Climate Change and Adaptation Strategies at Smallholder Farmer's Level

The case of three districts of Tigray, Northern Ethiopia

Dissertation for the Master of Art in Rural Development

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DECLARATION

I, **Tewodros Gebreegziabher Asresehegn** hereby declare that the Dissertation entitled "**CLIMATE CHANGE AND ADAPTATION STRATEGIES AT SMALLHOLDER FARMER'S LEVEL, THE CASE OF THREE DISTRICTS OF TIGRAY, NORTHERN ETHIOPIA**", submitted by me for the partial fulfillment of the M.A in Rural development to Indira Gandhi National Open University, (IGNOUS) new Delhi is my own original work and has not been submitted earlier either to IGNOUS or to any other institution for the fulfillment of the requirement for any course of study. I also declare that no chapter of this manuscript in whole or in part is lifted and incorporated in this report from earlier work done by me or others.

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CERTIFICATION

This is to certify that Mr. **Tewodros Gebreegziabher Asresehegn** student of M.A (RD) from Indira Gandhi National Open University, New Delhi was working under my supervision and guidance for his project work for the course MRDP – 001. His project work entitled "**Climate change and adaptation strategies at smallholder farmer's level, the case of three districts of Tigray, northern Ethiopia**", which he is submitting, is his genuine and original work.

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ABSTRACT

Agriculture in general and smallholder farming in particular is extremely vulnerable to climate change as higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. For a country like Ethiopia where agriculture accounts for more than 40% of the GDP and is the main economic stay for more than 80% of the population, the economic performance can highly be affected by such events unless climate change adaptation measures are put in place. Adaptation to climate change at smallholder farmers' level requires that farmers first notice that the climate has changed, and then identify useful adaptations and implement them.

This study examined perception of the household on climate change and climate change impacts on their farming practice, climate change adaptation measures employed by the farming households as a response to the perceived climate change and factors determining rural household's adoption of climate change adaptation strategy.

A three-stage sampling procedure was employed. In the First stage Emba-Alaje, Kolla Tembien and Tahtay Maichew districts were purposively selected having the knowledge of having long term meteorological data records which fall in different livelihood zone of the region. At the second sampling stage, Gezeme, Merere and Etan Zere villages, respectively from the three districts were again purposively selected knowing the villages are target areas of the Global Climate Change Alliance project intervention in the region.. In the third stage, 10% of the total households in each village were sampled randomly for the survey.

Descriptive statistics such as Mean, standard deviation, percentages, average, ratio, and chart were used to describe, compare and contrast farmers' perception on climate variability and impact of climate change and adoption of climate change adaptation strategies. Multinomial logistic regression model were also used to analyse factors determining household's adoption of climate change adaptation strategy. Agriculture, both crop and livestock production was found to be the primary occupation of the households and 76% percent of the households perceive that the climate has changed over the last ten years. Meteorological data (2002 to 2011) from nearby station in the respective villages also showed decreasing trend of rain fall and slightly increasing trend of maximum temperature. 72% of the sampled households perceived that the change in the climatic condition has affected crop and livestock production in the study areas and 60% of the households have adopted climate change adaptation measures as a response to the perceived climate change impact on the farming system. Crop diversification, Crop selection, Soil moisture management and changing cropping calendar was reported to be the adaptation strategies employed by the farming households for crop production while enhancing production and conservation of animal feed, reducing herd size and seasonal migration and sifting from large to small animals were the adaptation strategies employed for livestock production. Past exposure to drought and hot temperature, level of education of the household heads and family members and access to extension service was found to be important factors which affect adoption of climate change adaptation measures for crop and livestock production.

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ABREVATIONS AND ACRONYMS

ACCCA: Advancing Capacity to support Climate Change Adaptation

CEEPA: Centre for Environmental Economics and Policy in Africa

CC: Climate Change

CFC: Chlorofluorocarbon

CO_2 : Carbon Di-Oxide

CRGE**:** Climate Resilient Green Economy

ESSP: Ethiopian Strategic Support Porgram

GCCA-E: Global Climate Change Alliance, Ethiopia

GDP**:** Gross Domestic Product

GHG: Green House Gas

HH: Household

IPCC**:** Intergovernmental Panel on climate change

MASL: Meter Above Sea Level

MDG: Millennium Development Goal

MoFED: Ministry of Finance and Economic Development

NAPA: National Adaptation Program of Action

NRC: National Research Council

SLM: Sustainable Land Management

SST: Sea Surface Temperature

U.S EPA: United States Environmental Protection Agency

U.S. NOAA: United States National Oceanic and Atmospheric Administration

UNFCCC: United Nations Framework Convention on Climate Change

USGCRP: United States Global Change Research Program

WOCAT: World Overview of Conservation Approaches and Technologies

CHAPTER ONE

1. INTRODUCTION

1. 1. Background

Tigray regional state is found in the northern part of Ethiopia. Agriculture, mainly smallholder farming is the main livelihood for large majority of the population. The diverse agro-ecology induced by the undulating landscape have lead to wide range of livelihood zones in the region of which the Cereal-livestock mixed farming dominant farming system in the region.

Thornton, et. al., (2006) noted that smallholder farming is extremely vulnerable to climate change as higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Crop failure induced by more and more extreme weather events and shifting seasons, combined with the rapid population growth, is threatening food security in the region and everywhere in the world as well. Although there will be some gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative.

A recent mapping on vulnerability and poverty in Africa put Ethiopia as one of the country most vulnerable to climate change with the least capacity to respond (Yosuf et. al., 2008). Moreover, projections of the World Bank on climate change impact indicate that wheat (staple crop) yield in Ethiopia will reduce by 33% due to climate change (World Bank, 2007). This amounts to a serious threat to food security and to the achievement of major developmental goals as the country in general and Tigray region in particular is highly dependent on the agricultural sector for income and food security.

Many development practitioners recognize that promotion of development paths that make households and communities more resilient to climatic stresses can also help to reduce poverty in more robust and sustainable ways. Hence, the need for greater understanding of how to design poverty reduction projects and programs in ways that increase the capacity of individuals, households and communities in the regional state to respond to climate variability and change is becoming important through time.

The international communities through the UNFCCC and in collaboration with the respective National authorities have also developed NAPA outlining urgent and immediate actions required to face climate change impacts and adaptation measures (Alemneh Dejene, 2010). Among the objectives as defined by the NAPA, special attention is given to strengthening the capacities of smallholder farmers to deal with the adverse effects of climate change and promote public education activities and information dissemination on climate change.

As an effort to join hands to the global and national initiative, the Ethiopian government has played a leading role in designing and implementing pro-poor development strategies to achieve broad based and sustainable economic growth over the last decade. In light of the strategy, objectives of green growth, has been put in place to reduce climate change impacts and poverty (CRGE, 2011).

The country has also developed a country wide Sustainable Land Management program for which Tigray regional state is pioneering. The program is aiming at enabling farmers and communities to adapt as well as become more resilient to climate change by increasing food production, conserving soil and water, enhancing food security and restoring productive natural resource.

As a result of the above concerted efforts in the last decades, poverty head count in Ethiopia fell from 38.7 % in 2004/05 to 29.6% in 2010/11 (MoFED 2012). With this track the country is considered as one of those countries who will achieve the MDG goals of reducing poverty by half by the year 2015

Considering the high dependency of the Ethiopian economy on agriculture coupled with the high rainfall variability (see figure 1 which implies the higher the coefficient of variation the more will be the unpredictability of the rainfall occurrence), the development path of the country in general and Tigray region in particular need to take in to account climate variability and climate change adaptation strategies. Burton, (1996) and Smith et al., (1999) indicated that sustainable development actions need to be complemented by planned adaptation strategies so as to adapt to the anticipated climate change impacts.

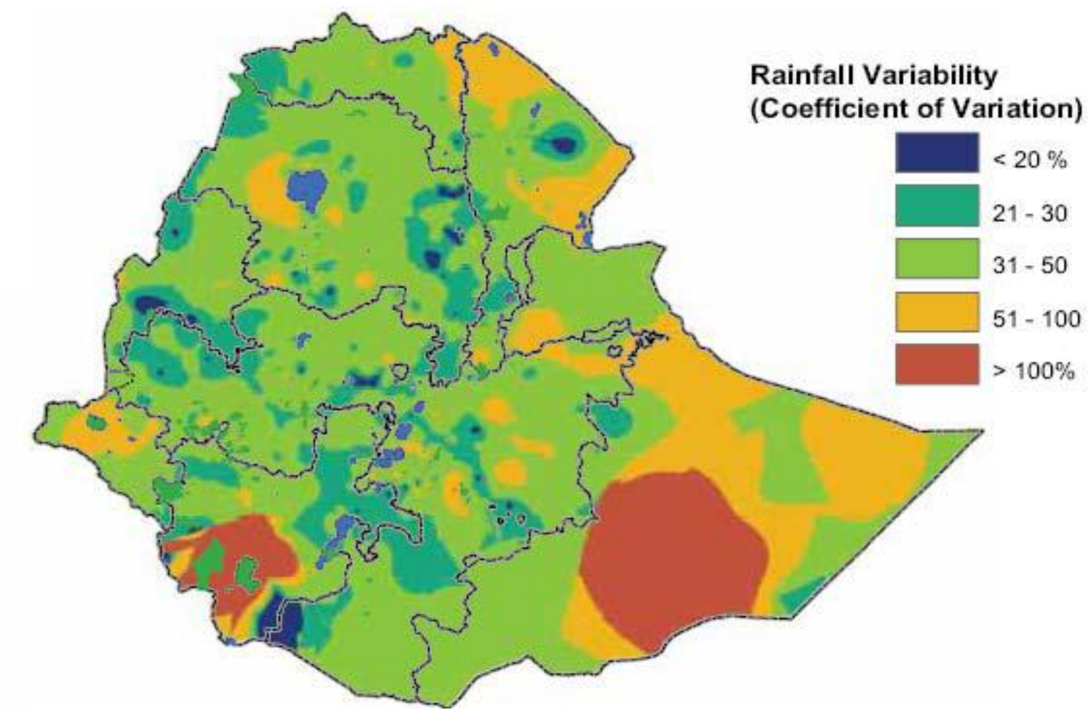


Figure 1: Rainfall variability map of Ethiopia

As a complementary action to the sustainable land management practices in the region, The Global Climate Change Alliance-Ethiopia (GCCA-E) Project is being implemented in nine districts distributed in four livelihood zones of Tigray Region. The project is aiming at testing/piloting and documenting climate smart agriculture at smallholder farmer's level for further up scaling.

The study aims at understanding and documenting adaptation strategies at smallholder farmers in different livelihood zones and factors determining choice of climate change adaptation strategies so as to serve as an input for the GCCA project intervention and to inform policies to face future climate change impact on the smallholder agriculture.

The study was conducted in three districts (Emba- Alaje, Kolla Tembien and Tahtay Maichew) located in three different livelihood zones of the ongoing Global Climate Change Alliance Project intervention Woredas in Tigray. This study addresses three main objectives: the first one analyses farmer's perception on climate change. The second objective assess and document the kinds of adaptation strategies employed by the smallholder farmers if any and the third objective analyses factors affecting farmer's decision making on choices of climate change adaptation measures.

1. 2. Statement of the problem

The increasing pressure on available land combined with inappropriate land use practices makes traditional farming practice in Africa unsustainable, even without the complications that climate change brings with it. Unfortunately, however, the climate is changing; many regions of the world in general and Africa in particular are vulnerable to the impacts of climate.

Erratic and irregular rainfall patterns, longer dry spells, droughts, which have implications for agriculture, e.g. calendar, productivity, new pests, are becoming common phenomenon in Ethiopia and more and more in Tigray region, which constrained the conventional agricultural production system. Reports from the national meteorological Agency in Ethiopia indicates that the average occurrence of drought related disaster is becoming more frequent with time (Table 1).

Table 1. Frequency of drought in Ethiopia

Year interval	Number of disaster	Average occurrence
1252-1400	8	Roughly once in 18 years
1400-1800	27	Roughly once in 15 years
1800-1900	10	Roughly once in 10 years
1900-1987	14	Roughly once in 6 years
1988-2002	5	Roughly once in 3 years

Source: National Metrological Agency, Ethiopia

For a country like Ethiopia where agriculture accounts for more than 40% of the GDP and is the main economic stay for more than 80% of the population, the economic performance is highly affected by such events.

Moreover; national projections from Ethiopia indicate that climate change is expected to increase rainfall variability and the frequency and magnitude of extreme events. According to Gebreegziabher et.,al. (2011) the overall impact of these changes on GDP would be substantial, averaging 10% per capita loss in rural areas over the projection period of 40 years from now under no total factors productivity scenario. World Bank (2007) also projected 33% wheat (staple crop) yield reduction in Ethiopia which will seriously affect food security endeavours in the country.

The dry land population such as the northern Ethiopia, where this study has been conducted, is much vulnerable to climate change impacts because of its geographic location, low income and greater reliance on the climate sensitive sector (Stern, 2006)

These multiple stresses on the Ethiopian and Tigray farmers induced by climate variability and climate change can only be relieved through “planned adaptation”. IPCC, (2001) noted that adaptation can greatly reduce vulnerability to climate change by making rural communities better able to adjust to climate change and variability, moderating potential damages, and helping them cope with adverse consequences.

Maddison (2006) noted that adaptation to climate change requires that farmers first notice that the climate has changed, and then identify useful adaptations and implement them. Indeed, farmers possess valuable indigenous adaptation strategies that include early warning systems (Ajibade and Shokemi 2003) and recognize and respond to changes in climate parameters (Thomas et al. 2007).

The communities in the study area are paying increasing attention to find sustainable ways of managing their agricultural production under the prevailing climatic condition based on the indigenous knowledge built for generations and support from the extension. However; adoption of climate change adaptation strategies widely varies among communities and even among farmers within the same community in the region. It is natural Farmers and communities who perceive the fact that the climate is changing start to adjust the farming practice to adapt the prevailing condition and build resilience. However; some communities and farmers do not respond to climate change despite having perceived changes in temperature and rainfall for some reasons.

Hence, better understanding on factors affecting farmers’ perception on climate change, ongoing adaptation measures, and the decision-making process on adoption of climate smart farming practice is important to inform policies so as to promote successful climate change adaptation strategies for the agricultural sector in the region.

Considering the long years of experience in soil and water conservation and land management practices in Tigray many studies has been conducted on the impacts of soil and water conservation and land management practices in the rural livelihood and ecological restoration. However, as to my knowledge the land management practices and technologies adopted by the community members in the different livelihood zones of the region as a strategy to cope up the climate change and factors affecting farmer's adaptation to climate change are not systematically documented.

Moreover; regardless of the diverse understanding and perception of the academia and the international community on climate change and climate change impacts, information and knowledge on the perception, response and preparedness of the smallholder farmers in the study area is not studied.

In light of the upcoming climate change challenges still a lot of efforts are needed to document smallholder farmer's knowledge on climate change adaptation strategies. Many win-win solutions on climate change adaptation and livelihood improvement at smallholder farmers level exists which need to be further tapped for up scaling.

1. 3. Research objective

The general objective of this research is to broaden the knowledge as to how the smallholder farmers perceive on climate change which is becoming global concern, the coping mechanisms of smallholder farmers to the variable climatic condition and factors affecting the adaptive capacity of the local community in the study areas to climate change related problem. The specific objectives of the study are:

- Asses farmers perception and understanding on climate change impacts on agricultural productivity
- Identify the climate change adaptation strategies of the smallholder farmers in the study area
- Identify factors determining farmer decision on the climate change adaptation strategies

1. 4. Research question

The central question of the study is 'Does the smallholder farmers perceive the climate is changing? In order to answer this question, the study has worked on answering the following questions

- Do the farmers in the study area observe any change in their cropping calendar?
- Do the farmers make shift in their crop and livestock production system?
- Do all farmers have the same feeling and understanding on climatic condition?

1. 5. Hypothesis

The hypothesis of the study is the smallholder farmers in the study area do perceive the climate is changing and have developed local level climate change adaptation strategy.

1. 6. Significance and scope of the study

The study is believed to contribute to the efforts being done to understand the perception of smallholder farmers on the current global concern on climate change and find out locally applied climate change adaptation strategies which will serve as a basis in designing coping strategies for the upcoming possible climate change impacts.

For a country like Ethiopia where agriculture is the main economic stay for large majority of the population, there is doubtless need to understand farmer's perception on climate change impacts and preparedness to adapt possible climate change impacts. Hence, this study will provide valuable inputs to the country wide and local level planning to support smallholder farmers to cope up climate change impacts in semi-arid areas with similar socio-cultural setting. In general the study will contribute to:

- The understanding of current perception and feeling of the small holder farmers on the global concern "climate change and its impact"
- The knowledge on diversified climate change adaptation strategies proven at local level in response to the prevailing climate change impacts
- The knowledge on factors affecting adaptive capacity of smallholder farmers

CHAPTER TWO

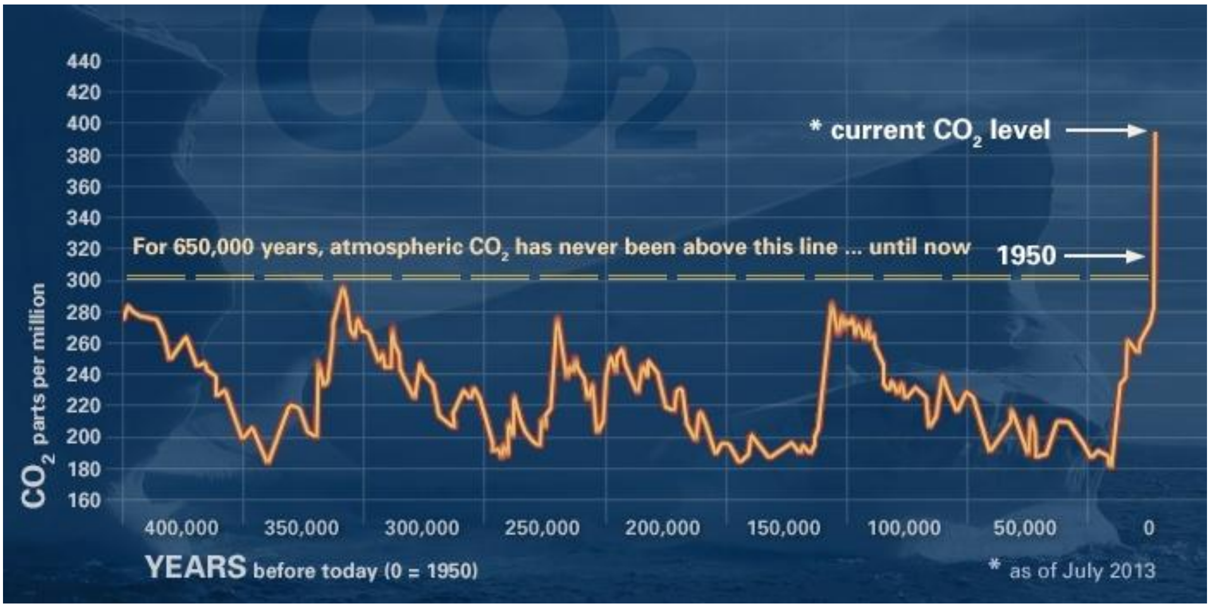
2. REVIEW OF LITERATURES

2. 1. Global climate change and its impact

Earth-orbiting satellites and other technological advances have enabled scientists to see the big picture, collecting many different types of information about our planet and its climate on a global scale. Studying these climate data collected over many years reveal the signals of a changing climate. Empirical and local evidences witnessed that the global climate is changing through time at an alarming rate.

