IMPACT OF CLIMATE CHANGE ON CROP PRODUCTION AND ADAPTATION STRATEGIES: THE CASE OF LEMO DISTRICT, HADIYA ZONE, SOUTHERN ETHIOPIA

M.Sc. THESIS

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This is to certify that the thesis entitled “**Impact of Climate Change on Crop production and Adaptation strategies: in Hadiya Zone, Lemo district**” submitted in partial fulfillment of the requirements for the degree of Master's with specialization in Climate Change and Sustainable Agriculture, and has been carried out by Temesgen Defar Dobamo , Id. No CCSAR/0011/2019, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the CCSA Msc program.

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STATEMENT OF AUTHOR

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DEDICATION

I dedicated this Thesis manuscript to my parents and my friends for their dedicated partnership in the success of all my life.

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LIST OF ABBREVATION AND ACRONYMS

CSA	Central Statistical Agency
FGD	Focus Group Discussion
GHG	Green House Gases
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
LDC	Least Developed Countries
MoFED	Ministry of Finance and Economic Development
NAPA	National Adaptation Program of Action
NMA	National Meteorological Agency
SPSS	Statistical Package for Social Science
UNFCCC	United Nations Framework Convention on Climate Change
LWADO	Lemo Woreda Agricultural Development Office
KII	Key Informant Interviews
NGO	Non-Government Organization
GO	Government Organization
FDREMoWR	Federal Democracy Republic Minister of Ethiopia Water Resource
LWANROR	Lemo Woreda Agriculture and Natural Resource Office report
LWFEDOR	Lemo Woreda Finance and Economic Development Office Report

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Impact of Climate Change on Crop Production and Adaptation Strategies: The case of Lemo district Hadiya Zone, SNNPR, ETHIOPIA

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ABSTRACT

Climate change is one of many challenges that negatively affect climate-dependent livelihoods. Agriculture in general and smallholder farming in particular is vulnerable to climate variability and change. The study area is potential for wheat and teff production, however, the yield is declining due to the climate change effect. This research aimed to assess the impacts of climate change on teff and wheat production and adaptation strategies implemented by the farmers in Lemo District, Hadiya Zone. This research designed to cross-sectional (one shot) and time series research methods were employed. *For this purpose 150 respondents were selected using multy-stage sampling technique from three kebele's. To collect data, interview schedule, key informant interview and focus group discussions instruments were implemented. Both descriptive statistics and econometric model were employed to analyze the collected data. About* 88.%) *of the respondents have indicated that the rain fall amount has decreased during the last three decades. Similarly, the meteorology data confirmed that the annual rainfall is declining by a rate of* 7.08 mm *annually over the past 29 years. The mean annual rain fall was 1143.7 mm and coefficient of variance was* 38.2% *which means highly variable based on degree of variability. Similarly,* 69% *of the respondent confirmed an increasing trend in temperature. According to the meteorology data, mean average temperature is increasing by 0.056^{o}C per annum. The teff and wheat producing farmers also found to practice several adaptation options including crop diversification* 38.7*%, selecting drought tolerant crops* 22.6*%, planting dates adjustment* 30.7*%, practicing soil and water conservation* 31.3*%, and supplemental irrigation* 14.7*% in response to climate impact on crop production. The marginal multinomial logit model /MNL/ results indicated that the choice of adaptation options used by farmers were significantly (P<0.05) influenced by age, education, farm size, access to extension service, credit and climate information. The overall analysis leads to conclude that despite the presence of awareness on climate change and its likely effects on livelihoods of the farmers, development intervention at local level were not systematically designed to address the problems of the resource poor farmers with regard to climate change effect. Therefore, an urgent need to work on strengthening the existing awareness, and timely dissemination of climate information and introduction and promotion of suitable adaptation option, to overcome the impacts of climate change on crop production.*

Key words: Adaptation, Climate change impact, Crop production, Multinomial logit model

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

Climate change is a global issue because it affects all countries in the world (Winsemius *et al.*, 2018; Vona, 2019). It is most distressful event posing tremendous negative impact on several sectors (IPCC, 2014).

Climate change is already putting extra pressure on agriculture and its effects are expected to become more severe in the future (Apata *et al.*, 2009; Lobell *et al.*, 2011; Rosenzweig *et al.*, 2014). The main challenge for agriculture in the twenty-first century is the need to nourish increasing numbers of people while conserving the on-going soil degradation and water depletion in the face of limited resources and growing pressures associated with an increasing global population and changing diets (Tubiello, 2012). Despite technological advancements that have already been reached, the agricultural system is still highly dependent on the climatic condition in many areas of the world (Müller *et al.*, 2011).

Climate change affects agriculture directly and indirectly. Directly, it affects by influencing weather variables such as rainfall, temperature, solar radiation, wind speed and humidity (Sowunmi, 2010; Daron, 2014). Indirectly, it affects through disease and pest outbreak as well as favouring the development of climate related diseases like malaria that affect the workforce (Newton *et al.*, 2011). Studies on global climate change indicated that developing nations are expected to withstand the worst of the associated damages (Ericksen *et al.*, 2011; Skoufias *et al.*, 2011).

Sub-Saharan Africa (SSA) is arguably the most vulnerable region to many unpleasant effects of climate change due to a very high dependence on rain-fed agriculture (Cooper *et al.*, 2008). Thus, the impacts of climate change are likely to fall unreasonably on poorer nations and on poorer households. Ethiopia is among the most vulnerable countries in SSA due to its great reliance on climate vulnerable economy (Conway and Schipper, 2011).

Ethiopian economy is an agrarian economy as agriculture comprises about 41.3% of GDP, 80% of export earnings, and employs more than 73% of the population (MoE, 2015). However, the performance of this sector is seriously eroded due to climate change induced problems. It is estimated that in Ethiopia, one drought event in 12 years lowers GDP by 7 to 10% and increases poverty by 12 to 14% (Makombe *et al.*, 2011).

Ethiopia is one the agrarian country whose main livelihood depends on agriculture as source of income. Farmers whose livelihoods depend largely on rain-fed agriculture face with different climate variability related problems (Atinkut & Mebrat, 2016). Condition such as being low economic development, inadequate infrastructure and lack of institutional capacity contributes in Ethiopia for being vulnerability to climate change. These conditions also lead country for land degradation and climate-related natural hazards (World Bank, 2011). Climate change is becoming a serious problem for Ethiopian farmer by affecting lives and livelihoods (Daze, 2014). The Government of the Federal Democratic Republic of Ethiopia (FDRE) is responding to the challenge of climate change through ratification of different policies.

The fact that climate has been changing in the past and continues to change in the future implies the need to understand how farmers perceive climate change and adapt in order to guide strategies for adaptation in the future. Some studies indicate that farmers do perceive that climate is changing and that they adapt to reduce the negative impacts of climate change (Mertz *et al*., 2009). Other studies show that the perception or awareness of climate change and selection of adaptive measures is influenced by different socio-economic and environmental factors(Semenza *et al*., 2008; Akter and Bennett, 2009).

In different part of the country, households adapt different strategies in order to tackle the effects of climate change related risks (Abate, 2016). Indigenous knowledge as strategy appears pertinent for sustainable development, addressing issues of protection of biodiversity and starting point for the construction of alternative agriculture in the rural communities. Besides, recognizing indigenous adaption strategies of communities can be valuable for decision-making processes and reduction of climate change hazards, which face the country's population (World Bank, 2011)

According to Abate (2016), communities utilize different adaption strategies. However, the researcher did not clearly show for which climate variable those indigenous adaption strategies were utilized. According to Sisay (2016) vulnerability of small holder farmers to climate change vary from district to districts based on adaptive capacity of farmers and natural resource endowment (like water). However, the researcher did not identified climate change variables and indigenous knowledge as adaption strategy for climate change.

In the Lemo district, rural Farmers are affected by climate change effects such as drought, flood and untimely rain; most of the households in this area are under the productive safety net program and many rural households have lost their means of livelihood due to recurrent drought and rain failure which are vulnerable to negative climate change impacts (Lemo Woreda Agricultural & Natural Resource Office, 2019). This research was conducted with the aim to assessing the trends of climate (temperature and rainfall) and impacts of climate change on crop production in Lemo District, Hadiya Zone. On top of this, understanding adaptation strategies choice decision-making process at grassroots level is important to inform policies intended at promoting successful adaptation strategies for the agricultural sector particularly.

1.2 Statement of the problems

Ethiopia is among the developing country whose economy is dominated by subsistence farming with high vulnerability to climate change effects (Negash, 2013). The rain fed agriculture in the country is exposed to the effect of failure of rains or occurrence of successive dry sign during the growing season, which could lead to food shortage (MoARD, 2010).

The major factors responsible for the low productivity include dependence on traditional farming technologies, soil erosion caused by deforestation and overgrazing, weak complementary services such as extension, credit, marketing and infrastructure, and climatic factors such as drought and flooding. These factors reduced adaptive capacity or increased the vulnerability of farmers to future change in climate and negatively affect the performance of the already weak agricultural production (Temesgen, 2010).

In my observation and information obtained from District of Agriculture and Natural Resource Office; the study area has a potential to produce teff and wheat crop, but the area is affected by climate change. The rain does not come on time or the rain stops right after planting, and unreliable rainfall in the rainy seasons, causing drought and reduction in crop yields.

Similarly, Teff and Wheat producing farmers in the study area are constrained by the multiple environmental challenges, like flooding and crop pests and disease, which directly affecting crop yield and food availability. As site specific issues require site specific knowledge, it is therefore, very important to undertake study at local levels to forward possible solutions. Although several researches has been carried out in the study area, there is no in depth study conducted on assessing the impacts of climate change on Teff and Wheat production and efforts of adaptation choices.

Smallholder farmers in the study area have been responding to climate change through different adaptation strategies. However, there is no empirical data that supports the existing adaptation strategies practiced by them in the area. Adaptation strategies vary within communities and even within individuals. Hence this study was intended to inquire site specific information on climate change and its impact on crop production of household farmers and asses' major adaptation strategies implemented to cope with the adverse climate change effects in Lemo District Hadiya zone ,SNNP Region.

1.3. Objectives

General Objective

To assess the impact of climate change on crop production and adaptation strategies practiced by farmers in the Lemo district, Hadiya Zone.

Specific Objectives

1. To assess the trend of temperature and rainfall in the study area for the period of1990 to 2018.
2. To assess the impacts of climate change and variability on the major cereal crops (wheat and teff) yield,
3. To assess farmer's perception towards climate change.
4. To identify determinant factors that influence farm households adaptation strategies towards climate change.

1.3 Research questions

In order to achieve the above specific objectives this study attempts to answer the following research questions:

1. What is the trend of rainfall and temperature in period of 1990 to 2018 for the study area?
2. What are the impacts of climate trends on major cereal crops (wheat and teff) yield?
3. How do farmers perceive the concept of climate change?
4. What are the factors that influence farm households' to implement climate change adaptation strategies?

1.5 Significance of the Study

The findings of this study are important for further improvement of adaptation strategies to climate change and it is contribution to the agricultural development in the study area. This study are conducted at micro level so that it is very interesting to use as guideline document for further research in this study area and to the same climatic, socioeconomic and geographical areas. In addition, it may provide significant contribution to local and national government use it as an effort to minimize the negative effects of climate change intended of policy at grassroots level. In addition, the findings of this study may be important for all development partners interested in issues of climate change such as researchers, extension workers, policy makers, education institutions, NGOs and planners of adaptation strategies to climate change by creating awareness and make understanding about issues of adapting to climate change.

1.6 Scope and limitation of the Study

The scope of the study is limited to Lemo district, Hadiya zone, and to assess the level of rural farmers' towards climate change and adaptation strategies practiced at local level and to assess some of the factors that determine rural farmers' perception towards climate change and adaptation mechanisms. This is due to the assumption of shortage of time and budget constraints for further study of the rest of the factors.

1.7. Organization of the Thesis

This thesis has five chapters. The first chapter deals with the introduction part which includes the background of the study, statement of the problem, objectives, research questions, significance of the study, limitation of the study and organization of the thesis. The second chapter is all about review of related literature. The third chapter describes research methodology with brief description of the study area, sample size and sampling procedure, data type, source and data collection methods, data analysis tools, specification of the model and finally presents definition of variables and working hypothesis. The fourth chapter mainly focuses on result of descriptive statistics and multinomial logit model output of determinants of adaptation strategy choice of the farmers. Finally, the fifth chapter summarizes the major findings and made conclusion and recommendations based on the key findings.

CHAPTER TWO

2. REVIEW OF RELATED LITERATURE

2.1. Concepts and Definitions

Climate is among the most important environmental aspects that the human community is gifted with. Climate implies the long-term average of the individual weather conditions that communities experience every day (Davies, 2011).

Climate change is defined as any change in climate over time, whether due to natural variability or because of human activity. It is already putting extra pressure on agriculture and its effects are expected to become more severe in the future (Lobell *et al.*, 2011; Rosenzweig *et al.*, 2014).

Climatic variability means the rise and fall that occurs from year to year and the statistic of extreme conditions such as severe storms or unusually hot seasons (ISDR, 2010). In most of developing countries where the majority of the population has the dependence on natural resources based livelihoods, this can an impact on socio economic and difficulty to the overall threats to sustainable development. It also means that, variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events.

Adaptation to climate change: adaptation to climate change as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities **(**Heidelinde *et al.*, 2016). Adaptation can be planned or autonomous. Planned adaptation is implemented before the impacts of climate change are observed. This type of adaptation can respond to specific projected impacts of climate change. Autonomous adaptation does not constitute a deliberate response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. This type of adaptation often occurs at the community and local level. Action and policies by governments, international organizations and other stakeholders can often influence the autonomous adaptation action undertaken directly, for example by increasing the resources available on the ground, or indirectly through measures that shape the incentives, knowledge sharing and capacity available for autonomous adaptation.

As we know climate change is increasingly recognized as a critical challenge to ecological health, human well-being and future development (IPCC, 2007). It is one of the main environmental challenges that affect both the current and future generations. The global community took initial steps in 1992 (United Nations Framework Convention on climate change-UNFCCC) and then Kyoto Protocol in 1997 by formulating rules to limit global greenhouse gas emissions. However, these efforts have produced only modest gains in a handful of countries. The resulting emission reductions are nowhere near, what they should be in order to halt or slow the pace of climate change (GLCA, 2009). In addition, local community based adaptation practice is urgent issue particularly in developing countries. However, little is known about local community perception worldwide. Building on this notion, this research explores public understandings of climate change in Lemo *district*.

2.2 Global climate change trend

Rising fossil fuel burning and land use changes have emitted, and are continuing to emit,increasing quantities of green house gases into the Earth's atmosphere. These green house gases include carbon dioxide (CO2), methane (CH4) and nitrogen dioxide (N2O), and arise in these gases has caused arise in the amount of heat from the sun with held in the Earth's atmosphere. This increase in heat has led to the green house effect, resulting in climate change.The main characteristics of climate change are increases in average global temperature (global warming); changes include cover and precipitation particularly overland; melting of ice caps and glaciers and reduced snow cover; and increases in ocean temperatures and ocean acidity due to sea water absorbing heat and carbon dioxide from the atmosphere (UNFCCC, 2007).

As a result of global warming, the type, frequency and intensity of extreme climate change events, such astropical cyclones (including hurricane and typhoons),floods,droughts and heavy precipitation events, are expected to rise even with relatively small average temperature increases. Changes in some types of extreme events have already been observed, for example, increases in the frequency and intensity of heat waves and heavy precipitation events (Meehl *et.al.*, 2007). Change in the state of the climate that could be identified (e.g.using statistical tests) by changes in the mean and/ or the variability of its properties,and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC ,2007). According to the United Nations Frame work Convention on Climate Change (UNFCCC, 2009), climate change referred to director in direct activities of humans, leading to change in global atmosphere components and create changes of natural climate variability observed over comparable time.

Climate change is expected to have adverse ecological, social and economic impacts.

2.3 Impact of Climate change in Sub Sahara Africa (SSA)

Climate change affects many institutions and productive sectors including agriculture, forestry, energy, and coastal zones, across the sub-Saharan Africa (SSA).The economy of developing nations is more affected by climate change, particularly due to their greater exposure to climate shocks and also because of their limited adaptive capacity. However, no country is immune (World Bank, 2013) and the developing countries, mainly Africa are being the most vulnerable to climate variability and change (ACCRA, 2011 and Mortimore, 2011). Poor agricultural productivity is one of many factors driving vulnerability of developing countries.

Climate change will create large incremental risks (UNDP, 2007) and a small incremental risk of more droughts can lead to large human development setbacks. Studies indicate that Africa's agriculture is negatively affected by climate change (Mertz *et al*., 2009); particularly sub-Saharan Africa is likely to face the most severe challenges on food security due to climate change and other pushing factors of global change. Many farmers in Africa are likely to experience net revenue losses as a result of climate change, particularly as a result of increased variability and extreme events. Dry land farmers, especially the poorest ones, are expected to be severely affected. Kurukulasuriya and Mendelsohn (2006a) estimated that a 10 percent rise in temperature will lead to visible loss net incomes that could be gained per hectare; that is on average 8.2 percent for rain fed production. On the other hand, irrigated farmers are likely to have better gains in productivity (as higher temperatures support yield increment in most of Africa as long as sufficient water is available). This suggests that irrigation might be an effective adaptation strategy.

2.4 Impact of Climate Change and variability in Ethiopia

Currently climate change and variability is already impose significant challenge to Ethiopia by affecting food and feed production, water and energy supply, health, poverty reduction and sustainable development efforts (Abebe, 2007). Furthermore, extreme weather events, such as droughts, floods, or landslides, may cause death to domestic animals. Livestock suffering and death often means that farmer's wealth is decreased and they lose much of their resources (Pettengell, 2010). The adverse impact of climate change are not only these particularly climate change and variability also has significant impact on rain fed agriculture (IPCC, 2007). According to IFPRI (2009), agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns increase the likelihood of short run crop failures and long run production declines. The overall impacts of climate change on agriculture are expected to be negative.

Agriculture plays a dominant role in the economy of Ethiopia, contributing about half of the GDP, provides employment opportunity for majority of working force and generates considerable foreign exchange earnings (MoFED, 2015). Despite its high contribution to the overall economy, this sector is challenged by many factors, of which climate related disasters like drought and flood (often causing famine), are the major ones (Temesgen *et al.*, 2009).As a result of this, the country becomes highly vulnerable to climate change and variability. It has been indicated that climate change and variability could have significant impact in Ethiopia for various reasons; its economy mainly depends on small scale rain fed agriculture, which is very sensitive to climate variation.

Large part of the country is arid and semiarid and is highly prone to desertification and drought. It has also a fragile highland ecosystem, which is currently under stress due to population pressure (NMA, 2007). Abate (2009) argued that, climate change affects agriculture and its effect is pronounced on the subsistence farmers, which have low adaptive capacity. Under dry-land conditions where the biological productivity is low and majority of the poor are found, climate change is manifested not only by increasing temperature but also through changes in hydrological cycles characterized by both increased droughts and flooding (Thomas *et al*., 2007). Generally, climate changes will most likely increase poverty in Ethiopia (Mideksa, 2010). Long term trends towards reduced rainfall, and recurrent droughts, have played a role in weakening of Ethiopian economy (USAID, 2004).

