest in off farm activities against the changing climate and farmland fragmentation among the member of households (Figure 4.6).

4.5.3. Factors hindering climate change adaptation

In the study area, there are various barriers that deter farmer's capacity to practice climate change adaptation strategies. These include shortage and high cost of farm inputs, lack of adequate irrigation facility, poor access to credit, insufficient extension services, lack of technology, poor market access and shortage of land. As shown in Figure 4.7, 29% of the respondents reported that shortage and high cost of farm inputs is barrier to practice adaptation strategies. The price of improved seed variety and fertilizer is increasing from time to time and many farmers are poor and could not afford to adequately use on their farmland. Besides shortages, the timely supply of these inputs is a challenge and seeds and fertilizers arrive after the pick period of sowing or planting date which resulted in low yield and poor seed quality. The second main barriers to adopt climate change adaptation strategies lack of land (27%) to practice different climate change adaptation strategies. About 15%, 11% and 10% of respondents perceived insufficient extension services, lack of adequate irrigation facility and lack of technology respectively as a barrier to climate change adaptation.

Furthermore, 6% the surveyed households reported that poor access to credit services, and hence financial constraint, is one of the key factors constraining farmers’ adaptation capacity in the study area. On the other hand, 2% of respondents perceived poor access to market is the constraints to implement climate change adaptation strategies due to road infrastructure and distance from the capital town of the Woreda. This study is in agreement with the results obtained by Alemayehu & Bewket (2017) and Marie et al. (2020) which concluded that shortage and high cost of farm input, poor extension service and lack of technology were the major constraints to hinder farmers' willingness to adopt adaptation strategies in response to climate change effects.

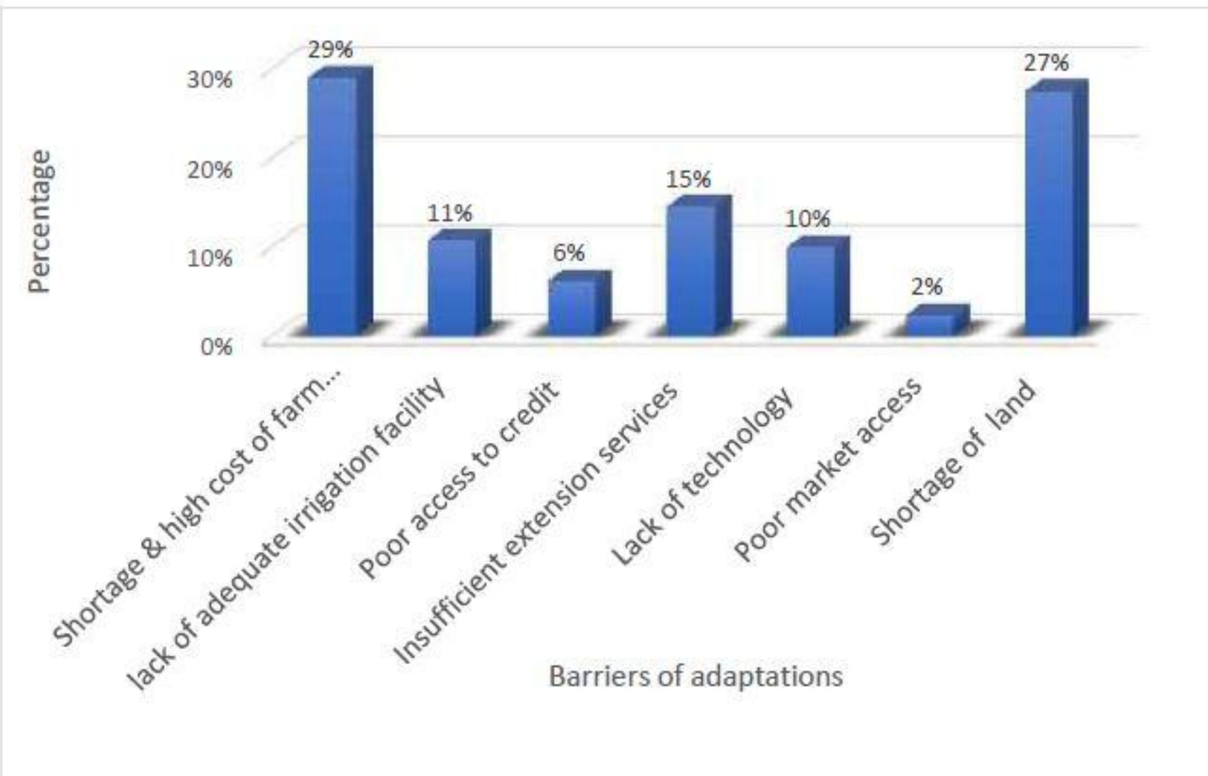

Figure 4.8 Barriers to climate change adaptation

4.6. Determinants of Farmers' Choice of Adaptation Strategies to Climate Change

Multinomial logistic regression analysis was estimated to determine the factors influencing a households' choice of adaptation strategies to reduce adverse effect of climate change. Table 4.9 presents the summary statistics of the independent variables and estimated results of MNL regression model. Among the nine independent variables considered in the multinomial logistic regression model, six variables were found statistically significant.

The results of this study reveal that male-headed households are better in adapting some measures to climate change than female households. Male-headed households were 55% more likely to adapt crop diversification (table 4.9). The result is in line with Tazeze et al. (2012). They found that male households are better in adapting some measures to climate change like crop diversification as they are relatively flexible in search of improved crop varieties and in a better position to pull their labor force in order to adapt crop diversification. Moreover, the results of this study indicates that female headed households are better in practicing diverse sources of income like participation in petty trading and sell of beverages which eventually increases the income of household that enable them to meet the demand of household food security.