2.1. 1. Global evidences on climate change

A recent CO $_2$ trend analysis by NOAA (figure 2) provides evidence that atmospheric CO_2 has increased since the Industrial Revolution.



(Source NOAA)

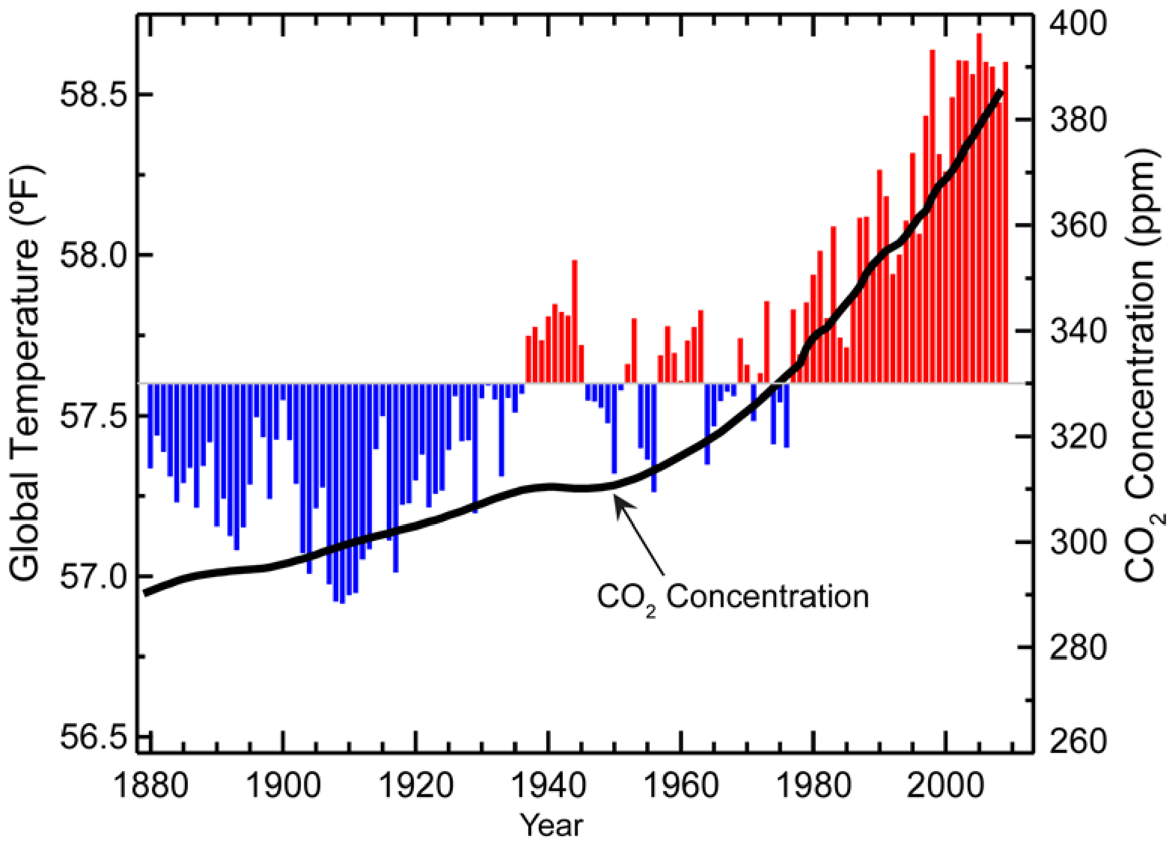
Figure 2: Global trend of Carbon Dioxide Concentration in the Atmosphere

Direct experimental evidence through satellites measure on heat escaping out to space revealed that heat escaping at the particular wavelengths that CO_2 absorbs is getting less (Harries et.al. 2001. Wang, and Liang, (2009) confirm more downward infrared radiation through surface measurements and a closer look at the downward radiation revealed more heat returning at CO_2 wavelengths. Evans, (2006) concluded based on the above findings that there is strong connection between greenhouse gas increases in the atmosphere and global warming.

Alexander (2006) have observed faster warming of the planet during night than during the day which is considered as a change in the pattern of warming of our planet induced by increased greenhouse effect. Furthermore; Jones et.al., (2003) observed cooling in the upper atmosphere, known as the stratosphere, which is distinctive pattern of the greenhouse warming. (Jones et. al., 2003)

The U.S NOAA also identified high overland and ocean temperature and rise of global sea level as key planet wide indicators among others of global climate change.

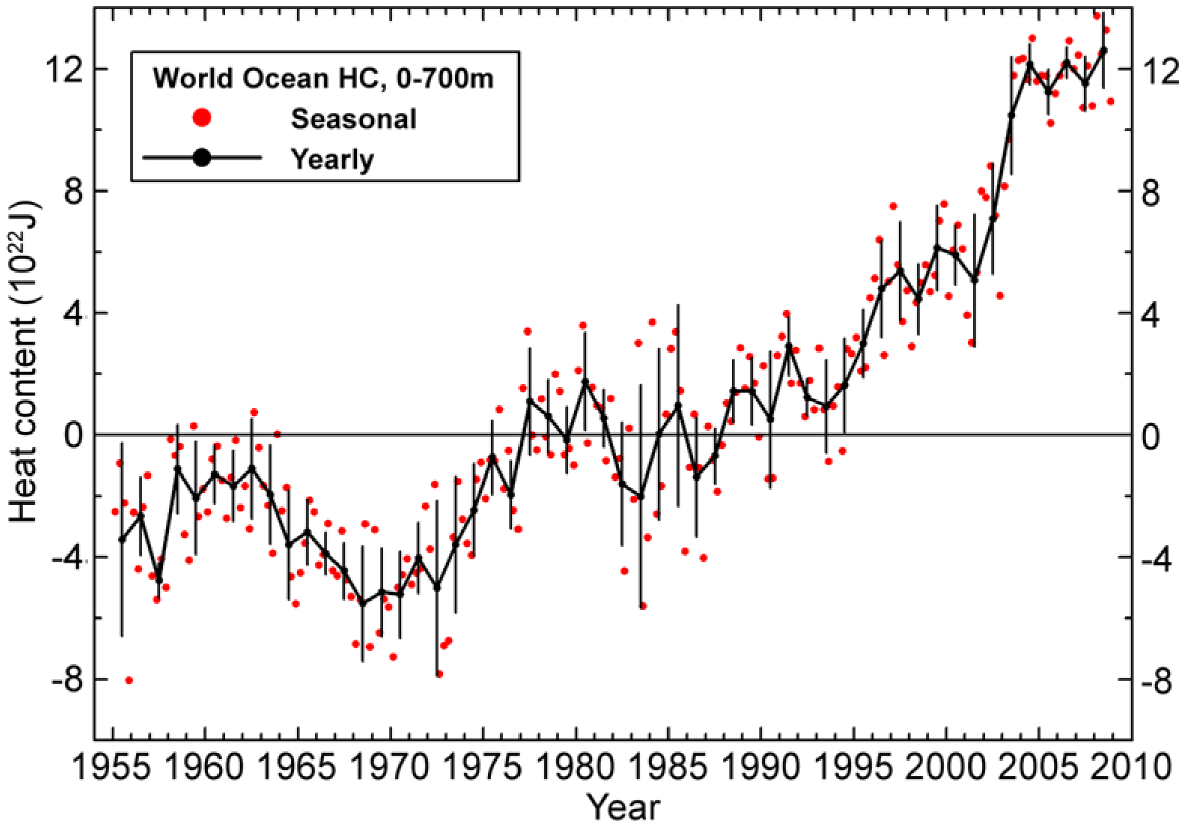
High temperature overland: Global average temperature is one of the most-cited indicators of global climate change. The NOAA shows an increase of approximately 1.4°F since the early 20th Century (figure 3). The global surface temperature is based on air temperature data over land and sea-surface temperatures observed from ships, buoys and satellites. The report indicated that there is a clear long-term global warming trend, while each individual year does not always show a temperature increase relative to the previous year, and some years show greater changes than others. These year-to-year fluctuations in temperature are due to natural processes, such as the effects of El Ninos, La Ninas, and the eruption of large volcanoes. Notably, the 20 warmest years have all occurred since 1981, and the 10 warmest have all occurred in the past 12 years (Tufa, 2010).



Source NOAA

Figure 3: Global temperature and Carbon Dioxide concentration

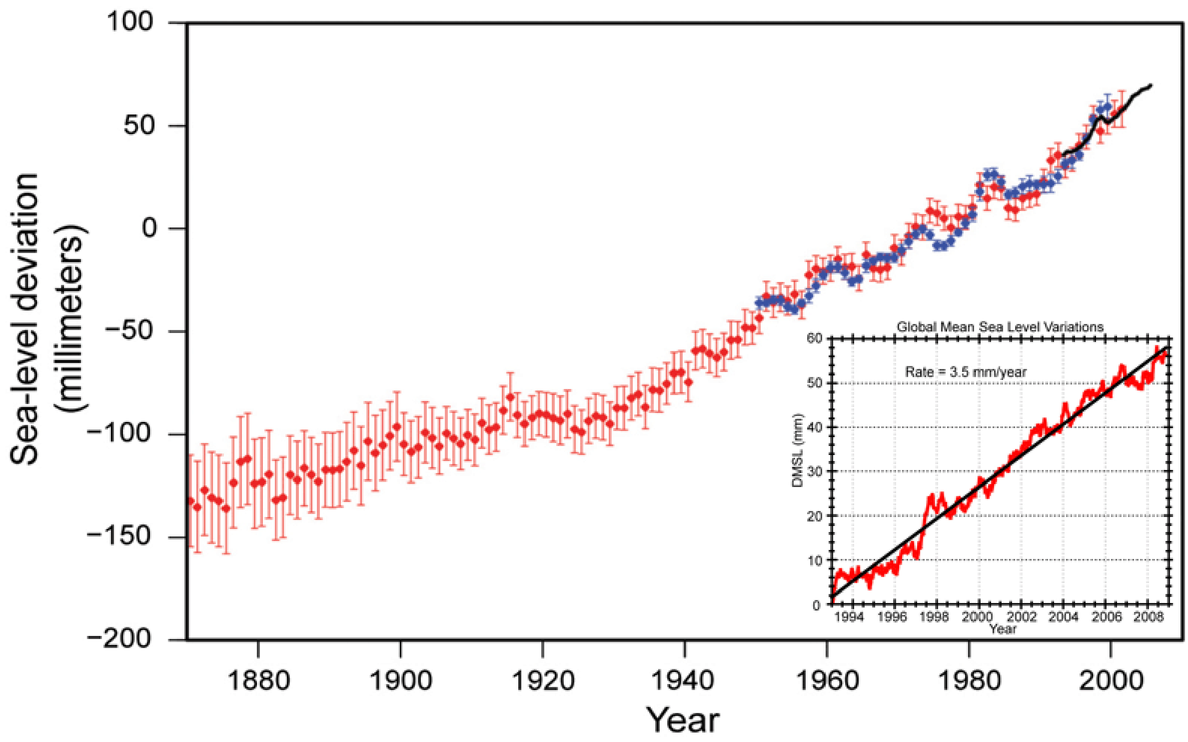
Higher temperature over ocean: the report indicated that even though there is significant variation in the heat content of the ocean from place to place and from year to year due to changing ocean current and natural variability, there is a strong increase trend during the period of reliable measurements (Figure 4). Levitus, et al., (2009) also reported rise in ocean temperature of the top 700 meter by about 0.302 degree Fahrenheit since 1969 due to absorption of the increased heat in the atmosphere.



Source NOAA

Figure 4: Global Trend of Ocean Temperature

Higher sea level: the NOAA reported indicated that Global mean sea level has been rising at an average rate of approximately 1.7 mm/year over the past 100 years (measured from tide gauge observations), which is significantly larger than the rate averaged over the last several thousand years. Church and White (2006) also noted global sea level rise in the last decade nearly double the rate of the last century (figure 4). According to the NOAA report much of the sea level rise to date is a result of increasing heat of the ocean causing it to expand and It is expected that melting land ice (e.g. from Greenland and mountain glaciers) will play a more significant role in contributing to future sea level rise.



Source NOAA

Figure 5: Global trend of sea level

2.1. 2. Local Evidences on climate change

A study by Hadgu et.al., (2013) on trend and variability of rainfall in northern Ethiopia indicated that frequency occurrence of below normal rainfall increased in the last decade. The study revealed that 60% of the years in the recent decade had recorded below long term average in all stations. Viste et.al., (2012) also indicated that weather related shocks are becoming more frequent in the study areas conducted in Tigray, Northern Ethiopia.

A study by Meze-Hausken, (2004) in Tigray also indicated that farmers have a tendency towards fewer crop varieties and a shorter planting season, indicating that most crops are planted today during mid- to end of June, and are often harvested some weeks earlier as well. Sorghum, as a long-growing-season crop, wheat, and barley tend to be planted 2 week later than during the 1930s to 1950s. Barley is harvested 2 to 3 wk earlier, and wheat up to 6 week earlier. According to Hausken this indicate a shift towards faster-growing varieties with higher drought resistance (such as *Shahan* in the local language, a variety of soft wheat), which utilize the shorter summer rains. One species (*kinkina* wheat) has become almost abandoned since the 1970s in the village, due to the perceived lack of residual moisture in the soil after the generally poor spring rains, as well as possibly due to a decline of long-term fallow practices in the village (and in most of the region).

2.1. 3. Causes of global climate change

Earth's temperature depends on the balance between energy entering and leaving the planet's system. According to U.S EPA report the change in the earth's energy balance is affected both by human and natural factors such as changes in greenhouse effect, variation in the Sun's energy reaching earth and changes in the reflectivity of Earth's atmosphere and surface.

U.S EPA reported that the climate system varies naturally over a wide range of time scales. Climate changes prior to the Industrial Revolution in the 1700s was reported to be caused by natural phenomena, such as changes in solar energy, volcanic eruptions, and natural changes in GHG concentrations (NRC, 2010)

Climate change effect of the solar energy induced by fluctuation in intensity which natural occur in 11 years cycle, changes in the shape of earth's orbit and the tilt and position of earth's axis was reported to be constant (NRC, 2010). U.S EPA also reported that since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere. Concentration of green house gases such CO_2, CH_4 and N_2O has, however, substantially increased during the last 20^{th} Century (NRC, 2010). Atmospheric CO_2 concentrations have increased by almost 40%, Methane concentrations are now more than two and half times pre-industrial and concentrations of N_2O have risen approximately by 18% since the start of the Industrial Revolution, with a relatively rapid increase towards the end of the 20th century

(Jansen et. al., 2007 and Solomon, S. et.al., 2007). These greenhouse gas emissions are reported to increase the greenhouse effect and caused Earth's surface temperature to rise (Sthapit BR et.al., 2012). The primary human activity affecting the amount and rate of climate change is greenhouse gas emissions from the burning of fossil fuels.

U.S EPA also reported change in Earth's reflectivity induced by human change in land use and land cover of our planet. Processes such as deforestation, reforestation, desertification, and urbanization often contribute to changes in climate in the places they occur. These effects may be significant regionally, but are smaller when averaged over the entire globe
Considering the above facts different studies have concluded that the recent climate changes especially warming since the mid 20th century can be explained to be of human cause (IPCC, 2007).

NRC (2010) also reported that this enhanced Greenhouse Effect comes about because of the addition of huge volumes of greenhouse gases, such as carbon dioxide (CO_2), methane, nitrous oxide, water vapour, and CFC's , into the atmosphere throughout the industrial age. Baumert et al. (2009) also noted that net carbon dioxide emissions come from energy consumption, i.e. burning of fossil fuels and land use change and forestry, especially deforestation and degradation, are the next largest emitters of carbon dioxide. The NRC, (2010) report indicates that human activities currently release over 30 billion tons of CO_2 into the atmosphere every year.

The global warming potential over 100 years of methane and nitrous oxide is estimated to be 23 and 289 CO_2 equivalent respectively (Baumert et al. 2009). One CO_2 equivalent implies the warming effect caused by one molecule of carbon dioxide over a given period of time, usually chosen as 20 or 100 years (Sthapit et.al., 2012). The high CO_2 equivalence of nitrous oxide as compared to carbon dioxide dictates that even small increases in emissions of these GHGs can result in significant warming effect.

Generally, warmer surface temperatures lead to an increase in evaporation from the oceans and land, leading to an increase in globally averaged precipitation. However, According to the U.S EPA report some regions can get more precipitation, shifting storm patterns and increased evaporation which can cause some areas to experience more severe droughts than they have in the past. Scientific studies (NRC, 2010) also indicate that extreme weather events such as storms, floods, and hurricanes are likely to become more intense.

Seleshi and Zanke, (2004) indicated that the annual rainfall variability in the central highlands of Ethiopia during the Kiremt season (the main rain season) is mostly associated with the equatorial eastern Pacific sea level pressure, the southern oscillation index and the SST over the tropical eastern Pacific Ocean Pacific. The Authors noted that the Warm SST (El Niño) leads to reduction in the summer rains, while the cold phase (La Niña) has the opposite effect.