2.5 The impacts of climate change on crop production in Ethiopia

Different studies conducted on climate change impacts over the past decades in Ethiopia have reported mixed relationships between climate change and crop production. Alemayehu and Bewket (2016) and Bewket (2009) reported that the existence of significant correlations between climate change and crop production, while Admassu (2004) identified no significant correlations between total annual, main rainy season (Kiremt) and small rainy season (Belg) rainfall, and production of those crops (barley, maize, sorghum, teff and wheat) in most parts of the country. In light of these contradictory views, it is necessary to further quantify the impact of climate change on crop production at the local level.

The previous assessments of climate change impacts on crop production in Ethiopia were either at the national (Deressa and Hassan 2009 ; Admassu 2004) or larger scale such as the East African regional levels (Bryan et al. 2009 ; Thornton et al. 2009). There are only a few studies at sub-national levels within Ethiopia exist (e.g., Alemayehu and Bewket 2016 ; Muluneh et al. 2015).

crop production is low which is attributed to several factors amongst which frequent droughts, declining soil fertility, poor agronomic practices, limited use of inputs, insufficient access to technology, lack of credit facilities, poor seed quality, incidence of diseases, pests and weeds (Taffesse et al., 2011)

The impacts of climate variability and change on crop production are more negative, but they can vary substantially between crops (IPCC, 2015). Crop production is highly sensitive to climate. It is affected by long-term trends in average rainfall and temperature; inter annual climate variability, shocks during specific phonological stages, and extreme weather events (Gornall et at., 2010).

Crop production is the most significantly influenced by Climate variability year to year, even in high yield and high-technology agricultural areas (Kang et al., 2009). Similarly, the crop yield can be increased with irrigation application and precipitation increase during the crop growth; meanwhile, crop yield is more sensitive to the precipitation than temperature. The growing period will reduce, and the planting date also needs to change for higher crop production with climate change.

Maize, wheat, rice and barley, which were once rare plants, have become the dominant crops on earth and staples in human diets (FAOSTAT, 2014). Soil degradation is another critical concern. In agricultural ecosystems depleted of soil organic carbon, it will be increasingly difficult to produce higher yields. In soils that have already experienced significant losses of soil organic matter, increased fertilization does not usually generate a net sink for carbon, because the production, transport and application of fertilizer releases higher amounts of carbon dioxide (Corsi *et al*., 2012).

Challenges facing wheat and teff production such as climate change, increased cost of inputs, increased intensity of abiotic (drought, heat) and biotic (diseases and pests) stresses, on the other hand, make the wheat demand-supply chain very volatile and at times lead to social unrest. It is projected that demand for wheat in developing countries will increase by 60 per cent in the year 2050 (Rosegrant, 2010).

2.6 Teff and wheat crops production in Ethiopia

Ethiopia's major staple crops include varieties of cereals, pulses, oilseeds, and coffee. Grains are the most important field crops and chief element in the diet of most Ethiopians. Five major cereals (teff, wheat, maize sorghum, and barley) are the core of Ethiopia's agriculture and food economy. There has been substantial growth in cereals, in terms of area cultivated, yields and production since 2000, but yields are low by international standards and overall production is highly susceptible to weather shocks, particularly droughts. Thus, both raising production levels and reducing its variability are essential aspects of improving food security in Ethiopia, both to help ensure adequate food availability, as well as to increase household incomes (Alemayehu et al.,211).

The most important wheat producing countries in SSA are Ethiopia, South Africa, Sudan, Kenya, Tanzania, Nigeria, Zimbabwe and Zambia in descending order. Ethiopia accounts for the largest production area (1.7 Mha) followed by South Africa (0.5 Mha) (ICARDA, 2016).

Teff and wheat are the two major food crops grown in the central Ethiopian highlands. Teff is staple food for over 60 million Ethiopians. Wheat is one of the five top crops grown in Ethiopia, and the country is the second largest wheat grower in sub-Saharan Africa (ICARDA, 2016). Crop residues mainly from teff and wheat remained main sources for livestock feed (World Bank, 2011).

In Ethiopia teff and wheat can grow under wide and diverse agro-ecologies. Even though there are areas where the crops are grown during the short rainy season (Belg), teff and wheat are mainly cultivated during the main rainy season (Meher). Teff and wheat crops are mainly produced in Amhara, SNNP regions, Oromia, and with smaller quantities in the Tigray.

In the area teff and wheat cereal crops are mainly produced and grow widely. Wheat is one of the five top (teff, wheat, maize sorghum, and barley) crops grown in In the area.

2.7 Farmers' Perceptions to temperature and precipitation

Perception is the process by which we receive information or stimuli from our environment and transform it into psychological awareness (Agbarevo (2013). Peoples in any community have their own knowledge about their surrounding environment. They perceive there is an increase in temperature and decrease in precipitation but their perception about climate change not evidenced from weather monitoring stations (Maddison, 2006). In most parts of Ethiopia, people perceive declining in rainfall and increased in frequency of drought but it did not confirmed from weather station. Research report from Oxfam (2010) indicated that

observations on metrological stations lack congruence with local farmers' perception. This lack of congruence could be due to the fact that farmers' assess rainfall in relation to the needs of particular crops at particular times; small changes in quality, onset, and cessation of rain over days or even hours can make a big difference, whereas meteorological data is more likely to measure totals and larger events. (Maddison, 2006) also argued that this lack of congruence between farmers' perception and meteorological records could emanate from the analysis of short term climate data and/or due to averaging of record from wider areas.
Perception level towards climate change is differ by sex, education level, age and farming experience, agro ecology and many other factors. According to (Maddison ,2006) educated persons are assumed to be more perceived than uneducated because education is associated with access to information on climate change, improved technologies and consequences on productivity.Asfaw and Admassie ,(2019) also argued that female-headed households are often considered to be less likely to get information about new technologies and take risky businesses than male-headed households. Similarly, Amadou et.al, (2015) argued that, the more experience farmers have, the more likely they are to claim that temperatures have increased and the less likely they are to claim there has been no change.

In developing countries like Ethiopia, the common approach to studying the perception of farmers to climate change is based on comparing farm survey or farm group discussion results with data records from meteorological stations. Although informative in terms of understanding the level of awareness of farmers and the possibility of validating farmers' claims of perceptions of change against meteorological data, these approaches do not explicitly identify factors influencing awareness of climate change (Deressa et al., 2011).

The study of Paulos Asrat and Belay Simane (2017) and Deressa et al. (2011) revealed that farmers living in the dry lowland area perceived more change in climate than farmers in the wet lowland. This could either be associated with the repeated drought events occurring in the area in recent years or could be linked to various environmental changes that cause reduced water availability and agricultural yield in the dry lowland areas. With regard to adaptation, better awareness and use of adaptation measures is revealed in the wet lowland condition as compared to the dry lowland. This difference between the two locations may call for further heightening of intervention to facilitate the scene for enhanced climate change perception and adaptation.

Smallholder farmers' perception plays a big role for successful implementation of adaptation strategies to mitigate climate change impacts on agricultural practices concerned (Bisrat K, Gizaw M, Gerrit H, 2017). Nevertheless, drawing from behavioral research, many have argued that climate-change experience and its perception play an important role in adaptation and mitigation behavior as well as in supporting policy actions (Howe, *et al*., 2013). The reason for this observation is that people who perceive or experience change in the climate system indicated that farmers strongly perceive a change in climate with a reduction in rainfall that contrasts with the climate records. The study only focused on rainfall and attributed the differences between peoples‟ perception and recorded rainfall data to the increase of farmers‟ "need for rainfall" and possible errors in rainfall data recording. Another study by Deressa *et al*. (2011) looked into the perceptions of adaptation to climate change using the Heckman selection model on a sample of 1,000 households in five regions in Ethiopia. They found that farmers‟ perceptions are related to age, wealth, and information on climate change, social capital and agro ecological settings.

A large percentage of Ethiopian farmers perceived changes in rainfall and temperature, but have not made any adjustments to their farming practices (Bryan et al. 2009). This might be due to many reasons. The main barriers to adaptation cited by farmers in Ethiopia were amongst others lack of access to or shortage of land, labor, credit, and information on adaptation methods, poor potential for irrigation, and financial constraints (Bryan et al., 2009, Deressa et al., 2009). Shortage of land has been identified as a barrier to adaptation.

A more recent study by Kassie *et al.* (2013) examined farmers' perception in Central Rift valley and Kobo valley areas based on a household survey of 200 farmers. They used qualitative data gathered through key informant interviews and FGDs. Their findings show that farmers in both areas perceive a change in their local climate and implement various adaptation strategies that are mostly related to changing farming practices.

2.8 Adaptation to Impact of climate change/ variability

Adaptation strategies are methods that local people used to adjust themselves with the existing change to minimize and adapt the impact of climate change (Negatu, 2016).
Adaptation is adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Change management focuses on modifying behaviors over the medium-to-long term to avoid

disruptions or declines in global and local food supplies due to changes in temperature and precipitation regimes, and to protect ecosystems through providing environmental services**.**

Adapting to climate change involves managing risk by improving the quality of information and its use, providing insurance against climate change risk, adopting known good practices to strengthen the resilience of vulnerable livelihood systems, and finding new institutional and technological solutions (Killmann, 2008).

As agriculture is directly affected by climate change; adaptive strategies and technological practices are becoming increasingly important issues for promoting development (UNEP, 2011).

Ethiopia is on its way to setting up a national panel on climate change with functions more or less similar to that of the Intergovernmental Panel on Climate Change (Wondwossen, 2014).Despite the challenges, Ethiopia hopes to capitalize on its current economic growth by becoming more resilient to the impacts of climate change while developing its economy in a carbon neutral way.

2.9 Determinants of Adaptation Strategies to Climate Change and Variability

Farmers' adaptation to climate change is influenced by frequent and more accurate climate information from meteorological center, formal and informal institutions, access to credit and extension information, amount of seasonal rainfall, geographical location, household size, age and literacy of household head Yesuf *et al.* (2008). Nhemachena and Hassan (2007) found that markets, access to electricity and technology, land ownership and sex of the household head significantly influence household choice when adapting to climate change while Gbetibouo (2009) cited poverty, lack of secure property rights, lack of savings, farm size, lack of technical skills and off-farm employment as additional barriers to adoption of climate change adaptation strategies. Deressa *et al.* (2009) urged that type of crop produced, local temperatures and amount of precipitation also determines the choice of households when adapting to climate change

2.10 Farmers adaptation efforts in Ethiopia

According to Asrat and Simane, (2018), the use of improved crop varieties, agroforestry practices, soil conservation practices, irrigation practices, and adjusting planting dates are the most important adaptation strategies by smallholder farmers. However, adaptation decision is location-specific and influenced by key drivers such as socioeconomic, environmental, and institutional factors (Abirham, 2016). Accordingly, the following are among the adaptation strategies implemented.

Mixed farming

In the drier areas of Ethiopia, cropping is largely difficult and certainly risk full both with regards to production and environmental degradation (Cooper et al., 2019). In these areas pastoralism dominates. In other areas of the country, crop production can be mixed with pastoralism and risk can be reduced this way. (Ariel et al., 2012) stated that, owning livestock may buffer the farmers against the effect of crop failure or low yields during harsh climatic conditions. If the farmers have these types of resources it may function as an important safety net and also contribute to extra income, because animal products can be sold, and livestock can also be sold during difficult periods. Selling of livestock is identified as a coping mechanism to climate variability and extremes in Ethiopia (Abebe, 2007).

Selling of assets

Sale of agricultural tools and other assets are identified as coping mechanism to climate variability and extremes in Ethiopia. Farmers may sell some of their resources, and this can be an important extra income, and can also function as a safety net and a coping mechanism. Material assets within the household can be seen as buffer against difficult periods (Meron et al., 2018).

Crop diversification

This strategy seeks to avoid risks of total crop failure rather than maximizing yields of one particular crop. In Ethiopia, crop diversification is widespread. Crop diversification is the most commonly used method to overcome climate changes in Ethiopia. Greater use of different crop varieties in the same season could be associated with lower expenses and ease of access by farmers (Kristiansen, 2011). (Legesse B. et al., 2013) noted that crop diversification together with soil and water conservation and water harvesting practices were commonly used climate change adaptation strategies in eastern Ethiopia.

Crop diversification is the most commonly used method to overcome the impact of climate change and variability in Ethiopia (Temesgen et al., 2009). Diversification is identified as a coping strategy that has evolved to deal with both expected rainfall uncertainty and seasonal fluctuations in rainfall (Cooper et al., 2019).

Off-Farm Activities

Farmer’s vulnerability to climate change can be mitigated if they have off-farm work on the side. (Meron et al., 2018) Found that, sale of labor was a successful coping strategy among farmers in the Upper Awash Basin of Ethiopia during drought periods because, it reduces dependency on agriculture. Traditional and contemporary coping mechanisms in Ethiopia also include increased petty commodity production (Abebe, 2007). Off-farm activities can for instance be selling of honey, or home made products like mattresses, hot food, beverages, and ropes. Where opportunities exist, working as wage laborers and trading commodities are also common in Ethiopia (Cooper et al., 2019).

Tree Planting

(Temesgen et al., 2009) identified that, tree planting to be one of the major methods used by farmers to adapt to climate change in the Nile Basin of Ethiopia. Vegetation like trees and grass are valuable because the roots protect the soil from erosion. Trees are valuable during floods and droughts, and many trees together will give lower temperatures in the near area, a fresh air, and also shadow.

Soil and water conservation

In Ethiopia, they have often used different kinds of soil and water conservation strategies since around 1990, and soil and water conservation strategies have probably developed much since that time. Soil and water conservation strategies are mainly used because of soil degradation and soil erosion, and because farmers due to this, want to rehabilitate their fields. These activities are increasingly important today because climate changes to some extents are accelerating these processes (Kristiansen, 2011).

One of the adaptation strategies found in (Temesgen et al., 2009) research in the Nile Basin of Ethiopia was soil conservation. Many areas of Ethiopia are mountainous and crop fields are rarely flat. Often they are located in a hill side or in a valley side. This creates extra demand for soil and water conservation to prevent the soil and rainwater from being washed away.

2.11 Adapting to Climate Change at Farm Level

The adaptation strategies listed are mainly agricultural practices that can be performed at farm level in order to moderate negative impacts of climate change stimuli and/or to benefit from the opportunities such impacts bring. Several adaptation options on farm level exists i.e. diversifying the farming system, the use of new crop types and varieties, the use of new livestock species and breeds, the adjustment of planting dates, altering cropping location, improved land management, expanded rainwater harvesting, and improved water use efficiency. However, implementation of these individually will only have limited effect and therefore a combination of several of the options should be applied. Furthermore, it is important to high light that not all adaptations may be beneficial to an agricultural system in the long-term.

Crop Adaptation Option

In areas where climate change leads to an increase of drought frequency and duration, an adaption option for the farmer is to use crop types or varieties that are more droughts tolerant and can withstand temperature and water stresses better (Howden *et al*., 2007). Another adaptation strategy is to avoid critical crop growth stages to coincide with periods of harsh climatic stresses. This can be ensured through altering the length of the growing period by varying planting and harvesting dates and/or by changing to crop types with a more appropriate thermal time is an adaptation option (Howden *et al*., 2007). For example using crop types with a shorter growing period than the previous crop can be applied in areas where climate change results in an earlier end of the rain period. This strategy will similarly ensure that the new crop is fully matured and thus not in a critical growth period when the period of rain deficit starts. Irrigation is another method to adapt to changes in precipitation and generally seen as effective method to increase agricultural productivity in rain-fed systems by supplementing rainwater during dry periods (Gebrehiwot & van der Veen, 2013). However, broad-scale irrigation can have destructive side effects and can therefore also be viewed as mal-adaptation.

2.12 Empirical review on Adaptation Strategies to Climate Change

Evengelista (2011) examined farmers' adaptation to climate change in Chivi district of Zimbabwe based on a cross sectional data collected through a household survey. This study was conducted with the major aim of examining the factors that influence farmers' decisions to adapt to climate change. A logit model was employed in the study. The study revealed that education level of the household head; farm size household, access to credit; farming experience and exposure to information on climate change all positively and significantly influence farmers' decisions to adapt to climate change.

Study on farmers' perception and adaptation to climate change in sub-Saharan Africa revealed that most of farmers in sub-Sahara Africa are aware that the continent is getting warmer, and precipitation or rainfall patterns have changed. In addition, the precipitation patterns are different for different regions in Africa. The result indicates crop diversification, planting different crop varieties, changing planting and harvesting dates, irrigation, planting tree crops, water and soil conservation techniques are the major adaptation to the changing of

pattern of precipitation. In this case the year of farming experience, household size, year of education, access to credit, access to extension service and off-farm income are among the significant determinant of adopting climate change adaptation measures (Juana *et al.,* 2013).
Negash Mulatu (2011) analyzed households' preference for five different types of climate change adaptation strategies i.e. multiple cropping, livestock, soil conservation, irrigation, and changing planting dates in North Showa Zone using rank-ordered logit model revealed that, multiple cropping is the most preferred and frequently used adaptation strategy to climate change, while livestock production is the least preferred. In addition, he revealed that gender, age, farming experience and education level of the household head, household size, and farm and nonfarm income, farm size and farm distance to homestead, agricultural extension services and access to climate forecast information, farmers' perceptions on temperature and rainfall affect farmers' preference for the climate change adaptation strategies.

Temesgen *et al.* (2008) in their studies analyzing the determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Using a multinomial logit model to determine the smallholder farmers' adaptation measures to climate change. Revealed that the methods identified included use of different crop varieties, tree planting, soil conservation, early and late planting and irrigation. The results from the discrete choice model employed also indicate that the level of education, gender, age, wealth of the head of household, access to extension and credit, information on climate, social capital, agro ecological setting, and temperature all influence farmers' to choice adaptation method. The main barriers included lack of information on adaptation methods and financial constraints. Moreover, whose analysis reveals that age of the household head, wealth, information on climate change, social capital, and agro ecological settings have significant effect on farmers' perceptions of climate change.
Temesgen *et al.* (2009) Analyses the determinants of farmers' choice of adaptation methods in the Nile Basin of Ethiopia using cross sectional data from a survey of farmers. They are used a multinomial logit model to analyse the determinant of farmers' choice of adaptation strategies. In this study found that the adaptation methods are changing planting dates, using different crop varieties, planting tree crops, irrigation, soil conservation and not adapting. According to the finding, the most common adaptation method was use of different crop varieties while irrigation was the least common method. The result indicated that the reasons for not to adapting are lack of information on climate change impacts and adaptation

technology, lack of financial resources, labor constraints and land shortages. The levels of education, age, sex, household size of farmers' were to be significant determinants of adaptation to climate change in the study area.