Table 4.9 Parameter estimates of the multinomial logit climate change adaptation model

Explanatory variable	Crop diversification		Destocking & stall feeding		Agroforestry		Income source diversification		Drought re-sistance variety		Changing plant-ing data		Soil & water conservation	
	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Sex	.055*	.050	-.319	.442	-.029	.391	-.080*	.050	-.009	.723	-.034	.306	-.001	.980
Age	-1.022	.172	-4.847	.100	.100	.898	-.699	.391	-.333	.640	.337	.709	-1.283	.118
Edu	3.05***	.000	1.201	.695	-.341	.641	-.573	.505	1.34*	.030	1.307	.127	1.9*	.045
Farm size	.088	.811	-1.972	.338	1.3**	.002	.299	.503	.083	.806	.005	.991	-.008	.986
HHSZ	.070	.526	.725	.239	-.016	.899	.044	.790	-.006	.958	-.064	.711	.027	.861
Farm Income	.000	.062	.000	.445	.000	.430	.000	.700	.000	.575	.000	.496	.000	.317
Market access	-.388	.506	-1.539	.428	-.713	.280	2.3*	.030	-1.091	.059	-.235	.781	.861	.254
Credit access	.275	.672	-17.265	.997	.080	.910	.814	.333	1.6**	.002	2.31**	.002	.881	.293
Extension ser-vice	-.251	.720	-3.048	.405	.890	.246	-.490	.602	1.5**	.010	20.319	.996	-1.267	.166
cons	-4.833	.003	9.071	.522	-2.707	.107	-.246	.913	-1.470	.291	-20.355	.996	-2.323	.231

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

Source; own survey study 2020

Education of the head of household improves the probability of adapting to climate change. As can be presented in Table 4.9, crop diversification, use of drought and disease resistant variety (both crop and livestock) and soil and water conservation are significantly influenced by education. For instance, the result showed statistically significant (coefficient = 1.34, $P < 0.030$) positive association between education and use of drought resistant crop and livestock variety. This indicated that increase in educational status would result in increasing the probability of using drought resistant variety, soil and water conservation methods and crop diversification and hence improved in household food security status. This results are in agreement with Deressa et al. (2009) and Tazeze et al. (2012).

Farm land size can significantly affect farmers' adaptation strategy to climate change. Similarly, Belay et al. (2017) showed that farm size has a positive and significant relationship with many climate change adaptation strategies. Large farm plot size provides the opportunity of planting different fodder trees and integrating crop with livestock production. The result of this study revealed that households with relatively large farmland were most likely to adapt to agroforestry practices (coefficient = 1.3, $P < 0.002$) than those farmers with small land holdings (Table 4.9). Shortage of farmland has been associated with the limited capacity of farmer to intensify their agricultural production that lead to household food insecurity unless other option like of farm activities are widely practiced.

The result shows that farmers with better access to market has the opportunity to diversify their income sources than farmers those who have poor access to market (Table 4.9). This implies improvement of market access for the rural community by developing the necessary infrastructures like road networks and marketplaces which can significantly increase the diversification of income sources of the community that enable them to improve their food security status. Maddison (2006) stated market access as an important determinant for adaptation method hence it serves as a means of income source diversification as well as exchanging of information.

This study reveals that credit has a positive and significant impact on likelihood of using adjusting planting date and drought resistant crop and livestock variety. The result showed that a statistically significant (coefficient = 2.31, $P < 0.002$) positive association between credit access and change of planting date (Table 4.9). According to Nhemachena and Hassan (2008) affordable access to credit can increase financial capacity of farmers to adapt climate change adaptation through changing planting date. Thus, increasing access to credit can improve farmer's adaptation practices to climate change adaptation and its adverse effect. Hence, the more farmers are accessible to credit, the better they can produce and increase food availability and access to improve household food security. The result of this study is similar with the findings of Deressa et al. (2009) and Tazeze et al. (2012).

Access to extension service has positive impact on creating awareness and dissemination of technologies for climate change adaptation and its adverse effect. Likewise, this study shows that access to extension service has positive and significant impact on using drought resistant crop and livestock varieties (coefficient = 1.5, $p < 0.01$) (Table 4.9). The purpose of extension service is to introduce more appropriate technological packages and provide the support necessary to ensure widespread adoption of improved technologies among smallholders to increase productivity and improve food availability in the rural areas. Hence extension service play a key role to improve food security at household and community level by increasing their ability to adapt to changing climate.

CHAPTER FIVE: CONCLUSIONS RECOMMENDATIONS

5.1. Conclusions

This study aims to investigate the impact of climate change on agriculture and key adaptation strategies practiced by farmers in Negelle Arsi Woreda. Negelle Arsi Woreda is characterized by bimodal type rainfall; the main rainy season is during *Kiremt* (June to September) and *Belg* (March to May) where rainfall provides a substantial importance of crop production to the high-land and midland part of the District. The large areas in the low land of the District are not prac-ticing *Belg* production due to low precipitation. The findings of the study show that farmers at the higher altitude have better options of adaptation practices to climate change compared to the low landers due to better precipitation and potential access to irrigation through surface water.

The result indicates About 86% of respondent farmers reported the occurrence of frequent drought during production season as major impacts associated with climate change affecting their food security and livelihoods. In the low land parts of the study area particularly Hadha Bosso kebele flooding is also a frequently mentioned impact of climate change and variability (28% of respondents confirmed). About 71% of respondents reported the occurrence of animal and crop pests and disease. Furthermore, 70% and 68% of respondents perceived soil erosion and water shortage as the major impacts of climate variability and change in the study area.

Late on set, early cessations and erratic nature of rainfall are the key problems emphasized by the farmers during discussion. Such trends are more frequent across the agro-ecologies in the district and hence negatively affected both crop and livestock production. Discussion from FGD re-vealed that farmers were trying to adapt through traditional and modern ways like crop rotation, use of disease resistant crop varieties, crop diversification, changing planting date and agrofor-estry. They have also identified the preferred and effective adaptation options but hampered from practicing them due to poor access to irrigation technologies, insufficient extension services for desired types of disease resistant crop varieties, fertilizers and herbicides. American Ball Worm on maize plants and bacterial wilt on potato are becoming the key cause of yield reduction and crop failure as per interview conducted with farmers and the field observation by the researcher.