2.1. 4. Impacts of global climate change on agricultural practices

Generally, warmer surface temperatures lead to an increase in evaporation from the oceans and land, leading to an increase in globally averaged precipitation. USGCRP, (2009) also reported that changes in temperature, amount of carbon dioxide(CO_2) and frequency and intensity of extreme weather could have significant impact on crop yield. According to the report crops tend to grow faster in warmer conditions. However, for some crops (such as wheat), faster growth reduces the amount of time that seeds have to grow and mature (Gourdji S., et.al., 2013). This ultimately reduces crop yield per unit area. Alemneh Dejene, (2010) also reported that some area are expected to have unfavorable changes in temperature and precipitation patterns, such as droughts or floods, posing risks to agricultural production and thereby food security in rural areas.

Large numbers of agriculturalists in Africa already perceive that the climate has become hotter and the rains less predictable and shorter in duration (CEEPA, 2006). The report indicated that climate-related vulnerability of the rural poor will further be worsened with increased susceptibility to pests and disease. Climate change and related variability is critically jeopardizing some of the progress made over recent years in overcoming hunger and poverty reduction in many parts of Africa (Alemneh Dejene, 2010). The IPCC (2007) report also indicated that least developed countries, of which a significant number are in Africa, are most vulnerable to the impact of climate change and bear the highest risks to their socioeconomic development.

The occurrence of droughts and floods has been found to reduce Ethiopia's annual growth potential by more than one third (Grey and Sadoff, 2006). It is estimated that the 1984-85 drought reduced Ethiopia's agricultural production by 21 percent, which led to a 9.7 percent fall in the GDP (World Bank, 2006). Crop and livestock losses over North-Eastern Ethiopia, associated with droughts during 1998-2000, were estimated at US$266 per household, which is greater than the average annual income for 75 percent of the households in this region (Carter et al., cited in Stern, 2007).

The impact of climate variability includes ex ante (before onset of the event) and ex post (after the event) impacts (Tufa, 2010). The author elaborated that ex ante impacts are the opportunity costs associated with conservative strategies that farmers might employ to buffer themselves against climatic extremes at the expense of lower average productivity and profitability, also inefficient resource use. This may include avoidance of improved production technology, selection of less risky but less profitable crops, under-use of fertilizers, shifting household labour away from farming enterprises and shifting from productive to non-productive (Hansen et al., 2004). As a result, the poor farmer may suffer from the impact of climate variability even in the years when climate conditions are favourable. On the other hand, ex post impacts are direct results of a climate shocks such as droughts and floods which ultimately decrease yields or even complete losses due to total or partial destruction of crops, livestock, infrastructure and other assets (World Bank, 2007).

According to Tufa, (2010) these direct and indirect impacts of climate variability may contribute to both transitory and chronic poverty for the resource poor farmers.

2. 2. Adaptation to climate change and adaptive capacity of smallholder farmers

Adaptation is defined as the process of adjustment to actual or expected climate and its effects in order to moderate harm or exploit beneficial opportunities (IPCC, 2007). Adaptation actions may be undertaken by public or private actors, and can be anticipatory or reactive, and incremental or transformative (World Bank, 2007, Adger et al., 2007; Stafford Smith et al., 2011). In both principle and practice, adaptation is more than a set of discrete measures designed to address climate change; it is an ongoing process that encompasses responses to many factors, including evolving experiences with both vulnerabilities and vulnerability reduction planning and actions, as well as risk perception (Tschakert and Dietrich, 2010; Weber, 2010; Wolf, 2011).

According to Armitage (2005) adaptive capacity can also be described as the capability for innovation and anticipation. Adger (2003) also defined adaptive capacity of community or individuals to climate change impacts as the ability to learn from mistakes and the capacity to generate experience in dealing with change (Berkes et al., 2003). The above definitions illustrate that adaptive capacity to climate change impacts is derived from combination of strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake adaptation.

Enhancing adaptive capacity under climate change entails paying attention to learning about past, present, and future climate threats, accumulated memory of adaptive strategies, and anticipatory action to prepare for surprises and discontinuities in the climate system (Nelson et al., 2007).

Adaptive capacity is uneven across and within sectors, regions, and countries (K. O'Brien et al., 2006). Although wealthy countries and regions have more resources to direct to adaptation, the availability of financial resources is only one factor determining adaptive capacity (Moss et al., 2010; Ford and Ford, 2011). Other factors include the ability to recognize the importance of the problem in the context of multiple stresses, to identify vulnerable sectors and communities, to translate scientific knowledge into action, and to implement projects and programs (Moser and Ekstrom, 2010). Parry et al., (2007) noted that the capacity to adapt is in fact dynamic and influenced by economic and natural resources, social networks, entitlements, institutions and governance, human resources, and technology. However; it is particularly important to understand that places with greater wealth are not necessarily less vulnerable to climate impacts and that a socioeconomic system might be as vulnerable as its weakest link (O'Brien et al., 2006; Tol and Yohe, 2007). Therefore, even wealthy locations can be severely impacted by extreme events, socially as well as economically, as Europeans experienced during the 2003 heat wave (Salagnac, 2007).

Current adaptation planning in many countries, regions, and localities involves identification of a wide range of options, although the available knowledge of their costs, benefits, wider consequences, potentials, and limitations is still incomplete (NRC, 2010). In many cases, the most attractive adaptation actions are those that offer development benefits in the relatively near term, as well as reductions of vulnerabilities in the longer term (Agrawala, 2005; Klein et al., 2007; McGray et al., 2007; Hallegatte, 2008a; NRC, 2010). An emerging literature discusses adaptation through the lens of sustainability, recognizing that not all adaptation responses are necessarily benign; there are tradeoffs, potentials for negative outcomes, competing interests, different types of knowledge, and winners and losers inherent in adaptation responses (Beckman, 2011; 2011; Owuor et al., 2011). Sustainable adaptation is defined as a process that addresses the underlying causes of vulnerability and poverty, including ecological fragility; it is considered a way of generating social transformation, or changes in the fundamental attributes of society that contribute to vulnerability (Eriksen and O'Brien, 2007).

Adaptation to climate change requires that farmers first notice that the climate has changed, and then identify useful adaptations and implement them (Maddison 2006). Indeed, farmers possess valuable indigenous adaptation strategies that include early warning systems (Ajibade and Shokemi 2003) and recognize and respond to changes in climate parameters (Thomas et al. 2007).

Farmers adapt to possible climate change impacts by increasing diversification and by protecting sensitive crop growth stages from coinciding with very harsh climatic conditions such as mid-season drought (Nhemachena and Hassan, 2008). The authors classified the different climate change adaptation options of African farmers in to three major categories namely diversifying in to multiple crops and mixed crop-livestock system, switching from crop to livestock and shifting from dry land to irrigated agriculture.

ACCCA, (2010) also reported that crop diversification, using different crop varieties, using short growing crop varieties, increased use of labor input per unit of land, increased use of soil and water management techniques, plating more trees at plot, use of external fertilize at plot level and borrowing lost crops from community are employed by farmers in Tigray, Northern Ethiopia as an adaptation to climate change.

2. 3. Factors determining choice of adaptation strategies at smallholder farmers' level

A number of studies look particularly at the factors that influence farmers' decision to choice climate change strategies (ACCCA, 2010; Nhemachena and Hassan, 2008; Vogel and O'Brien, 2006; Ziervogel et al., 2005). These studies examine farmers' perceptions, use of information, and other factors influencing the decision-making process. Thomas et al.,(2007) also indicated that farmers' perceptions of climate change and their behavioural responses may be more related to recent climate events or trends as opposed to long-term changes in average conditions. Moreover, the study stresses the importance of local knowledge in decision making regarding climate risk. That is, farmers base their decision to adapt their farming practices not only on changes in average conditions, but on a number of other climate factors observed through personal experience such as extreme events; rainfall frequency, timing, and intensity; and early or late frosts (Roncoli et al., 2002; Vogel and O'Brien, 2006). Examining the role of forecast climate information in decision-making, Hansen et al. (2004) suggest that information derived from personal experience and information from external description yield different choice results under conditions of climate risk and uncertainty—decisions based on personal experience are likely to give greater weight to recent events. Ziervogel et al. (2005) also found out that the use of accurate climate forecasts can improve household well-being while poor forecast information can actually be harmful to poor farmers. Hansen et al., (2007) also noted that climate information needs to be accurate, accessible and useful for farmers in order to support adaptation and help farmers manage risks. The ability to respond to climate forecasts and the benefits obtained from their use are determined by a number of factors including the policy and institutional environment and the socio-economic position of the household (Ziervogel et al., 2005; Vogel and O'Brien, 2006). Promoting the use of climate information for adaptation among the poorest farmers also requires resources needed to implement adaptation options (Vogel and O'Brien, 2006).

Formal and informal institutions and social relationships are also important factors in facilitating or hindering adaptation to climate change (Agarwal and Perrin, 2008). The Authors noted that institutions influence and shape the ability of individual actors to respond to climate change and the options they choose, and they deliver and govern access to external resources to facilitate adaptation. The study also highlights the potential for rural institutions to strengthen adaptive capacity and facilitate local level adaptation to climate change (Agarwal and Perrin, 2008). Rural extension services being the important source of information on agronomic practices as well as on climate is noted as important institution in the rural areas to be considered in climate change adaptation (Nhemachena and Hassan, 2007). Maddison (2007) and Tizale (2007) also reported the importance of extension education to motivate farmers to adopt specific soil and water conservation practices to cope up climate change. Other adoption studies, however, have found that extension was not a significant factor affecting the adoption of soil conservation measures (Pender et al., 2004; Nkonya et al., 2005; Birungi, 2007).

Seo & Mendelsohn (2006b) also pointed out that farmer's choice of crop and livestock species is influenced by seasonal climate attributes (temperature and precipitation). Nhemachena and Hassan (2008) indicated that drier and warmer climates favor livestock production and irrigation but reduce the incidence of crop cultivation, especially under rain fed conditions.

Different studies indicated that Household size has mixed impacts on farmers' adoption of agricultural technologies. Larger family size is expected to enable farmers to take up labor intensive adaptation measures (Nyangena, 2007; Dolisca et al., 2006; Anley, 2007; Birungi, 2007). Alternatively, a large family might be forced to divert part of its labor force into non-farm activities to generate more income and reduce consumption demands (Tizale, 2007). However, the opportunity cost of labor might be low in most smallholder farming systems as off-farm opportunities are rare. Therefore under such circumstance it is expect that farm households with more labor are better able to take up adaptations in response to changes in climate. Although farmers can hire extra labor, most rural farmers are not able to do this, which limits their ability to take on labor intensive crop and livestock activities.

Similarly the influence of age on the choices has been mixed in different studies. Bekele & Drake, (2003) found that age had no influence on a farmer's decision to participate in forest and soil and water management activities. Another study by Anley et al., (2007), however, found that age is significantly and negatively related to farmers' decisions to adopt and Bayard et al. (2007) found that age is positively related to the adoption of conservation measures.

Gender is also an important variable affecting adoption decision at the farm level. Female farmers have been found to be more likely to adopt natural resource management and conservation practices (Dolisca et al., 2006; Bayard et al., 2007). However, Bekele & Drake (2003) found that household gender was not a significant factor influencing farmers' decisions to adopt conservation measures.

Education, farming experience and perceptions are also important socio-economic factors influencing adoption decisions. Tizale (2007) and Anley et al., (2007) have shown that improving education and disseminating knowledge is an important policy measure for stimulating local participation in various development and natural resource management initiatives. Better education and more farming experience improve awareness of potential benefits and willingness to participate in local natural resource management and conservation activities. However, Clay et al. (1998) found that education was an insignificant determinant of adoption decisions, while Okeye (1998) and Gould et al. (1989) found that education was negatively correlated with such decisions. Educated and experienced farmers are expected to have more knowledge and information about climate change and agronomic practices that they can use in response (Maddison, 2006).

Awareness of the problem and potential benefits of taking action is another important determinant of adoption of agricultural technologies. Maddison (2007) found that farmers' awareness of changes in climate attributes (temperature and precipitation) is important for adaptation decision making. Araya & Adjaye (2001) found that farmers' awareness and perceptions of soil erosion problems positively and significantly affected their decisions to adopt soil conservation measures. In this study it is hypothesized that farmers who notice and are aware of changes in climate would take up adaptation measures that help them reduce losses or take advantage of the opportunities associated with these changes.

Farm assets and wealth factors are another important socio-economic factors influencing choice of climate change adaptation measures. Empirical adoption studies have found mixed effects of farm size on adoption. For example, a study by Anim (1999) on soil conservation measures in South Africa showed that farm size was not a significant adoption factor. Other studies by Anley et al., (2007), however, found that farmers with larger farms were found to have more land to allocate for constructing soil bunds (embankments) and improved cut-off drains in Haiti. On the other hand, Nyangena (2007) found that farmers with a small area of land were more likely to invest in soil conservation than those with a large area. This study hypothesizes that farmers with large farms would adopt measures that require a large area of land such as livestock systems, while farmers with small farms are expected to diversify their options.

Access to agricultural services such as credit, input supply and output market are also important factors influencing decisions on choice of adaptation measures. Tizale (2007) found that access to credit is an important determinant enhancing the adoption of various technologies. With more financial and other resources at their disposal, farmers are able to make use of all their available information to change their management practices in response to changing climatic and other conditions. For instance, with financial resources and access to markets farmers are able to buy new crop varieties, new irrigation technologies and other important inputs they may need to change their practices to suit the forecasted climate changes.

Market access is another important factor affecting adoption of agricultural technologies (Feder et al., 1985). Input markets allow farmers to acquire the inputs they need such as different seed varieties, fertilizers and irrigation technologies. At the other end, access to output markets provides farmers with positive incentives to produce cash crops that can help improve their resource base and hence their ability to respond to changes in climate (Mano et al., 2003).

CHAPTER THREE

3. MATERIALS AND METHODS

3. 1. Description of the study area

3.1. 1. Location

The study sites are located in three districts of Tigray Region, Northern Ethiopian (See location map). Gezeme Village is found in Emba Alaje at 39^{0}29’18”E and 12^{0}57’30” N with altitude range from 1900 to 2250 MASL and at a distance of 98km south of Mekelle (the capital city of Tigray region) along the high way to Addis Abeba (capital of Ethiopia). The second study site (Merere Village) is found in Kolla Tembien district at 38^{0}50’06” E and 13^{0}42’32” N with an altitude range from 2670 to 1090 MASL at a distance of 90 km North East of Mekelle along the road to Mekelle to Adwa. The third study site (Etan Zere Village) is found in Tahtay Maichew district at 38^{0}33’28” E and 14^{0}07’13 N with an altitude range of 2500 to 1780 MASL and at a distance of 260km north east of Mekelle.

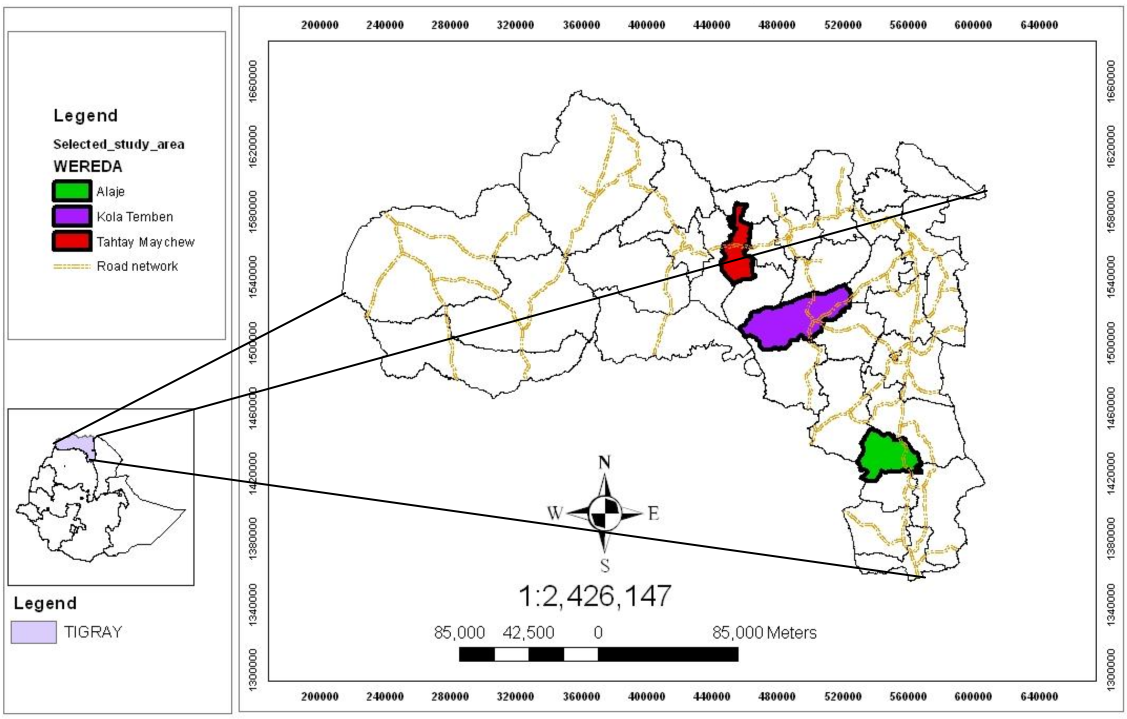


Figure 6: Location Map of the Study Areas

3.1. 2. Climate and agricultural practices

The climate in Ethiopia varies considerably with altitude. As part of the Ethiopian highland massif, Tigray has in general a cool tropical semi arid climate. It is characterized by recurrent drought induced by moisture stress. The length of crop growing period varies generally between 45 and 120 days (CND, 2002). In general, two rainfall seasons can be distinguished in Tigray: the "Belg" or small rains that takes place from March till May and the ‘Kiremti’ or big rains that take place from July to September. The rainfall amount in Tigray is highly dependent on the altitude. Mountain areas are more humid and have a longer rainy season than low land areas.

Ten year (2002 to 2011) rainfall data from the nearest meteorological station in Adishihu which is 10 km from the Gezeme village indicated shows that the rainfall is characterized by uni-modal distribution with more than 80% of the annual rain occurring between July and August (fig. 7). The ten years average annual rainfall is 533 mm ranging from 238.7 mm in 2002 to 893.5 mm in 2006 (see Annex 1).