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

Similarly, the finding of Belaineh *et al.* (2013) on smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, western Hararghe, Ethiopia. Investigating the determinant factors influencing adaptation strategies to climate variability and change. Found the adaptation strategies were crop diversification and the use of soil and water conservation practices, integrated crop and livestock diversification, engaging in off-farm income activities and rainwater harvesting. The result of the MNL model revealed that agro-ecological location, sex, family size, plot size, off-farm income, livestock holding, frequency of extension contact and training are the determinant of factors influencing adaptation strategies.

A study conducted by Tagel (2013) in three districts of Tigrai, northern Ethiopia was focused on the farmers' perception of change in climatic attributes and the factors that influence the farmers' decision to choice adaptation measures to climate change and variability. He used multinomial logit model to determine the factors that influence farmers' choice of adaptation measures to climate change. The results revealed that level of education, age, and wealth of head of household; access to credit agricultural services; information on climate, and temperature all influences farmers' choice of adaptation. Moreover, lack of information on adaptation measures and lack of finance are the main factors inhibiting adaptation to climate change.

Aemro *et al*. (2012) analyzed determinants of farm level climate change adaptation in Babile district of east Hararghe Zone using multinomial logit. Showed that sex of the household head, age of the household head, education of the household head, family size, livestock ownership, household farm income, non/off-farm income, access to credit, distance to the

market center, access to farmer-to-farmer extension, agro ecological zones, access to climate information, and extension contact have a significant impact on choices of climate change.
The empirical literature review indicates that the determinants of adaptation choices differ from place to place. This implies that there is a need for location specific study about the determinants of climate change adaptation options, so that appropriate measures are taken to reduce its adverse effects. Therefore, studying at micro level farm household in different agro-ecological zone is appropriate to make policy implications. So that, this research intended to study on micro level impact of climate change on crop production, community perception and adaptation strategies to climate change by taking in Lemo District as a case study

2.13. Conceptual framework

The study uses the following framework to conceptualize and understand or perceive climate change and climate change factors and its impacts on teff and wheat production and adaptation strategies.

Studies targeted the assessment of climate change impacts showed that climate component, institutional, physical and socioeconomic characteristics of households farmers plays the important roles in addressing the levels of impacts on agriculture in general and on crop production in particular (Deressa and Hassan, 2009; Kurukulasuriya and Mendelsohn, 2008).

Climate change is change of rainfall and temperature. Demographic, socio-economic and institutional factors are among the factors that affect adaptation strategy. Adaptation strategy are crop diversification, using soil and water conservation and use of drought tolerant crops.

The original data from conceptual framework was tells about economic impacts of climate change on teff production and adaptation strategy. I modify these original conceptual framework by own assumption because, original data tells specific only economic impacts of climate change on teff production and adaptation strategy don’t included impacts of climate change on crop or teff and wheat production. Because my original data was tells about impacts of climate change on crop production and adaptation strategy practiced by farmers, so that I modify these original data of conceptual framework their own assumption.

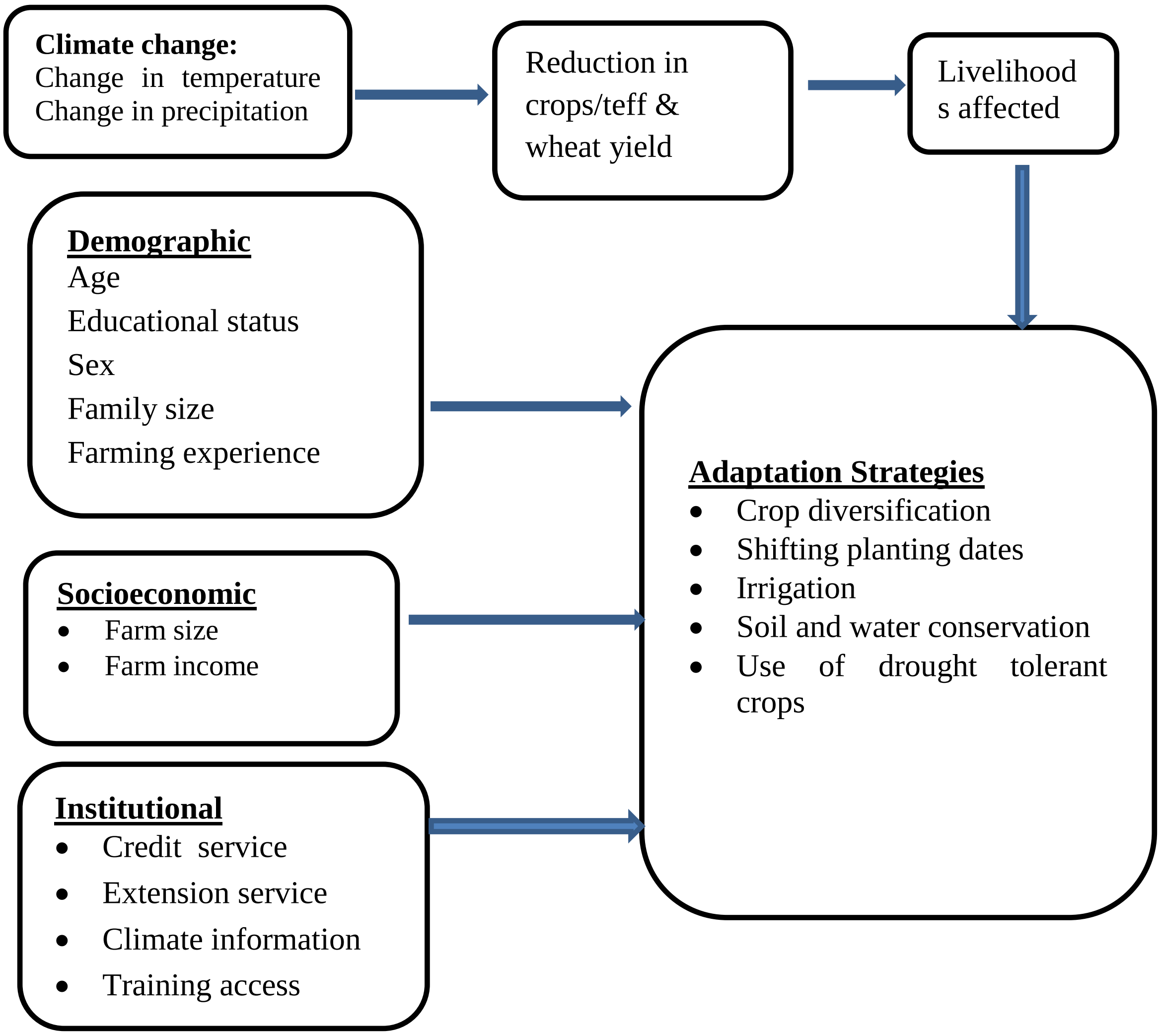

Figure 1 Conceptual framework of impacts of climate change on teff production
Source: Modified from Kebede, (2013)

CHAPTER THREE

3. RESEARCH METHODOLOGY

In this chapter, brief description of the study area, map, data sources and types, sampling techniques, methods of data collection, methods of data analysis, specification of multinomial logit model and finally, definition of variables hypothesized are presented.

3.1. Description of the Study Area

3.1.1 Location

Lemo district is one of the seventeen districts in Hadiya zone. It is bordered on the South and Southeast by the Kembata Tembaro zone, on the Southwest by Duna and Soro districts , the West by Gombora, and on the Northwest by Misha, on the Southeast by Shashogo districts . Astronomically, it roughly lies between $7^{0}31'$-$7^{0}37'$ North latitude and $37^{0}48'$- $38^{0}54'$ East longitude (LWFEDOR, 2019).

Its population reaches 118,594 (CSA, 2007). By 2016 based on the census report projection, it has increased to 133,974 from which 65769 men and 68205 women.

Figure 2 shown the map of Ethiopia and SNNP, Hadiya Zone and the study district and sampled kebeles.

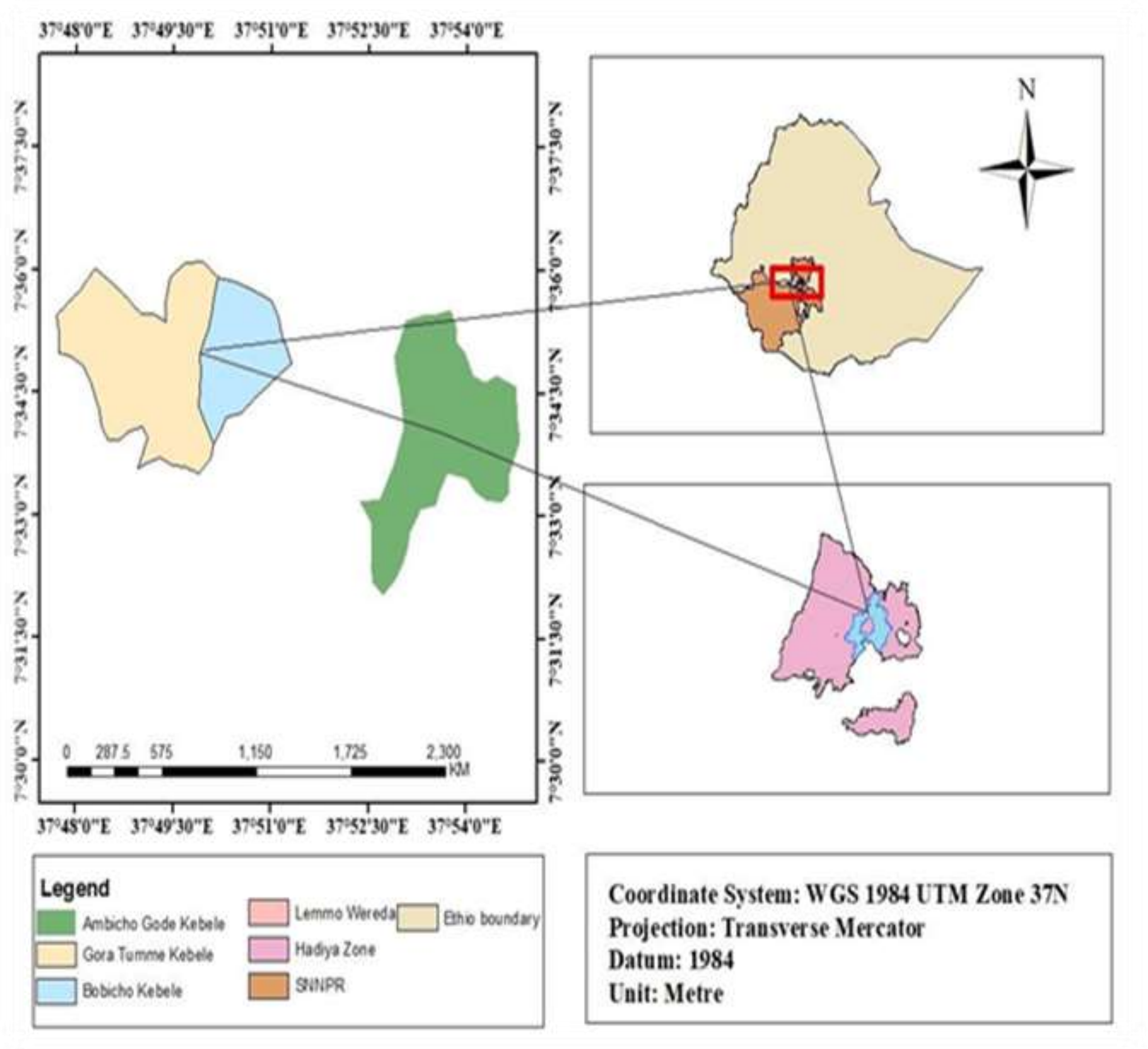

Figure 2 map of study area

Source; Done by ARC GIS Software (2019)

3.1.2. Topography and climate

The altitude of the study area range from 1700 to 2400 meters above sea level, most of the district falls in the wet midland and highland (*dega*). The income of the residents in this district is based on subsistence mixed farming. Currently the rural farmers of the districts exposed to food insecure and start using aid from the government and non-governmental organization (LWANRO, 2019).

Annual rainfall of the district ranges from 700mm-1300 mm. Distribution of rainfall varies from one season to another and is characterized by bi-modal rainfall distributions. Hence, there are two rainy seasons "*Belg*" (spring) and "*Kiremt*" (summer). "Belg" (winter) is the short rainy season that lasts between February and May. "Kiremt" is the longest rainy season and occurs between June and September. The highest rainfall occurs during this season especially in July and August. The mean annual temperature ranges from 21.6 °C to 23.8 °C.

3.1.3. Land use

The current land use can be categorized broadly into three categories; Arable land covering the largest proportion of the district with about 84.3%, grazing land covering 10.5% and Forest 5.2%. The dominant activities under land use pattern in the study area include cultivation of perennial crops such as enset, stimulants (coffee, chat), timber (eucalyptus).Whereas the annual food crops, including cereals (wheat, teff, maize, sorghum barley), pulses (beans, soybeans), and root crop (potato). A very small fraction of farmers produces vegetables or fruits. These crops are grown mainly in homestead gardens or where irrigation exists (LWANRO document, 2019).

The wide diversity in climate, topography and vegetation cover in the study area has given rise to marked variations in soils, even within relatively small area. As farmers' classification, the dominant soil types are red-brown to red clay soils on undulating land to steeping lands including the rolling plateau. These soils are relatively fertile and productive than grayish soil types which dominated the flat to undulating lands. The common soil types are Vertisol, Cambisol, Rigosol (LWANRO document, 2019).

3.2. Study Design

Cross sectional (one shot) and time series research methods were employed in this study with mixed approach research design that is the use of both qualitative and quantitative approaches. Time series methods were used to analyse trends of the three decades of rainfall, temperature data and crop yield data.

3.3. Sampling methods and Procedures

Multi-stage sampling techniques were used with a combination of purposive and random sampling techniques to select district, sample kebele and households. Out of the 17 districts in Hadiya zone, Lemo district was purposively selected because they were teff and wheat crops growing areas and vulnerable to climate change factors like unreliable rainfall in the rainy seasons, bringing drought, reduction in crop yields, floods, and soil erosion. There has been an increase in temperature which disturbs the physiology of crops and the soil system on which they produced.

To select sample kebele administrations, with consideration of budget and time constraints, three sample kebele's out of thirty three rural kebele's namely Gora-tume, Bobicho and Ambicho-gode were selected using simple random sampling method because, the kebeles are homogeneity on climatic condition.

Sample size determination

Out of the total 1,120 household heads in the three kebeles, 150 sample household heads were selected randomly using a sample size determination formula. To compute estimation of population proportion in case of finite population the following formula was suggested by (Kothari, 1990) cited in Demisse, (2018).

This study was also adopted this formula to determine sample size of survey respondents.

$$n = \frac{(Z)^2 * p * q * N}{(e)^2 \ (N-1) + (Z)^2 * p * q}$$

Where:

"n" stands for estimated sample size taken from total household farmers in sample kebeles,

Z stands for Z score (as per table of area under normal curve for the given confidence level of 95%),

P is proportion of population to be included in sample size of 0.13, and "q" is estimate of the proportion of the population to be sampled (1-p = 0.87).

"N" stands for total number of HH in three kebeles of the study area

e = acceptable error (allowable error) - in this case it would assumed to be 5% (0.05)

Substituting this numbers and computing the process by using the above formula it gives:

$$\mathbf{n} = \frac{(1.96)^2 * 0.13 * 0.87 * 1{,}120}{(0.05)^2 (1{,}120-1) + (1.96)^2 * 0.13 * 0.87}$$

$$= 150$$

Based on the above formula, the sample size for the study is 150 household heads. Sample size for each kebele was determined through sampling with probability proportional to size technique.

Table 1. Proportion of respondents across the three sample Kebeles

Kebeles	Total number of household heads	Sample household heads from each kebele
Gora-Tume	400	54 = 400/1120*150
Bobicho	330	44
Ambicho-Gode	390	52
Total	1120	150

Source: Field survey, (2020)

After calculating sample size for each sample kebele, an individual sample household heads (respondents) in each sample kebele were selected using systematic random sampling technique. This kind of sampling method is the most practical way of sampling to select every K^{th} item on a list. The sample household heads were drawn for each kebele administrations, from the list of names from kebele administrations after a certain sampling interval (K). The interval can be identified by calculating k value through the following formula, Which is determined by dividing the total number of households by the predetermined sample size of each selected kebele; (k^{th} interval) which is($\mathbf{k} = \frac{\mathbf{N}}{\mathbf{n}}$).

Hence, N is total household in each sample kebele, K *is* the sampling interval and ‘n ‘is the sample size.

Accordingly, the total number of households (1,120) were divided by the sample size (150), it gives seven i.e. $\mathbf{k} = \frac{\mathbf{1120}}{\mathbf{150}} = 7.4$). So that the n^{th} value is seven. Selecting one case from seven cases from listed sampling frame and getting one random number between one and seven as a starting point and continuing by adding sample respondents within 7^{th} interval from list of names of households from selected respective kebele’s until total sample size can reach 150. This kind of sampling method can be taken as an improvement over a simple random sample in as much as the systematic sample is spread more evenly over the entire population. It is an easier and less costly method of sampling and can be conveniently used even in case of large population.

3.4. Data collection methods and data sources

Both Primary and secondary data source were used for this study. Primary data in this study were collected from focus group discussion, key informant interview and sample household heads. Secondary data were collected from published and unpublished sources such as office report, census report, documents, internet, Meteorology, and CSA to supplement analysis of impacts, and climate change adaptation.

Focus group discussion: Focus group discussion (FGD) helps to generate data on group dynamics, and allows a small group of respondents to guide by a skilled moderator, to focus on key issue of the research topic (Mwanje, 2001). Six respondents in each kebele involved in FGD selected based on their knowledge on the present and past environmental, social and economic status of the study area. At each *kebele*, one focus group discussion was held. The focus group discussions were made with member of selected educated person, local elder, female, and young farmers of the sample *'kebele's*. Each focus group discussion was composed of 6 individuals. The main purpose of the focus group discussion was to understand impacts of climate change, its cause and farmers responses strategies. The major discussion topics were the local community understanding about climate change and its cause, major hazards and their impact and adaptation strategies and barriers to employ them effectively.

Key Informant Interview: Key Informant Interviews (KIIs) are aimed to obtain detail information on the issues specifically, change of temperature and rainfall on teff and wheat crops, Which groups of people are more vulnerable, main effect of climate change on teff and wheat crop production in woreda/village/kebele. To get detailed information, the researcher used semi structured interview method because of its flexibility and makes clear any time when there is ambiguity. The key informant interview is conducted with development agents (3), model farmers (3) and 1 woreda agricultural development office representative, about the cause and impacts of climate variability in the study area.

Household survey: It is the commonly used approach in various data collection activities. For this study it was the major source of data. (Structured questions) were prepared to collect data on major research objective areas such as, impacts of climate change on crop production, and adaptation strategies of farmers in face of climate change and variability and key challenges they faced to adapt and also socio economic and demographic characteristics of respondents were included in the questionnaire.

3.5. Description and operationalization definition

3.5.1. Dependent variables

Adaptation strategies: It is the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (IPCC, 2012).

