UNIVERSITY OF NAIROBI

SMALLHOLDER FARMERS VULNERABILITY TO CLIMATE CHANGE IMPACTS ON AGRICULTURAL PRODUCTION IN KOLLA TEMBEN DISTRICT IN NORTHERN ETHIOPIA

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PLAGIARISM STATEMENT

This Thesis was written by me and in my own words, except quotations from published and unpublished sources which are clearly indicated and acknowledged as such.

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DEDICATION

This thesis is dedicated to my father Addisu Abrha, my late mother Desta Abrha and my late sister Hilfey Addisu for all the affection I received from them.

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ABSTRACT

Agriculture is one of the climate sensitive sectors in Africa. The sector mainly includes crop production and livestock rearing, which are the main sources of food and income for smallholder farmers in Africa. This study aimed to establish smallholder farmers' vulnerability levels to climate change impacts and its implications to agricultural production in Ethiopia in relation to total incomes, food consumption; farmers' perceptions on climate change and their adaptation choices to the impacts, the association among climate change impacts, households adaptive capacity and food security. This is because the impact of climate change on food production is a global concern and poses a big threat for African countries like Ethiopia to feed their rapidly growing population. It is a gap that is yet to be addressed especially since the understanding of diverse climate impacts across different agricultural production systems and different topographical settings is low. Secondary data on temperature and rainfall for the past three decades (1983-2013) from the Meteorological Agency of Ethiopia were analysed for trends. Households survey data was compiled and analysed from a sample of 400 smallholder farmers in Kolla Temben District in North Ethiopia. Four Kebelles also known as administration units namely Newi, Awetbekalsi, Atakility and Begasheka were selected using simple random sampling technique out of the total 27 Kebelles in the District. Data were also collected from four focus group discussions (FGDs) from 48 farmers in four Kebelles to enrich and validate the findings from the household surveys and climate data. In addition, key informant interviews (KII) were conducted with 24 interviewees comprising of development agents, agricultural extension workers, experienced farmers and Kebelle administrators, all of whom were believed to be knowledgeable on climate change and agricultural production issues. various computer software were used to analyse the climate and household survey data. Multiple regressions were also used to examine the relations between household's level of vulnerability to climate impacts in relation to agricultural production, adaptation strategies and its implications on crop productions. The rate of temperature rise in the past three decades (1983-2013) was found to be 2.08 °C which was more than double compared with the global rate of 0.85°C for the past hundred years. Household's vulnerability level to climate change impacts had a negative correlation with agricultural production, livestock size, total income and food consumption. The study established that a household's food security status depends on household's adaptive capacity to climate change impacts and climate variability. Households with lesser adaptive capacity to climate change were the most vulnerable to food insecurity. Besides, farmers' adaptation decisions determined the growth potential of agricultural production in subsistence farming areas. Short gestation and drought resistant crop varieties and irrigation were the most effective adaptation strategies to climate change impacts. Adaptive capacity and food security were positively related. Improving farm land resilient to climate change impacts through reforestation, improvements of household's adaptive capacity to climate change impacts and effective public services delivery systems were the most recommended interventions by the majority of farmers to address food insecurity at the household level.

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LIST OF ABBREVIATIONS

ADB	Asia Development Bank
AE	Adult Equivalent
AgEx	Agricultural Extension
ANOVA	Analysis of Variance
ATVET	Agricultural Technical Vocational Education and Training
CSA	Central Statistics Agency
CVI	Climate Vulnerability Index
DA	Development Agent
EPRDF	Ethiopian People's Revolutionary Democratic Party
FGD	Focus Group Discussion
FTC	Farmers Training Centre
GDP	Gross Domestic Product
GHE	Greenhouses Gas Emission
GHG	Greenhouse Gases
Hh	Households
Ha	hectare
HRD	Humanitarian Requirement Document
ICCA	Institute for Climate Change and Adaptation
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
Kcal	Kilocalorie
Kg	Kilogram
KII	Key Informant Interview
MAD	Mean Absolute Deviation
MAPE	Mean Absolute Percentage Error
MSD	Mean Squared Deviation
MOA	Ministry of Agriculture
NMA	National Meteorological Agency
PhD	Doctor of Philosophy
PPS	Probability Proportion to Size
SD	Standard Deviation

SPSS	Statistical Package for Social sciences
SRS	Simple Random Sampling
TAMSAT	Tropical Applications of Meteorology using Satellite and ground based
TD	Transdisciplinary
TLU	Total Tropical Livestock Unit
T_{max}	Maximum Temperature
T_{min}	Minimum Temperature
VIF	Variance Inflation Factors

GLOSSARY OF TERMS

Capacity: "It is the combinations of all the strengths, attributes and resources available to an individual, community, society or organizations that can be used to achieve goals" (IPCC, 2012).