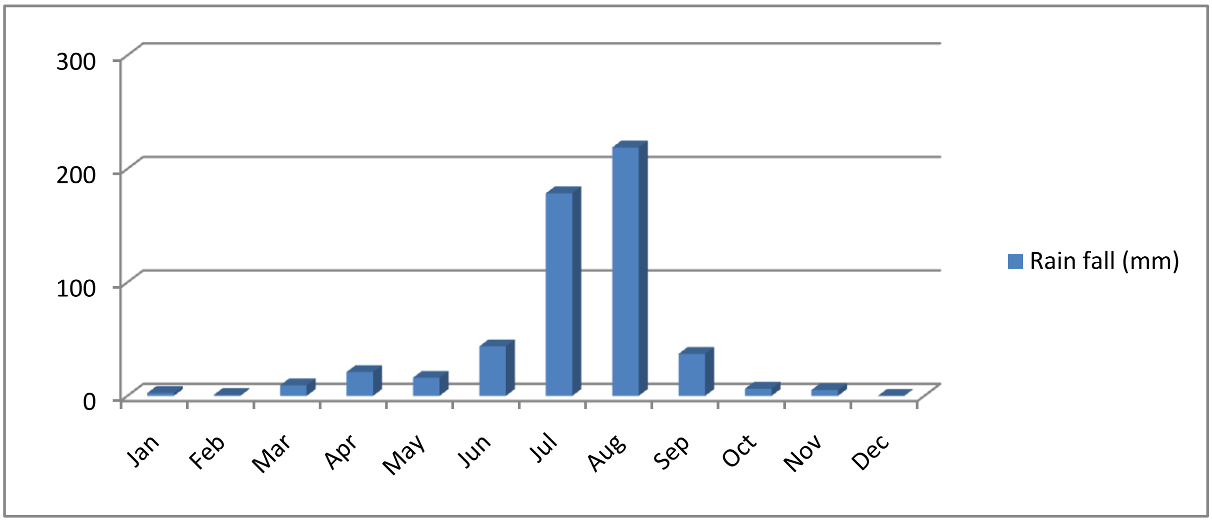


Figure 7: Ten years average monthly rainfall of Adi-shihu (Gezeme area)

As shown in figure 8, Barley and wheat are the dominant crops grown in the Gezeme village (the study area) mainly for home consumption. Legumes and pulses are also planted in the area as crop rotation and soil fertility management. The crop growing period starts in June and crop harvest, under normal condition, goes up to November. Land preparation is made following first rain shower using oxen draft power.

Livestock production also contributes significantly to the household economy in the area through sale of animal product and by-products. Furthermore, beekeeping is commonly practices by the households near their homestead and in protected areas.

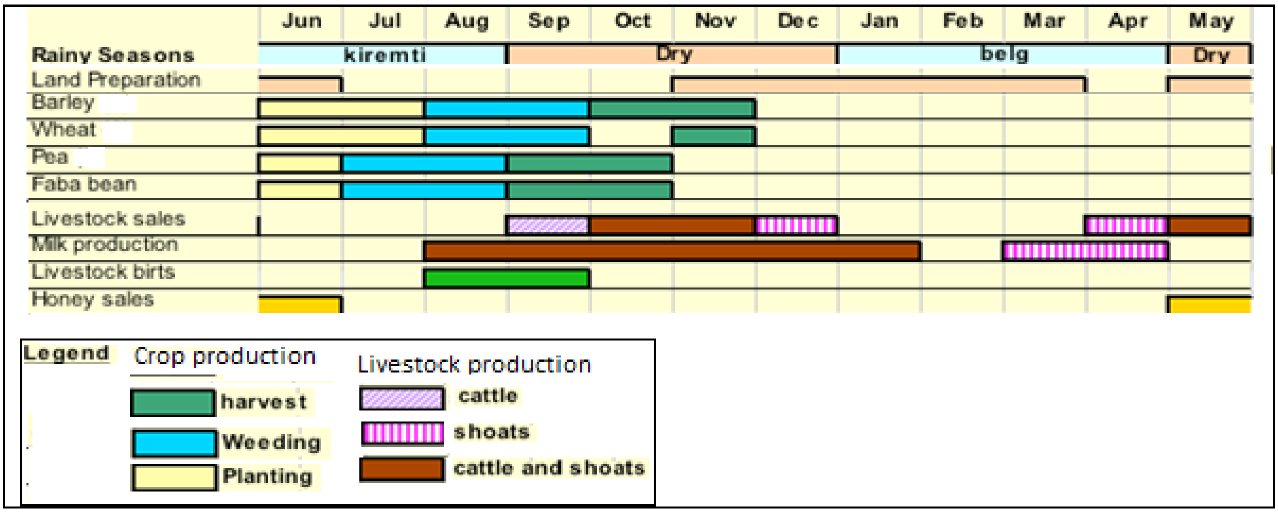


Figure 8: Agricultural calendar of Gezeme village

Similarly, the rainfall condition in Merere village is characterized by uni-modal with the rain season starting in June and ending in the beginning of September under normal rain season. Rainfall data from Abi-Adi (20 km from the study area) indicates that the ten years average annual rainfall is estimated to be 888.6 mm with more than 60% of the rain occurring in July and August (figure 9). The highest (1793.7 mm) and lowest (520.7 mm) annual rainfall in the last ten years (see Annex 2) was recorded 2011 and 2002 respectively.

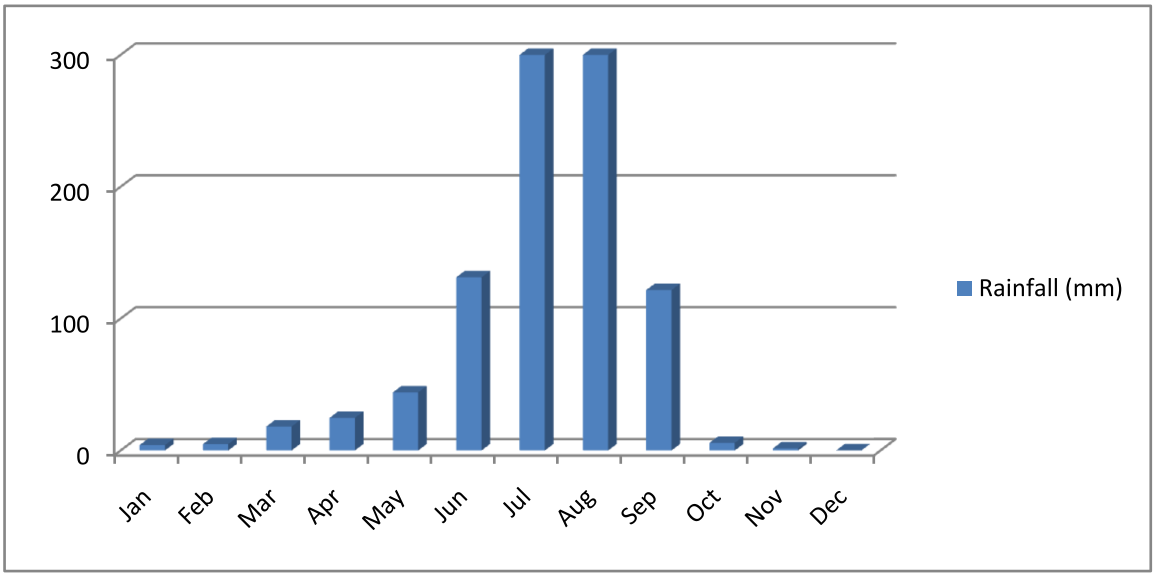


Figure 9: Ten years average monthly rainfall of Abi-Adi (Merere area)

As depicted in figure 10, sorghum, maize, figure millet, barley wheat and teff are commonly grown crops in the area mainly under rain fed agriculture. Sorghum and figure millet are planted in May and planting of the other crops such as Maize, Wheat, Barely and teff follows in June. Sorghum is intercropped with haricot bean and other legumes. Pulses are also intercropped with teff. Harvest of all crops is in October and November. The onset of rain in June heralds the start of the livestock birthing season. The lactation period begins in July and lasts until November, when the livestock heat period begins. Livestock are sold in January, April, June and September. The June selling period is spurred by the increased demand for oxen labor during the land preparation period. Shoat sales increase in December April and September because of the Epiphany, Easter and festivals. In a bad year livestock migrates to the Tekeze Gorge in Tselemti to search for pasture.

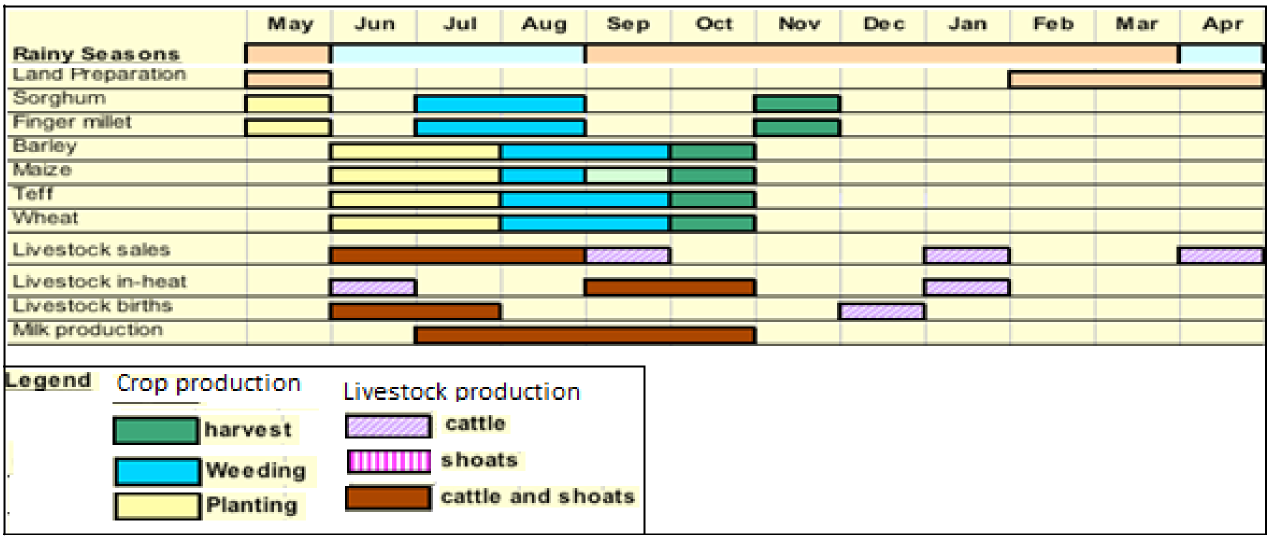


Figure 10: Agricultural calendar of Merere village

Similar to the other two sites described above, the rainfall condition in Etan Zere village is also characterized by uni-modal distribution with more than 60% of the annual rainfall occurring in July and August (figure 11). The ten years (2002 to 2011) annual rain fall data from Axum meteorological station (18 km from the study area) indicates that the average annual rain fall is 652.4 mm with the highest rainfall (1027.3mm) recorded in 2006 and lowest (354.6 mm) in 2002.

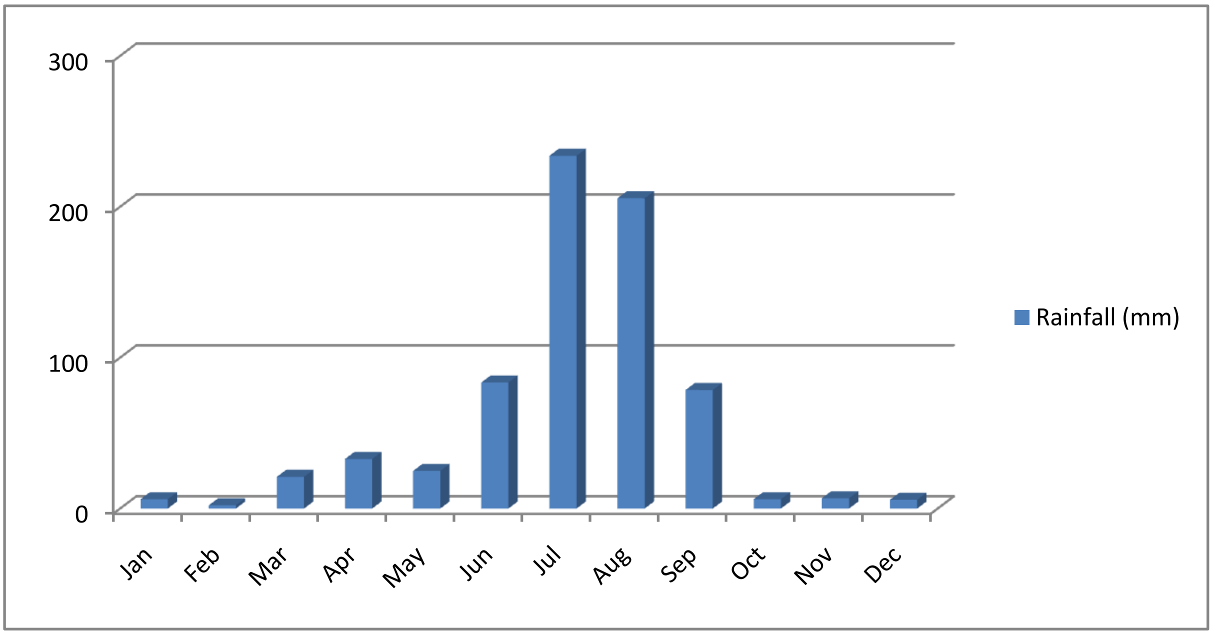


Figure 11: Ten years average monthly rainfall of Axum area (Etan Zere village)

The agriculture season is planned around the kiremti rains, which fall from mid-May to mid-September. A brief rain spell starts at the beginning of May and lasts for two weeks, until the middle of the month. The initial showers allow for land preparation and planting of long season crops such as maize, sorghum and millet. The rain resumes for the main season in mid-June and lasts until mid-September. Land preparation, particularly for teff, starts intermittently in February, and becomes more frequent as the May rains approach. Teff requires repeated plowing of the land before planting to enhance the soils capacity to absorb moisture and improve the harvest. During land preparation, the demand for plough oxen increases, as households with plough oxen can cultivate larger pieces of land. As depicted in figure 12, planting of maize, sorghum, finger millet, teff and pulses occurs between May and July. Weeding follows in July and August, and continues up until September. The consumption year begins with green consumption of maize in September, thus breaking the hunger season. Household expenditure on food declines with the onset of green consumption. The pulses harvested in September supplement household food consumption. The main harvest for all crops is from October to November. Just before the harvest, farmers are concerned that a late rain spell could destroy the drying crop.

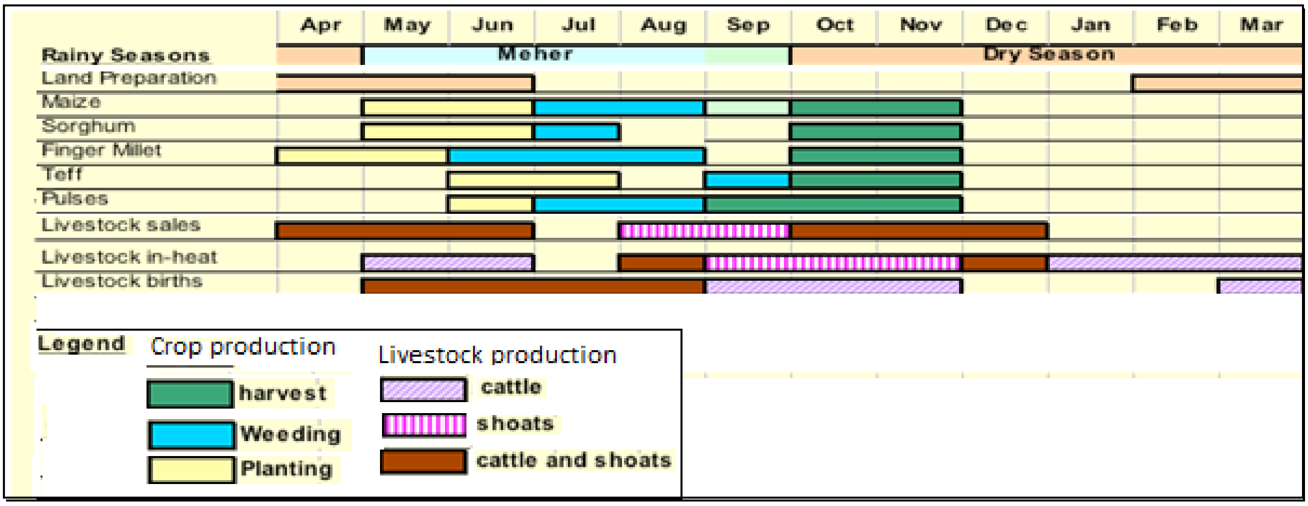


Figure 12: Rainfall and agricultural calendar of West Central Teff Livelihood zone

3. 2. Sampling technique and procedure

For this particular study a three-stage sampling procedure was employed. First, three districts having long term meteorological data records which fall in different livelihood zone of the region were selected purposively. At the second sampling stage, the study village in the three districts were again purposively selected. In the third stage, 10% of the total households in each village were sampled randomly for the survey. Hence, data from a total of 119 households, 23 households from Gezeme, 32 households from Etan Zere and 64 households from Merere Villages, was collected for analysis.

3. 3. Data collection

The main methodological approach of this research was survey method. Structured and semi-structured interview schedules were used to collect the primary data on the perceptions of the household on climate trends and variability, impact of climate change on the household economy and factors affecting the adaptive capacity of the households in the study sites. Both qualitative and quantitative data was collected with the help of the questionnaires from the sampled households of the three districts. In addition discussions were held with elders and key informants to access additional information on climate change impacts and local adaptation strategies in the study sites. In order to make necessary modification on the questioner and to check its appropriateness sample pre-test was conducted and based on it corrections and modification was made to capture the necessary information for the analysis. Secondary data related to the research topic and objective was also collected from respective offices to substantiate the primary data. Furthermore, an inventory of relevant past and current climate change SLM measures was made using the WOCAT.

3. 4. Method of data analysis

The collected data from each site was encoded for analysis using different tools as indicate below.

3.4. 1. Descriptive statistics

Data obtained from the sample households were subjected to statistical analysis. Descriptive statistics are employed to describe, compare and contrast farmers' perception on climate variability and climate change, impact of climate change and types of climate change adaptation strategies adopted by the households. Mean, standard deviation, percentages, average, ratio, chart are also used to analyse the collected data from the sampled households. Qualitative data of perception on climate change from the farmer households and key informants are also examined and presented in tabulated forms.

The quantitative data are edited, coded and entered in a computer and the Statistical Package STATA software version 9 is used for the analysis. Multiple response questions are analyzed so as to give frequencies and percentages. Tables and graphs are used to present different variables.