The adaptation choices for this study are based on asking sample households the actions they take to counter balance the negative impact of climate change and variability these include, use drought tolerant crops, crop diversification, using irrigation ,using soil and water conservation practices, and adjusting planting dates. Thus, the dependent variable in the model is a categorical variable taking a discrete value of 1, 2, 3, 4, and 5 representing the above choices.

Crop production: is the most significantly influenced by Climate variability year to year, even in high yield and high-technology agricultural areas (Kang et al., 2009). Similarly, the crop yield can be increased with irrigation application and precipitation increase during the crop growth; meanwhile, crop yield is more sensitive to the precipitation than temperature. The growing period will reduce, and the planting date also needs to change for higher crop production with climate change.

3.5.2 Independent variables

Independent variables are those variables which are expected to have influence on the dependent variables. The independent variables that are hypothesized to affect positively or negatively on community farmer's adaptation decision of various factors:-

Age of the household head (AGE): This is a continuous variable measured as the number of years of the farmer household. According to Deressa et al. (2011), the age of the head of the household represents experience in farming and studies have indicated that experienced farmers are more likely to perceive climate change. Age of the household head increases, the person is expected to acquire more experience in weather forecasting and that helps increase in likelihood of practicing different adaptation strategies to combat climate change Deressa *et al.* (2008); Ajibefun and Fatuase (2011).This variable is expected will be negatively associated with local people's adaptation to climate change.

Gender of the household head (GENDER): This is a dummy variable, indicating the sex of the household head. A value of 1 represents if the household is female or 0, if male. Male-headed households have better access for information than female households to, which helps for adoption of climate change perceive and adaptation strategies. Therefore, male status of household head is positively correlated with adoption of climate change perception and adaptation strategies (Temesgen, 2008). Moreover, Tenge and Hella (2004) argued that having a female head of household may have negative effects on the adoption of soil and water conservation measures, because women may have limited access to information, land and other resources due to traditional social barriers.

Household size (HOSIZ):

This is a continuous variable and the total family member of the household. It is assumed to represent the labour input to the farm. Large number of family member can adopt the effect of climate change easily (Hassan and Nhemachena, 2008). Croppenstedt *et al.* (2003) argue that households with a larger pool of labor are more likely to adopt agricultural technology and use it more intensively because they have fewer labor shortages at peak time. This study hypothesized that households with large families may have either negative or positive relation to the using soil and water conservation, crop varieties or planting different crops, shifting planting dates, irrigation and improving crops and livestock as adaptation strategies to climate change.

Education level of household head:

It is a continuous variable measured by years of schooling in grades completed. Education level is believed to be associated with access to information on improved technologies and higher productivity (Norris and Batie, 1987). Literate increases the probability of adapting to climate change. This could possibly, literate farmers who are more likely to respond to climate change by making best adaptation option based on his preference and influences individual decision-making as it tends to reduce farmers' risk aversion (Aemro *et al*., 2012) and (Gutu *et al.* (2012). In addition, literate farmer are able to acquire and process information easily which may lead to more adoption of technology (Maddison, 2007) argues that education diminishes the probability that no adaptation is taken. Therefore, education status was hypothesized to have positive influence on the use of different climate change adaptation strategies. Therefore, this study hypothesized that education level of the household have a positive or negative influence on farmers‟ decision to use climate change perception & adaptation strategies.

Annual farm income of household (AIHH):

This is a continuous variable, which measures the amount of annual farm income obtained from sale of crop and livestock or livestock products. Families with more annual farm income have more capacity to adapt and perceive to climate change (Temesgen, 2006). This could be obvious because adaptation to climate change is capital intensive and hence increased income will encourage the investment capacity on adaptation options. In addition, Farm income of the household has a positive and significant impact on conserving soil and using improved crop varieties adaptation options (Temesgen *et al*., 2008).

Hence, increase in the availability of family income is expected to have positive influence to farmer's decision in adapting to climate change. Thus, for this study farm income was hypothesized to affect positively/negatively the use soil and water conservation, crop diversification, shifting planting date, drought tolerant crops and irrigation practices as adaptation strategies to climate change.

Access to training (ACTRA): It is a dummy variable taking the value 1 if the farmer has access to training related to the shock of climate change, 0 otherwise. Participation in climate variability and change related training programs enhances awareness of farmers about the impact of climate change. (Isabirye *et al.*,2010) indicated that training on adoption technologies increases the use of soil and water conservation practices and other adoption technologies. Thus, for this study access training was hypothesized to affect positively the use of climate change adaptation strategies.

Access to credit availability/ (CRED): This is a dummy variable indicating 1 if the farmer has access to credit 0, otherwise. The availability of credit is important for the farmers' in order to make adaptation strategies. Access to affordable credit increases financial resources of farmers and their ability to meet transaction costs associated with various adaptation options they might want to take (Nhemachena and Hassan, 2007). Credit used by the farmers to introduce new technology, to buy improved crop, fertilizers and oxen. Access to credit significantly influences the farmer to adapt to climate change strategy Temesgen *et al., (*2009), Aemro *et al.* (2012) and Gebre *et al.* (2015). Thus, for this study, access to credit was hypothesized to affect positively or negatively the use soil and water conservation, crop diversification, shifting planting date, drought tolerant crops and irrigation practices as adaptation strategies to climate change.

Extension service (EXTEN): This is categorical variable, which represent if farmers' get agricultural extension service weekly, monthly, half in the year, and yearly. This is a formal service and plays a great role that affects for farmers' to adapt strategies in response to climate change. It is imagine that time of contact with extension agents will increase farmers knowledge of climate change adaptation. Therefore, that, farmer who have an access to contact extension agents would have a better chance to adapt to climate change (Juana *et al.,* 2013). Thus, for this study farm extension service was hypothesized to affect positively/negatively the use soil and water conservation, crop diversification, shifting planting date, drought tolerant crops and irrigation practices as adaptation strategies to climate change.

Farm size (FARMSIZ): this is continuous variable which measured in hectare. Farm size is the total landholding of the farm household that is used for farming activities. This variable is measured in hectares. Aklilu *et al.* (2007) and Ajibefun and Fatuase (2011) and Seid (2014) argue that the bigger the farm size, the more likely the farmer use suitable climate change adaptation options. Therefore, its expected sign will be a negative for the farmers' who are used adaptation method and perception to climate change.

Farming experience (EXPER): Farming experience is the total number of years the respondent farmer who has experience in farming and the variable is continuous. The more experienced the farmer is likely to employ adaptation measures that reduce the effect of climate change on his/her agricultural activities. Hassan and Nhemachena (2008) contents that it is farming experience that matters more than merely the age of the farmer when it comes to adaptation and perception to climate change.

Access to climate information (INFOC): This is dummy variable indicating 1 if the household head access to climate change 0 other wise. Access to information on climate change through extension agents or other sources creates awareness and favorable condition for adoption of farming practices that are suitable under climate change. Having accurate information on climate change is not an easy task. The presence of well-functioning weather stations and proper processing of weather data and dissemination of weather forecasts as well as acceptance of the information by users is assumed to influence adaptation efforts to climate change Ayesha, *et al., (*2012), Aemro *et al.* (2012). This variable is also expected a positive sign for the farmers' who use adaptation method to climate change.

3.6. Methods of data Analysis

Both descriptive statistics (qualitative and quantitative collected data) and Multi nominal logit model (adaptation options chosen by farmers and determinants of farmers' adaptation choices to climate change) were used to analyze the collected data. Descriptive statistical techniques such as mean, standard deviation, coefficient of variation, percentages, frequency were used along with collected data dealing with farmer's perception on climate change, meteorological and CSA(central statistical agency) data. Multi Nominal logit Model were used to analyze adaptation options chosen by farmers and determinants of farmers' adaptation choices to climate change. SPSS version 20 was used to analyze descriptive results, Excel sheet used to analyze patterns and trends of rainfall, temperature and CSA data, whereas STATA version 14.2 was used to analyze result of Multi nominal logit model. Data which were obtained from key informant and FGDs were analyzed using narration.

Econometric model specification

In this study, the determinants of farmers' adaptation decisions to climate change were analyzed using a multi nominal logit (MNL),(Kurukulasuriya and Mendelsohn, 2008).The model was used to analyze the choice of farmers adaptation strategies and what factors determine those choices. The MNL model was used based on the previous literature on determinants of farmers' adaptation to climate change (Deressa *et al.*, 2009). This model suits to such type of analysis as it permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories. However, the model requires that households are associated with only their most preferred option from a given set of adaptation strategies. Unbiased and consistent parameter estimates using this model need to assume independence of irrelevant alternatives that requires the probability of using a certain adaptation method by a given household is independent from the probability of choosing another adaptation method. According to (Dasgupta, 2014) collecting and using only the most preferred adaptation option for each household risks underemphasizing the known importance to smallholder farmers of using multiple adaptation strategies but the approach has allowed a high level of specification of the relations between adaptation strategies and underlying socioeconomic variables. The model is specified as follows.

Let Y denote a random variable with values {1, 2, 3…J} for a positive integer J and X set of variables (Deressa, 2011). In this study, Y is a dependent variable and represents the adaptation alternatives (strategies) from the set of adaptation measures, whereas the X represents the factors that influence choice of the adaptation strategies which contains household attributes as described in hypothesis, and P1, P2…Pj as associated probabilities, such that P1 + P2 + … + Pj = 1. This tells as how a certain change in X affects the response probabilities P(y = j/x), j = 1, 2…J. Since the probabilities must sum to unity, P(y = j/x) is determined once the probabilities for j = 2…J are known.

$$P(y = 1/x) = 1 - (P2 + P3 + \cdots Pj) \ldots\ldots (1)$$

In the MNL model, it is usual to designate one as the reference category. The probability of membership in other categories is then compared to the probability of membership in the reference category. Consequently, for a dependent variable with j categories, this requires the calculation of j − 1 equations, one for each category relative to the reference category, to describe the relationship between the dependent variable and the independent variables. The choice of the reference category is arbitrary but should be theoretically motivated. The estimation of MNL model for this study was conducted by normalizing one category which is named as "base category" or "reference estate." The adaptation measures are grouped into 4(four) because farmers used more than one strategy, and the base category is crop diversification. The theoretical explanation of the model is that in all cases, the estimated coefficient should be compared with the base group or reference category (Gujarati, 2004). The generalized form of probabilities for an outcome variable with j categories is:

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

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

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

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

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

Before running the model, it is useful to look into account the problem of multi co linearity among the independent variables. Variance Inflation Factor VIF or VCC (Xi) was used to test the degree of multi co linearity among continuous variables. Thus, a measure of multi co linearity associated with variance of inflation factor is defined as: -

VIF or VCC (Xi), $=(1 - {R_i}^2)^{-1}$……………………………………….......................... (4)

Where, R^2 is the multiple correlation coefficients between explanatory variables. VIF shows how the variance of an estimator is inflated by the presence of multicollinearity. As R^2 approaches 1, the VIF approaches infinity. That is as the extent of co-linearity increase, the variance of an estimator increase, and in the limit it can become infinite. On the contrary, if there is no co-linearity between independent variable VIF will be 1 (gujarati, 2004).

4. RESULTS AND DISCUSION

This chapter discusses the finding of the fieldwork of this study. It is divided into four sections. The first section discusses demographic, institutional and socioeconomic characteristics of sample respondents. The second section identify and discusses Trends of climatic patterns. The third section identifies and discusses impacts of climate change and variability on teff and wheat crops yields. The fourth section identifies and discusses farmer perception towards climate change and adaptation strategies using by the farm household farmers.

4.1. Demographic and socio-economic characteristics of the respondents

Of the total respondents, 61.3% were male-headed household and 38.7% of them were female-headed households. With regard to age, 59.4% of respondents were in a productive age group that is, between 25-65 years old (Table 2).

As shown in Table 2, out of the total respondents, 52% are illiterate, and only 5.7% completed higher education. This was less probably to help them to make sensible decision and adoption of new changes with regard to the farming activities. The literacy status determines readiness (willingness) of households to accept new ideas and technologies and enhance ability of farmers to cope with climatic hazards (Temesgen et al., 2008). This is because education is an indispensable tool to easily understand climate information to adjust and develop adaptive capacity to the changing climate.

Of the total sample respondents, 53.3% had a farming experience of more than 20 years. More experienced farmers may have better information to evaluate the impacts of climate variability and change on crop production as well as implement the adaptation strategies (Hassan and Nhemachena, 2008). The mean farming experience was 29.6 year (Appendex 5) this implies that farmers with high years of experience should be more efficient, have better knowledge of farming conditions and climatic situation, thus likely to take up adaptation strategies than farmers with little years of experience. Therefore, the farming experience is among the factors determining the adaption capacity of the farmers (Getahun, 2016).

Table 2 Demographic characteristics of the respondents, (n= 150)

Variables	Frequency	Percent
Gender		
Male	92	61.3
Female	58	38.7
Education level		
Illiterate	63	52.0
Read and write	40	26.7
Primary education completed	28	8.7
High school completed	11	6.9
Higher education completed	8	5.7
Farm experience		
Less than 5 year	17	12.0
6-10 years	40	26.0
11-20 year	13	8.7
More than 20 years	80	53.3

Source: Own field survey, 2020

The result of the household interview indicated that majority (67.3%) of respondents in the study area have no access to credit while only 32.7% have access to credit(Table 3). This implies that farmers in the study area have not adequate finance service to purchase the necessary inputs and other associated equipment. This will be the major barriers to implement adaptation strategy against climate change.

As depicted under Table 3, of the respondents 28.7% have accesses to extension services whereas, the majority 71.3% poorly visited by extension agents. Adequate extension service have a positive relationship with the adoption of agricultural technologies since extension agents transfer modern agricultural technologies and agronomic practices to farmers, it help them to reduce the negative effect of climate change on crop production (Juana *et al.,* 2013).

According to the survey result 63.3% of household farmers have access to training while 36.7% of household farmers have not access to training in the area.

According to the survey result, 22.7% of household farmers have access to climate information whereas 77.3% of them poorly access to climate information. In agreement with the interview result, participants of FGDs also stated that to reliable information about seasonal forecast of the weather condition and climate change is necessary to predict the coming weather condition, and to take measures in order to reduce the shock. The presence of well-functioning weather stations and proper processing of weather data and dissemination of weather forecasts as well as acceptance of the information by users is assumed to influence adaptation efforts to climate change (Ayesha, *et al.*, 2012).

Regarding the land holding status, nearly half of the HHs 43.3% have < 0.5 ha of farm land and 0.1% have more than 2.1 ha and above. Bradshaw et al. (2004), reported that land holding are both small scale in size which make them less economically feasible, and fragmented here and there which can adversely affect agricultural performance and land management because travel to and from home require longer time and effort to use different climate change adaptation strategies.

Table 3 Institutional and socio economic characteristics of respondents, (n= 150)

Variables	**Frequency**	**Percent**
Have access to credit	49	32.7
Do not have access to credit	101	67.3
Access to extension services	43	28.7
No access to extension services	107	71.3
Access to training	95	63.3
No access to training	55	36.7
Access to climate information	34	22.7
No access to climate information	116	77.3
Farm size/landholding size(in ha)		
< 0.5 ha	65	43.3
0.51 – 1	50	33.3
1.1 – 2	20	13.3
2.1-3	12	0.08
More than 3	3	0.02

Source: own filed survey, 2020

4. 2. Trends of climatic patterns in the study area

Based on the time series analysis, major trends of climatic patterns in terms of rainfall and temperature, which would affect crop production, are included in this study. Three decades climatic data such as rainfall, maximum and minimum temperature were obtained from the National Meteorology Agency (NMA). While the crops yield data were obtained from CSA and the district agriculture office.

4.2.1 Annual rainfall trend and change in the study area

The results of the current study showed that average annual rain fall of the study area in the years 1990-2018, ranged from 791.1 mm to 1299.5 mm. The analysis also showed that, the mean annual rain fall for those years is about 1143.7 mm (Figure 2), with the coefficient of variation (CV) and standard deviation (SD) of the 38.2% and 437.0 respectively **(**Appendix-1). The mean annual rainfall of the study area was decreased by 7.1 mm yearly (Figure 2). The rain fall of the study area has also shown annual variability and erratic over the past 29 years. Analysis of the rainfall records at Meteorological stations revealed that there is a general declining trend of the annual rainfall during the past 2 to 3 decades.

According to the climate trend analysis the driest year was 2015, which contains the minimum rain fall of all years and the wettest year was 1998. Annual rain fall is below average in the years 1990-1991, 1994, 1999, 2001, 2004, 2011-2013, 2015 and 2017(Figure 2). The study area had been suffering from shortage of rainfall in the above eleven years, while the remaining eighteen years demonstrated seldom heavy and erratic rainfall. Therefore, agricultural production in the area was adversely affected by the annual rainfall variability of the area in the last three decades in the study area. This finding is also supplemented by all participants of Focus group discussion and key informant as there were changes in rainfall timing, amount and distribution in the area over the past 29 years.
In line with this, the findings from national and regional level rainfall trends analysis reported a decreasing trend in Ethiopia (Belay, 2014).

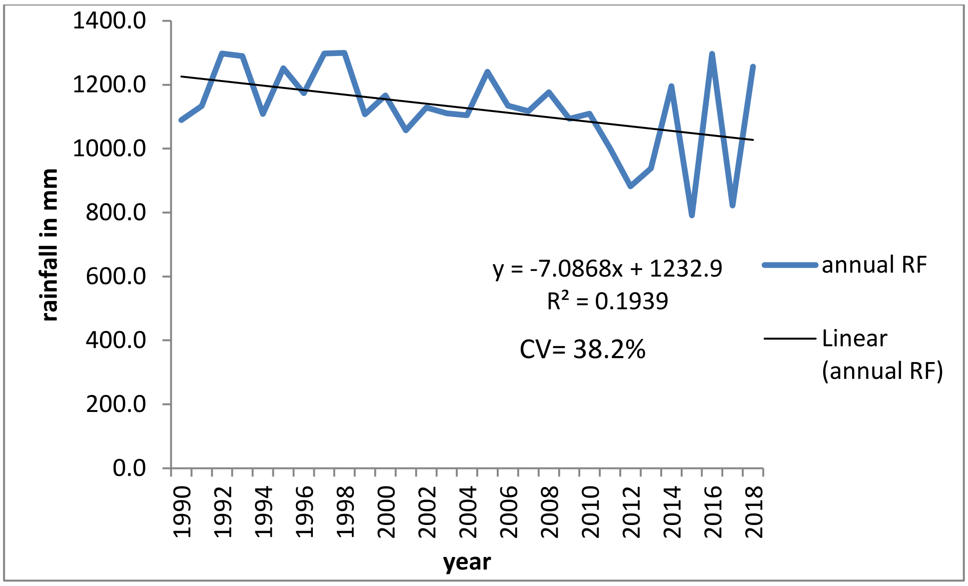

Figure 3 Annual rainfall variations in the study area, R^2 shown coefficients of determination, CV shown degree of variability.