Meteorological data analyses indicate the *Kiremt* maximum, mean and minimum temperature have been increasing by 0.60, 1.22, and 1.84 degree Celsius respectively for the last 34 years or

0.18, 0.36, and 0.54 per decade from 1983-2016 respectively and are statistically significant. The *Belg* maximum, mean and minimum temperature have been increasing by 1.04, 1.46, and 1.87 degree Celsius respectively for the last 34 years or 0.31, 0.43, and 0.55 per decade from 1983-2016 respectively and are also statistically significant. On the other hand, rainfall data analyses revealed that the mean annual and *Kiremt* rainfall (June–September) in the study area from 1983 to 2016 was 649 and 404.4 mm respectively and 178.5 mm for *Belg* season. The amount of annual rainfall had decreased by 28.3 mm per 34 years and by 8.3 mm per decade and for *Belg* rainfall had decreased by 23.8 mm per 34 years (7 mm per decade).

Among many adaptation strategies practiced, almost 29% of sample households confirmed drought resistant crop varieties as the primary adaptation strategy followed by changing of planting date (24%). Assessment of their preferred adaptation choices with sample households indicate that large number of respondents (75%) prefer to use short season and disease resistant crop variety as their first option and irrigation (48%) in adapting to the changing climate even though they were not using irrigation due shortage of water and limited access to irrigable farm land.

The MNL adaptation model with these adaptation strategy choices was run and showed some significant levels of the parameters estimates. Crop diversification, use of drought and disease resistant variety (both crop and livestock) and soil and water conservation are significantly influenced by education. This indicated that increase in educational status would result in increased the probability of using drought resistant variety, soil and water conservation methods and crop diversification. Male-headed households are better in adapting some measures to climate change than female households like crop diversification as they are relatively flexible in search of improved crop varieties and in a better position to pull their labor force in order to adapt crop diversification. However, the results of this study indicate that female headed households are better practicing income source diversification like participation in petty trading and sell of beverages. Access to credit has a positive and significant impact on a likelihood of using adjusting planting date and drought resistant crop and livestock variety.

5.2. Recommendations

Based on the findings indicated in this research, the following recommendations are formulated. In the recent years, as rainfall is becoming less predictable and uncertain, policy driven actions to provide water harvesting and irrigation facilities based on existing water resources potential are vital importance. Moreover, enhancing and promoting off-farm activities are critical options as this helps them to engage in those endeavors that are less sensitive to climate change. Since early maturing and drought resistant crop and livestock varieties were well identified and under adoption, they should be scaled up and expanded in terms of coverage and quality through the three agroecological zones. Especially the desired crop varieties should be multiplicated in sufficient quantity and supplied in time before it is too late for sowing date. Crop diversification and agroforestry are existing coping strategy in the midland and lowland agro-ecologies and this should also be strengthened by the government extension services.

Farmers' adaptation practices to climate change and variability should be context based specific and consider existing natural resource potential of the area. Thus, existing rich water resources at the highland kebeles can be developed and expanded to the farmers living in the low land to use for human and livestock consumption as well as irrigation purposes. The government and all concerned body should also give emphasis to address this issue of climatic change by considering recommended actions stated above. Improved information management systems, expansion of agricultural extension and implementation of short-listed adaptation options listed in the document of Ethiopian Climate Resilience and Green Economy are key role to be played by the ministry of agriculture.

This study was limited in scope and sample size; it is suggested to undertake further studies at a larger scale to figure out the resilience strategy of vulnerable peoples and their livelihoods at different agroecological settings within the district to save their lives and food security challenges they frequently encountered.