More specifically, the SLM practices and technologies adopted by the households to cope with the changing climatic condition in the study areas is analysed using WOCAT framework.

3.4. 2. Logistic Regression Model

Following the descriptive statistics, multinomial logit model which is commonly used in an adoption decision study involving multiple choices is employed to analyse factors determining selection of climate change adaptation choices at the smallholder farmer level. The approach is also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies (Hausman & Wise, 1978; Wu & Babcock, 1998).

The advantage of using a MNL model is its computational simplicity in calculating the choice probabilities that are expressible in analytical form (Tse, 1987). This model provides a convenient closed form for underlying choice probabilities, with no need of multivariate integration, making it simple to compute choice situations characterized by many alternatives. In addition, the computational burden of the MNL specification is made easier by its likelihood function, which is globally concave (Hausman & McFadden, 1984). The main limitation of the model is the independence of irrelevant alternatives (IIA) property, which states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternative in the choice set (Hausman & McFadden, 1984; Tse, 1987). Alternatively, the multinomial probit model (MNP) specification for discrete choice models does not require the assumption of the IIA (Hausman & Wise, 1978), and a test for this assumption can be provided by a test of the 'covariance' probit specification versus the 'independent' probit specification, which is very similar to the logit specification. The main drawback of using the MNP is the requirement that multivariate normal integrals must be evaluated to estimate the unknown parameters. This complexity makes the MNP model an inconvenient specification test for the MNL model (Hausman & McFadden, 1984). Let *i A* be a random variable representing the adaptation measure chosen by any farming household. We assume that each farmer faces a set of discrete, mutually exclusive choices of adaptation measures. These measures are assumed to depend on a number of climate attributes, socioeconomic characteristics and other factors X. The MNL model for adaptation choice specifies the following relationship between the probability of choosing option *i A* and the set of explanatory variables X as (Greene, 2003): 0

$$Prob(A_i = j) = \frac{e^{ß_j X_i}}{\sum_{k=0}^{j} e^{ß_k X_i}}, j = 0,1 \dots \dots J \qquad (1)$$

where *j* β is a vector of coefficients on each of the independent variables X. Equation (1) can be normalized to remove indeterminacy in the model by assuming that β0 = 0 and the probabilities can be estimated as:

$$Prob(A_i = j/x_i) = \frac{e^{ß_j X_i}}{1+\sum_{k=1}^{j} e^{ß_k x_i}}, \mathrm{j} = 0,2 \ldots \ldots \mathrm{J}, ß_0 = 0 \quad (2)$$

Estimating equation (2) yields the J log-odds ratios

$$l_n\left(\frac{P_{ij}}{P_{ik\,i}}\right) = X_i^{'}\left(ß_j - ß_k\right) = X_i^{'}ß_j, if\ k = o \quad (3)$$

The dependent variable is therefore the log of one alternative relative to the base alternative. The MNL coefficients are difficult to interpret, and associating the *j* β with the j^{th} outcome is tempting and misleading. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as (Greene, 2003):

The marginal effects measure the expected change in probability of a particular choice being made with respect to a unit change in an explanatory variable (Long, 1997; Greene, 2000). The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients.

3.4. 2.1.Definition of variables and working hypothesis used for the logistic regression model

Once the analytical procedure and its requirement are known, it is necessary to identify the potential explanatory variable and describe their measurements. Different variable are expected to affect climate change adaptation choices of household in the study sites. The major variables that are expected to affect climate change adaptation choices of the households are presented and explained below:

The Dependent Variables of the Model: the choice of climate change adaptation strategy of the households, which is the dependent variable for the logit analysis, is a variable representing the adoption of climate change adaptation measures of the household for crop and livestock production. It is represented in the model by 0 for not using adoption of climate change adaptation measures and 1 for using any appropriate adaptation measures in the area.

Independent variable: different literatures (Kandlinkar & Risbey, 2000 and Nhemachena and Hassan, 2007) and publications have noted that household's choice of climate change adaptation measures is expected to be influenced by the following factors

- ***Farmer socioeconomic attribute:*** Larger family size is expected to enable farmers to take up labour intensive adaptation measures. We therefore expect that farm households with more labor are better able to take up adaptations in response to changes in climate. Although farmers can hire extra labor, most rural farmers are not able to do this, which limits their ability to take on labor intensive crop and livestock activities. This study hypothesize that multiple cropping, irrigation and mixed farming systems are more labor intensive and hence it is expected that family size to have a positive influence on the adoption of such adaptation measures.
- ***Climatic condition:*** This study hypothesizes that warmer spring temperature and low precipitation during summer has both positive impacts on adaptation measures. It is assumed that warm spring temperature and drier summer trigger farmer to look for climate change adaptation measures such as irrigation, crop diversification and section of drought tolerant crop and livestock varieties and breads respectively.
- ***Gender:*** is an important variable affecting adoption decision at the farm level. Female farmers have been found to be more likely to adopt natural resource management and conservation practices. This study hypothesize that female- and male-headed households differ significantly in their ability to adapt to climate change because of major differences between them in terms of access to assets, education and other critical services such as credit, technology and input supply.

- ***Education, farming experience and perceptions*** are important factors influencing adoption decisions. Several studies have shown that improving education and disseminating knowledge is an important policy measure for stimulating local participation in various development and natural resource management initiatives. It is expected that improved knowledge and farming experience will positively influence farmers' decisions to take up adaptation measures.
- ***Access to extension services:*** Awareness of the problem and potential benefits of taking action is another important determinant of adoption of agricultural technologies. This study expected that farmers who notice and are aware of changes in climate would take up adaptation measures that help them reduce losses or take advantage of the opportunities associated with these changes.
- ***Farm assets and wealth factors:*** Empirical adoption studies have found mixed effects of *farm size* on adoption. This study hypothesizes that farmers with large farms would adopt measures that require a large area of land such as livestock systems, while farmers with small farms are expected to diversify their options

CHAPTER FOUR

4. RESULT AND DISCUSSIONS

This chapter deals with the analysis and interpretation of the survey data. The results of the survey on farmers' perception of climate change, climate change adaptation measures employed by the sampled households and factors determining choice of climate change adaptation measures of the households are analysed and described using descriptive statistics. Moreover, correlation between adoption of climate change adaptation measures by households and socioeconomic setting of the household in the study area is discussed in this chapter.

4. 1. Characteristic of Sampled Households

As indicated in Table 2, out of the 119 household heads interviewed during the survey, 29 % were women headed. The average family size of the households was 4.8 with the maximum family size being 11 and minimum family size of 1. The survey result on the level of education of the household heads and the family revealed that 71 % of the sampled household heads are illiterate, 24% are elementary complete and 5 % are high school complete. 77% of the households have at least one elementary school complete family member.

In Gezeme Village, 17% of the 23 sampled households were women headed and the average family size was estimated to be 3.4 with the biggest and smallest family size being 7 and 1respectively. 78% of the sampled household heads were illiterate and 17% and 4% of the households heads were elementary school and high school complete, respectively. However, 87% of the households had at least one elementary complete family member.

31% of the sampled household heads in Etan Zere village were women and the average family size of the households was 5.3 with the biggest and smallest family size being 11 and

1, respectively. 69% of the sampled household heads were illiterate and the rest 28% and 3 % were primary school and high school complete respectively. 69% of the households had at least one primary school complete family members.

Similarly, 31% of the sampled household heads in Merere village were women and average family size of the households was 5 with the biggest and smallest family size being 10 and 1, respectively.69% of the sampled household heads were illiterate and the rest 25% and 6% were primary school and high school complete, respectively.78% of the households have at least one primary school complete family member.

Table 2: Characteristics of the sampled households in the study sites

Characteristics	Village names						χ^2	Total	
	Gezeme		Etan Zere		Merere				
Sex of Household	N	%	N	%	N	%		N	%
Male	19	83	22	69	42	69	2.2	85	71
Female	4	17	10	31	20	31		34	29
Education status									
Illiterate	18	78	22	69	44	69	0.32	84	71
Literate	5	22	10	31	20	31		35	29

4. 2. Socioeconomic conditions of the sampled households

As the vulnerability of the households to climate change impact largely depends on the socio-economic conditions such as access to productive assets and households income source, the survey also assessed the socio-economic conditions of the sampled households.

4.2. 1. Land holding and land distribution of the sampled households in the villages

The descriptive analysis of the survey data in the villages indicates that 93% of the sampled households have less than 1 ha and 7% of the households are landless. The survey result revealed that there is no household with landholding greater than 1 ha and 100% of the sampled women headed household had access to land which is less than 1 ha. According to the respondents of the survey, households who have oxen acquire more land through sharecropping from those who have no oxen. Women headed households used to give their land to sharecroppers as they rarely own oxen.

The survey result shows that 87% of the sampled households in village Gezeme have landholding of less than 1 ha and the rest 13% are landless.

Similarly, in Village Etan Zere and Merere 94% and 95% of the sampled households, respectively have land holding of less 1 ha and the 6% and 5% of the sampled households in Etan Zere and Merere village, respectively were landless.

Based on the description of Adeleke S. (2010), 100% of the sampled households can be considered smallholder farmer which indicates with high population densities smallholder farmers usually cultivate less than 1 ha of land.

Table 3: Distribution of the households by landholding size

Size of farm land (ha)	Village name						Total	
	Gezeme		Etan Zere		Merere			
	N	%	N	%	N	%	N	%
No land	3	13	2	6	3	5	8	7
≤ 1	20	87	30	94	61	95	111	93
> 1	0	0	0	0	0	0	0	0
Total	23	100	32	100	64	100	119	100
Chi-square								

4.2. 2. Income source of sampled households

The survey result of the sampled households in the three villages as presented in table 4 revealed that agriculture both crop and livestock production is the primary occupation of the sampled households. Mixed crop and livestock production was found to be the main economic stay for 58% of the sampled households, while the rest 20% and 22 % of the sampled households depend on crop production and livestock production respectively. Causal labour, remittance and sale of firewood was reported to be complementary income sources for the households during the off farm season.

The analysis result of the survey in village Gezeme indicated that crop –livestock mixed farming is the main livelihood for 61% of the sampled households. The rest 22% and 17% of the sampled households depend on crop and livestock production respectively. Causal labour mainly during off farm season and remittance was reported during the survey to be complementary income source for the sampled households (see table 4).

Similarly, crop and livestock mixed farming is the main economic stay for 53% of the sampled households in village Etan Zere and the rest 22% and 25% depend on crop production and livestock production respectively. Off farm activities such as casual labour and remittance are also complementary source of income for the households in this village as in the other villages. Unlike to the other two villages, sale of fire wood is used by the households as additional source of income for 13% the sampled households.

The analyses result of the survey in Merere village also shows that mixed crop and livestock production is the main source of household income for 52% of the sampled households. The rest 19% and 29% depend on crop production and livestock production respectively to feed their family. Similar to the above two villages, off farm activities such as casual labour and remittance are complementary income source for the households in this village.

Table 4: Main source of income of the sampled households by village

Variable	Gezeme		Etan Zere		Merere		Total	
	N	%	N	%	N	%	N	%
Crop production	5	22	7	22	12	19	24	20
Both crop and livestock production	14	61	17	53	38	52	69	58
Livestock production	4	17	8	25	14	29	26	22
Total	23	100	32	100	64	100	119	100

Table 5: Complementary income source of the sampled households by village

Variable	Gezeme		Etan Zere		Merere		Total	
	N	%	N	%	N	%	N	%
Casual/skill labor	18	78	20	62	51	80	89	75
Sale of fire wood	0	0	4	13	0	0	4	3
Remittance	5	22	8	25	13	20	26	22
Total	23	100	32	100	64	100	119	100

4. 3. Actual and perceived climate of the study sites

This section briefly compare the perceptions of the farmers in the study sites on climate change, based on data from comprehensive survey of the sampled households across the three villages and the actual climate based on climatic data from nearby meteorological stations of the study sites. Details of the sample survey result from 119 households as presented in table6 indicates that 76% of the sampled households perceive that the climate has changed over the last 10 years while the rest 24% of the sampled households are either not sure about the change or perceive the climate is not changing.

Follow up question was asked, for these farmers who perceive the climate is changing, about their perceptions on long-term temperature and precipitation changes. The results as presented in Table7 show that 90% of the sampled households perceive that long-term temperatures are warming, more than two third of the respondents also perceive that precipitation is declining, 89% of the sampled households believe that extreme rainfall events such as hail and storm which mainly occurred in the month of August has increased and 69%

of the respondents perceive that dust and heavy wind has increased over the last ten years. Furthermore, more than three fourth of the respondents reported that timing of the onset and cessation of the rainy season has become too late and too early, respectively.

The survey result from Village Gezeme shows that 74% of the sampled households perceive that the climate has changed over the last ten years. 100% of them perceive that long term temperature is getting warmer and 87% of the respondents perceive that rainy season precipitation is becoming irregular in timing and declining in amount. Furthermore, 100% of the respondents perceive that extreme rainfall events has increased in the village and 74% of them reported that dust and heavy wind events are becoming common in the village.

The actual climatic condition of the village analyzed based on ten years annual rainfall data (2003 to 2012) from nearby meteorological station in Adi-Shihu, revealed that the amount of total annual rainfall over the last ten years was variable ranging from 313mm in 2008 to the highest 1059mm in the following year, 2009. Trend analysis of the total annual rainfall indicates the amount of annual rainfall in the village has declined with time in the last ten years. The small R^2 value of linear regression indicates the amount of annual rainfall and time is not strongly correlated and hence it is difficult to predict the rainfall will decline with time in the future. As the agriculture in the village is mainly rain fed, the amount of rainfall during the crop growing season is much important than the total annual rainfall (Hadgu et al., 2013). Accordingly, trend analysis of the rainfall amount during the main rainy season was made and the result shows the amount of rainfall has declined with time in the last 10 years. (See figure 13)

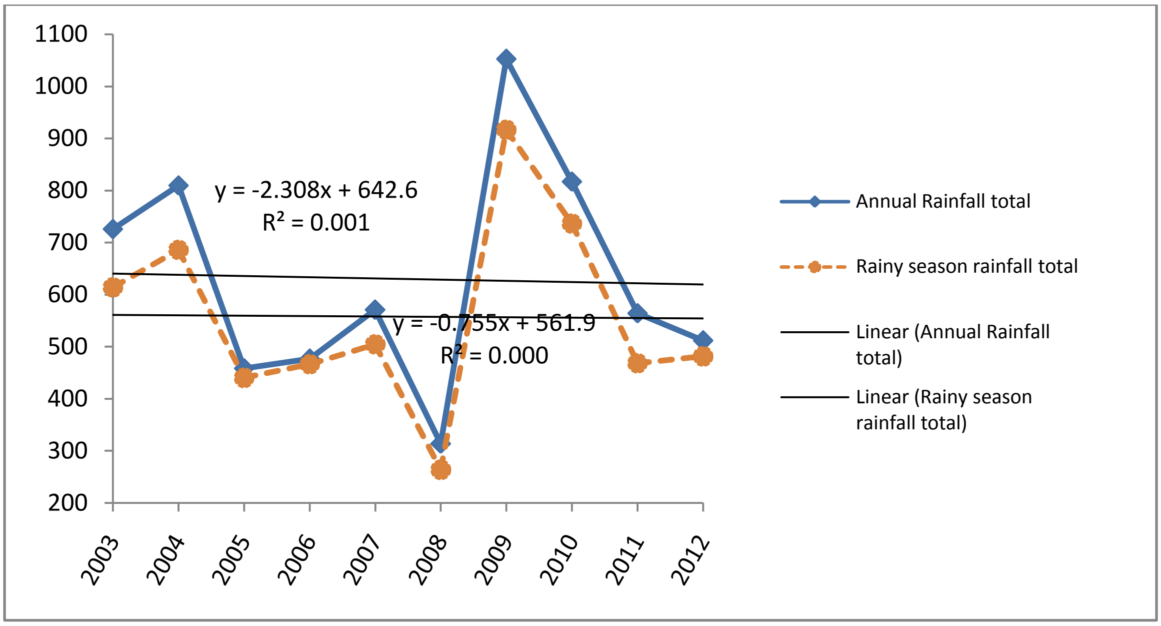


Figure 13: Ten years annual and rainy season rain fall amount seasonal of Gezeme village

The survey result from village Merere indicated that 75% of the sampled households perceive the climate has changed over the last ten years. Detailed analysis of the survey result of the household's perception on long term climatic conditions of the village indicated that 88% of the respondents perceive that temperature has become warmer and 50% of them perceive precipitation has declined through time.

Trend analysis of the total annual rainfall data from the nearest metrological station in Abi-Adi shows the total annual rainfall and rainy season rainfall amount in the village has declined with time over the last 10 years (2003 to 2012). As presented in Figure 14, the amount of rainfall is negatively correlated with time and the relatively higher R^2indicates strong correlation between amount of total and seasonal rainfall with time.