Source: Sketched using NMA data (2019)

4.2.2 Seasonal variability of rainfall trend (1990-2018)

The study area receives bimodal rainfall i.e. summer (*Meher*) season, the main rainy season from (June to September) and spring (*Belg*), smaller rainy season which falls from (March to May) and (Appendix-1) the mean *Belg* rainfall is 353.3 mm and the mean of *Meher* rainfall is 590.1 mm. The coefficient of variation (CV) of the *belg* shows 50.16 % high variability and *meher* 11.37% less variability seasonal rainfall based on degree of variability between the years 1990-2018 (Figure 3). The *Belg* season showed a decreasing trend at a rate of 2.39 mm per a year while the *kiremt* rainfall was showed a decreasing trend at a rate of 3.35 mm. Therefore, the variability and the decreasing pattern of rainfall in the both *belg* and *meher* rainfall have a critical implication on rural livelihoods in Lemo district.

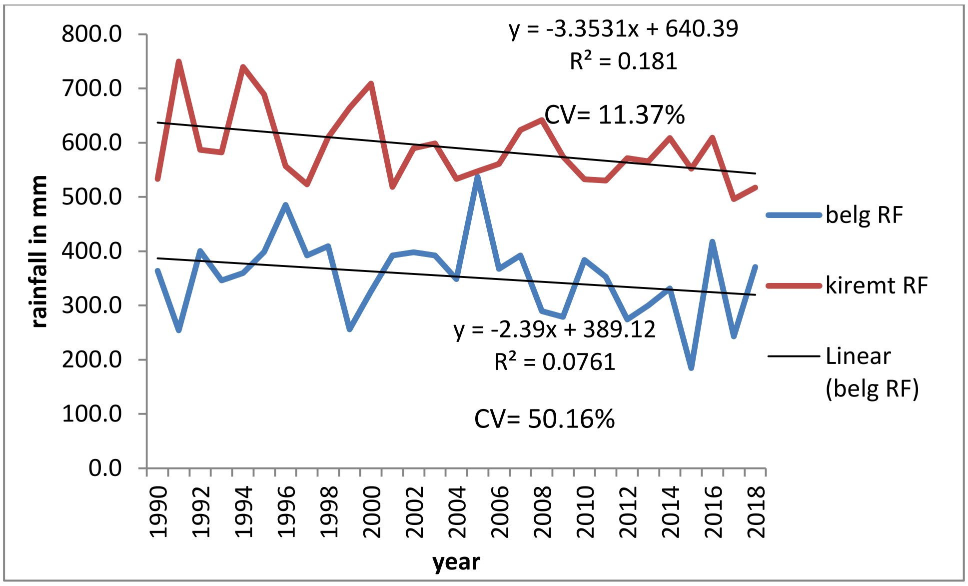

Figure 4 Seasonal *belg* and *kiremt* rainfall in study area

Source: NMA (2019)

4.2.3 Temperature trend of yearly average, maximum and minimum temperature in the study area (1990-2018)

The result of the current study showed that there was an increase in annual temperature in the study area. The average yearly maximum temperature of the Lemo district was 24.0^{0}C while the average minimum temperature was 21.8^{0}C (Appendix2). The average maximum temperature of the study area over the past 29 years increased by about 0.029°C annually, while average minimum temperature is increasing by 0.109°C (Figure 4). The results obtained from respondents are in line with the focus group discussion and key informant interviews, which indicate the change in temperature pattern, have shown an increasing trend in amount and intensity. The present result was in line with that of Kassie *et al.* (2013), wherein the climate of Central Rift Valley of Ethiopia will get warmer in the coming decades and the increase in minimum temperature will be higher than the maximum temperature, particularly under the emission scenarios. Likewise, this result was in line with that of NAPA (2007), Conway and Schipper (2011), Setegn *et al.* (2011), and Ayalew *et al.* (2012) that reported an increase in minimum and maximum temperature in Ethiopian regions.

The results of IPCC mid-range emission scenario showed that compared to the 1961-1990s the average mean annual temperature across Ethiopia will increase by between 0.9 and 1.1°C by the year 2030 and from 1.7 to 2.1°C by the year 2050 (NMA, 2007). The temperature across the country is predicted to rise from 0.5 to 3.6 °C by 2080. In contrast to the temperature patterns showing defined trends, it is hard to notice long-term rainfall trends in Ethiopia, due to the high variability across inter-annual and inter-decadal periods.

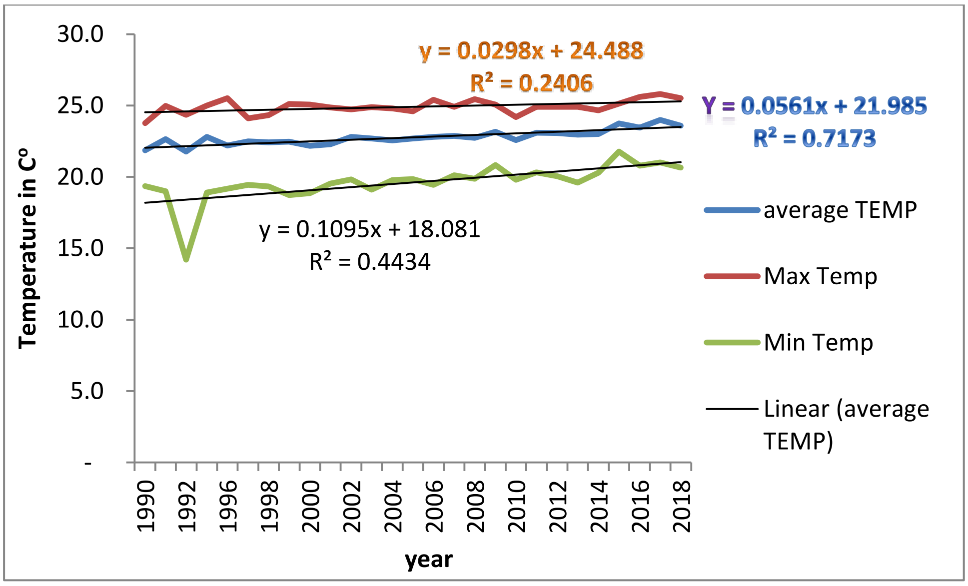

Figure 5. The yearly maximum, minimum and average temperature in the study area

Source: Sketched using NMA data (2019)

4.2.4 Annual and Seasonal Standard Precipitation Index as a Measure of Drought

Annual standard precipitations anomality (departure) for the past 29 years 1990-2018 in terms of drought frequency revealed that the study area experienced moderate drought with its SPI of -2.5 and -2.3 in 2015 and 2017 years respectively, while the rest of years were relatively moist (Figure 6).

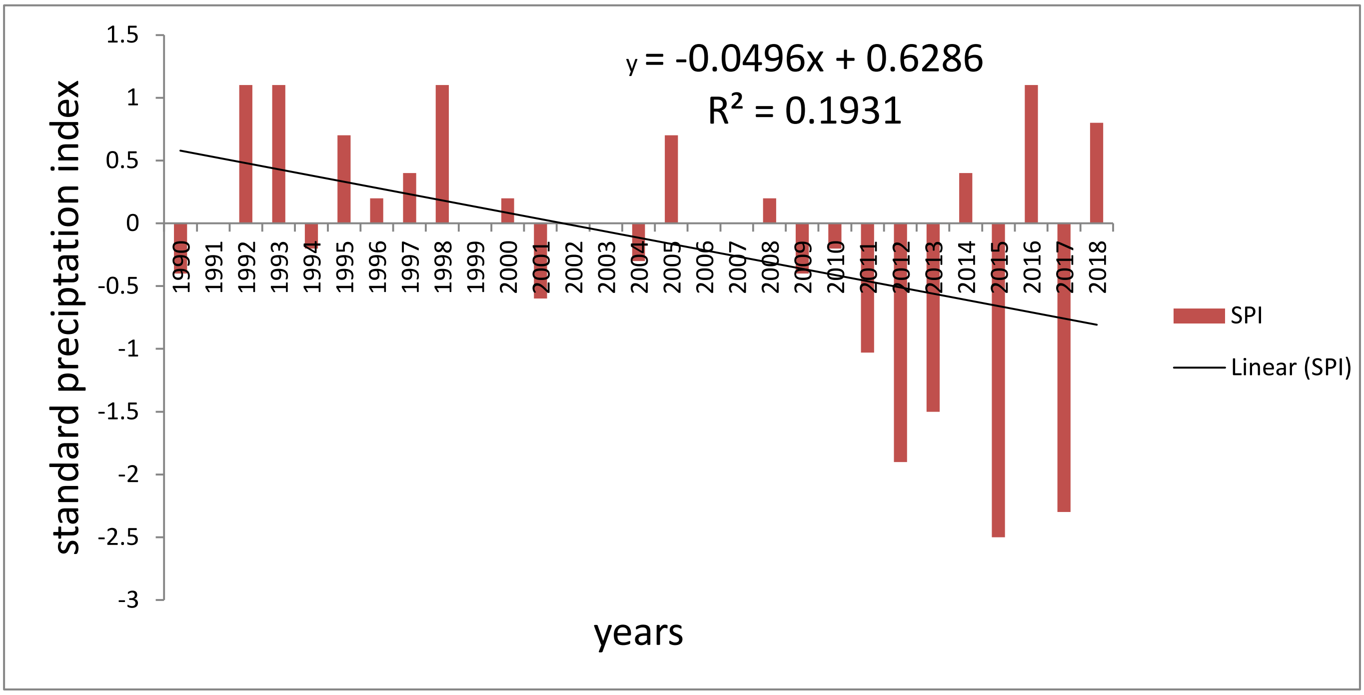

Figure 6 Annual SPI of Lemo district
Source: Analyzed based on NMA (2019)

4.3 Teff and wheat Production and Trend of Productivity in Lemo district

4.3.1 Teff and wheat production

Table 4 presents summary statistics on teff and wheat production in the Lemo district during the period 2009-2018. According to the household survey result and agriculture and natural resource office report; the crop production is highly vulnerable to climate variability and change. As a result, the annual variability in crop production is observed and the general trend in crop yield is declining. The yields of the major crops of the area (teff and wheat) were fluctuating across times (Table 4).

Table 4. Teff and wheat production (area coverage, total production per annum, yield qu per ha) in the study area

year	Wheat production			Teff production		
	Area (in ha)	Pr/qu	Yield(qu/Ha	Area (in ha)	Pr/qu	Yield(qu/Ha)
2009	35795.2	1028947.00	28.74	38850.27	570199.92	14.7
2010	37149.1	1021579.29	27.50	35559..27	500951.86	14.0
2011	37665.4	995472.36	26.40	32138.77	474610.06	14.8
2012	31888.8	792861.32	24.90	39514.53	497513.97	12.6
2013	39701.7	1035271.60	26.08	30469.14	373626.15	12.6
2014	36339.7	820853.66	22.59	38038.63	438784.21	11.5
2015	155,660.7	3,089,909.82	19.85	196,701.83	2,336,961.52	11.8
2016	34,339.1	757,696.73	22.07	29,388.60	313,418.13	10.7
2017	35,325.2	662,122.01	18.74	44,909.03	506,418.09	11.3
2018	28865.6	550257.63	19.06	43847.85	24651.19	9.7

Pr = production, qu = quntal, Ha = hector,

Source: Lemo woreda agricultural and natural resource office, (2020)

Table 5. Average annual wheat and teff yield in Lemo district, during 3 time segments with SD and CV

Years	Mean		Standard deviation		Coefficient of variance	
	teff	wheat	teff	wheat	teff	wheat
2009-2018	12.30	23.60	1.70	3.63	13.80	15.30
2009-2014	13.31	26.03	1.36	2.13	10.20	8.20
2015-2018	10.87	19.93	0.93	1.50	8.50	7.50

Source: Field survey (2020)

The wheat crop yields in *Lemo* district appeared inconsistent as shown with coefficient of variation 15.3% with an average of 23.60 and range between 18.74 qu/ha to 28.74 qu /ha (Table 4). Also teff crop yield shown with coefficient of variation 13.80 % with an average of 12.30 and range between 9.7 Tone /ha to 14.8 Tone /ha.

The first six year (2009-2014) production of wheat crops fluctuated with a coefficient of variation of 8.2% with an average of 26.03 and range between 22.60 qu /ha to 28.74 qu ha. Also teff crops fluctuated listed by the coefficient of variation 10.20% with an average of 13.31 and range between 22.59 Tone /ha to 28.74 Tone /ha.

The second four year (2015-2018) production of wheat crops yield shown with coefficient of variation 7.5% with an average of 19.93 and range between 18.74 qu /ha to 22.10 qu /ha relative to teff yield shown with coefficient of variation 8.5% with an average of 10.9 and range between 9.7 qu /ha to 11.9 qu /ha.

4.3.2 Trend of teff and wheat productivity in Lemo district (1994-2018)

Figure 5 shows the trend of teff and wheat production in the time series for the past 26 years based on the data from CSA. The teff and wheat crop yield/ production were decreased by the rate of (42kg/ha) and (43kg/ha) per annum respectively. Regression lines coefficient of determination which were fitted to determine evidence of trends in teff and wheat production; it depicted 1.62% and 0.59% decrease in productivity in the meantime respectively. The declining trend of teff and wheat yield (productivity) in the lemo district is mainly due to variable onset and seasonal rainfall fluctuation, and effects of climate of temperature and rainfall on teff and wheat yields.

Generally increased warming has a tendency to accelerate the loss of water from soil thereby affecting teff and wheat growth from germination to vegetative growth and later grain filling. According to the household survey result, the crop production is highly vulnerable to climate variability and change. As a result, the annual variability in crop production is observed and the general trend in crop yield is declining.

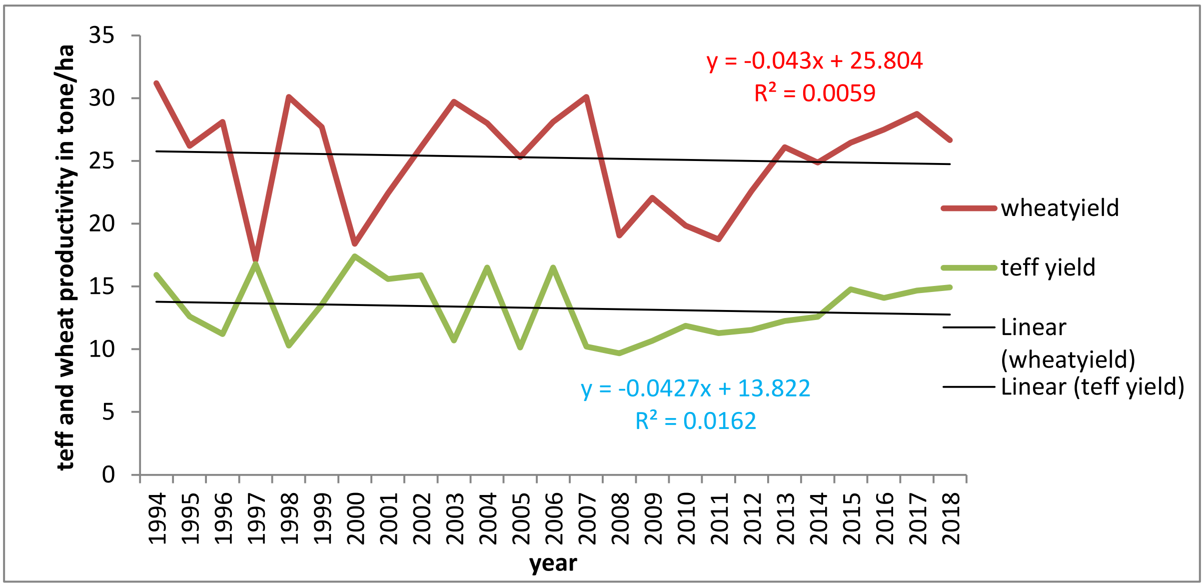

Figure 7 Trend of teff and wheat productivity in Lemo district (1994-2018)
Source: Sketched using the CSA data (2020)

4.3.3 Climate Change Impact on teff and wheat Production in Lemo district

The study had suggested that, the harmful effects of climate change were felt among teff and wheat producers in Lemo district. Teff and wheat producing farmers reported that the decline in teff and wheat yield 60% and 56% out of 150 surveyed respondent farmers respectively in (Figure 8) were the most important impact indicators that the climate has imposed on teff and wheat production followed by crop disease incidence caused the teff and wheat production constrained. others decline in production area and increased cost of pesticide and insecticide, were found the important impact indicator (Figure8).

The intensity of rainfall had reduced but number of rainy days which had declined imposed a greater effect on teff and wheat yields besides the decreased amount of rainfall (FGDs). Likewise KIIs explained that the occurrence of extreme climate variability may be characterized by a prolonged dry period or unusual heavy rainfall spell coinciding with the critical stages of teff and wheat growth and development lead to reduced teff and wheat yields and extensive losses.

The possible reasons/causes might be reduction of wheat and teff yield due to unpredictable rainfall, increased pest and disease, low soil fertility, high price of farm inputs, shortage of labor, inadequate farm land, the rain doesn't come on time or the rain stops right after planting when the seedling starts to grow; there has been more erratic and unreliable rainfall in the rainy seasons, bringing drought and reduction in crop yields; the annual river runoff and water availability has been decreasing year to year. Thus, finally the amount of production has decreased in the last three decades the combined effects are responsible to yield decreasing.

The impacts of climate change on crop production are more negative, but they can vary substantially between crops (IPCC, 2015). Rising temperatures lead to crop failure through lowering crop water availability, causing heat stress in crops, and increasing pollen sterility (Anandh, 2011).

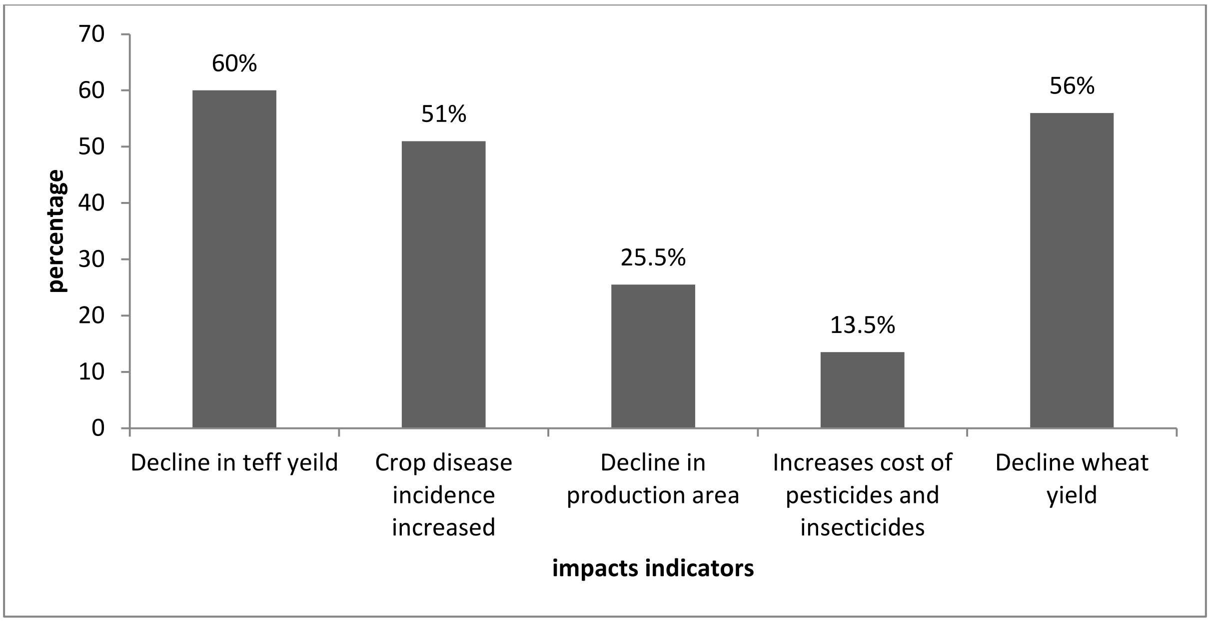

Figure 8 Impact of drought on teff and wheat production surveyed farmers

Source: Field survey (2020)

4.3.4 Climatic data and teff and wheat productivity

4.3.4.1 Rainfall-teff Production Relationships

The patterns of inter-annual rainfall variability and fluctuations in maize production are presented graphically (Figure 9) to gain a better insight into rainfall-maize production relationships in the zone.