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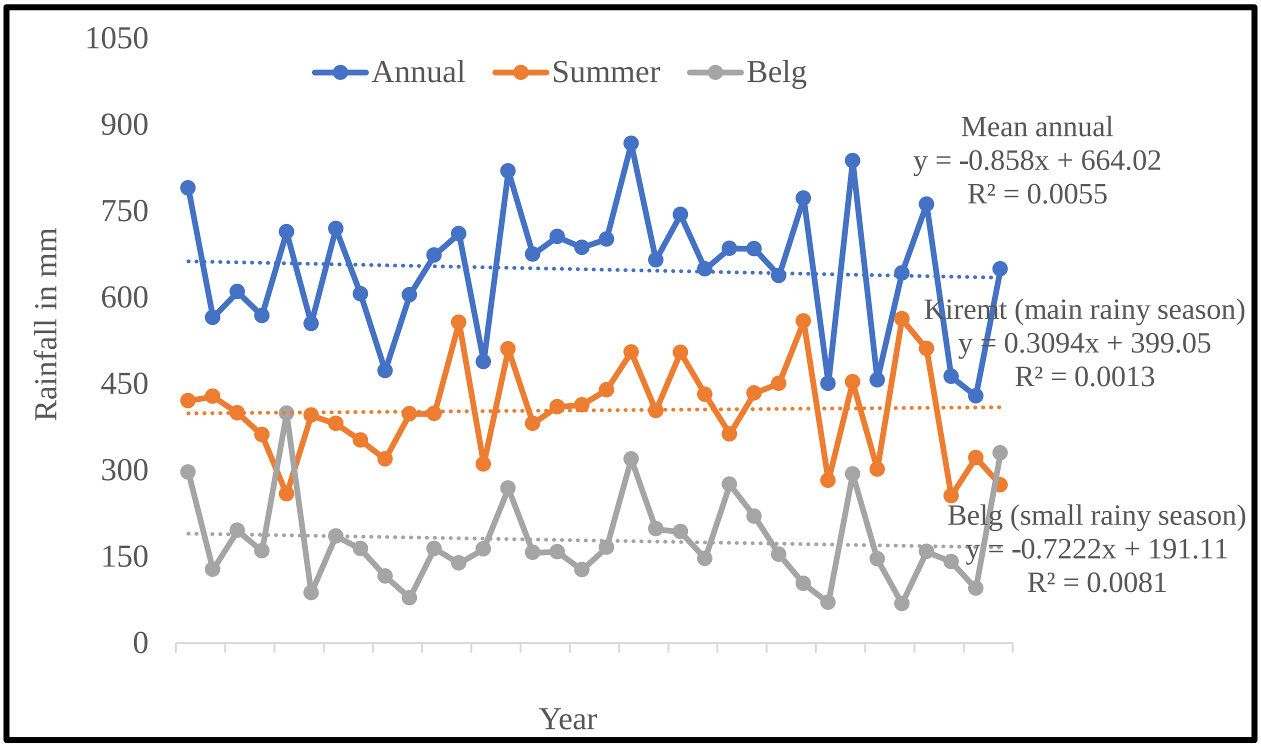
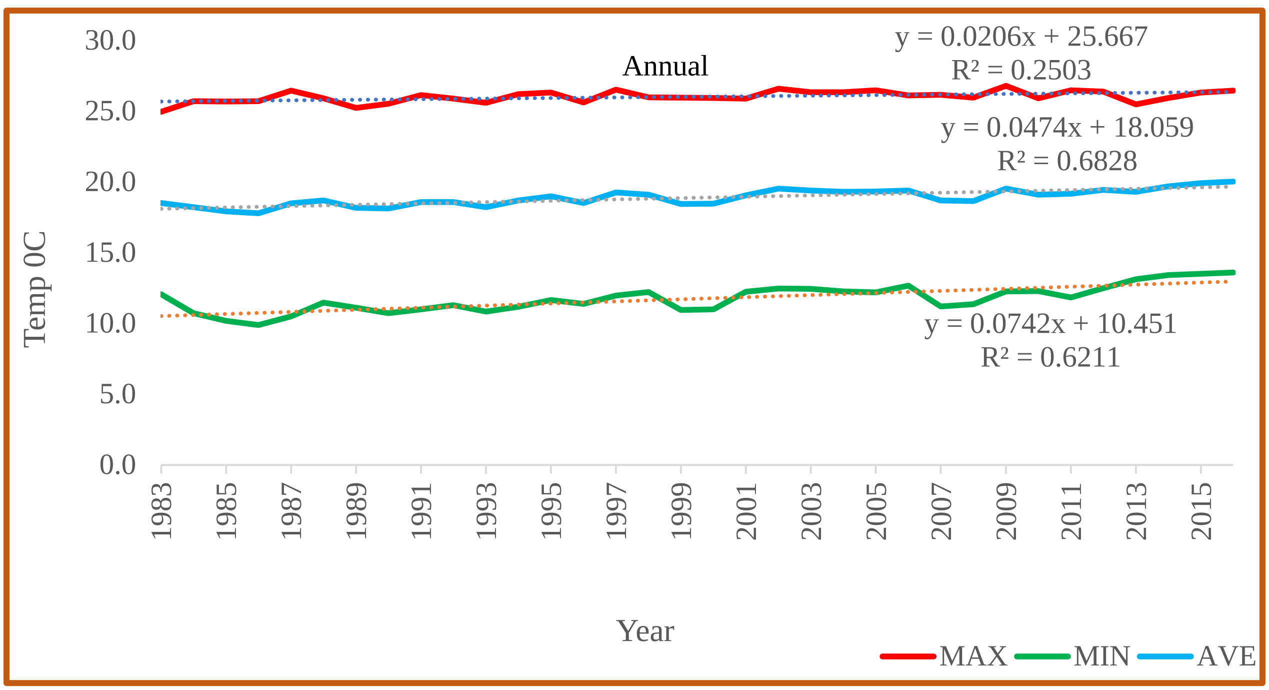
Appendixes

Annex 1. Sample photos from field

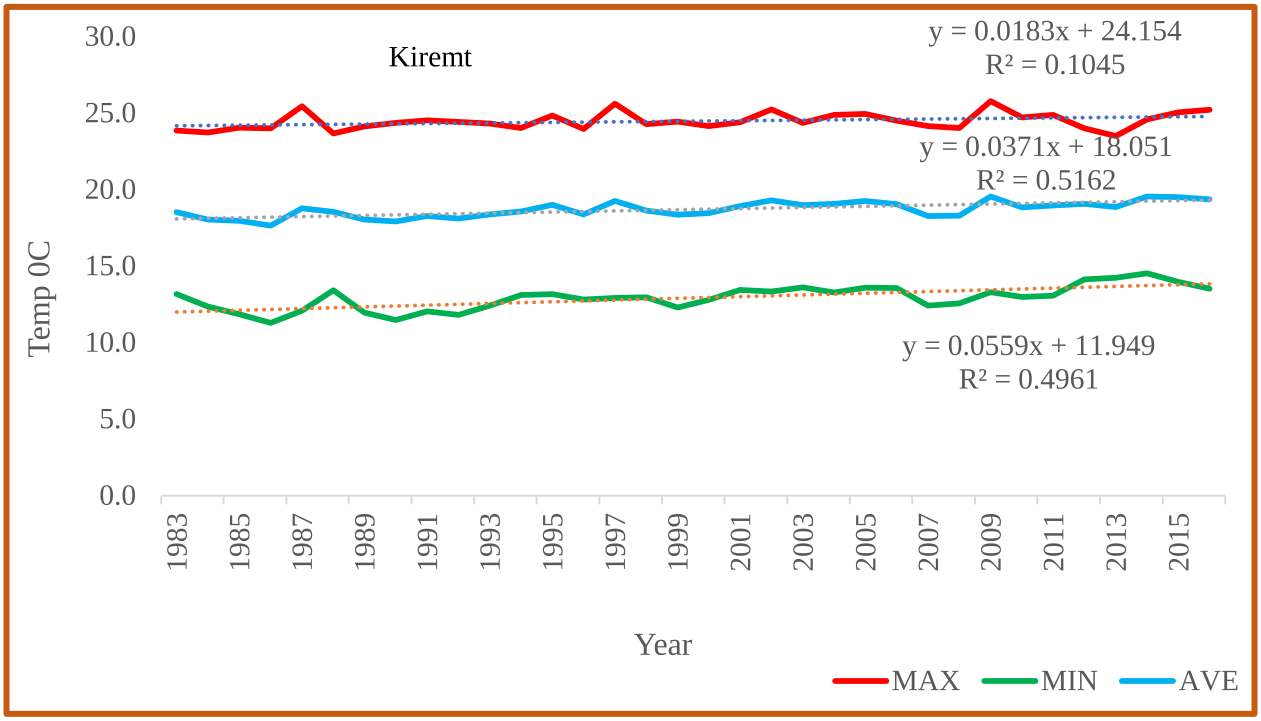
Annex 2. Rainfall pattern of (Annual, *Kiremt* and *Belg* in Negele Arsi during 1983-2016