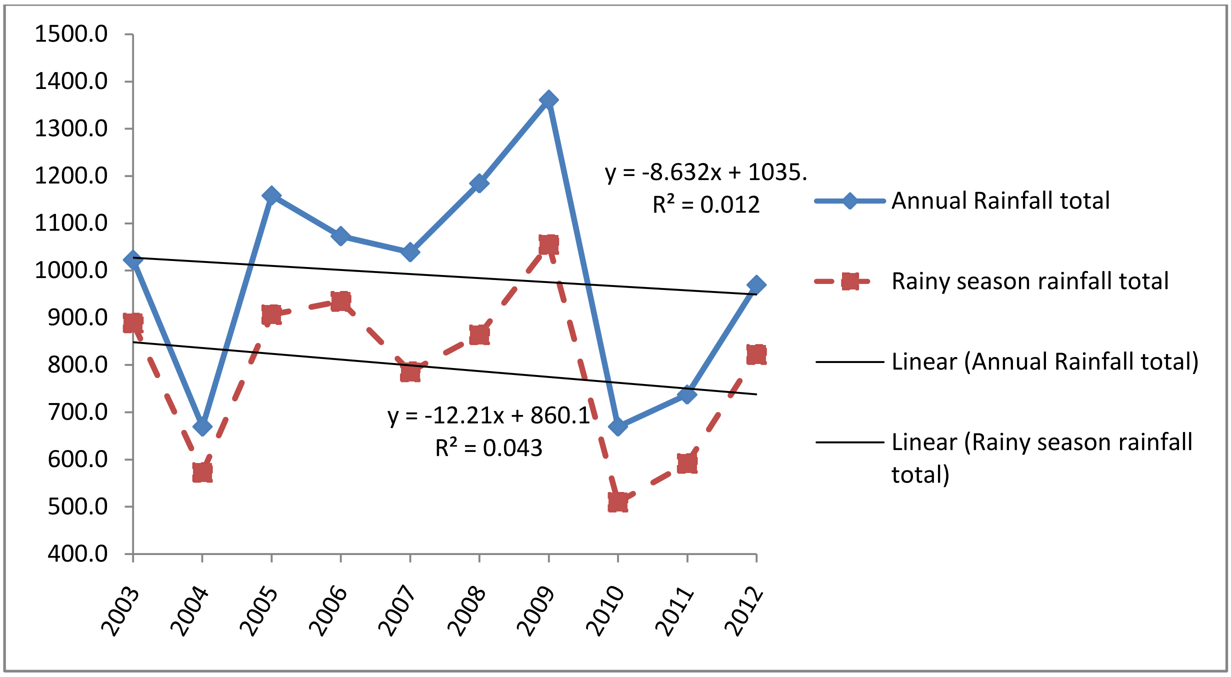


Figure 14: Ten years annual and rainy season rain fall amount seasonal of Merere village

Similarly, the trend analysis result of the last ten years (2003 to 2012) temperature data from Abi-Adi meteorological stations as presented in figure 15 indicate that Annual average Maximum temperature has increased while the annual average minimum temperature has decreased over the last ten years. The R^2 value of the time series maximum and minimum temperature data revealed strong correlation between temperature and time.

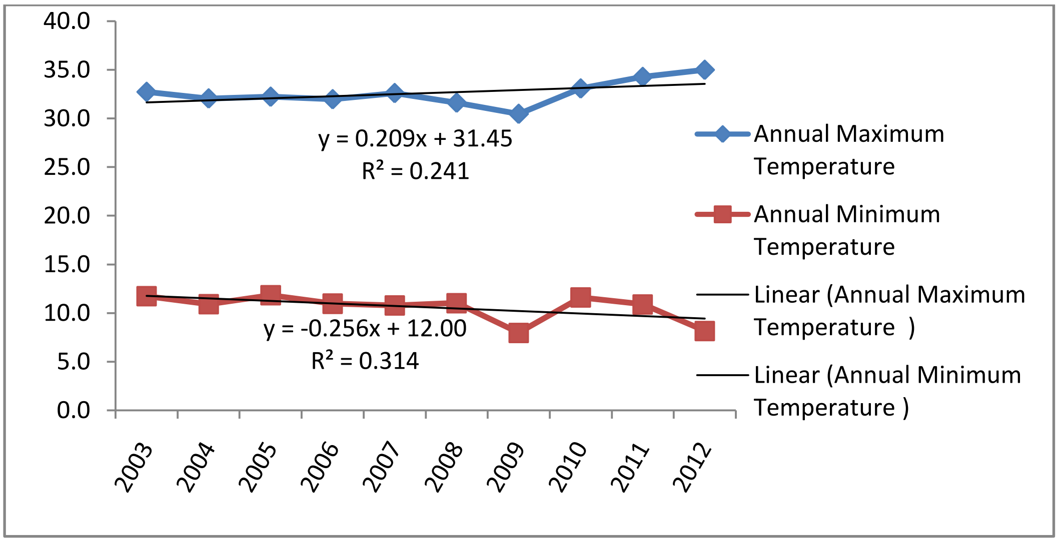


Figure 15: Ten Years Average Maximum and Minimum Temperature of Merere Village

Similarly, the survey result in village Etan Zere revealed that 78% of the sampled households perceive that the climatic condition of the village has changed over the last 10 years. The survey result on perception of the sampled households on the long term trend of temperature and precipitation show that 88% of the sampled households perceive that temperature has become warmer over the years and 69% of the sampled households perceive that precipitation has declined with time.

The trend analysis result of precipitation and temperature data from Axum meteorological station revealed that the total annual and rainy season precipitation has generally decreased over the last10 years with strong positive correlation.

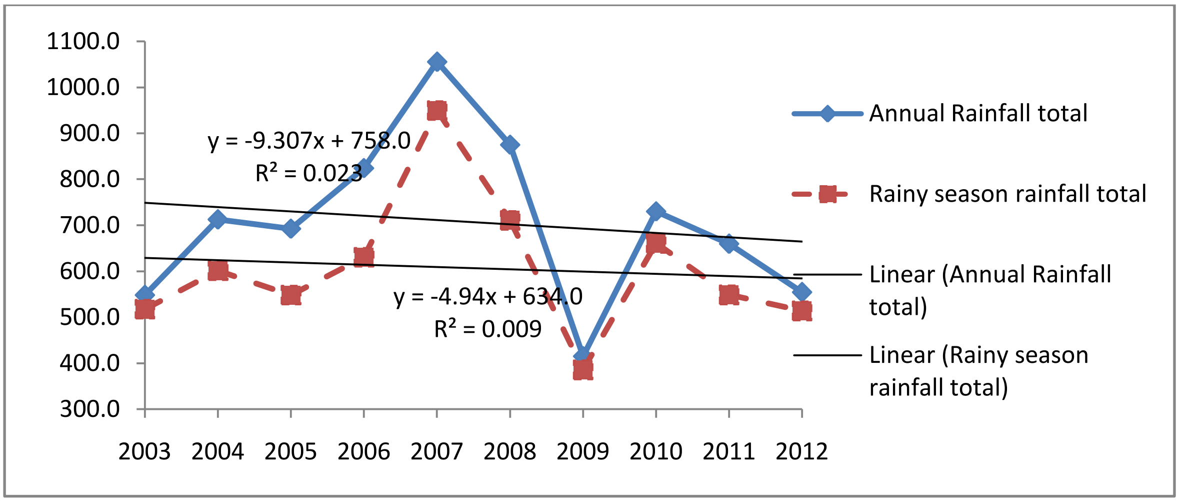


Figure 16: Ten years annual and rainy season rain fall amount seasonal of Etaz Zere village

The trend analysis result of the temperature data from the nearby meteorological station ,as presented in figure 16, also revealed that the annual average maximum temperature in the village has got warmer with time while the annual average minimum temperature get cooler over the last ten years.

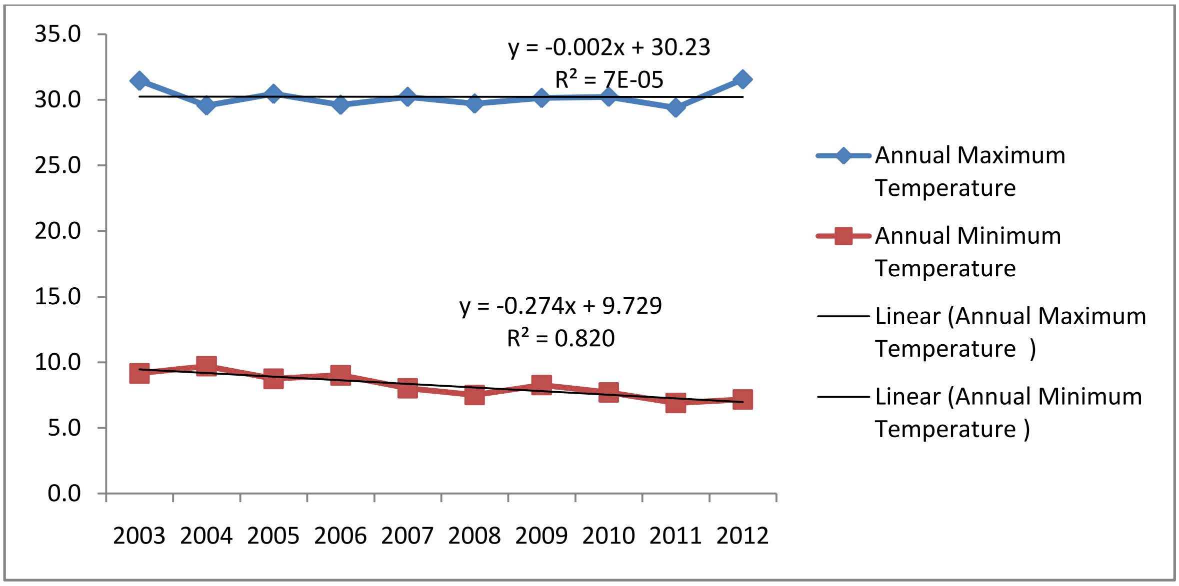


Figure 17: Ten Years Average Maximum and Minimum Temperature of Etan Zere Village

The above analysis results on climate change perception of the sampled households and actual climatic data from nearby meteorological stations indicates that the perception of the majority of the respondent agree with the actual climatic condition. Hadgu et al., (2013) also found similar result from his study in five district of Tigray region that the annual and season rainfall amount has declined taking 30 years rainfall data of his study area.

Table 6: Perception of Sampled households on climate change

Village	Perception of sampled households on Climate change					
	No	%	Yes	%	Total	%
Gezeme	6	26	17	74	23	100
Merere	16	25	48	75	64	100
Etan Zere	7	22	25	78	32	100
Total	29	24	90	76	119	100

Table 7: Perception of sampled households on long term change of climate variables

Variable	Respondents by Village						Total	
	Gezeme		Merere		Etan Zere			
	No.of Respondent	%	No.of Respondent	%	No.of Respondent	%	No.of Respondent	%
Increased Dry season temperature	23	100	56	88	28	88	107	90
Extreme temperature events increased	23	100	55	86	32	100	110	92
Rainy season temperature increased	22	96	51	80	17	53	90	76
Dry season precipitation decreased	20	87	49	77	16	50	85	71
Rainy season precipitation decreased	20	87	44	69	16	50	80	67
Heavy rainfall events increased	23	100	53	83	30	94	106	89
Heavy wind and dust storm increased	17	74	43	67	22	69	82	69

4. 4. Climate Change Impact as perceived by the sampled households

The survey result on perceived climate change impact by the households in the study areas indicate that 62% (See table 8) of the sampled households perceived climate change has affected both crop and livestock production in the area in the last ten years while the other 10 % perceive that the change in the climatic condition has affected crop production only. The rest 28 % replied that they did not recognize any effect on crop and livestock production as induced by climate change.

Table 8: Perception of sampled households on climate change impact

Effect of Climate Change	Response by village							
	Gezeme		Merere		Etan Zere		Total	
	No.	%	No.	%	No.	%	No.	%
Reduced Crop and livestock production	12	52	44	69	18	56	74	62
Reduced crop production only	2	9	6	9	4	13	12	10
Reduced livestock production only	-	-	-	-	-	-	-	-
Increased crop and livestock production	-	-	-	-	-	-	-	-
Increase crop production only	-	-	-	-	-	-	-	-
Increase livestock production	-	-	-	-	-	-	-	-
No effect on crop and livestock production	9	39	14	22	10	31	33	28

4.4. 1. Perceived climate change impact on crop production

The survey result from Gezeme village as indicated in table 8 revealed that 52% of the sampled households reported that the change in climatic conditions has affected both crop and livestock production whiles the other 9 % respond climate change affected crop production only. The rest 39 % reported that they did not notice any effect on crop and livestock production induced by climate change.

The same survey result from Merere village indicated that 69% the sampled households perceive that climate change has affected both crop and livestock production whiles 10% of the respondents perceive the change in the climatic condition has affected crop production only. The other 22% of the respondents did not recognize any effect on both crop and livestock production in the area induced by climate change.

The survey result from Etan Zere village also indicated that 56% of the sampled households perceive that climate change has affected both crop and livestock production while 13 % of the respondents perceive that climate change has affected crop production only. The other 31% of the respondents perceives that there is no effect on the crop and livestock production induced by climate change.

In-depth analysis of the survey data on farmers perception of climate change impact on crop and livestock productions as indicated in table 9, revealed that 70 % of the sampled households perceive that the change in the climatic condition can no more allow them to plant the long cycle crop varieties which were used in the study areas and were reported to be high yielding. Respondents from Merere Village reported that crops such as *"Tsaeda", "Zingue"* and *"Wedi-Gebremedhin"* which were commonly growing varieties of Teff, Millet and Maize, respectively, are extinct due to shortage of crop growing period and the farmers are compelled to adapt short cycle crops.

Another 65% the respondents reported that cost of crop production is increasing due to high weed infestation induced by time shortage for land preparation as the rainy season is shrinking from time to time.

The analysis result also revealed that 60% of the sampled households in the study sites perceive that high flooding hail and extended dry spells, especially during flowering period, are negatively affecting crop production in the study sites and the households are losing confidence on the rain fed agriculture.

Table 9: Perceived impacts of climate change on crop and livestock production

Effect of Climate Change	Response by village							
	Gezeme		Merere		Etan Zere		Total	
	No.	%	No.	%	No.	%	No.	%
Long cycle crop varieties are no more produced	15	65	48	75	20	63	83	70
Climate change has increased cost of crop production	14	61	42	66	21	66	77	65
Flooding, hail and moisture stress has increased risk of crop production	11	48	42	66	18	56	71	60

4.4. 2. Perceived climate change impact on Livestock production

Analysis of the survey result on farmer perception of climate change impact on livestock production as presented in table 10 indicate that 60 % of the sampled households reported that livestock production is being affected by feed deficiency (both quality and quantity) and heat stress induced by shortage of rain and increased temperature. The respondents reported that the palatable forage grasses are being diminishing and replaced by unpalatable and nexus weeds due to insufficient rainfall amount. Furthermore; 67 % of the sampled households replied that productivity of the pasture lands is decreasing due to land degradation, induced by heavy flooding, and moisture stress and 61% of the respondents reported that access to livestock water point is decreasing and cattle production which is sensitive to availability of enough water is being affected in the area.

Table 10: Perceived impacts of climate change on crop and livestock production

Effect of Climate Change	Response by village							
	Gezeme		Merere		Etan Zere		Total	
	No.	%	No.	%	No.	%	No.	%
Moisture stress and lack of forage is negatively affecting livestock production	15	65	39	61	17	53	71	60
Productivity of pasture lands is decreasing	14	61	43	67	23	72	80	67
Access to livestock watering in decreasing	16	70	38	59	18	56	72	61

4. 5. Adaptation strategies adopted by the HHs in response to perceived CC

Analysis of the survey data on adoption of adaptation strategy as a response to the perceived climate change impact as presented in table 11 revealed that even though 72% of the sampled households perceive that the climate change is affecting their faming practice both crop and livestock production in the study site, only 60% of them have employed climate change adaptation strategies. Analysis of the survey data on the type of climate change adaptation strategies employed by the sampled households as presented in table 12 shows that the households have employed wide range of adaptation strategies for crop and livestock production to cope with the perceived changing climatic condition.

Table 11: Perception of hh's on climate change impact and adoption of adaptation strategies

Perception on climate change impact and adaptation strategies	Response by village							
	Gezeme		Merere		Etan Zere		Total	
	No.	%	No.	%	No.	%	No.	%
Perceived climate change impact on agricultural practice	14	61	50	78	22	69	86	72
Adoption of climate change adaptation strategy	14	61	41	64	16	50	71	60

4.5. 1. Adaptation strategies for crop production

Crop production being the main economic stay for more than 78% (Table 4) of the sampled households, maintaining or even increasing crop production under the perceived changing climatic condition has paramount significance in the livelihood of the households in the study area. The assessment result revealed that the sampled households have adopted crop diversification, crop selection, soil and water management and changing cropping calendar as a coping strategy for the climate change impact on crop production.

4.5. 1.1.Crop diversification

As indicated in the analysis result of the survey (table 12), 64% of the sampled households reported that they applied crop diversification such as planting different crops at a time in different or the same plot to avoid risks of crop failure induced by drought, flooding, hail and wind storm. The sampled households in the study areas reported that they used to intercrop or mix the main crop with complementary crops such as teff with niger seed or tomato, barley and wheat with Sunflower, Millet with Maize or sorghum and sorghum and maize with beans and peas. Moreover, the sampled households reported that it is seldom that they plant the same crop in different plots.

Figure 18a: Mixed cropping of Teff with Niger seed in Etan Zere village (left) and Wheat with Sunflower in Gezeme village (Right).

Figure 18b: Planting different crops in different plots of household at a time in Merere village

The survey result also revealed that 15% of the sampled households have adopted planting perennial with annual crops to diversify their income and make use of the unexpected rain during the dry season. Perennial fruit trees such as Guava, Banana and Rhemnous has been planted in the farmlands of the study areas to maximize productivity of the land and with stand climate change risks (see figure 19).

Figure 19: Mixed planting of perennial fruit with annual crops in Merere Village

4.5. 1.2.Crop selection

Analysis of the survey result shows 56% of the sampled households have shifted from long cycle to early maturing and drought tolerant crop varieties. Furthermore, 12% of the sampled households who have access to supplementary irrigation have shifted from seasonal to perennial/annual crop. The respondents reported that they choose planting hail and frost resistant crops such as barely, wheat, teff and finger millet and Faba bean, Maize and Sorghum are reported by the respondents to be sensitive to frost, hail, wind storm and drought and hence planting these crops under rain fed agriculture is reducing.

4.5. 1.3.Soil moisture management

Availability of water in general and soil moisture in particular is important element in agricultural production in Tigray region and in the study area as well. UNDP/ECA/ FAO, (1994) reported that the number of food insecure people in a given year in the region is positively correlated with rainfall shortage. The assessment result also indicated that more than 80% of the sampled households recognize availability of soil moisture make significant difference in crop production.

Analysis of the survey result indicated that 70% of the sampled households constructed water harvesting structures in their farmland. Construction of terraces, soil bunds and trenches were adopted by the households to retain the runoff in the farm fields. Contour furrowing and tied ridging were also applied by these farmer households to keep in situ moisture.

Figure 20: Water harvesting in farm field in village Gezeme

Furthermore; 20% the sampled households applied supplementary irrigation to complement the rain fed agriculture. Shallow hand dug wells, spring diversions and farm ponds were used as source of irrigation water by the households. The respondents reported that construction of the irrigation infrastructures was supported by the regional and local government and the Sustainable Land Management program. Underground water recharging structures such as trenches, percolation ponds and pits which capture excess runoff from the catchments and enhance spring and well discharge has been extensively constructed in the study sites.