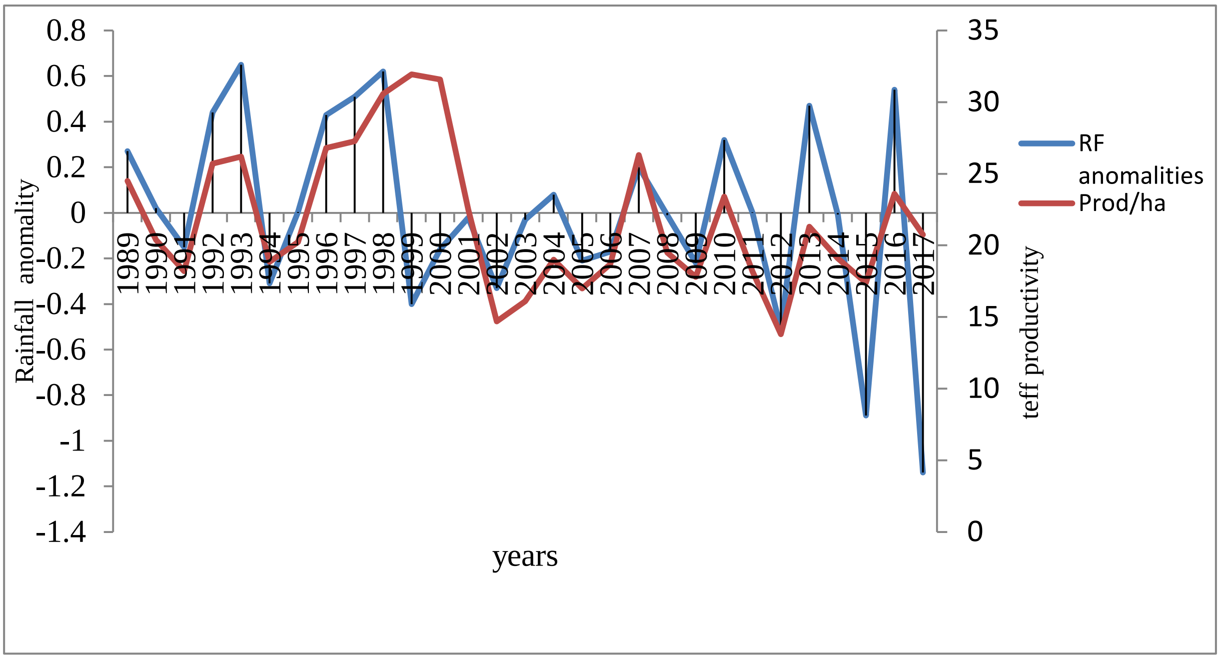

Figure 9. Standardized anomalies of production of teff and seasonal and annual rainfall amounts in the lemo district (1990-2018)

4.4. Farmers Perception towards temperature and rainfall trends

Climate change was well perceived by farmers in the study area as most of them have been observing changes in temperature, precipitation and timings of rainfall and related frequent drought. Particularly, perceptions on temperature and precipitation change of farmers of the study area Table 6.

The result indicates that most of the respondents, 63.7% perceived/believed that there is climate change, while 20.0% and 16.3% of the respondents were perceived that there is no climate change and didn't understand about climate change respectively.

Among the interviewed respondents, 69% perceived increase in temperature whereas 15% claimed decrease in temperature the remaining 22.5% did not perceive the change in the area over the last 29 years. The results obtained from respondents were in line with the focus group discussion and key informant interviews, which indicate the change in temperature pattern since 1990 (the downfall of the Derg regime) and have shown an increasing trend in amount and intensity.

The majority of the respondents were 88.2% observed decrease of rainfall; 17% did not perceive the change in rainfall trend of the study area over the last three decades. This was verified by all participants of Focus group discussants and key informant as there were changes in rainfall timing, amount and distribution in the area.

Similarly, a large number of farm household respondents confirmed that in Table 6 late on set of rain fall 66.6%, early cessation of rain fall 68.2%, frequent and high volume flood 51.3% have become evident features of the climate and it is affecting crop production in general and teff and wheat production in particular**.**

Weldlul, (2016) revealed that farmers' perception of climate change governance and adaptation is pivotal for the future plans aiming to deal with challenges arising as result of climate change. Similarly, Gebre (2015) noted clear understanding of the level of perception of temperature and rainfall pattern by farmer is assumed as an important element to guide future actions on climate adaptation endeavours. For any kind of climate change adaptation including agriculture, natural resource management and health, farmers who perceive the change in climate are hypothesized to make adjustments in their farms to reduce climate change impacts unless they face difficult barriers.

Table 6 Farmers' perception towards climate change

Perception	No of Respondents	Yes, in (%)	No, in (%)	I don't know in(%)
Climate change 3 decade in the area	150	63.7	20.0	16.3
Temperature increased in the area	150	69.0	21.0	10.0
Temperature decrease in the area	150	22.5	65.0	12.5
Precipitation increased in the area	150	11.3	73.7	15.0
Precipitation decrease in the area	150	88.2	9.8	2.0
Early onset of rain fall	150	37.6	48.0	14.4
Late on set of rain fall	150	66.6	27.4	6.0
Early cessation of rain fall	150	68.2	17.4	14.4
Rainfall fluctuation/timing of RF	150	47.0	39.0	14.0
Frequent high volume flood	150	51.3	37.3	11.4
Climate change reduced crop yield	150	58.8	29.2	12.0

Source: own field survey, (2020)

4.5 Adaptation Strategies practised by Farmers

The sampled households were asked if they have used adaptation strategies to reduce the impact of climate change in the study area. Accordingly, they reported that they were using different adaptation strategies to reduce the negative impact of climate change (Figure 10).

The measures being used include: farmers use diversification of crops 58.1% while the remain was farmer not use of crop diversification, farmers taking soil and water conservation 46.9% the remaining was not taking soil and water conservation, farmers use drought tolerant crops varieties 33.9% the remain was not use , farmers use adjusting planting dates 46.1% while remain not use and irrigation practices (22.1%) were actually identified as the main adaptation strategies to climate in study area. The majority of the farmers use crop diversification followed by soil and water conservation measures to respond to the climate change effect. However, irrigation is the least among the adaptation strategies implemented by the respondent farmers (Figure 10). These findings were in support of strategies put forward by Deressa *et al*, (2009); (Gbetibouo, 2009); Di Falco *et al* ., 2011) , they were suggested that as much as climate variability and change are inevitable, crop production systems should be able to adapt to weather fluctuations and climatic aberrations to minimize their negative effects. Various adaptation measures have been reported in many studies in the world, (Fosu-Mensah, 2012; Adjei-Nsiah and Kermah, 2012; Tachie-Obeng *et al.*, 2013), they confirmed that due to the impact on the yields of crops, many farmers have adopted numerous adaptation measures. These include changes in the planting dates, cultivating varieties with drought and heat tolerant abilities. Others are inclusion of tree crops on farmlands and diversification of crops and income activities.

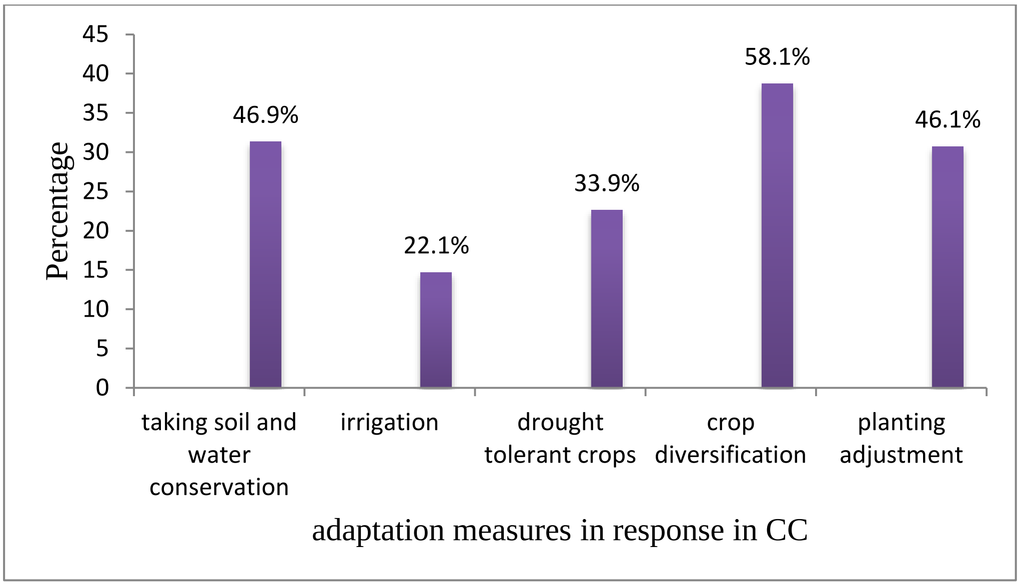

Figure 10 Adaptation measures adopted by wheat and teff producers in study area
Source: Own survey, (2020)

4.6 Challenges for implementing Climate Change Adaptation Strategies

The findings also focused on the perception of the respondents regarding the significant challenges or constraints that affect the implementation of existing climate change adaptation measures by the responsible bodies in the study area. The majority of respondents mentioned major constraints in the study area is lack of information followed by lack of improved seed variety and lack of finance. However lack of access training is the least among the constraints of adaptation to climate change which affect household respondents (Figure 11). Key informants and FGD participants also confirmed that the major challenges of the existing climate change adaptation strategies in the study area are lack of access to adequate and up to date information on the issues of climate change and the technology which reduce the impacts of climate change. They also indicated that as majority of the community members in the study area are poor and shortages of financial capacity are also the constraints that affect the implementation of adaptation measures in the study area.

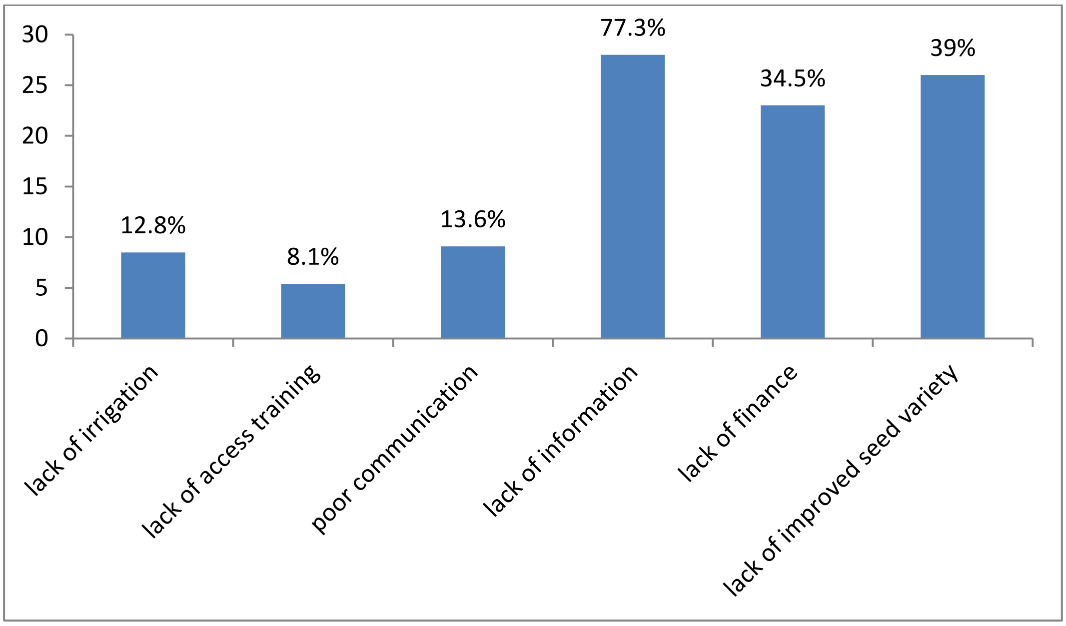

Figure 11. Constraints of adaptation to climate change in study area
Source: Own survey, (2020)

4.6.1 Factors determining the choice of adaptation strategies/ practices

The results of MNL model showed that factors influencing farmers' choice of adaptation measures in the study area. (Appendix- 6) the likelihood ratio statistics as indicated by ch2 statistics (LR chi-square (44) = 78.06 are highly significant ($P < 0.000$) suggest that the model has a strong explanatory power. In all cases, (Appendix- 6) the estimated coefficients should be compared with the base category of soil and water conservation. Therefore, the MNL results along with the levels of statistical significance. The coefficients of MNL tell us about the direction of effect of independent variables presented in and the marginal effect explain the effect of a unit change in explanatory variables on the dependent variable in (Table 7).

Table 7 Marginal effects after MNL logit model that estimates magnitude of adaptation choices conducted in the Lemo district 2020

Explanatory Variable	Drought tolerant crops and variety	Soil and water conservation	adjusting planting dates	Irrigation practice
	Marginal P-value	Marginal P-value	Marginal P-value	Marginal P-value
Sex	-.1063369 (0.753)	.0674352 (0.877)	.079216 (0.844)	-.0674982 (0.129)
Age	.0279413 (0.008)***	.0067655 (0.242)	.0324754 (0.007)***	.0024244 (0.297)
household size	.0200231 (0.994)	-.0310986 (0.126)	.0140912 (0.642)	-.0204887 (0.947)
Education	0.0417231 (0.078)*	.0137921 (0.189)	.0230105 (0.046)**	0.1477 (0.837)
Farm size	.295078 (0.004)***	.0175685 (0.939)	.2306282 (0.002)***	.6361981 (0.289)
Farm income	.2903853 (0.389)	.0080218 (0.351)	.0175685 (0.562)	.2706282 (0.352)
Farm experience	.0994573 (0.464)	.1674043 (0.958)	.0097192 (0.614)	.0743977 (0.176)
Extension-service	.0402332 (0.861)	.9953586 (0.475)	.1466428 (0.067)*	.019063 (0.093)*
Climate-information	.249524 (0.012)**	.5155677 (0.035)**	.9953586 (0.409)	.0356642 (0.923)
Access-to Credit	.0330547 (0.882)	.345792 (0.014)**	.0148615 (0.191)	.0260719 (0.138)
Training access	.2903853 (0.501)	.0080218 (0.316)	.0175685 (0.987)	.2706282 (0.666)

*Note that *, ** and *** are significant at 10%, 5% & 1% probability level respectively*.

Source: Computed by STATA version 14.2 based on survey result (2020)

Age of the household head: Age of the household head which is considered as a proxy indicator for farming experience, affects negatively the farmer's climate change adaptation options. As presented in Table 7, age of the farmers have posetive and significant influence on use drought tolerant crops practices and shifting planting dates as an adaptation measures. The result of this study depicted that a percent decrease in the age level of household probability of both drought tolerant crops practices and shifting planting dates by 2.7% and 3.2% at 1% of significance level respectively. This means that the likelihood of taking up climate adaptation measures was higher among older farmers. Because as the age of the household head increase, the person is expected to acquire more experience in weather forecasting and that helps increase in likelihood of practicing different adaptation strategy to climate change. This might be attributed to the experience of older farmers perceiving changes in climatic attributes. This result is in line with the findings of Deressa *et al.* (2008); Ajibefun and Fatuase (2011); Nhemachena and Hassan (2007); Maddison (2007) and Ishaya and Abaje (2008).

Education level of the household head: education of the household head increase the probability of up taking drought tolerant crops as adaptation measures to climate change. Also as can be observed in Table 7, education level significantly increase shifting planting dates in the study area. One year increase in the number of years of schooling promotes 4.1% increase in drought tolerant crops at 10% significant level and increase likelihood of shifting planting dates by 2.3% at 5% significant level. This suggests that being educated would improve access to information, capable to interpret the information, easily understand and analyze the situation better than less educated farmers. The study was hypothesized that farmers with higher levels of education are more likely to better adapt the climate change. The result of this study indicated that educational status increase the awareness of farmer about the consequence of climate change on agricultural productivity and has made farmers to adopt feasible adaptation technology to reduce the impact of climate change. This finding was similar with Maddson (2007); Aemro *et al.* (2012) and Gutu *et al.* (2012), they noted that higher levels of education is likely to enhance information access to the farmer for improved technology up take and higher farm productivity.

Farm size: household farm size is the significant factor that affects farmer's preferences for the adaptation strategies to climate change. In similar way, a one hectare increases in the farm size, the probability of the farmers to abandon drought tolerant crops, and shifting planting date by 29.5% and 23.06% respectively at 1% significant level holding other variables constant Table 7. The result of this study revealed that farmers with relatively large farm size were more likely to take up more adaptation strategies when compared to farmers with small farm size. This indicates that the larger the size of the farm, the greater the proportion of land allocated for different adaptation measures that the farmers are likely to adopt. Because farm size is always associated with greater wealth, more capital and resources Deressa *et al*. (2008); Ajibefun and Fatuase (2011) and Seid (2014).

Extension services: the result indicate that the frequency of extension visit has positive and significant influence on use of shifting planting dates which could in turn helps to reduce the negative impact of climate change. The result showed that a unit increase in extension services is likely to increase the probability of farmer to using shifting planting dates and irrigation practices had also increased by 14.6% and 1.9 % respectively at 10% significant level which could in turn helps to reduce the negative impact of climate change in wheat and teff production Ttable7. (Juana *et al.,* 2013), Temesgen *et al* (2009), Minale (2012), and Belaineh *et al.* (2013) also found similar results. This is due to the fact that extension services provides information on the importance of crop diversification, climate change and adaptation strategies. Farmers with more access to information and technical assistance on agricultural activities have more awareness about the consequence of climate change. Therefore, this study suggests that the availability of better climate and agricultural information helps farmers to take comparative decisions among alternative adaptation options and enable them to adapt better with changing climate.