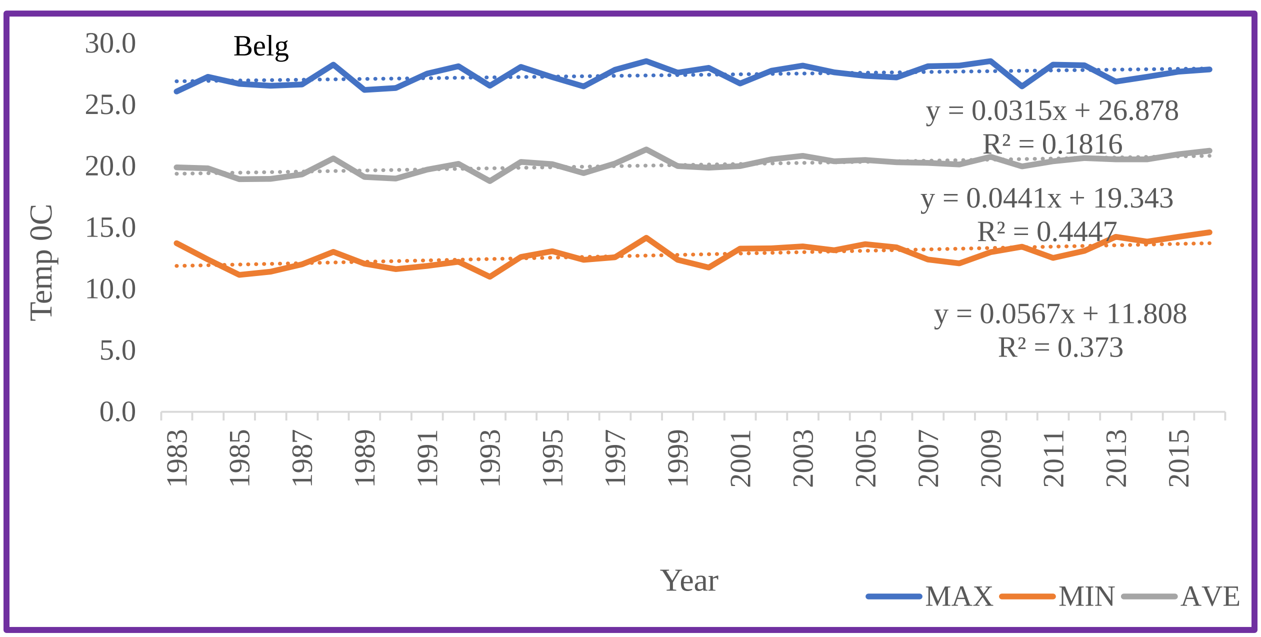
Annex 3. Annual maximum, minimum and average temperature



Annex 4. *Kiremt* maximum, minimum and average temperature



Annex 5. *Belg* maximum, minimum and average temperature



Annex 6. Data collection instruments: questionnaire and checklists

1. **Household questionnaire**

Woreda--

Kebele ---------------------------------- Garee___________________

A. Questionnaire used to elicit data about climate change adaptation strategies in crop and livestock production

Name of respondent---------------------------Questionnaire Number------------------------

Part I: Personal information

1. Age: (1) 20 – 40 ☐ (2) 41 – 60 ☐ (3) 60 and above ☐

2. Sex: (1) Male ☐ (0) Female ☐

3. Marital status: (0) Married ☐ (1) Single ☐ (2) Divorced (3) Widow

4. Educational status: 1. illiterate 2. 1-8 ☐ 3. 9-12 ☐ 4. Diploma & above ☐

5. Years of experience in farming: (1) less than10 years ☐(2) 10-25 years☐ (3) More than 25 years☐

6. Secondary occupation (Main): (1) Livestock ☐(2) petty trade ☐) apiculture ☐ (4) others ☐

Part II: Socioeconomic information

1. Size of farm (hectares) ________

2. Number of members in household______

3. Number of household members who work on the farm________

4. Farming system; (1) Crop production (2) Livestock production (3) mixed

5. Main source of household income: (1) Crop ☐ (2) Livestock ☐ (3) both ☐

6. What are the major crops you are producing?

7. Which are the major livestock you are rearing?

8. What is the total annual income from crop and livestock farm? (Eth. Birr) _____

9. Is your annual income/yield varies from year to year? 1. Yes 2. No

Answer question 10 and 11 if your answer is yes only

10. The annual yield/income 1. Increasing 2. Decreasing

11. What are the major reasons? 1. Shortage of rain 2. Excess rain 3. Erratic rain 4. Diseases

Part III: Institutional related information

1. Do you get information on rainfall and other weather actions? (1) Yes ☐ No ☐

If yes, from where? (1) Meteorological staff ☐ (2) Agric. Extension ☐ (3) Radio/ television ☐

2. Do you have access to market for your farm produce? (1) Yes ☐0) No ☐

3. Do you have ready access to credit facilities? (1) Yes ☐) No ☐

4. For what purpose do you use credit? 1. Fertilizer and improved seeds 2. uy livestock 3. Buy food items for family 4. Buy labor for agricultural activities

5. Do you have access to Agricultural Extension Agents & officers? (1) Yes ☐) No ☐

If yes, how many visits per month? (0) 1- 2 ☐) 3 -4 ☐2) More than 4 ☐

6. Do you belong to any farmer-based organization? (1)Yes ☐ (0) No. ☐If NO, why? ________________________________

7. Following from question 6, if YES, how many meetings do you clutch in a month? _________

Part IV: Trends of climate change as per household perception

Fill the right-column with the appropriate number (4) High ☐ (3) Moderate ☐

(2) Less ☐ (1) Not at all ☐

Description	**yes**	**No**
Perception of Rainfall Variability Indicators		
Little rainfall (rainfall amount decreases)		
Increase in rainfall amount		
Decrease in rainy days		
Increased in the intensity of rainfall		
The onset of rainfall become more unpredictable		
The cessation of rainfall become more unpredictable		
Drought occurrence frequency increase		
Flood after rain		
Perception of Temperature Variability Indicators		
Temperature increases		
Decrease in temperature		
No of hot days increase		
Number of warm nights increased		
No change in temperature		

Part V: Impact of climate change on production

1. Do you normally encounter challenges in the production due climate change? (1) Yes ☐ (0) No ☐

If yes respond to the following as 1. High 2. Moderate 3. Low.