Food System: "Food availability, food access and food utilization and its outcome household's food security" (Ericksen, 2008).

Perception: "It is the process by which we receive information or stimuli from our environment and transform it into psychological awareness" (IPCC, 2014).

Resilience: "The ability of a system (social, economic, and environmental systems) to cope to recover from the effect of a hazardous event, disturbance" (IPCC, 2014).

Sensitivity: "It is the degree which a system is affected or responsive to climate stimuli" (IPCC, 2012).

Vulnerability: "The propensity or predisposition to be adversely affected" (IPCC, 2012).

Exposure: "The presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected'' (IPCC, 2012).

CHAPTER 1: INTRODUCTION

1.1 Background

Projections have shown that the demand for food crop will increase globally by 100-110% from 2005 to 2050 due to the rapidly expanding human population, making the food security issue a pertinent and global problem. In order to feed the rapidly growing population, it was estimated that food production needed to double from the year 2002 to 2022 (Cakmak, 2002). Garrity et al. (2010) reported that more resource is needed to improve the lives of millions of Africans by alleviating the adverse impacts of climate change. Ensuring adequate food production requires transformative actions to adapt to impacts of climate change and variability if food security is to be attained (Campbell et al., 2016).

In the African region, previous research studies have focused more on the impacts of climate change either on crops or livestock (Amwata, 2013) but few studies have adopted a landscape lens approach. Other studies have documented climate change impacts on different agriculture sub-sectors; however, little attention has been paid to the impacts of climate change on agricultural production as an integrated system, integrating all its sub-sectors (Campbell et al., 2016). As a result, various interventions have been carried out by different actors to help meet the food demand through, for example, sustainable intensification of crop production through use of farm inputs and irrigation, and use of drought tolerant and disease resistant crop varieties. However, limited attention has been paid on linking the impacts of climate change and variability from the food production and vulnerability perspective (Tilman et al., 2011). Some of the studies on impacts of climate change on agricultural production have focused on modelling of impacts of climate change using temperature and rainfall changes (Luck et al., 2011). Others have focused on the specific adaptation strategies for crops, animals, and fishes, each in isolation (Amwata, 2013). Yet, different food production sub-sectors interact with each other by complementing and competing against each other.

Agriculture refers to the production of crops and livestock (Henao & Baanante, 2006) and remains central to the sustainable development of many African countries especially Ethiopia. This sector influences the economic growth of other sectors and the overall economy. It contributes about 43% of the GDP and 86% of exports. The export of Ethiopia is dominated by coffee and oil seeds, which together accounted to 50.6% in 2008/09. Other principal export commodities are 'chat', flowers, pulses, and live animals[1]. For example, crop production constitutes 60%of the sector's outputs, livestock accounts for 27%, and other areas contribute 13%. However, the sector is dominated by smallholder farmers who practice rain-fed mixed farming which accounts for 95%of the total area under agricultural use and these farmers are responsible for more than 90% of the total agricultural output. Despite the great contribution of smallholder farmers to agricultural production in Ethiopia, they face several challenges such as use of traditional technologies, low input use and low production, impacts of climate change and variability, limited access to credit facilities, among others. Of all these factors, the uncertainty associated with the impacts of climate change and variability is increasingly becoming of great concern nationally and across the globe on how it influences farmers' adaptation to agricultural production and food security.

1.2 Problem statement

Subsistence farmers in Kolla Temben District, which lies in Tigray Regional State in north Ethiopia rely on rain fed farming and face immense challenges of ensuring adequate supply of food for their households throughout the year. A total of 2.9 million farmers in Ethiopia were in need of emergency food aid in March 2015, of which 12% were from the Tigray Regional State (HRD, 2015). Tigray Regional State has 5.8% (4,314,456) of the total Ethiopia population (73,918,505) (CSA, 2007). The productivity of the land has become low, failure in seasonal rains has become common, the environment is degraded and the fast growing population has increasing food demand. In Tigray Regional State, farmers are unable to produce enough food even with relatively good seasonal rainfall (Tagel, 2008; Tagel and Veen, 2013). Tagel and Veen (2013) reported that Kolla Temben District was the most food insecure due to ownership of small farmland size and low agricultural production. His study, however, failed to show the implication of impacts of climate change on agricultural production and food security. Furthermore, Tagel (2008) revealed that the farming communities in Kolla Temben District are virtually food insecure and the severity of the food insecurity problems is growing day by day despite the many efforts by different actors in the region. Teka (2018) suggested the adoption of more water harvesting practices to improve food security but failed to recognise the role of the impacts of climate change and variability on water availability and food production. Other studies have looked at determinants of household's food insecurity using an integrated approach (Amwata et al., 2015a; Kakota et

[1]http://ethemb.se/wp-content/uploads/2013/07/Investment-Opportunities.pdf

al., 2015). However, these studies have emphasised the need for an integrated approach to understanding climate change impacts, agriculture production and food security because it helps to maximise on complementarities and promotes efficient utilisation of the resources. However, these studies were conducted in Kenya and Malawi respectively and owing to the geographical differences, the recommendations may not fully suit the Ethiopian context.