Access to climate information (CLINF): Information on climate change represents access to the reliable information required to take the decision to adapt climate change. Accesses to information on climate change (temperature and rainfall) have significant and positive impact on the likelihood of the farmers. Getting information about seasonal forecasts and climate change, increase the probability of farmers access to climate change information has significant effect on the drought tolerant crop and soil and water conservation by 24.9% and 51.5% respectively at 5% significant level as teff and wheat production adaptation measures to cope up the negative effects of climate change in the study area Table 7. Farmers who are aware of changes in climatic conditions have higher chances of taking adaptive measures in response to observed variability. The survey result revealed that, having information on seasonal forecasts and climate change; increases the probability of using soil and water conservation Aemro *et al.* (2012), Ayesha, *et al., (*2012) and Gebre *et al.* (2015) argued that access to temperature and rain fall information from different sources has significant impact on the likelihood of using different adaptation measures like, soil and water conservation.

Credit used (CREDIT): farmers who have access to credit are more likely to using soil and water conservation as adaptation measures to climate change in study area. This means that farmers who had the access to credit increase the likelihood of soil and water conservation by 34.5 % at 5% significant level Table7, as adaptation strategies to climate change impact on teff and wheat production. According to Nhemachena and Hassan, (2007) access to affordable credit increases financial resources of farmers and their ability to meet transaction costs associated with the various adaptation options they might want to take. With more financial and other resources at their disposal farmers are able to change their farm management practices in response to changing climatic and other factors. This result also implies the important role of increased institutional support in promoting the use of adaptation options to reduce the negative impact of climate change and it is consistent with the finding of Temesgen *et al.* (2009), Aemro *et al.* (2012), Minale (2012), and Gebre *et al.* (2015) those who worked on climate change adaptation strategy, reported that access to credit have a negative and significant impact on likelihood of using shifting planting dates and a positive and significant impact on likelihood of using soil and water conservation.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and conclusion

This study attempted to assess the impact of climate change on teff and wheat production, climatic trends, farmer's perception and farmer's adaptation strategy in Lemo district. The meteorological data confirmed that the rainfall of the study area is characterized by greater annual and seasonal variability in line with several empirical research findings conducted in Ethiopia. The rainfall is also described by alteration of wet and dry years in a periodic pattern over the past three decades years (1990-2018). Annual temperature in the study area showed increasing trend for the last three decades (1990 - 2018).

The survey result revealed that both maximum and minimum temperature had increased while the rainfall followed a decreasing trend. Most of the respondent farmers perceive variability in the rainfall and temperature trend for which they are undertaking different adaptation mechanisms. Farmers in the district have been facing climate change impacts like drought, flood, frost, early cessation of rainfall, late onset of rainfall, crop disease increase, unpredictable rainfall, and decrease production/yield. Although climate change and variability is causing an impact the farmers not getting information daily, monthly and annually weather conditions. Similarly, the FGD revealed lack of access to information on weather variables.

The study has confirmed that Lemo district found to be increasingly becoming vulnerable to the risks of climate change and associated extreme weather events like drought and flood.

Teff and wheat production on the study area depends immensely on rain fed production and rainfall variability affects its production. The results have shown that more the rainfall variability, the lower Teff and wheat yield in study area. Warming temperature speed Teff and wheat development so does it decreases growth period. It has also a negative relationship with Teff and wheat production indicating that temperature decreases the yield of Teff and wheat by shortening its growth period.

The most common adaptation options in response to climate change impact on crop production in study area include: crop diversification (diversifying Teff and wheat varieties with other crop varieties), drought tolerant crops, soil and water conservation, shifting planting dates and irrigation.

Current study revealed that, challenges faced practicing climate change adaptation strategies were lack of climate information, lack of credit access, lack of access to technology and training are among the important factors containing the farmers to optimally apply the adaptation strategies.

According to the multinomial logit model result, age, educational status, access to extension services, farm holding size, access to credit, access to climate information have negative impact on adaptation to climate change impact. Farming experience, family size, farm income, gender, training access have positive impact on adaptation to climate change impact.

5.2. Recommendations

Based on the findings of the study, the following recommendations are made to reduce the negative effect of climate change on crop production, strengthening efforts on enhancing the household farmers' adaptive capacity to climate change and helping planner and decision makers in making decision towards adaptation to climate change.

- ✓ Concerned government body such as education sectors access to education to farm household farmers to adapt climate change.
- ✓ Stakeholder must do like agriculture sectors facilitate farm inputs such as fertilizers and seeds to the house hold farmers for implement to climate change adaptation.
- ✓ Agricultural extension experts facilitate extension services to kebeles farmers to adapt climate change adaptation or development agents strong relationship with farm households farmer by giving climate/ weather information.
- ✓ National meteorology agency facilitate weather station site in the district farmers know/ hear climate information for implementation to climate change adaptation.
- ✓ Omo macro-finance sectors access to credit to farm households farmers to adapt climate change.
- ✓ Generally, increase the farmer's access to education, extension services, and climate change information, improved inputs including seeds and fertilizer. Furthermore, establishing meteorological station and infrastructures will have a paramount to enhance the farmers' response capacity to climate change and improve their livelihood.

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APPENDICES

Appendix-1 Rainfall record from 1990-2018 in the study area lemo district

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual RF	belg RF	kiremt RF
1990	0,0	144,8	153,1	95,6	114,9	107,2	133,8	156,6	135,3	40,5	6,8	1,0	1089,6	363,6	532,9
1991	7,3	45,7	94,0	31,6	128,7	175,9	210,5	182,9	180,4	9,7	0,0	66,3	1133,0	254,3	749,7
1992	59,2	88,1	119,6	174,5	106,2	171,7	121,4	189,5	104,3	106,2	52,9	3,7	1297,3	400,3	586,9
1993	78,1	107,0	20,6	150,3	175,1	75,6	116,8	199,0	190,4	177,2	0,0	0,1	1290,2	346,0	581,8
1994	0,0	0,0	146,7	83,9	128,9	160,5	197,3	189,1	192,8	0,0	8,8	0,0	1108,0	359,5	739,7
1995	0,5	61,7	70,0	219,6	109,3	170,8	201,0	156,5	160,6	3,2	0,0	98,9	1252,1	398,9	688,9
1996	90,7	17,8	152,0	170,4	162,7	115,1	186,7	129,3	125,6	6,6	16,3	0,0	1173,2	485,1	556,7
1997	22,1	0,0	84,3	177,6	130,1	119,7	113,1	150,2	140,2	275,5	85,3	0,0	1298,1	392,0	523,2
1998	73,8	63,2	107,7	180,4	121,3	135,9	155,1	167,3	151,3	143,5	0,0	0,0	1299,5	409,4	609,6
1999	1,0	0,0	56,5	77,0	122,5	143,5	181,7	211,4	127,7	185,9	0,0	0,0	1107,2	256,0	664,3
2000	0,0	0,0	15,4	205,8	105,2	145,5	200,0	185,7	177,9	64,9	21,0	45,5	1166,9	326,4	709,1
2001	4,8	70,1	110,3	109,6	172,1	181,4	100,4	134,6	101,8	61,9	4,7	5,5	1057,2	392,0	518,2
2002	83,2	47,2	150,7	111,7	135,5	90,0	200,0	144,9	154,7	2,8	0,4	6,9	1128,0	397,9	589,6
2003	35,8	58,9	118,9	194,4	78,7	108,3	135,9	171,3	182,9	11,7	13,5	0,0	1110,3	392,0	598,4
2004	96,8	19,4	90,6	176,2	82,0	123,4	133,6	152,3	123,9	74,8	17,3	14,0	1104,3	348,8	533,2
2005	31,5	18,8	177,8	162,1	197,2	64,6	160,1	160,2	162,6	37,7	67,7	0,0	1240,3	537,1	547,5
2006	28,9	53,9	131,5	160,0	75,8	137,0	152,2	183,2	88,2	90,2	6,0	27,2	1134,1	367,3	560,6
2007	31,8	50,7	118,7	152,1	121,3	163,1	147,9	132,2	180,3	19,0	0,0	0,0	1117,1	392,1	623,5
2008	0,0	1,2	43,0	71,3	175,2	144,6	147,3	211,3	138,6	126,1	117,5	0,5	1176,6	289,5	641,8
2009	43,1	4,8	73,4	85,5	120,1	123,5	153,1	143,6	154,2	169,4	5,1	17,3	1093,1	279,0	574,4
2010	11,8	110,0	139,9	111,3	132,6	123,9	116,0	154,0	138,5	18,9	19,3	33,7	1109,9	383,8	532,4
2011	15,5	11,2	101,7	120,8	130,2	128,6	123,3	158,9	119,3	43,1	49,2	0,0	1001,8	352,7	530,1
2012	0,0	0,0	67,4	138,3	68,3	120,1	157,3	143,9	150,2	1,4	28,5	7,1	882,5	274,0	571,5
2013	1,0	17,4	111,8	67,9	120,2	120,9	150,1	159,3	135,1	46,4	0,4	7,9	938,4	299,9	565,4
2014	18,2	91,2	76,6	123,4	131,2	176,9	132,5	143,2	156,2	130,1	14,2	2,2	1195,9	331,2	608,8
2015	0,0	3,0	45,1	19,2	120,1	157,9	142,6	131,2	120,2	20,0	20,3	11,5	791,1	184,4	551,9
2016	92,8	0,0	81,2	200,4	135,9	122,8	148,3	200,4	138,0	68,8	90,4	17,3	1296,3	417,5	609,5
2017	0,6	69,5	77,9	44,6	120,5	130,2	121,0	123,5	121,0	12,4	1,2	0,0	822,4	243,0	495,7
2018	12,0	90,2	47,7	200,0	123,5	100,9	109,7	155,5	151,2	139,9	121,2	5,3	1257,1	371,2	517,3
STDVE													437,0	73,7	67,1
AVERAGE													1143,7	353,3	590,1

Appendix-2 Temperature record from 1990-2018 in the study area Lemo district

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	aver Temp	Max Temp	Min Temp
1990	23.0	22.0	22.9	22.6	22.2	20.6	195	19.4	20.7	22.0	23.6	23.8	21.9	23.8	19.4
1991	24.7	24.2	23.5	25.0	24.1	21.6	200	19.0	21.0	22.3	23.7	22.5	22.6	25.0	19.0
1992	23,1	22,4	24,4	23,5	23,1	20,3	188	14,2	21,3	22,7	23,5	23,9	21.8	24.4	14.2
1995	24,2	25,0	24,9	22,9	23,2	22,1	189	19,3	21,1	23,2	24,6	24,3	22.8	25.0	18.9
1996	22,5	25,5	23,9	22,9	22,2	19,8	194	19,2	20,9	22,6	23,6	23,9	22.2	25.5	19.2
1997	24,0	24,1	24,0	22,5	23,4	21,3	195	20,4	22,5	22,2	22,3	23,7	22.5	24.1	19.5
1998	23,6	24,1	24,3	24,3	23,1	21,1	193	19,5	21,3	21,5	23,1	23,8	22.4	24.3	19.3
1999	24,6	25,1	23,5	24,5	23,5	21,0	187	19,7	21,3	20,9	22,6	24,0	22.5	25.1	18.7
2000	25,1	21.0	24,2	24,1	22,7	20,9	193	18,9	20.9	21,8	22,9	23,2	22.2	25.1	18.9
2001	23,4	24,9	22,9	24,1	21,7	19,9	195	19,8	21,8	22,3	23,2	24,1	22.3	24.9	19.5
2002	23,1	24,7	23,4	23,9	22,9	20,8	207	19,8	21,6	23,8	24,6	24,4	22.8	24.7	19.8
2003	23,4	24,3	24,7	23,4	24,9	21,6	191	19,3	21,1	23,0	23,8	23,6	22.7	24.9	19.1
2004	24,1	24,1	24,8	22,5	23,5	20,5	198	20,2	21,4	21,8	23,7	24,1	22.5	24.8	19.8
2005	24,0	24,5	24,6	24,0	22,2	21,4	198	20,8	21,2	22,5	23,1	24,0	22.7	24.6	19.8
2006	24,8	25,4	23,9	22,9	23,7	21,7	207	19,4	20,9	23,0	23,8	23,4	22.8	25.4	19.4
2007	24.5	24,5	24,9	24,1	23,5	20,8	203	20,1	21,1	22,7	23,7	24,2	22.9	24.9	20.1
2008	25,5	24,5	24,8	24,9	22,7	21,0	199	19,9	20,9	22,5	22,3	23,8	22.7	25.5	19.9
2009	23,9	25,1	22,5	24,5	24,7	23,3	209	20,8	22,2	22,7	23,5	23,9	23.2	25.1	20.8
2010	24,2	23,3	23,8	23,8	23,3	21,3	198	19,9	21,3	22,7	23,5	23,9	22.6	24.2	19.8
2011	24,2	24,9	24,8	24,3	23,3	21,3	212	20,3	21,1	23,8	23,9	24,2	23.1	24.9	20.3
2012	24,8	24,9	24,9	23,0	24,6	22,1	200	20,3	21,1	23,4	23,5	24,3	23.1	24,9	20,0
2013	24,9	24,9	24,9	24,3	23,4	21,3	199	19,6	21,6	22,8	24,2	23,9	23.0	24,9	19,6
2014	24,5	24,4	24,7	24,4	23,1	22,5	203	20,3	20,9	22,8	24,0	24,3	23.0	24.7	20.3
2015	25,1	24,9	24,6	24,5	23,9	22,0	218	21,8	22,6	24,7	24,8	24,4	23.7	25.1	21.8
2016	24.7	24.6	24.3	23.4	22.9	21.4	250	20.8	21.4	23.4	25.6	23,9	23.4	25.6	20.8
2017	24,9	25,8	24,6	24,9	23,5	22,5	210	23,4	21,5	25,5	25,8	24,3	24.0	25.8	21.0
2018	24,6	25,2	25,5	22,6	22,8	21,2	255	20,7	22,7	24,3	23,3	24,6	23.6	25.5	20.7
avg	24.2	24.5	24.2	23.8	23.3	21.3	20.3	19.9	21.4	22.8	23.7	23.9	22.8	24.9	19.6

Source: NMA (2019)

Appendix 3 Time series data of teff and wheat productivity in Lemo district

Year	Wheat Production in quintal per hectare/yield/	teff Production in quintal per hectare/yield/
1994	31.2	15.91
1995	26.2	12.6
1996	28.1	11.2
1997	17.1	16.8
1998	30.1	10.3
1999	27.7	13.56
2000	18.4	17.4
2001	22.43	15.6
2002	26.1	15.9
2003	29.7	10.7
2004	28.0	16.5
2005	25.3	10.13
2006	28.1	16.5
2007	30.1	10.2
2008	19.06	9.68
2009	22.07	10.66
2010	19.85	11.88
2011	18.74	11.28
2012	22.59	11.54
2013	26.08	12.26
2014	24.86	12.59
2015	26.46	14.77
2016	27.5	14.09
2017	28.75	14.68
2018	26.65	14.93
Average	25.24	13.26
ST	4.10	2.47
CV	26.3	28.8

Source: CSA (2019)

Appendix- 4 wheat and teff crop production Lemo woreda agricultural office report

year	Wheat production			Teff production		
	Area ha	Pr/Quintals	Yield(Qt/Ha	Area ha	Pr/Quintals	Yield(Qt/Ha)
1999	35795.2	1028947	28.74	38850.27	570199.92	14.66
2010	37149.1	1021579.29	27.5	35559..27	500951.86	14.0
2011	37665.4	995472.36	26.4	32138.77	474610.06	14.8
2012	31888.58	792861.32	24.9	39514.53	497513.97	12.6
2013	39701.73	1035271.6	26.08	30469.14	373626.15	12.26
2014	36339.73	820853.66	22.59	38038.63	438784.21	11.54
2015	155,660.71	3,089,909.82	19.85	196,701.83	2,336,961.52	11.88
2016	34,339.10	757,696.73	22.07	29,388.60	313,418.13	10.66
2017	35,325.23	662,122.01	18.74	44,909.03	506,418.09	11.28
2018	28865.58	550257.63	19.06	43847.85	24651.19	9.68

Source: own field survey, (2020)

Appendex 5 summary explanatory variable that affect farmers choice of adaptation measures

Appendix- 6 Result of Multi nominal logit model

. mlogit adaptationchoice sex age education households income creditaccess farmsize farmingexprience trainingaccess extensionservices climateinformation

Iteration 0: log likelihood = -229.15111

Iteration 1: log likelihood = -193.15929

Iteration 2: log likelihood = -190.20353

Iteration 3: log likelihood = -190.12241

Iteration 4: log likelihood = -190.12201

Iteration 5: log likelihood = -190.12201

Multinomial logistic regression Number of obs = 150

LR chi2(44) = 78.06

Prob > chi2 = 0.0002

Log likelihood = -190.12201 Pseudo R2 = 0.5703

Adaptationchoice	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
1 | using drought tolerant crops						
Sex	.18942	.602131	0.31	0.753	-.990735	1.369575
age	-.0579413	.021962	-2.64	0.005	-.1009861	-.0148965
education	-.1431226	.0812703	-1.76	0.078	-.3024094	.0161642
households	.0010332	.133646	0.01	0.994	-.2609081	.2629744
income	.0000676	.0000785	0.86	0.389	-.0000862	.0002214
creditaccess	.0938767	.6300581	0.15	0.882	-1.141014	1.328768
farmsize	-1.295078	.4541482	-2.85	0.004	-2.185192	-.4049636
farmingexprience	-.0087042	.0118998	-0.73	0.464	-.0320275	.014619
trainingaccess	.3969085	.5895031	0.67	0.501	-.7584964	1.552313
extensionservices	-.1175759	.670692	-0.18	0.861	-1.432108	1.196956
climateinformation	1.749535	.6965623	2.51	0.012	.384298	3.114772
_cons	4.469726	2.465135	1.81	0.070	-.3618488	9.301302