No	Impacts	Yes	No
1	Complete crop failure		
2	Death of livestock		
3	Pest and disease		
4	shortage of fodder		
5	Flood		
6	Drought		
7	Shortage of water		
8	climate change induced migration		
9	Soil erosion		

Part VI: Adaptation to climate change

1. Do you adapt any strategies or measures to reduce the effects of climate change on your farming activities? (1) Yes ☐ (0) No ☐

2. If yes can you list the adaptation practices?

Where do you get the modern strategies or measures from? (1) Farmers training center/FTC ☐ (2) NGO ☐ (3) Others ______________________________

3. Choices of adaptation strategies;

Adaptation strategies	**Response**			
	Highly	**moderately**	**Less**	**not at all**
Crop rotation				
changing crop varieties				
Irrigation				
Crop spp diversification				
Farm diversification				
Soil conservation				
Income generating activities				
Agro forestry practice				
Changing in planting dates				

4. Actual adaptation practices being used. If your answer is yes write the specific practices.

Please select one adaptation strategies to climate changes which is the most comfortable for implementation in your farm.

Adaptation strategies	**Tick**
Use of climate change resilient variety (both crop and livestock)	
Changing of planting date	
Soil and water conservation methods	
Income source diversification	
Agroforestry practice	
Destocking and stall feeding	
Crop diversification	

1. Barriers of adaptation practices by the farmers (tick)

No	Description	N	%
1	Shortage of farm inputs		
2	Shortage of water		
3	Poor access to credit		
4	Insufficient extension services		
5	Lack of technology		
6	Poor market access		
7	Shortage of land		

Which of the following are key coping strategies during severe situations of climate variability?

2. Coping strategies

S/N	Description	Yes	No
1	Temporal migration for sell of labor		
2	Permanent movement from the area		
3	Sell of livestock		
4	Grain reserve		
5	Reduced frequency of meal		
6	Borrowing of food item/money		
7	Food aid		
8	Other (specify)		

Farmers Key Informant Interview (KII) checklist

1. What do you understand about the climate change and its impact on agriculture (in both crop and livestock sectors)?
2. How climate changes affect agricultural production and productivity in this area? Mention in order of importance
3. How do you response or adapt to the changing climate to improve agricultural production and their livelihood?
4. How do you observe the impact of climate change from time to time? What are existing short term coping strategies?
5. What are the major activities practiced by the community and individual farmers to reduce climate change and its impact on their livelihoods
6. What are the pros and cons of adaptation strategies practiced by the farmers on yield, crop quality and preferences? Complement from livestock sector as well
7. What are some of your challenges to adapt to changing climate?

Government staff (Agriculture and DRR)

1. Is there appropriate government structure in your office responsible for the climate change and its impact on the life and livelihood of the community?
2. What are key climate changes or variability related problems in Negelle Woreda
3. What are the existing plans in place to reduce the impact of climate change?
4. How do farmers response or adapt to the changing climate to improve agricultural production and their livelihood?
5. What are the barriers and commonly known challenges of adaptation practices in this area?
6. What are the pros and cons of adaptation practices in increasing production and productivity?

NGO working in the study area

1. Is your organization working on food security and climate change?
2. How do you understand the impact of climate change on agriculture and food security from your personal experience?
3. What is your organization role concerning agricultural production and food security in this community?
4. How long is your organization working with this community?
5. Which kebele is your priority area and why?
6. What are your planned major interventions to reduce the impact of climate change?

7. What are major challenges you are facing in implementing your program?

   Name________________________

   Name of NGO ___________________

   Role in the organization ________________________

<u>Focus Group Discussion Checklist</u>

1. What do you understand about the climate change? Compare with the past, current and your future anticipation.

2. What are the key impacts of climate change on agriculture and farmers' livelihood in this area?
   a. Impact on crop production

   b. Impact on livestock husbandry
3. Can you tell me adaptation strategies and practices used by farmers to curb the effect of climate on agriculture in this area?

   a. crop production

   b. livestock husbandry
4. Which adaptation strategies and practices are more effective/ efficient to reduce climate change and its impacts and why they are effective and efficient?
   a. crop production

   b. livestock husbandry

5. What are the barriers of adaptation practices? What do you suggest as a solution to improve it in the future?
   a. Impact on crop production

   b. Impact on livestock husbandry

6. Are there any emerging adaptation strategies used by farmer to reduce climate change and its effect on agriculture? Explain

Annex 7. Meteorological Data (1983-2016)