Most of food security studies (Altman et al., 2009; Alemu, 2012; Mango et al., 2014; Frelat et al., 2016; Sibhatu and Qaim, 2017; Abadi et al., 2018) focused only on the household characteristics and production (family size, consumption and household total income, market, age and education of household heads) whereas climate change vulnerability, an important factor with respect to farmer's agricultural activities, has not been considered. Research studies have concentrated on simulated changes of climate (temperature and rainfall) on food production but few have provided evidence on the impacts at household level through empirical study. Previous studies also fall short of providing appropriate, holistic and integrated adaptation options that consider the area-specific climate impacts on agricultural production and farmers adaptation choices (Teka, 2018). Therefore, this research was undertaken to fill the knowledge gaps on the implication of household's vulnerability to climate change impacts to agricultural production and its relation to food security, and assess perceptions and farmers' choice of adaptation strategies implication for sustainable agricultural production. It aims to establish the influence of the climate change impacts on agricultural production and household food security in Kolla Temben District of Ethiopia.

1.3 Research questions

1) What are the relations between farmer households vulnerability and climate change impacts on agricultural production and total income?

2) What are the farmers' perceptions on climate change impacts, adaptation strategies and their implications on agricultural production?

3) What are the implications of the farmers' adaptive capacity on household's food security status?

1.4 Hypothesis

Null Hypothesis, H_0:

The null hypothesis made for this study was that there is no relationship between smallholder farmer household's vulnerability to climate change impact and household's total agricultural production (crop production, livestock size, total income and food consumption).

Alternative Hypothesis, H_1:

The alternative hypothesis made for this study was that there is a relationship between smallholder farmer household's vulnerability level to climate change impact with household's total agricultural production (crop production, livestock size, total income and food consumption).

1.5Objectives

Main Objective: The main objective of this study is to investigate smallholder farmer household vulnerability to climate change impacts and its implications on agricultural production in Kolla Temben District, Northern Ethiopia.

Specific objectives:

1) To establish the relations between farmer households vulnerability and climate change impacts on agricultural production and total income.

2) To assess of farmers' perceptions on climate change impacts, adaptation strategies and their implications on agricultural production.

3) To examine the implications of the farmers' adaptive capacity on households- food security status

1.6 Justification and significance of the study

1.6.1 Justification

Climate changes exert stress on agricultural systems and constrains attainment of current and future food demands (Aggarwal, 2008; Amwata et al., 2015b; Abererton et al., 2016). Local knowledge is important to facilitate adaptation and ease vulnerability to climate impacts (Nyong et al., 2007; Reyes-Garcia et al., 2016; Amwata et al., 2018). The fundamental lessons emerging in the areas of vulnerability is the urgent need for more research work to improve understanding of the root causes of vulnerability and its impacts (Eriksen and Kelly, 2007; Abela et al., 2019). Hence, this research output will contribute to new insights to policy makers, researchers to address climate impacts on smallscale agricultural production in Kolla Temben District, Tigray Regional State. Further, the research will contribute to the growing body of knowledge on climate change and agricultural production in order to increase awareness and provide scientific evidence for decision making. Also, it will guide development interventions in the study area by relevant actors by ensuring agricultural activities are climate resilient as a prerequisite for sustainable agricultural production.

1.6.2 Significance of the study

Farmers in Kolla Temben District are facing chronic food insecurity problems and the agricultural production is declining because of the changing climate. The local government and most of the stakeholders have limited and/ or lack the necessary capacity to advise farmers on how to deal with agricultural production in the face of the changing climate. Household's vulnerability level to climate change impact in Kolla Temben District is not yet investigated and its real impacts to the agricultural production of the district are unclear to governors, farmers and researchers. As a result, the farming community in the District has been depending on relief food for survival for many years. This research helps to identify household's vulnerability level to the impacts of climate change and possible adaptations strategies (vulnerability reduction mechanisms). The research helps policy makers and development workers to know households perception to climate change impacts as perception is very important for farmers to decide on the types of adaptation. Practitioners and researchers in Kolla Temben District will get clear information on the implications of farmer vulnerability level to food security in the District. The study will also propose clear policy intervention options for decision makers and areas for future research.