Figure 21: Stream diversion (left) and water harvesting pond (right) supplementing the rain fed agriculture in Merere village

4.5. 1.4.Changing cropping calendar

Analysis of the survey result (see table 12) revealed that 65% of the sampled households have shifted the planting calendar of the main crops from beginning of June to the last week of June so as to avoid crop failure at early crop development stage. The respondents reported that unless they are secured with supplementary irrigation water, early planting, locally called "*Azemera cropping"* has become risky. The other 32% of the sampled households reported they continued planting in the usual way hoping that the rain starts on time however they reported that they noticed irregularity in the performance of the crops in the last ten years depending on the amount and distribution of the rainfall. The remaining 3% of the sampled households, mainly from Etan Zere village, reported that they used to plant the crops, especially long cycle crops, in small plots and irrigate it for a while until sufficient soil moisture is secured and transplant to the main field when the rainy season fully started. Transplanting was commonly used for vegetables and fruit seedlings in the region and it is being adopted recently by few innovative farmers in Etan Zere village. ISD (2011) also reported that crop seedling in small plots and transplanting after full start of the rain season is a recent innovation in the region and is considered as strategic way out to cope with climate change and increase yield of long cycle crops such as finger millet, sorghum and maize. The report also indicated that yield of finger millet has tripled using transplanting as compared to the conventional cropping in Mai-Berazio Kebelle (close to Etan Zere village)

Figure 22: Transplanted (Top) Vs directly sown figure millet (bottom) in 2013/14 rainy season in Etan Zere village

Table 12: CC adaptation strategies applied by the sampled households for crop production

Type of climate change adaptation strategies adopted by the households	Response by village							
	Gezeme		Merere		Etan Zere		Total	
	No.	%	No.	%	No.	%	No.	%
Crop diversification	16	70	41	64	19	59	76	64
• Inter/mixed cropping	8	35	18	28	8	25	34	29
• Using different crops in different plots at a time	5	22	13	20	6	19	24	32
• Planting perennial fruit trees along with seasonal crops	3	38	10	16	5	16	18	15
Crop selection (drought tolerant, hail and frost resistant crops)	14	61	37	58	16	49	67	56
• Shifting from seasonal to annual crops	1	4	10	16	3	9	14	12
Soil moisture management (water harvesting and management)	18	78	45	70	20	63	83	70
• Use of irrigation water	4	17	15	23	5	16	24	20
Changing cropping calendar (delaying crop planting period)	15	65	43	67	19	60	77	65
• Transplanting after full start of rain season					4	13	4	3

4.5. 2. Adaptation strategy for Livestock production

As indicated in table 4, Livestock and livestock products is source of income for 80% of the sampled households. 22% of the sampled households live mainly with income from livestock and livestock products. Livestock as in the other part of the country is being used as source of traction and threshing power (figure 23) on top of the direct economic contribution through sale of livestock products and by products such as meat, milk, butter, egg and hide and skin.

Figure 23: Livestock used as source power for threshing and ploughing in Village Merere

Furthermore; Animal dung is also used as source of household energy and manure for soil fertility management (figure 24).

Figure 24: Livestock dung used for manure (left) and household fuel (right) in village Etan Zere

As indicated in table 8, 82% of the sampled households, who own livestock, perceived that livestock production is affected by climate change impacts. Analysis of the survey data on adoption of climate change adaptation strategy for livestock production (see table 13) revealed that only 65% of the sampled households, who own livestock, adopt adaptation strategy for the perceived climate change impact on their livestock.

Enhanced production and conservation of animal feed, seasonal migration of animals to other areas during severe drought and shifting from big to small animals were reported during the survey as adaptation strategies adopted by the sampled households to cope up with the perceived climate change impact on livestock production.

Table 13: Perceived CC impact and adaptation strategies of the HH's for livestock production

Parameter	Response by village							
	Gezeme		Merere		Etan Zere		Total	
	No.	%	No.	%	No.	%	No.	%
Ownership of livestock	18	78	52	81	25	78	95	80
Perceived climate change impact on livestock production	15	65 (83*)	45	70 (87*)	18	56 (72*)	78	65 (82*)
Adoption of climate change adaptation strategy for livestock production	11	48 (61*)	39	61 (75*)	12	37 (47*)	62	52 (65*)

Note: (*) of the households with livestock

4.5. 2.1.Enhancing production and conservation of feed

Analysis of the survey data on source of animal feed in the study sites indicated that crop residue, hay and straw and grazing from pasture and crop lands are the main source of animal feed. Result of the survey data on access to livestock feed as presented in table 13 revealed that 75% of the sampled households who have livestock reported that they started to enhance livestock feed by planting feed and food crops and forage trees and shrubs along the farm bund as a response to scarce livestock feed. The respondents reported that livestock feed is becoming scarce and productivity of their livestock is positively correlated with the amount of feed collected in a year.

Analysis of the survey data on conservation and management of animal feed as presented in table 14, indicated that 68% of the sampled livestock owner households reported that they purposively planted food and feed crops such as maize, sorghum, wheat and teff of which the residue is used as animal feed while the grains are used as human feed and 9% of them reported that they have no private land for forage planting and hence they secured their animal feed needs by purchasing from local market and collecting from communal pasture and range lands. The remaining 23% of the sampled households who have livestock did not take special measure to enhance availability of feed for their livestock (they were doing business as usual).

Planting forage grasses, shrubs and trees along their backyards, farm bunds, and underneath the main crops so as to supplement the crop residues and straws during the dry season by fresh leaves of the planted forages was adopted by 32% of the sampled households who own livestock as a means to enhance feed availability. Fresh leaves of cactus and *sesbania sesban* are reported to be commonly used by the households to supplement the main feed.

Figure 25: Collected crop residue in Gezeme Village (right) and fresh leave collection to supplement animal feed in Etan Zere village (left)

The households reported that supplementary feed is given to selected animals such as oxen, milking cows and emasculated cattle, in selected months of the year, usually January to June, at which grazing is not sufficient to support daily feed need of the animals.

4.5. 2.2.Reducing number of animal heads and seasonal migration

Analysis of the survey data on the sampled household's livestock holding characteristic revealed that 29% of the sampled households who have livestock adopted seasonal migration of their livestock, during severe scarcity of feed induced by drought, flooding and hail, to relatives living in other villages with better access to animal feed in a given year.

The other 50% of the sampled households reported that they used to sale a number of animals from their herd and keep few but very important animals such as oxen during bad season. The rest 37% had no livestock.

Access and availability of feed, which is significantly affected by the distribution and amount of rainfall in a given rainy season, is important factor affecting the number and type of livestock holding in rural area (ESSP II, 2012).

4.5. 2.3.Shifting from big to small animals

Analysis of the survey result on trend of livestock holding by type, of the sampled households revealed that 21% of the sampled households have shifted from cattle to small ruminant production in the last 10 years. The other 30% of the sampled households reported that they prefer to have more of small ruminants than cattle in the future while the rest 12% of the sampled households do want to continue cattle production. The remaining 37% of the sample households do not have livestock and have no plan for livestock production in the future.

Report from ESSP II (2012) also confirm that Small ruminant production such as sheep and goat are proven to be less sensitive to variable climatic conditions as compared to large ruminants. The study reported that households and community with access to sufficient feed keep more big animals (cattle) as compared to households and communities in a fragile ecosystem and climate risk.

According to the study report small ruminant to cattle ratio in Tigray has increased in the years between 2001/2002 to 2007/2008.

Table 14: CC adaptation strategies applied by the sampled HHs for livestock production

Type of climate change adaptation strategies adopted by the households	Response by village							
	Gezeme		Merere		Etan Zere		Total	
	No.	%	No.	%	No.	%	No.	%
Enhancing livestock feed production and conservation	15	65	39	61	17	54	71	60 (75*)
• Planting food and feed crops	11	48	35	55	18	57	64	54 (68*)
• Planting forage grasses, shrubs and trees in back yards and farm bunds	6	26	15	23	9	29	30	26 (32*)
Reducing number of livestock heads and seasonal migration	14	61	42	66	19	59	75	63 (79*)
• Seasonal migration of livestock	5	22	14	22	8	26	27	23 (29*)
• Sale of livestock	9	39	28	44	11	33	48	40 (50*)
Shift from cattle to shoat production	4	17	14	22	7	22	25	21(26*)

(*)Percentage out of households who own livestock

4. 6. Factors affecting households choice of climate change adaptation practices

Analysis of the survey data on climate change adaptation strategies adopted by the sampled households in the study area revealed that even though 76% of the sampled households perceived that the local climatic condition is changing (see table 10) and 72 % of them perceive that the change in the climatic condition over the last ten years is considerably affecting the farming practice in the study areas (table 11), only 60% of the households respond to the climate change impact by adopted different adaptation strategies (see table 11).

Analysis of the survey data on factors affecting adoption of climate change adaptation measures for crop and livestock production as presented in table 15 and 16 revealed that past exposure to drought and warm climate, access to extension service, farm and family size, gender, level of education of the household head and number of literate family members are found to be important factors affecting adaptation strategy of the sampled households to climate change for crop and livestock production.

4.6. 1. Factors affecting Household's adoption of climate change adaptation strategies for crop production

Analysis of the survey data on household's climate change adaptation strategy for crop production as presented in table 15 employees the conventional cropping system which is described as mono cropping of the common crops following the traditional cultivation and cropping calendar as the base category for no adaptation and evaluates the other choices as alternatives to this option. The first column of Table 15 for instance, compares the choice of multiple crops/crop diversification in same or different plot with no adaptation where the marginal effects and their signs reflect the expected change in probability of preferring to grow multiple crops to mono-cropping (the base) per unit change in an explanatory variable. The same applies to the remaining choices in the table.

Table 15: Factors affecting adoption of CC adaptation strategy for crop production

Variable	Marginal Effect			
	Crop diversification	Selecting tolerant crops	Soil moisture management	Shifting cropping calendar
Exposure to drought and warm temp	0.0634***	0.1490***	0.0982***	0.0732***
Access to extension service	0.0950***	0.0148*	0.1212**	0.2521***
Farm size	-0.0005*	0.0019*	0.1579***	0.1185***
Household size	0.0146***	0.0311	0.0208***	0.0462***
Male headed households	0.1443***	0.2796	0.2065***	0.0913***
Level of education of HH head	0.0032***	0.0109***	0.0051***	0.0103***
Number of Literate family members	0.0363*	0.0013	0.0713*	0.3324*

The results suggested that past exposure of the households to drought and extreme warm temperature during winter promotes switching to use of multiple/mixed cropping, selection of drought tolerant crops, use of soil moisture management practices which includes developing irrigation infrastructures for supplementary irrigation and shifting the cropping calendar.

The magnitudes of the marginal coefficients suggest that exposure to drought and warming is a strong factor influencing the probability of switching to selecting drought tolerant crops and soil moisture management than crop diversification and changing cropping calendar. This means the risks associated with using the common crops under poor soil moisture management system are higher with drought and warming temperature.

Better access to extension services such as provision of weather forecast, inputs and technical advises seems to have a strong positive influence on the probability of adopting crop diversification, soil moisture management and shifting cropping calendar and abandoning the relatively risky mono-cropping systems. However; access to extension service does not relatively seem to have strong positive influence on selection of drought tolerant crops. This could be because farmers need to be pre-informed about the climatic condition before making crop choice for which the extension is not strong enough is providing timely and accurate weather fare at local level that the farmers can rely on.

Analysis of the survey result also revealed that households with larger farm size are able to adopt climate change adaptation measures such as selection of drought tolerant crops, soil moisture management and shifting cropping while crop diversification decreases with increased farm size. This means risks associated to not adapting to climate change is much high for the households with smaller farm size than larger size and farmers opt for multiple cropping such as mixed/intercropping of different crops per plot of land to adapt to climate change impacts when they own smaller farm field.

Similarly; the magnitude of the coefficients revealed that households with larger farm size do opt for soil moisture management practices such as soil and water conservation in their farm as compared to the other climate change adaptation measures. This could be because the access to large farm size allows them to take part of the farm field for soil and water conservation infrastructures.

Households with larger family size are able to apply climate adaptation measures such multiple cropping, soil moisture management and shifting cropping calendar. However, the analysis result revealed that family size has little to do with selection of drought tolerant crops to adapt to climate change. The analysis result suggests that multiple cropping, soil moisture management and shifting cropping calendar is more labor intensive while selecting drought tolerant crops is unlikely to be affected by family size as it largely depends on the exposure and access to drought tolerant crop seeds.

The analysis result of the survey data also revealed that male headed households are in a better position to apply multiple cropping, soil moisture management measures and shifting cropping calendar. This could be because such measures are labor intensive practice which the female headed families are lacking in most cases. Selection of drought tolerant crops is less sensitive to sex of the household head as it is less sensitive to labor.

The level of education of the household head and number of literate family members has strong positive influence on adoption of climate change adaptation measures. Literate household heads are more likely to apply multiple cropping, selection of drought tolerant crops, soil moisture management measures and shifting cropping calendar than the illiterate families. This could be because the literate families get access to information from the extension and formal and informal education which enable them to easily switch the conventional farming to more climate change adaptive farming system as compared to the illiterate families.

The analysis result also indicated that the total number of literate family members did not seem to be of significance in influencing selection of drought tolerant crops as adaptation strategy to climate change, as the marginal effect coefficients was statistically insignificant and the sign does not suggest any particular pattern. The results suggest that it is the level of education of the household head that matters than the total number of family members to climate change as the decision on the type of crop to be planted in a year is mainly made by the household head.

In general; analysis of the survey data on factors determining choice of suitable climate change adaptation measure for crop production suggest that exposure to climate change impact such as drought and warm climate, access to extension services, farm and family size, gender and level of education of the household head and number of educated family members are important factors for coping with and adapting to climate change. The choice of the suitable adaptation measure depends on factor endowments (i.e. exposure, family size and farm size and access to education of the household head and whole family) at the disposal of farming households.

4.6. 2. Factors affecting HH's adoption of CC adaptation strategy for livestock production

Analysis of the survey data on household's climate change adaptation strategy for livestock production as presented in table 16 employees the conventional livestock production system which is described as maintaining big herd size dominated by big ruminants under open grazing/browsing of livestock as the base category for no adaptation and evaluates the other choices as alternatives to this option.

Table 16: Factors affecting adoption of CC adaptation strategy for Livestock production

Variable	Marginal Effect		
	Enhancing livestock feed production	Reducing Livestock Heads	Shifting from Big to small animals
Exposure to drought and warm temp	0.0549	0.164**	0.002***
Access to extension service	0.162***	0.065	0.165**
Farm size	0.019***	0.0187	0.0128
Household size	0.097***	0.011	-0.002
Male headed households	0.191**	0.106	0.069
Level of education of HH head	0.0276	0.091	0.179
Number of Literate family members	0.0945	0.004	0.067

The first column of Table 16 for instance, compares the choice of enhancing livestock feed production in the farm and/or pasture land with no conventional livestock feed production where the marginal effects and their signs reflect the expected change in probability of preferring to enhance feed production through multiple forage planting to open grazing of livestock in the field (the base) per unit change in an explanatory variable. The same applies to the remaining choices in the table.

Analysis of the survey data revealed that households who experienced drought and warm temperature used to reduce size of their herd and shift from big to small animals. However; exposure to drought and warm temperature does not seem to influence livestock feed production. This could be because drought and warm temperature unable farmers to grow forage and hence are discouraged to go for enhanced livestock feed production.

The survey result also indicated that access to extension services such as provision of inputs, weather related information and relevant trainings and reference materials seems to positively influence enhanced livestock feed production and shift from big to small animals while not affecting sampled household's livestock holding. This could be because the extension mainly focuses on provision of inputs such as forage seeds and plants and encourage the households to shift for small ruminants as a response to reduced forage resources.

Farm size seems to significantly influence enhanced forage production but has no effect on adopting reduced herd size and shift from big to small animals. Similarly enhanced livestock feed production seem to significantly influenced by family size and gender of the household head while reducing herd size and shifting from small to big animals is not influenced by family size and gender of the household heads. Moreover; analysis of the survey data revealed that level of education of the household head and number of educated family members has no influence on all adaptation strategies adopted by the community for livestock production. This could be because enhanced feed production is sensitive to labor availability while the other climate change adaptation options are less sensitive to labor and labor related factors.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5. 1. Conclusions

This study analyzed socio-economic characteristic of the sampled households, perceived and actual climate change and its impact of the study sites, climate change adaptation strategies adopted by the sampled households and factors determining household's adoption of climate change adaptation measure both for crop and livestock production. Descriptive statistics was used to analyze characteristics of the sampled household's, perception of households and actual change of local climatic conditions and its effect and farming practices adopted by the sampled households as a strategy to withstand the perceived climate change while multinomial discrete choice model was used to analyze the determinants of household's adoption of climate change adaptation strategies for crop and livestock production. The survey was made based on a cross-sectional survey of over 100 farming households from 3 sites in the region.

The analysis result of the descriptive statistics on the household characteristics shows that large majority of the sampled households are male headed (71%) and illiterate (71%) with Gezeme village having relatively lowest women headed households (17%) and relatively highest proportion of illiterate households (78%). The average family size was found to be 4.8 ranging from 11 to 1 with village Etan Zere having relatively highest family size (5.3).

Large majority of the sampled households (93%) have access to land but no one of them had land exceeding 1 ha.100% of the women headed households have access to land. Agriculture in general and mixed crop and livestock production in particular is the main economic stay for majority (58%) of the sampled households while some households depend on crop production (22%) and livestock production (20%) alone to feed their families.

Off farm activities such as casual labor; petty trading and remittance are also reported to be complimenting incomes sources to the sampled households.

The perception of large majority (76%) of the farmer households sampled from the three study sites on changes of the local climatic conditions agrees with the climatic data collected from nearby meteorological stations. The rainfall data collected from the meteorological stations indicate that annual and rainy season rainfall has decreased over the past ten years (2003 – 2012) in village Merere and Etan Zere. Similarly, decreasing and increasing trend of maximum and minimum temperature respectively was recorded over the past ten years in village Merere and Etan zere.

There is strong perception by majority of the sampled households that the prevailing change in climatic conditions has affected the agricultural production both crop and livestock production in the study sites. Crop failure and lack of animal feed induced by shortage of ample rain and increased temperature are considerably affecting the agricultural production. Farmers in the study area are unable to grow long cycle crops which were used in the area and are reported to be better yielding as the crop growing period is shrinking through time. Flooding, heavy rain and hail are accentuating the climate change impact on crop and livestock production in the study sites.