Rainfall, minimum and maximum temperature

- **Rainfall**

LON **38.70061**

LAT **7.479542**

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	8.0	10.4	49.7	93.4	153.8	26.6	106.5	139.2	148.4	45.2	8.7	0.0
1984	0.0	0.0	8.5	3.7	115.3	92.8	146.7	132.7	56.2	1.7	3.5	4.4
1985	3.2	0.0	21.2	74.7	99.5	30.2	167.3	129.1	73.0	9.5	0.2	2.2
1986	4.5	18.6	19.3	71.8	68.6	112.1	122.1	78.3	49.0	23.9	0.0	0.3
1987	0.4	22.8	131.5	90.9	176.6	29.7	69.8	100.2	59.2	31.7	0.0	1.1
1988	6.1	16.3	5.3	54.5	27.3	51.9	94.2	125.0	124.3	49.8	0.0	0.0
1989	10.1	91.8	64.8	107.0	14.0	79.6	79.9	101.6	120.0	21.3	0.9	28.7
1990	0.0	83.9	50.3	84.0	29.4	52.9	135.4	94.9	69.3	2.0	4.3	0.0
1991	0.8	31.5	93.3	2.8	20.2	46.9	130.9	70.1	71.5	4.8	0.0	0.3
1992	12.7	23.5	7.3	46.3	24.9	90.6	83.6	182.3	41.3	78.9	11.0	2.5
1993	19.4	44.0	3.9	79.0	81.2	56.4	118.9	119.1	104.0	47.6	0.1	0.0
1994	0.0	0.0	12.7	60.2	65.8	90.4	255.0	91.0	120.7	1.2	13.0	1.1
1995	0.0	5.5	17.7	115.3	30.1	27.1	102.6	118.0	63.0	1.6	0.0	7.7
1996	24.2	0.9	79.8	81.5	107.5	114.2	141.0	143.8	111.5	12.6	2.6	0.0
1997	9.8	0.0	38.2	74.1	44.9	108.4	99.9	120.2	53.0	102.2	23.1	1.2
1998	24.9	23.8	51.0	31.5	76.1	37.4	133.0	140.9	98.9	88.1	0.2	0.0
1999	2.9	0.7	37.6	18.7	70.8	115.8	114.2	77.3	106.3	142.5	0.0	0.2
2000	0.0	0.0	2.5	74.7	88.8	48.8	104.6	116.1	170.2	58.4	30.6	6.5
2001	0.0	13.3	135.1	37.0	147.6	128.0	142.0	108.1	127.3	27.2	0.1	1.7
2002	19.0	11.4	75.7	42.8	79.7	78.1	85.4	153.4	86.5	3.4	0.0	29.8
2003	11.6	9.1	59.1	124.2	10.0	79.4	159.4	132.1	133.8	3.4	9.4	12.6
2004	7.6	1.2	40.0	82.9	23.9	72.8	107.3	125.7	125.9	56.3	5.1	0.7
2005	25.1	0.7	49.9	118.1	107.4	47.6	149.1	82.8	83.3	8.4	11.7	1.3
2006	1.4	2.3	51.1	114.8	54.3	56.8	183.1	95.5	98.7	21.8	0.4	4.7
2007	9.6	14.8	22.2	54.8	77.1	68.1	122.4	116.9	143.3	9.0	0.0	0.0
2008	0.0	2.3	2.8	13.5	87.0	113.6	177.5	136.4	131.5	38.6	69.3	0.0
2009	5.6	1.0	8.8	11.1	50.6	47.3	112.5	62.0	60.4	82.4	1.5	7.7
2010	0.3	83.3	69.9	60.4	163.3	63.3	120.0	147.8	122.0	1.5	1.3	4.1

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	0.4	0.1	24.0	15.7	106.3	23.6	106.1	141.3	30.7	1.5	7.1	0.0
2012	0.0	8.9	14.5	38.0	15.9	116.3	170.0	126.0	150.4	1.5	0.9	0.1
2013	2.3	0.0	58.7	49.0	51.1	104.4	193.6	121.4	91.7	87.1	2.7	0.0
2014	0.0	9.0	23.7	24.8	92.8	13.7	88.8	78.9	74.4	55.6	1.1	0.0
2015	0.0	0.7	8.5	13.6	72.7	95.3	56.0	98.1	72.5	3.8	7.3	0.6
2016	1.8	0.2	18.4	246.5	65.4	72.3	107.2	51.1	43.9	37.0	5.5	0.0

- **Maximum temperature**

LON		38.70061										
LAT		7.479542										
Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	25.0	25.9	27.3	25.5	25.4	24.9	23.5	23.1	23.9	24.6	25.7	24.7
1984	25.7	27.1	28.1	28.6	25.1	23.9	23.4	23.6	24.0	26.5	26.5	25.9
1985	26.4	27.2	28.3	26.3	25.5	25.6	23.2	22.9	24.6	25.4	26.6	26.2
1986	26.3	27.1	27.4	25.9	26.2	24.2	22.8	24.4	24.7	26.1	27.1	26.3
1987	26.5	27.4	26.6	27.0	26.3	25.7	25.2	24.8	26.1	26.5	27.5	27.8
1988	27.3	28.1	29.3	27.7	27.8	25.3	22.3	23.0	24.1	24.8	25.7	25.6
1989	25.3	25.8	26.8	24.9	26.9	25.2	23.1	24.0	24.1	25.4	26.1	25.1
1990	25.9	24.9	25.7	26.2	27.2	25.8	23.6	23.4	24.7	26.0	26.8	26.3
1991	27.4	27.1	27.0	27.8	27.8	26.0	23.7	24.0	24.3	26.1	26.3	26.0
1992	25.9	26.4	28.8	28.1	27.5	26.0	24.1	23.2	24.4	24.8	25.5	25.9
1993	25.9	25.5	28.3	25.8	25.6	25.1	23.7	24.1	24.4	25.7	26.5	26.7
1994	27.5	28.5	28.8	28.3	27.1	25.0	23.0	23.2	24.8	26.3	25.7	26.0
1995	27.0	27.6	27.6	26.4	27.7	27.3	23.7	23.6	24.7	26.6	26.9	26.6
1996	25.4	28.3	27.4	26.3	25.8	23.9	23.5	23.7	24.8	26.3	26.2	25.9
1997	26.4	28.1	29.3	26.4	27.9	26.4	23.9	25.2	27.0	25.6	26.0	26.2
1998	26.4	27.4	28.1	29.7	27.8	26.7	23.2	23.1	24.1	24.3	25.4	25.5
1999	26.6	29.4	26.7	28.4	27.8	26.0	22.8	24.0	24.9	24.0	25.1	25.6
2000	26.7	28.2	29.6	28.1	26.3	25.5	23.6	23.2	24.2	24.7	25.3	25.8