1.7 Scope and limitation of the research

The livelihood means of the rural community in Kolla Temben District is directly linked with the natural resources base which is highly susceptible to changing climate and already under unclear present and future risks. Climate change study is a very complex area of research and needs temporally long data sets to detect changes and examine the long term impacts of the changes on human beings. This area needs a very comprehensive study approach and huge resources but the scope of this study was limited to household's vulnerability to climate change impacts and implications on agricultural production (crop production and livestock rearing). It mainly bounded itself to household's vulnerability level to climate change impacts and some indicators of food security (food availability, food access and food utilization). Lastly, the limitation of this study was that it was only conducted in one district due to funding constraints and this may not be enough to project the results to the wider Regional State that has diverse geographical representation.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews the past and current trends of impacts of climate change and variability with particular reference to small scale agricultural systems. It goes on to review the vulnerability to climate change of small scale farmers at the household level, and the related indicators of vulnerability that reflect their food security status. Thus, it reviews the current understanding of climate change impacts on farmer households' agricultural production, total income, food security and adaptation strategies, as well as their perceptions on climate change and variability and its impacts are outlined. The definition of terms used in this Chapter and the thesis as a whole are presented in the Glossary of Terms.

2.2 Trends and impacts of climate change and variability

Surface temperature has been anticipated to increase in the 21stcentury in all emission assessment scenarios (Pachauri and Meyer, 2014). The projected global mean temperature has risen by0.35°C from 1910 to 1940 but in the past a hundred years (1906-2005), surface temperature has increased by 0.74°C (IPCC, 2014). The combined land and ocean average global warming in the period of 1880 to 2012 was estimated at 0.85 °C (Pachauri and Meyer, 2014). The single longest dataset results revealed that mean temperature rise in the periods 1850 to 1900 and 2003 to 2012 were 0.72 and0.85°C respectively (Pachauri and Meyer, 2014) but Vinnikove et al. (1989) reported that global warming has increase by 0.5°C /100 years in the past century. Global temperature has increased by 0.5-0.7°C in the years 1980 to 1985 and there were strong global warming trends between 1965 to1980 (Hensen and Lebedeff, 1987). Globally, ocean surface temperatures are getting warmer near to the surface (Pachauri and Meyer, 2014). The upper 75m ocean surface has warmed by 0.11°C per decade over the period of 1971 to 2010 (Pachauri and Meyer, 2014). Temperature has increased by 0.90ºC in the 1950 and 2000 decades but for the period 1753 to 1850 temperature had suddenly dropped to 0.5ºC and some inconsistencies were observed (Rohde et al., 2013).

Atmospheric and surface boundary conditions could affect minimum and maximum temperature (Karl et al., 1993). Simulated trends in diurnal temperature range are much smaller than observed and T_{max}, seems to be over-estimated in climate models. According to

Mongiet al. (2010), T_{min} has increased faster than T_{max}. For instance, temperature increase has accounted for widening the geographical range of insects (Ho et al., 2014), animals and plants. Zhanget al. (2007) climate model result reported that there will be some increase in global mean precipitation with decreasing trends in tropics. New et al. (2001) reported that global land precipitation has increased by 0.89 mm/decade over the 20th century (New et al., 2001).

Temperature is anticipated to increase by 1.4–5.5°C in East Africa by the end of the 21st century (Adhikari et al., 2015). In the Southern part of Ethiopia, temperature increased by 0.03ºC per year whereas rainfall decreased by 0.04 mm per year between 1948 and 2006 (Jury and Funk, 2013). Kolawole et al. (2014) reported that total annual rainfall has increased in the past three decades. According to Daniel et al. (2013), T_{min} and T_{max} in the Blue Nile basin of Ethiopia has increased by 0.1 and 0.15^{O}C per decade respectively between 1981 to 2010.Cheung et al. (2008) reported that there was significant decrease of rainfall in Ethiopia from June to September between 1960 to 2002 but Daniel et al. (2013) reported that there was no significant change in mean annual rainfall in the Blue Nile basin of Ethiopia in the years 1981 to 2010. Further, Mulugojjam et al. (2013) reported mean annual rainfall increasing trends between 1995 to 2008 and decreasing trends in 1979 to 1994 in Western Amhara, Ethiopia. The impacts of climate change on rainfall in the Rift Valley of Ethiopia is projected to be very severe and may have consequences on agricultural production (Biniyam and Abdella, 2017).

Climate change and its impacts are expected to continue for many centuries despite the enormous efforts at global, regional, national and local levels on abatement of greenhouse gases (Pachauri and Meyer, 2014) and implementation of adaptation strategies. For instance, crop production losses in sub Saharan Africa as a result of climate change is projected to be 22% for maize and 17% for sorghum (Schlenker and Lobell, 2010; World Bank, 2012). The impacts of climate change on the food system are expected to be more complex and to cover wide areas; therefore, certain scholars have recommended more area-specific research to understand the dynamics of the problem (Vermeulen, 2012). Impacts of climate change and variability include the changes in the ecosystems, disturbances of agricultural production and water sources, damages in the infrastructural facilities and human settlements, destruction of property and injury and loss of human life (IPCC, 2014).Therefore, climate change impact risks are disproportionately distributed and its impacts are bigger for marginalized groups of people, especially women, children, youths and the physically challenged (Pachauri and Meyer, 2014).