2 |using soil and water conservation						
Sex	.0822956	.5319948	0.15	0.877	-.9603951	1.124986
age	-.0226546	.019375	-1.17	0.242	-.0606289	.0153197
education	-.0959323	.0729539	-1.31	0.189	-.2389192	.0470547
households	.1637575	.1070497	1.53	0.126	-.046056	.3735709
income	.0000645	.0000692	0.93	0.351	-.0000712	.0002002
creditaccess	1.544409	.6268449	2.46	0.014	.315816	2.773003
farmsize	.0310505	.4040318	0.08	0.939	-.7608372	.8229382
farmingexprience	-.0005099	.0097418	-0.05	0.958	-.0196034	.0185836
trainingaccess	.5300299	.5282793	1.00	0.316	-.5053785	1.565438
extensionservices	-.412926	.5777036	-0.71	0.475	-1.545204	.7193522
climateinformation	1.315576	.6228358	2.11	0.035	.0948401	2.536311
_cons	-1.558896	2.208157	-0.71	0.480	-5.886803	2.769012
3 | (base outcome) using diversification of crop varities						
4 |shifting planting dates						
Sex	-.1022693	.5208668	-0.20	0.844	-1.123149	.9186108
age	-.0524497	.0195368	-2.68	0.007	-.0907412	-.0141581
education	-.1477439	.0740115	-2.00	0.046	-.2928037	-.0026841
households	-.0551174	.1171162	-0.47	0.638	-.2846608	.174426
income	-.0000453	.0000781	-0.58	0.562	-.0001983	.0001077
creditaccess	-.7307594	.5592692	-1.31	0.191	-1.826907	.3653882
farmsize	-1.274764	.4074445	-3.13	0.002	-2.073341	-.4761873
farmingexprience	-.0052995	.0105138	-0.50	0.614	-.0259062	.0153072
trainingaccess	.008472	.5202011	0.02	0.987	-1.011103	1.028047
extensionservices	.9951791	.5433758	1.83	0.067	-.0698179	2.060176
climateinformation	.5432594	.6574206	0.83	0.409	-.7452613	1.83178
_cons	6.34245	2.222043	2.85	0.004	1.987326	10.69757
5 |irrigation practices						
sex	-1.229003	.8096896	-1.52	0.129	-2.815966	.3579595
age	-.0315035	.0302003	-1.04	0.297	-.0906951	.027688
education	.023644	.1147584	0.21	0.837	-.2012784	.2485664

households	-.0105749	.159074	-0.07	0.947	-.3223543	.3012045
income	-.0001108	.000119	-0.93	0.352	-.0003442	.0001225
creditaccess	1.398003	.9421744	1.48	0.138	-.448625	3.244631
farmsize	.6361981	.6005643	1.06	0.289	-.5408863	1.813283
farmingexprience	.0200628	.0148128	1.35	0.176	-.0089697	.0490953
trainingaccess	.3526969	.8182019	0.43	0.666	-1.250949	1.956343
extensionservices	-2.019964	1.20255	-1.68	0.093	-4.376919	.3369905
climateinformation	.0962029	.9899116	0.10	0.923	-1.843988	2.036394
_cons	-.5549725	3.283052	-0.17	0.866	-6.989636	5.879692

Margins, dydx(*)

Average marginal effects Number of obs = 150

Model VCE : OIM

dy/dx w.r.t. : Age GENDER FMS FRMSZ TLU FRMEXP EDUN ACCRDT EXTSRV ACCLINF FARMINCOM TRAINING

1._predict : Pr(ADCHOS==drought tolerant crops), predict(pr outcome(1))

2._predict : Pr(ADCHOS==soil and water conservation), predict(pr outcome(2))

3._predict : Pr(ADCHOS==shifting planting dates), predict(pr outcome(3))

4._predict : Pr(ADCHOS==irrigation practices), predict(pr outcome(4))

	dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age						
_predict						
1	.0279413	.0011756	4.71	0.008	-.0124973	-.0042535
2	.0067655	.0019033	-3.55	0.114	-.0104958	-.0030351
3	.0324754	.0011756	4.71	0.007	.0126331	2.0172413
4	.0024244	.0016076	-1.51	0.132	-.0055753	.0007265
GENDER						
_predict						

1	-.1063369	.07844	-1.36	0.175	-.2600766	.0474028
2	.0674352	.0908409	0.74	0.458	-.1106097	.2454801
3	.079216	.0747498	1.06	0.289	-.067291	.225723
4	-.0674982	.1041929	-0.65	0.517	-.2717124	.136716
FMS						
_predict						
1	.0200231	.0125827	1.59	0.112	-.0046386	.0446848
2	-.0310986	.0200103	-1.55	0.120	-.0703181	.0081209
3	.0140912	.0125864	1.12	0.263	-.0105778	.0387602
4	-.0204887	.0188575	-1.09	0.277	-.0574487	.0164713
FRMSZ						
_predict						
1	.295078	.0421607	-3.09	0.004	-.2130189	-.0477518
2	.0080218	.0553606	0.14	0.885	-.1004829	.1165266
3	.0175685	.03179	0.55	0.581	-.0447388	.0798758
4	.2306282	.0538352	1.50	0.002	-.0248869	.1861432
FRMEXP						
_predict						
1	.0994573	.0272596	-3.65	0.241	-.1528851	-.0460296
2	.1674043	.0452446	3.70	0.131	.0787264	.2560822
3	.0097192	.0327518	-0.30	0.767	-.0739117	.0544732
4	.0743977	.0394489	-1.89	0.159	-.1517162	.0029208
EDUN						
_predict						
1	0.0417231	.0299683	-2.60	0.078	-.1368024	-.0193289
2	.0137921	.037563	0.37	0.713	-.0598299	.0874142
3	.0230105	.0271725	-0.85	0.046	-.0762676	.0302465
4	0.1477439	.0355747	0.59	0.340	-.0485745	.0908758
ACCRDT						
_predict						
1	.0330547	.0468344	0.71	0.480	-.0587392	.1248485
2	.345792	.0695363	1.66	0.014	.2748678	1.0022906

Source: Marginal MNL result(2020)

3	.0148615	.0508115	-0.29	0.770	-.1144502	.0847273
4	.0260719	.0626944	-0.42	0.678	-.1489507	.0968068
EXTSRV						
_predict						
1	.0402332	.0603142	0.67	0.505	-.0779803	.1584468
2	.9953586	.082779	0.80	0.263	-.0958853	.2286024
3	.1466428	.0619568	1.37	0.067	.2680758	1.0252097
4	.019063	.0782897	1.30	0.093	-.0520387	.2548513
ACCLINF						
_predict						
1	.249524	.0532711	-0.21	0.012	-.115651	.0931681
2	.5155677	.0777767	-0.33	0.035	-.1780073	.1268718
3	.0028747	.0720823	-0.04	0.968	-.1441534	.1384041
4	.0356642	.0782036	-0.46	0.648	-.1889405	.117612

FARINCO						
_predict						
1	.2903853	.0421607	-3.09	0.324	-.2130189	-.0477518
2	.0080218	.0553606	0.14	0.885	-.1004829	.1165266
3	.0175685	.03179	0.55	0.581	-.0447388	.0798758
4	.2706282	.0538352	1.50	0.112	-.0248869	.1861432

TRAING						
_predict						
1	.2903853	.0421607	-3.09	0.234	-.2130189	-.0477518
2	.0080218	.0553606	0.14	0.885	-.1004829	.1165266
3	.0175685	.03179	0.55	0.581	-.0447388	.0798758
4	.2706282	.0538352	1.50	0.322	-.0248869	.1861432

Source: Marginal MNL result(2020)

VIF

Variable	VIF	1/VIF
age	1.74	0.574604
education	1.68	0.595514
income	1.15	0.872640
farmingexp~e	1.11	0.903411
households	1.10	0.908116
farmsize	1.05	0.948989
Mean VIF	1.30	

Variable	Obs	Mean	Std. Dev.	Min	Max
sex	150	1.613333	.4886176	1	2
age	150	52.85333	18.25891	25	85
education	150	5.966667	4.749308	0	12
households	150	6.253333	2.386164	1	12
income	150	2720.667	3730.849	100	15000
creditaccess	150	.6733333	.4705654	0	1
farmsize	150	1.761667	.6965499	.25	2.75
farmingexp~e	150	29.61333	26.35809	9	71
trainingac~s	150	.5066667	.5016305	0	1
extensions~s	150	.2866667	.4537194	0	1
climateinf~n	150	.2266667	.4200778	0	1

Appendix 6. Multicollinearity test result

Source; Tested by STATA version 14.2 (2020)

APPENDICES

Appendix 8: Questionnaire for household survey

Hawassa University

School of graduate studies

Department of Climate Change and Sustainable Agriculture

QUESTIONNAIRE FOR HOUSEHOLD SURVEY

Dear respondents: My name is **Temesgen Defar,** I am a graduate student of Hawassa University. I am conducting a research for the partial fulfilment of master degree in Climate Change & Sustainable Agriculture. The main objective of this questionnaire is to assess the impact of climate changes on crop production and their indigenous adaptation strategies in Lemo district. Thus, I am interested in your ideas and experiences; so I want your frank & honest opinion on this issue. There are no risks will happen in participating in this survey.

Name of respondent ____________________ ID/code_____________________

Name of Woreda _____________________________

Name of kebele_____________________________

Section one. Background information of the household head

Household Demographic characteristics

1. Sex of household head: 1) female 2) male

2. Age of household head

3. Marital Status 1) Married 2) Single 3) Divorced 4) Widowed

4. Educational Status 1) Illiterate 2) Read and write 3) Primary education completed 4) High school complete 5) Higher education complete

5. Total household size Number of Male ________Number of Female ______Total______

Socio-economic Characteristic of Household

Q6. What is your total annual farm HH income last year from farm activity ___________birr?

Q7. Do you have access to non-farm employment? 1) Yes 0) No.

Q8. If "Yes" for Q7, what is the type of work? 1) Hand craft 2) Trading 3) Casual labor Others (specify) ____

Q9. What is the total annual income earned from non-farm activities during this year? _________________Birr

Q10. Do you have access to credit from any sources? 1) Yes 0) No.

Q11, If "Yes" for Q10, would you please give us the following details?

Source	**Mark**

Micro-finance Institutes	
Cooperatives	
Bank	
Non-formal money lenders	
Relatives	
Others,	

Q12. If "No" for Q10, What is the reason? (Multiple answers are possible) 1) Fear of inability to pay 2) Lack of asset for collateral 3) No one to give credit 4) High interest rate 5) No need for Credit 6) I can use other sources 7) Others (specify)____

Q13. How much your farm size? —————————1) < 0.5 ha, 2) 0.51-1 ha, 3) 1.1-2 ha, 4) 2.1-3 ha, 5) 3.1 and above

Q14. What type of agricultural practice do you follow? 1) Rain fed 2) Irrigated 3) others (specify)____

Q15. For how long do you experience farming? ———————— 1) Less than 5 years, 2) 6-10 years, 3) 11-20 years, 4) over 20.

Q16. How do you perceive the fertility status of your land? 1) Very fertile, 2) fertile, 3) infertile, 4) don't know

Q17. Do you have access to a nearby market? 1.) Yes 0.) No

Q18. If "Yes" for Q17 how far is it? 1.) < 4Km 2) 5-9Km, 3) >10km

Q19. Have you got access to training? 1) Yes 0) No

Q20, If "Yes" for Q19, how often do you have to access training? 1) Monthly, 2) twice a month,3) quarterly 4) half of in a year 5) once in a year

Q21. If "Yes" for Q19, How was/is the amount of agricultural production after got access to training? 1) Has no change 2) Decreased in crop yield 3) Increased in crop yield 4) Standard crop growth

Q22, If "No" for Q19, why you haven't got the training access? ____

Household Institutional factors

Q23. Do you have access to agricultural extension services which could help improve your farming activities in your farm? 1.) Yes 0.) No

Q24. If the answer for the Q23 is "Yes", on what agricultural activity you got extension service? 1) Crop diversification 2) using drought tolerant crops 3) using of early maturing crop variety 4) crop rotation 5) Others_____________________________________

Q25 If the answer for the Q23 is "No", why you haven't got the extension service from agents? ____

Q26. Do you have access to climate change information? 1), Yes 0), No

Q27. If "Yes" for Q26, How often do you get climate change information? 1) weekly, 2) monthly, 3) twice a month, 4) others (specify) ___________________________

Q28. If "Yes" for Q26, what are the actions/ measures you take based on the climate change information you received? ____

Q29. If "No" for Q26, What is the main reason for not receiving the information? ____

Q30. Do you use fertilizer to improve agricultural production? 1) Yes 0) No.

Q31. If "Yes" for Q30, what types of fertilizer do you use, among organic fertilizers? 1. Compost 2.Green manure 3.Leaflitter 4.Ash 5) Other (specify).

Q32. If "Yes" for Q30, what types of fertilizer do you use, among inorganic fertilizers? 1, DAP 2. Urea 3, Both 4 specify others______________________________________

Q33. Which types of fertilizers are better to increase production of crop yield? 1) Organic fertilizers, 2) in organic fertilizers 3) both 4) I don't know

Q34 If "No" for Q30, what are the reasons? (1) Lack of money (2) lack of information, (3) lack of knowledge (4) Lack of Extension service (5) Lack of labor and 6) other (specify)____

Section two Farmer's perception on climate change

Q35, The following questions are used to measure the perception of respondents on climate change? please put the (X) below the table

	yes	No,	I don't know
Do you think climate of your area has been changing?			
Do you believe that the trend of temperature increased in your area has changed over the past 10 years?			
Do you believe that the trend of temperature decreased in your area has changed over the past 10 years?			
Do you consider that the trend of precipitation decreased in your area has changed over the past 10 years?			
Early onset of rain fall			
Late on set of rain fall			
Early cessation of rain fall			
Do you consider that the trend of precipitation increased in your area has changed over the past 10 years?			
Do you believe that there is a change in amount of rainfall			

during main rain season?			
Do you perceive that there is an increase in recurrences and intensity of floods?			
Do you think that climate change has reduced your crop yield?			
Does the climate change affects/fluctuates/ rainfall			
Does the climate change affect the harvesting period of the crop?			

Section Three: Assessments of the Impacts of Climate Change

Q36, what are the major factors affecting crop production in your area? 1) Unpredictable rain fall 2) Increased pest and disease 3) Low soil fertility 4) Lack of farm inputs (fertilizer, improve seeds, pesticides) 5) High price of farm inputs 6) Shortage of labor 7) Inadequate farm land 8) Lack of farm land

Q37. Did you say climate change influenced teff and wheat crop production? 1.) Yes 0.) No

Q38. If "Yes" for Q37, what are the problems you mostly faced while undertaking crop production? 1) Crop diseases 2) shortage of rain fall 3) Flood 4) frosts 5) late onset of rainfall 6) Early cessation of rainfall 7, other specify____

Q39. What are the main effects of climate change on your wheat & teff farm? 1) Total crop fail 2) Decrease in productivity 3) Occurrences of pests and diseases 4).Loss in quality of produce 5) Specify any____

40. How do you evaluate the Trend of teff and wheat productivity per a hectare for the past five consecutive years?

Year	Area grown in hectare	Yield obtained per a unit area/ha	Trends in productivity 1. Increasing 2. Decreasing 3.C constant
2014			
2015			
2016			
2017			
2018			

Q41. Which cropping decisions are influenced by climate in your locality? 1) Planting date 2) Fertilizer application 3) Choice of crop 4) Varieties to grow 5) other ____________________

Q42. What are the major crop production constraints do you have faced? 1) Seed shortages 2) Labor shortages 3) Draft power shortages 4) Shortage of fertilizers 5 other (specify) ____

Q43, what would be the fate of your crop production (wheat & teff) in the next 10 years if you don't take any adaptation measures? 1) I will lose total production from my land by erosion 2) Productivity will decrease as a result of weather variability 3) Nothing more will happen 4) I don't know 5.others (specify)____________________________________

Q44. Is there a change in water availability in your area? 1) Increased 2) Decreased 3) No change

Section Four: The Major Adaptation Practice and Challenges

Q45, Do you apply the adaptation strategies in order to adapt hazard due to climate change? 1) Yes, 0) No

Q46. If "Yes" for Q45 which of the hazards have been reduced? 1) drought due to less rainfall during rainy season, 2) drought due to drought during the rainy season, 3) flood due to excessive rainfall, 4) damage due to excessively heavy showers, 5) damage due to extreme temperature, 6) other specify____

Q47. Did you apply short season growing crop and drought tolerance varieties? 1) Yes 2) No 3) I do not know

Q48. What are the challenges of for use of adaptation options of combating climate change? 1) Lack of money to finance 2) Lack of technical knowledge 3) Lack of irrigation 4) Lack of weather information 5) Lack of improved seed variety 6) If any other specify____

Q49. What are the determinant factors that hinder the perception of climate change/ variability? 1) Distance from market 2) Lack of infrastructure 3) Poor communication with DAs 4) Lack of information 5) If any other specify_____________________________

Q50. What activities do you do to cope with the impacts of climate variability in your area? 1) yes 0) no. (Multiple answers are possible.)

Copping mechanism	**frequency**	**percent**
1.Borrow money		
2. Selling cattle		
3. Migration		

4.Reduce Meal size and frequency		
5. Look for daily work		

Section five Farmers i adaptation choice

51. In response to climate change, have you taken any adaptation measures in order to overcome the effects of climate change?

1) Yes 0) No

52. If yes to question no.51, have you employed any of the following climate change adaptation strategies in your farm over the past three decades?

Adaptation choices	Frequency	Percent
Crop diversification		
Drought tolerant crop varieties		
Changing planting dates		
Mulching		
Taking Soil and water conservation measures		
Agro forestry practice		
Irrigation		
Diversifying nonfarm activities and income sources		

53. If your answer to question no. 52 is No, why you did not?

Barriers to adaption strategy	No of respondent	Percentage
Lack of climate forecasting information		
Poor potential for irrigation		
Shortage of farm land		
Shortage of labor for implementing adaptation		
Low level of education		
Lack of contact with extension personnel		
Seed shortages		
Labor shortages		

Appendix 2

Questions for Key Informant Interview (KII)

Q1. How long have you been in the area? _________________________

Q2. What is climate change? ____

Q3. Do you think there is climate change in Lemo district? _________________________

Q4. Is there any variability of temperature and rain fall in your kebele in the past 10 years? 1) Yes 2) No

Q5. If you say yes to Q4; have you seen any long-term changes of temperature and rainfall for the last three decades? How do you detect, and what is the main cause to the climate change/ variability?

Q6. Which Kebeles are more vulnerable to the impacts of climate change? ____

Q7.Which groups of people are more vulnerable? ___________________________

Q8. What are the observed indicators of climate change/ variability?

Q9. Have you ever encountered any climate change related extremes in your local area?

Q10. What is the main effect of climate change on wheat and teff crop production of your district/village/kebele?

Q11. What are the coping mechanisms/adaptation choices the farmers used to reduce the climate change effects on agricultural production activity/ livelihood in your area?

Q12. What are the major challenges in coping the problem and what do you think should be done?

Q13. Have you seen any incidence of disease or pest causes on livestock and crop production? Over the past three decades? (Explain) ___________________________________

Appendix 3

Questions for Focused Group Discussion (FGD)

Q1. What does climate change mean?

Q2. Do you think there is climate change/ variability in your area?

Q3. What do you think the local indicators of climate change/ variability?

Q4. Would you like to explain the agricultural/crop production trend and productivity in this area?

Q5. What are the major affecting factors of the crop production and the main causes of climate change/ variability?

Q6. Is reduction in crop yield/ productivity in your area ?

Q7. For the last three decades how would you describe the rainfall pattern of your area? 1) Onset /Off-set and Cessation of rainfall 2) Amount of Rainfall 3) Seasonal rain distribution 4) Temperature

Q8. What are the barriers to climate change related shocks?

BIOGRAPHICAL SKETCH

The author was born in 1990 in Lemo Woreda, Hadiya Zone, 275 km west of Hawassa town. He attended his primary School at Gora-Tume and his secondary school at Bobicho, and high school at Wachamo Senior Secondary School in the Hossana town. He joined Hawassa University Wondo-Genet Collage of Forestry and natural resource graduated with BSc degree in Natural resource management on June, 2005 E.C. Soon after his graduation, he was employed in Government Organization, as expert at Agriculture and Rural development office in the Lemo woreda, Hadiya Zone until September 2010 E.C, and he joined School of Graduate Studies at Hawassa University college of Agriculture in 2018/19 academic year to pursue his MSc program in Climate change and sustainable agriculture.