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	25.9	27.8	26.2	27.7	26.2	24.3	24.0	24.0	25.2	26.4	26.1	26.9
2002	26.1	28.1	27.5	28.2	27.6	26.2	25.2	24.2	25.5	26.9	27.6	26.2
2003	26.4	29.0	28.8	27.2	28.6	26.0	23.0	23.8	24.7	26.8	26.7	25.2
2004	26.7	27.7	28.3	26.4	28.3	25.6	24.2	24.5	25.2	25.4	27.0	27.0
2005	26.8	29.1	28.3	28.1	25.6	25.3	24.1	24.9	25.4	26.4	26.4	27.1
2006	27.3	28.4	27.9	26.6	27.2	25.9	24.0	23.7	24.5	26.1	26.1	25.7
2007	26.7	27.6	29.1	27.7	27.6	24.6	23.8	23.7	24.5	26.2	26.2	26.0
2008	27.5	27.5	29.2	28.6	26.7	25.3	22.9	23.3	24.6	25.7	24.5	25.6
2009	26.2	27.9	29.4	28.0	28.3	27.6	24.6	24.8	26.2	25.9	26.8	26.0
2010	26.6	26.2	26.4	26.9	26.2	26.0	24.0	24.2	24.7	26.9	26.5	26.4
2011	26.9	28.5	28.2	29.4	27.2	25.9	24.5	24.0	25.2	26.3	26.4	25.3
2012	27.3	28.5	30.0	26.8	27.8	25.7	23.6	22.9	23.8	26.5	26.9	26.7
2013	26.4	27.9	27.9	26.5	26.2	24.9	22.3	22.5	24.3	25.3	25.4	26.2
2014	26.7	27.2	27.6	27.8	26.5	26.5	24.0	23.6	24.1	25.1	26.2	25.9
2015	26.2	27.7	28.3	28.1	26.8	25.6	24.7	24.5	25.4	25.6	26.7	26.2
2016	26.3	27.8	29.8	27.5	26.4	26.1	25.5	24.3	24.9	26.7	26.0	26.1

➢ **Minimum temperature**

LON 38.70061
LAT 7.479542

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	10.5	12.1	13.9	13.8	13.5	13.3	13.2	13.3	12.9	11.7	9.3	7.2
1984	7.7	7.1	10.7	12.9	13.6	12.2	12.8	12.5	11.9	10.0	9.9	7.3
1985	8.3	9.4	10.4	11.9	11.2	11.7	12.1	12.3	11.3	9.5	7.6	6.5
1986	7.8	10.0	10.5	12.3	11.5	12.1	11.6	10.9	10.6	8.9	6.6	6.0
1987	8.1	8.5	11.8	11.4	12.9	12.8	12.2	11.9	11.5	11.2	6.9	7.0
1988	8.1	10.7	12.7	13.3	13.0	13.9	14.5	13.1	12.1	11.0	7.4	7.7
1989	8.7	10.1	11.8	12.6	11.7	12.4	12.2	11.7	11.6	10.3	9.2	10.9
1990	9.5	12.1	11.5	11.7	11.7	11.5	11.5	11.0	11.9	9.8	8.6	7.8
1991	9.9	10.7	11.4	11.9	12.4	13.1	11.9	11.9	11.3	9.8	9.3	8.5
1992	11.0	12.2	12.0	12.5	12.2	12.6	12.0	11.9	10.8	10.6	8.8	9.0
1993	10.1	10.5	8.7	12.1	12.2	12.6	12.9	12.5	11.7	11.1	9.1	6.7
1994	8.0	9.5	11.9	12.9	13.0	13.4	13.4	13.3	12.4	9.9	9.0	7.4
1995	8.3	10.8	12.7	13.7	12.8	13.2	13.7	13.6	12.2	11.1	8.2	9.4
1996	11.3	10.2	12.0	12.6	12.5	13.1	13.1	12.9	12.2	10.1	8.8	7.8
1997	11.1	9.2	12.5	13.0	12.3	12.9	13.1	12.8	12.8	12.5	12.0	9.2
1998	12.3	13.7	14.1	14.1	14.4	13.2	13.1	13.2	12.3	11.9	8.4	5.8
1999	8.4	8.7	12.7	12.3	12.1	12.1	12.8	12.2	12.0	12.2	8.4	7.4
2000	7.8	8.0	10.1	12.7	12.5	12.4	13.2	13.2	12.4	12.0	9.6	8.2
2001	9.7	10.7	13.3	13.2	13.4	13.2	13.8	14.0	12.8	12.6	10.5	9.7
2002	11.8	10.9	13.1	13.2	13.7	13.7	13.4	13.3	13.0	11.6	9.9	12.2
2003	11.4	12.1	13.0	13.9	13.6	13.7	13.8	13.7	13.2	11.2	10.5	9.4
2004	12.5	11.7	12.1	14.3	13.1	13.6	13.4	13.4	12.8	11.1	10.0	9.4
2005	10.4	11.0	13.5	13.5	13.9	13.6	13.7	13.7	13.3	12.3	9.7	7.6
2006	11.0	13.0	13.0	13.9	13.2	13.7	13.9	13.6	13.1	12.5	10.1	10.8
2007	10.4	11.7	11.4	12.8	13.0	12.8	11.7	12.6	12.5	9.9	9.2	6.4

2008	9.4	10.3	10.5	12.6	13.2	12.7	12.3	12.6	12.7	12.0	9.2	8.6
2009	10.2	11.2	12.5	13.2	13.2	13.0	13.0	13.6	13.6	12.3	9.6	11.6
2010	11.3	13.3	12.6	13.5	14.2	13.2	13.2	13.4	12.1	10.7	10.0	9.9
2011	10.8	11.4	11.9	12.6	13.1	13.4	12.9	13.7	12.3	11.1	10.7	8.2
2012	9.5	9.8	12.2	13.3	13.8	14.4	14.4	14.1	13.6	11.9	11.6	11.2
Year/Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2013	11.7	12.1	14.0	14.3	14.4	14.4	13.9	14.2	14.4	13.2	11.6	9.1
2014	13.1	13.7	13.4	13.8	14.3	14.2	15.0	14.5	14.4	13.3	11.6	9.7
2015	12.1	13.5	14.3	14.2	14.2	14.2	13.8	13.9	13.9	13.4	13.1	11.3
2016	14.9	14.2	14.3	15.0	14.6	13.1	13.9	13.5	13.6	13.4	12.1	10.7