2.2.1 Climate change impacts on agricultural production

In the 21st century, agriculture remains central in tackling the three challenges of improved food security, adapting to the impacts of climate change and variability, and reducing greenhouse gas emissions at a time when resources are gradually becoming more limited for global food systems (Beddington et al., 2012). More investigation is essential to improve the understanding on the possible impacts of the changing climate in the food system in a2ºC+ temperature world compare with the pre- industrial level as the international community agreed in the Paris Accord to limit temperature increase to 1.5-2ºC (Thornton, 2011 and IPCC, 2018).

Weather is major factor that affects agricultural production and directly affects food production across the globe (Mahato, 2014). The impact of climate change and variability on crop yields in East Africa is largely negative. In East Africa, wheat and maize are the most vulnerable crops and their yields are projected to decline by 72% and 45% respectively by the 21st century (Adhikari et al., 2015). In addition, Kidist et al. (2018) simulation for maize yield a decline of 43% to 24% for Melkassa Village and 51% increase for Hawassa village by the end of the century. Kange et al. (2009) has reported that the impacts of climate change on crop yields can be positive or negative. However, Funk et al. (2008) reported that agricultural production is expected to decrease continuously. Ali et al. (2017) reported that temperature increase and relative humidity had positive impacts on sugarcane crop yields.

Climate change impacts affects food supply, biodiversity, wood fuel availability, and agribusiness negatively (Jonathan et al., 2009). Adams et al. (1998) have reported that there will be winners and losers from the impacts of climate change and variability. For example, some areas will benefit from increase in agricultural production while others will suffer a continuous decline in agricultural production. Lobell et al. (2011) projects that 65% of maize growing Africa regions will experience yield losses for 1ºC of warming but he failed to support his results through empirical data from farmers and also ignores the geographic specific contexts of climate impacts, households level of vulnerability, role of adaptation and quantification of impacts.

There is a growing body of knowledge on the impacts of climate change and variability on agriculture and food security sector at international and local levels. However, more area specific research work is still needed to understand the link between climate change and the different agricultural production from a systems perspective including profiling and characterising of the most vulnerable households(Beddington et al., 2012).Already, mass migration is expected to worsen (Sullivan and Meigh, 2005)as agricultural systems are stressed by climate change impacts and the food system are not adequately addressed due to limited empirical evidence to inform policy and actions. The frequency of incidences of drought and floods can have significant impacts not only in areas where they happen but also in the neighbouring regions (Sullivan and Meigh, 2005).

The impacts of climate change on the less fertile crop lands of East Africa are expected to be very severe (Jones and Thornton, 2008). Crop production is likely to decrease in future as water availability and precipitation will decrease (Kange et al., 2009). Livestock system is one of the climate sensitivity systems (Rojas-Downing et al., 2017). The impact of climate change on livestock is very severe globally but there are significant differences across region and developing and developed countries (Sejian, 2013). Previous climate impact studies on the agriculture have focused more at regional or continental levels. There is limited information on the impacts of climate change on agriculture and food systems and specific adaptation strategies defined by location in the agricultural system (Rojas-Downing et al., 2017).

2.2.2Impacts of climate change and variability on farmer households' food security

The impacts of climate change on economic bases, societies and environment is very significant (Sullivan and Meigh, 2005). Change in climate patterns (temperature and precipitation) and the distribution of the natural base leads to unpredictable and erratic rainfall pattern, warmer temperature and diminishing of water availability and agricultural production (Ishaya and Abaje, 2008). Crop modelling studies have paid limited attention to adaptation, vulnerability level and other indicators related to agricultural performance in simulating crop yields and total income (Reidsma et al., 2009). Sub-Saharan Africa will lose 26 million dollars by 2060 as a result of climate impacts (Dessalegn and Akalu, 2015). Agricultural returns and total income are likely to decrease (Montle and Teldemedhin, 2014). Increasing levels of CO_2 concentration in the atmosphere enhances agricultural productivity with minimum nutrient content (Myers, 2017). On the other hand, climate change and variability can have positive effects on agriculture production and income (Olesen and Bindi, 2002). The impacts of temperature increase on agriculture production and total revenue in rain fed agriculture is negative but precipitation increase has positive effects (Wang et al., 2009). Temperature increase in irrigation supported area has positive impacts on agricultural production (Wang et al., 2009).