Perception of farmers on the change and its impact is found to be important factor for them to look for adaptation measures. Past exposure, access to extension service and education play important role in changing perception of farmers and adopting adaptation measures. Access to the means of climate change adaptation and capability to implement the measures are also found to be determinant factors in adopting climate change adaptation strategies.

The households adopted combination of measures and practice as a response to the perceived climate change impact both for crop and livestock production which can be classified as two main kinds of modification in the production systems: a) increased diversification, and b) protecting sensitive growth stages by managing the crops to ensure that these critical stages do not coincide with very harsh climatic conditions such as midseason droughts Some strategies that serve as an important form of insurance against rainfall variability are: increasing diversification by planting crops that are drought tolerant and/or resistant to temperature stresses; taking full advantage of the available water and making efficient use of it; and growing a variety of crops on the same plot or on different plots, thus reducing the risk of complete crop failure since different crops are affected differently by climate events. These strategies can also be used to modify the length of the growing season, for instance by using the additional water from irrigation and water conservation techniques. The climate change adaptation measures adopted for crop production are used in combination which can be grouped in to four main measures such as: Crop diversification, crop selection, soil moisture management and shifting cropping calendar. Similarly; combination measures were applied as a strategy to cope up to the prevailing climate change impacts on livestock production which can be grouped in to three: enhancing livestock feed production and conservation, seasonal and permanent reducing livestock herd size and shifting from big to small livestock.

Analysis of the empirical data on factors determining adoption of climate change adaptation strategies showed that past exposure to drought and warm temperature promoted crop diversification, selection of crops, soil moisture management including irrigation and shifting cropping calendar for the crop producers and reducing herd size and shifting from large to small animals for livestock producers. Farmers appear to abandon mono-cropping as temperatures get warmer. With most parts of the region already warm and dry, any further warming compels them to take up various soil moisture management and multiple and mixed crop livestock adaptation measures.

The analyses confirmed the role of improved access to information (climate and production) through the extension service in enhancing farmers' awareness, which is crucial for adaptation decision making and planning. Access to extension ensures that farmers have the information for decision making and the means to take up adaptation measures. Provision of necessary and timely information and inputs as part of the extension service enables farmers to cope up with the prevailing climate change adaptation strategies for crop and livestock production.

Larger farm size was found to encourage the use of multiple cropping and enhancing livestock feed production. Large farm sizes allow farmers to diversify their crop and enhance livestock feed production options and help spread the risks of loss associated with changes in climate.

The analysis of the survey result also suggested that the adaptation strategies are labor intensive and hence family size and gender of the household head has strong influence to diversify the crops, apply soil moisture management practice and enhance livestock feed production. This suggests that availability of labor may be a critical factor constraining the switch away from the risky mono-cropping systems for small family size households.

Other enabling factors that have significant potential for promoting adaptation, especially for crop diversification, crop selection, soil moisture management and shifting cropping calendar (which usually need knowledge and skill), are level of education of the household head and total number of educated family members. Families with educated households heads and literate family members are in a better position to take up climate change adaptation measures as compared to that of uneducated household heads and illiterate families.

5. 2. Recommendation

As smallholder agriculture is the main economic stay in the study sites which is sensitive to climate change impacts, special emphasis should be give in enhancing climate change adaptive capacity of the farmers. Creating access to the extension services could be an important policy measure to improve their awareness of the potential benefits from adaptation and stimulating farm-level climate adaptation.

Policies aimed at promoting farm-level adaptation need to emphasize the critical role of providing information (through extension services) and the means to implement adaptations through affordable credit facilities. This study clearly shows the need for strategic government policies and investment support for improved access of the farmers to climate forecasting, research on the development of and information about appropriate farm-level climate adaptation technologies and practices and farmer education especially for the smallholder farmer where the farming system fully depends on the rain.

As most of the climate change adaptation measures are labor intensive, the inbuilt social networking and labor sharing culture within the community should be strengthened and capitalized so as to withstand climate change impacts.

Local experiences on climate change adaptation strategies should be documented and farmer to famer experience sharing should be organized to speed up dissemination of the already proven practices.

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ANNEXES

Annex 1: Ten years rainfall data from Adishihu (Arround Gezeme village) Meteorological station

Year	Amount of rainfall (mm) by month												Total Annual RF (mm)
	January	February	March	April	May	June	July	August	September	October	November	December	
2002	0.0	0.0	18.0	0.0	0.0	0.0	90.9	129.3	0.0	0.0	0.0	0.0	238.2
No Obs	31	28	31	30	31	30	31	31	30	31	30	31	
2003	0.0	3.6	0.0	30.9	0.0	87.8	173.4	272.6	20.4	2.4	0.0	0.0	591.1
No Obs	31	28	31	30	0	30	31	31	30	31	30	31	
2004	14.0	0.0	16.6	7.9	15.1	49.4	114.0	228.6	11.7	11.5	0.0	0.0	468.8
No Obs	31	29	31	30	31	30	31	30	30	31	30	31	
2005	0.0	2.6	0.0	31.6	32.7	83.1	246.7	279.8	30.5	3.2	10.0	0.0	720.2
No Obs	31	28	31	29	31	30	30	31	30	31	30	31	
2006	0.0	0.0	36.8	48.6	30.0	80.4	328.4	243.3	115.8	10.2	0.0	0.0	893.5
No Obs	31	28	31	30	31	30	31	31	30	31	30	31	
2007	0.0	0.0	0.0	27.7	25.4	69.6	304.9	179.9	101.7	0.0	10.8	0.0	720.0
No Obs	30	28	31	30	31	30	31	31	30	31	30	31	
2008	11.3	0.0	0.0	18.0	15.9	25.4	85.9	94.8	83.1	28.5	30.6	0.0	393.5
No Obs	31	29	31	30	31	30	31	31	30	31	30	31	
2009	0.0	2.3	0.0	0.0	0.0	12.8	267.9	491.2	0.0	1.5	0.0	0.0	775.7
No Obs	31	28	31	30	31	30	31	31	30	31	30	0	
2010	0.0	0.0	0.0	40.8	24.1	10.8	172.2	268.7	6.7	6.0	0.0	0.0	529.3
No Obs	31	28	31	30	31	30	31	31	30	31	0	0	
2011	0.0	0.0	21.6	4.5	16.4	17.2	0.0	0.0	0.0	0.0	0.0	0.0	59.7
Total	**25.3**	**8.5**	**71.4**	**205.5**	**143.2**	**419.3**	**1784**	**2188.2**	**369.9**	**63.3**	**51.4**	**0.0**	***5330.3***
Monthly Average RF	**2.53**	**0.85**	**7.14**	**20.55**	**14.32**	**41.93**	**178.4**	**218.82**	**36.99**	**6.33**	**5.14**	**0**	***533.0***

Annex 2: Ten years rainfall data of Abi-Adi (around Merere village) Meteorological station

Year	Amount of rainfall (mm) by month												Total Annual RF (mm)
	January	February	March	April	May	June	July	August	September	October	November	December	
2002	0.0	0.0	21.0	37.0	0.0	75.6	169.1	150.8	67.2	0.0	0.0	0.0	520.7
No Obs	31	28	31	30	31	30	30	30	30	31	30	31	
2003	0.0	32.7	17.1	11.1	5.0	146.3	234.5	414.2	124.3	0.0	0.0	0.0	985.2
No Obs	31	27	31	30	31	30	31	31	30	31	30	31	
2004	0.0	15.4	14.3	41.9	0.0	105.3	643.4	521.0	33.3	0.8	0.0	0.0	1375.4
No Obs	30	27	31	28	30	28	30	27	26	30	30	31	
2005	0.0	0.0	22.7	26.9	108.4	64.0	291.9	257.0	82.2	0.0	0.0	0.0	853.1
No Obs	31	28	31	30	31	30	31	28	29	31	30	31	
2006	0.0	0.0	19.4	46.1	66.6	177.8	257.9	410.6	137.8	26.8	0.0	0.0	1143.0
No Obs	31	28	31	29	29	28	30	29	27	31	30	31	
2007	17.6	0.0	17.6	24.1	22.4	220.8	424.5	415.9	161.4	0.0	0.0	0.0	1304.3
No Obs	31	28	31	30	31	30	28	29	30	31	30	31	
2008	8.0	0.0	0.0	17.5	74.9	146.9	287.6	392.9	99.6	8.9	14.8	0.0	1051.1
No Obs	31	29	31	30	31	30	24	23	29	31	30	31	
2009	0.0	0.0	47.0	19.6	26.6	46.9	237.7	249.5	41.0	9.4	0.0	0.0	677.7
No Obs	31	28	31	30	31	29	28	29	30	31	30	30	
2010	15.0	0.0	19.2	19.5	16.9	105.7	143.9	447.6	196.3	11.6	0.0	0.0	975.7
No Obs	30	27	30	28	30	30	31	31	30	31	30	31	
2011	0.0	0.0	2.8	3.4	119.6	223.8	380.4	790.7	273.0	0.0	0.0	0.0	1793.7
Total	40.6	48.1	178.3	243.7	320.8	1089.3	2690.5	3259.5	943.1	57.5	14.8	0.0	8886.2
Monthly Ave. RF	4.06	4.81	17.83	24.374	32.08	108.93	269.05	325.95	94.31	5.75	1.48	0	888.6

Annex 3: Ten years rainfall data of Axum (around Etan Zere village) Meteorological station

Year	Amount of rainfall (mm) by month												Total Annual RF (mm)
	January	February	March	April	May	June	July	August	September	October	November	December	
2002	0.0	8.8	10.0	15.3	9.2	31.1	102.3	96.5	50.6	1.3	1.8	27.7	354.6
No Obs	31	28	31	30	31	30	31	31	30	31	30	31	
2003	2.5	8.5	2.4	8.3	12.2	126.1	322.7	209.1	89.6	1.4	3.7	0.0	786.5
No Obs	31	28	31	30	31	30	31	31	30	31	30	31	
2004	18.2	3.8	3.9	41.0	0.0	132.4	269.9	173.6	16.8	24.4	34.8	0.0	718.8
No Obs	31	29	21	30	31	30	31	31	30	31	30	31	
2005	0.0	0.0	129.7	86.0	5.1	85.4	176.6	226.0	67.2	0.0	0.0	0.0	776.0
No Obs	31	28	31	30	31	30	31	31	30	31	30	31	
2006	0.0	0.0	0.0	31.1	61.0	86.5	230.7	240.6	123.9	9.5	0.0	30.5	813.8
No Obs	31	28	31	30	31	30	31	31	30	31	30	31	
2007	0.0	0.0	7.0	10.9	35.5	112.6	428.1	272.8	154.3	0.0	6.1	0.0	1027.3
No Obs	31	28	31	30	31	30	31	31	30	31	30	31	
2008	38.5	0.0	0.0	85.2	41.3	102.3	161.8	174.7	49.9	1.5	6.8	0.0	662.0
No Obs	31	29	31	30	31	30	31	31	30	31	30	31	
2009	0.0	0.0	0.9	6.0	8.6	35.6	231.9	288.6	1.8	0.0	2.9	0.0	576.3
No Obs	31	28	31	30	30	30	29	29	30	31	30	31	
2010	1.2	0.0	54.2	36.3	17.3	109.4	209.4	223.2	137.5	20.3	0.0	0.0	808.8
No Obs	30	28	31	30	31	30	31	31	30	30	30	31	
2011	1.2	0.0	1.9	7.9	58.7	13.5	204.2	151.1	93.7	3.4	11.8	0.0	547.4
Total	60.4	21.1	208.1	320.1	190.2	821.4	2133.4	1905.1	691.6	58.4	56.1	58.2	6524.1
Monthly Average RF	6.04	2.11	20.81	32.01	19.02	82.14	213.34	190.51	69.16	5.84	5.61	5.82	652.4

Annex 4: Maximum Temperature (0C) from Axum (around Etan Zere village) Meteorological station

					Element:- Average Maximum Temp. ^0C								Annual Highest Max.Temp	Annual average max.T
Year	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***		
2002	28.0	30.5	30.8	30.8	32.4	30.1	27.1	24.7	26.9	27.5	29.0	28.1	***34.6***	31.1
2003	29.1	30.7	32.5	32.5	30.5	29.5	27.0	27.8	28.3	28.6	28.0	28.4	***34.5***	31.4
2004	28.8	28.7	29.0	30.9	31.9	29.7	12.5	28.2	27.2	28.2	28.2	28.3	***35.4***	29.6
2005	27.6	28.5	29.0	29.0	30.1	28.8	27.5	28.2	28.7	28.7	27.9	28.2	***32.4***	30.4
2006	28.4	28.8	29.6	29.6	29.0	28.8	28.0	24.4	25.6	28.2	27.8	27.7	***31.7***	29.6
2007	28.0	28.1	29.1	29.1	29.8	28.7	26.8	28.0	27.0	27.4	27.4	27.0	***31.3***	30.2
2008	26.9	27.7	28.5	28.2	28.4	28.1	25.8	24.8	24.2	25.4	25.5	25.4	***32.5***	29.7
2009	27.4	27.7	30.6	27.9	30.2	28.9	25.6	24.6	26.1	25.9	27.2	28.3	***33.2***	30.1
2010	27.0	28.4	29.2	29.2	29.4	28.4	28.9	26.7	25.7	26.0	25.3	24.9	***32.2***	30.2
2011	26.1	26.3	29.1	29.6	29.9	29.5	26.0	25.2	25.2	24.1	23.0	22.1	***31.9***	29.4

Annex 5: Minimum Temperature (0C) from Axum (around Etan Zere village) Meteorological station

						Element:- Average Minimum Temperature ^0C						Annual Lowest Min. T	Annual Average Min.T
Year	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***		
2002	9.1	10.8	12.4	13.2	12.9	14.3	13.8	13.7	12.2	12.0	11.9	10.4	***7.2***	9.4
2003	7.4	10.8	12.0	11.1	11.8	13.3	12.9	14.5	14.3	12.2	10.4	9.1	***4.1***	9.2
2004	9.7	9.9	10.1	13.2	13.7	12.5	12.0	13.1	12.4	11.8	10.0	15.1	***7.0***	9.7
2005	7.4	10.6	11.9	13.3	12.4	12.4	12.7	12.9	11.7	10.7	9.9	8.9	***5.0***	8.7
2006	9.3	10.9	10.8	11.6	11.6	11.7	10.7	13.2	11.7	10.1	9.3	8.7	***7.0***	9.0
2007	9.3	10.3	11.0	11.0	11.9	13.4	11.5	12.7	11.5	8.8	8.9	6.3	***3.6***	8.0
2008	9.5	9.0	9.4	11.5	12.7	11.4	12.0	12.5	10.7	9.6	7.2	7.5	***5.0***	7.5
2009	6.9	10.0	12.2	12.3	13.5	14.7	12.5	12.8	11.1	11.0	10.4	8.4	***5.2***	8.3
2010	8.0	9.4	10.6	10.8	11.2	10.8	10.7	12.5	11.7	9.2	7.3	7.1	***5.0***	7.7
2011	8.5	8.6	9.7	11.9	13.3	13.8	11.7	12.0	10.5	7.7	7.5	4.9	***1.5***	6.9

Annex 6: Maximum Temperature (0C) from Abi-Adi (around Merere village) Meteorological station

					Element:- Average Maximum Temperature ⁰C								***Annual Highest Max.Temp***	annual average ***max.temp***
Year	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***		
2002	29.2	31.0	31.5	32.6	33.5	30.9	29.0	26.3	28.1	31.1	30.1	29.0	***35.3***	32.5
2003	29.3	31.7	32.5	33.1	34.4	31.5	25.5	25.6	30.6	31.4	29.1	28.2	***36.5***	32.7
2004	29.2	30.6	30.7	30.7	30.9	31.4	28.4	26.7	30.0	29.7	29.6	28.5	***35.5***	32.1
2005	29.4	31.5	33.0	35.5	34.1	32.6	28.7	26.8	28.9	29.4	30.1	29.6	***36.5***	32.2
2006	30.8	31.9	32.4	32.7	31.9	29.7	27.8	27.0	29.2	31.1	31.4	31.4	***34.2***	32.0
2007	31.3	32.4	32.4	31.4	31.6	30.3	28.2	28.1	29.0	30.3	31.0	29.8	***38.0***	32.6
2008	31.2	30.6	30.1	29.8	30.7	29.5	28.2	28.0	29.3	30.9	30.7	29.6	***32.8***	31.6
2009	28.6	28.8	30.8	31.1	30.9	30.6	28.2	27.3	28.4	28.8	27.6	29.6	***32.4***	30.5
2010	29.3	30.9	31.2	32.6	33.3	30.9	26.4	23.2	28.4	29.2	28.2	27.9	***40.0***	33.1
2011	27.1	28.5	31.3	35.5	32.9	33.0	29.0	27.2	27.1	28.6	29.7	29.1	***44.0***	34.3

Annex 7: Minimum Temperature (0C) from Abi-Adi (around Merere village) Meteorological station

													Annual Highest Max.Temp	annual average max.temp
						Element:- Average Minimum Temperature ^{0}C								
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
2002	11.0	11.5	12.4	15.1	15.7	16.7	15.9	15.1	14.4	14.5	13.3	12.9	7.3	11.0
2003	13.2	14.0	15.5	16.3	17.5	15.6	12.9	16.4	15.4	16.8	13.9	13.7	7.0	11.8
2004	12.7	12.6	13.2	12.7	12.6	12.5	11.7	11.9	14.5	13.2	12.5	12.1	10.0	10.9
2005	12.4	13.9	14.7	15.1	14.2	13.4	11.8	10.4	12.8	13.8	13.7	12.4	9.2	11.8
2006	12.6	13.9	13.9	13.5	12.3	10.1	10.0	10.5	11.6	12.5	12.9	12.8	8.8	11.0
2007	12.9	13.0	13.0	11.6	11.1	11.4	10.5	10.7	12.1	12.9	12.7	12.7	9.2	10.8
2008	12.7	12.6	12.1	11.7	11.3	10.8	10.7	11.3	14.1	13.5	13.1	12.4	9.5	11.0
2009	12.4	12.8	13.3	13.0	12.8	12.7	13.0	11.3	14.1	13.5	13.1	13.6	0.0	8.0
2010	13.1	14.4	19.5	17.9	18.4	16.0	15.3	13.1	15.2	15.4	14.9	15.5	9.0	11.6
2011	15.3	14.5	13.2	14.3	15.4	15.9	15.7	15.8	14.6	14.4	14.9	13.4	8.5	10.9