Significant changes may be needed in people's livelihood and agricultural production systems if household's food security status and total income is to be enhanced in the ever changing climate of East Africa (Jones and Thornton, 2008). Diversification of the means of livelihood improves household's incomes in the current ever changing climate (Yamba et al., 2017). Although agriculture is the main source of many households' income in East Africa, the impacts of climate change and variability in the sector have not been adequately addressed (Lunde and Lindtjorn, 2013).

2.3 Farmers vulnerability to climate change impacts

According to Schipper (2007), reductions of the vulnerability level of the poor through development is a better approach than reducing vulnerability through adaptation. The applications of climate vulnerability index(CVI) to sub national and community levels helps in identifying those mostly at risk and to allocate resources towards those in most need of it (Sullivan and Meigh, 2005). Irrigation can help subsistence farmers to manage climate change impacts (Gwimbi,2009). The guidelines available to structure vulnerability assessments that can also be used to compare and to make generalizations is very little (Polskya et al., 2007). Climate change will have different impacts on vulnerable groups (Bohle et al., 1994). Several adaptation measures such as agroforestry, diversification of livelihoods among others have been put in place to mitigate climate change. For example, agro-forestry is important in reducing a household's vulnerability to climate change (Thorlakson and Neufeldt, 2012) since the trees sequester carbon and often provide other benefits such as food, fruits, firewood and soil and water conservation (Polskya et al., 2007). A lot of research remains to be done regarding food systems' vulnerabilities to climate change impacts (Richard, 2001). All sectors and groups of societies are not at the same level of sensitivity and vulnerability to climate change impacts.

2.4 Household food security and adaptive capacity to climate change impacts

Climate change affects food and rural livelihoods (Akudugu et al., 2012; Amwata et al., 2015b). The shift of climate patterns associated with climate change requires good knowledge and understanding on how impacts of climate change on food systems and their linkages (Gina et al., 2006). There are commonalities and differences in understanding of food systems in light of climate extremes such as drought and flooding which require a good understanding of risk in order to respond appropriately and to support the most vulnerable groups (Gina et al., 2006). Farmers who mostly depend on the livestock sector are more vulnerable to food insecurity as a result of climate change (McKune et al., 2015). Crane et al. (2011) reported that the climate change model visualizes only potential future impacts and could not represent human adaptive capacity. There is gap between modelled adaptation and farmers' actual practices under different food systems.

Food system conceptualization is unclear and more empirical studies are needed to provide clear understanding to its vulnerability (Ericksen, 2008). Improved agricultural production, food distribution systems and good access to economic opportunities has great potential for enhancing coping and adaptation strategies of the food systems to the impacts of climate change. In contrast, some agricultural practices also contribute to greenhouse gases emission through production of greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) to the atmosphere. More empirical studies are important to improve the understanding of the impacts of climate change to food production and its inter-relations to food security (Gregory et al., 2005). The threshold for household food security is 2,100 calories per person per day or the total expenditures or money needed to attain the 2100 calories (Meade et al., 2013). It is projected that food insecure people will be 868 million by 2023 globally, which is 23% increment from the global figure of 668.36 million provided in the year 2013 (Meade et al., 2013).

2.5 Farmers perception of impacts of climate change and variability

Most of local people perceptions on climate variability in West Africa are consistent with research evidences (e.g. Piya et al., 2012; Oluwatobi and Oluwakemi, 2016) but Juana et al. (2013) reported that majority of farmers in Sub-Sahara Africa are aware of only for warmer temperature and precipitation pattern changes. A study conducted in Ethiopia reported that about 64% of farmers perceived that temperature had increased in 20 years (Okonya et al., 2013). Climate change perception varies with household's characteristics, namely; education level, age, willingness to accept risks, farm ownership and off farm employment status(Linden,2015). Menike and Arachchi (2016) reported that farmers perceived that temperature exhibits an increasing trend while the trend in rainfall is decreasing but he failed to cross-check for its consistency with instrumental climate records. Roco et al. (2014) revealed that young and more educated farmers have clearer perceptions on climate change impacts than older and less educated farmers. Sarkar and Padaria (2010) reported that majority of rural households lack climate information and they are less aware of the trends or impacts of climate change.

Similarly, Tazeze and Haji (2012) found out that gender, age, level of education, family size, livestock ownerships and total income have impact on household's adaptation strategies but missed to examine household's perceptions to climate change impacts. Safiet al. (2012) reported a negative correlation between gender and climate change perceptions. Women farmers understand their local climate better than their male counterparts but women's ability to cope with extreme climate event is low due to limited access to resources (Deborah and Yusuf, 2016). Understanding farmers' perception on climate variability is very crucial as perception is the most significant barrier to adaptation (Haque et al., 2012).

Public perceptions on local risks from global warming are ever more important as communities' face decisions on how best to adapt to impacts of climate change (Abuloye and Moruff, 2016). Integrated risk communications should get more attention to address the multiple aspects of human judgment and behaviour on climate change (Sikder and Xiaoying, 2014). Further study is needed to see if household's observed stances on climate change and variability are evolving over time (Linden et al., 2015). Continuous research work, regular monitoring systems, knowledge management and development are important to manage climate change and its impacts (Kumar et al., 2012).

2.6 Adaptation strategies to climate change impacts

Climate change is inevitable (Parry et al., 2007). Complementary actions are important to enhance adaptation planning and implementation at all levels, from individuals to government (IPCC, 2014). No one strategy is optimal in adaptation (Jonathan et al., 2009). Farmers can't use the same adaptation strategies in all agro-ecological zones (Parrya et al., 2003) and Falco et al. (2011) reported that age and education of household head are determinants of adaptation. The perceived hindrance to adoption of modern techniques as adaptation strategies of climate change impacts is limited access to resources (Ishaya and Abaje, 2008). The poor whose livelihoods are solely based on natural resources are the most vulnerable to climate change impacts, and have limited adaptation strategies (Ishaya and Abaje, 2008). Campbell et al. (2016) strongly recommended more researches on the impacts of climate on food system and people most vulnerable to climate change impacts and their adaptation strategies.

Community participation is an important tool for a successful adaptation (Ishaya and Abaje, 2008). The agriculture sector has many policy instruments with multiple objectives; increasing production, adapting to changing climate and minimizing further emissions (Ishaya and Abaje, 2008). Sectors are facing the challenges of high demand for food, less energy and water availability, and fast population growth (Ishaya and Abaje, 2008). Tacoli (2009) reported migration policy (top down adaptation strategy) as the most useful adaptation but neglected the need for bottom up adaptation to reduce vulnerability.

Thornton et al. (2009) revealed that household with adaptation strategies have 10% more net revenue compared with households without adaptation strategies but failed to specify the types of adaptation strategies which generated more revenue and were most effective. Thornton et al. (2009) listed farm production adjustments, intensification of crop and livestock production, land use change and use of irrigation as adaptation strategies but they failed to examine the effectiveness of the adaptation strategies in improving production. Tagel and Anne-Veen (2013) reported that age and level of education of household head have significant impacts on household’s adaptation options. They reported the most common adaptation strategies by households in the highland of Ethiopia to include crop diversification, soil conservation, irrigation and planting of trees. However, they failed to go further to evaluate the contribution of each adaptation option to total production. Also, Rojas-Downing et al. (2017) reported that the use of different crop varieties and mixed crop-livestock are widely applied adaptation strategies in agriculture but failed to see its relationship with production increment. Farmers’ adaptation strategies to climate change differ based on agro-ecological zone and is dependent on the severity of climate change impacts. Even though farmers in Delta State of Nigeria perceived that temperature is increasing and precipitation is decreasing but no farmers have used any adaptation strategies (Ofuoku, 2014). Farmers in

Laikipia District of Kenya perceive well their microclimate variation and also can easily adapt to perceived changes (Ogalleh et al., 2012) since climate impacts are area and context specific.

There is enormous accumulated knowledge on mitigation and adaptation to reduce the adverse impacts of climate change but that knowledge is not available or accessible to farmers level and its impacts on productivity is less known (Nyong et al., 2007). The global food production is under stress of climate impacts but many farmers are not using more adaptation strategies as expected, and it is expected that agricultural production in arid and semi-arid areas will continue to decline (Misra, 2014). However, farmers' farming experiences promote adaptation to climate change impacts (Hassan and Nhemachena, 2008).

More methods and tools are still needed to better respond to the impacts of climate change and variability (Laukkonen et al., 2009). Future policy should focus on facilitating adaptation strategies by encouraging more area specific research activities (Temesgen et al., 2009). There is a need for more area specific research work to improve the understanding of farmers' responses to climate shocks under various economic conditions and varying access to technology (Iizumi and Ramankutty, 2015). More research work is needed to improve understanding on farmers' responses to climate shocks under various economic conditions and varying access to technology (Iizumi and Ramankutty, 2015). Future research should focus on differentiating the most effective adaptation strategies that can improve productivity (Falco et al., 2011). More research work at local level is important to identify and know the most effective adaptation strategies (Abid, 2015). Further study is needed to see if household's observed stances on climate change and variability are evolving over time (Linden et al., 2015). Continuous research work, regular monitoring systems, knowledge management and development are important to manage climate change and its impacts (Kumar et al., 2012) on smallholder farmers.

CHAPTER 3: STUDY AREA AND METHODS

3.1 Site selection, location and description

The study area was selected on the basis of: high dependency on rain-fed agriculture; longstanding food insecurity and food aid dependency; unreliable rainfall pattern; high population growth; varied topography, and; perceived but un-evaluated climate impacts. The study area, Kolla Temben District, lies in the central zone administration of the Tigray Region, 95 km west of Mekelle City, the capital city of the Regional State. The Kolla Temben District bordered by Naeder Adet District to the northwest, Wereleke District to the north, Abergele District to the south, Western Zone District to the western and Hawzen District to the east part (Figure 3.1). The road network of the Regional State comprises 4,949 km of dry weather roads, 2,522 km all-weather roads, and 497 km of paved roads (CSA, 2007).

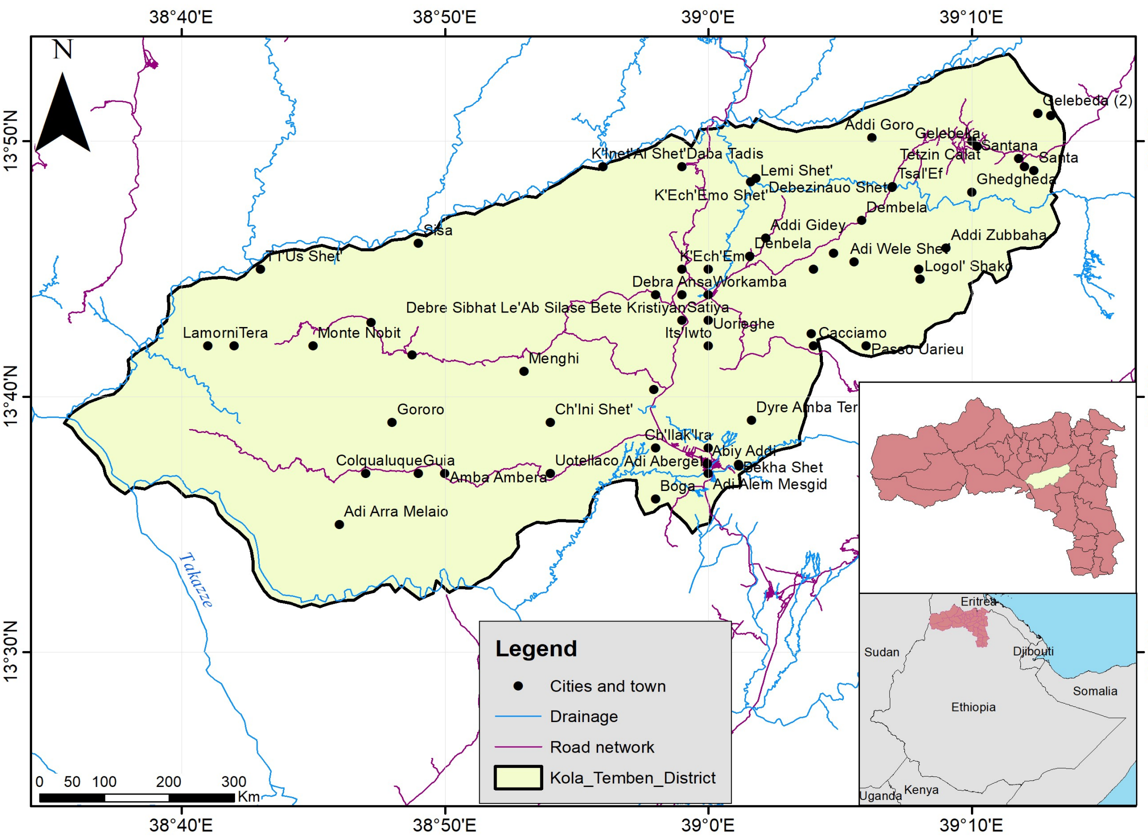

Figure 3.1: Map of Kola Temben District.
Source: Author, 2016

3.2 Biophysical setting

3.2.1 Climate

According to the Regional State Bureau of Agriculture, the Tigray Regional State has three Agro-Ecological Zones, namely, Lowland (hot area) at 1600 metres above sea level, Mid-Highland at 1600-2300metres and Highland (Cold land) at 2300-3000 metres above sea level. The climate of the Tigray Regional State is semi-arid ("Kolla") at 39%, warm temperate ("Woinadega") 49%, and temperate ("Degas") at 12%. The annual rainfall of the regional state is 450-980 mm and the estimated population density is 86.56 people per km^2.The average altitude of the Regional State Capital, Mekelle, is 2100 metres above sea level with temperatures between 11ºC and 23ºC with annual rainfall range of 900 to 1800 mm. The altitude of the Kolla Temben District (study area) is 1400 to 2300 metres above sea level, and therefore covers the following climatic zones: Lowland (Kola), 'Weyina Dega' (midland) and 'Dega' (highland). The Kolla Temben District annual rainfall is 500 mm to 800 mm with an annual average temperature of 25-30ºC (Hagos Gebru[2]).

3.2.2 Vegetation cover

There is more vegetation cover in the eastern and western parts of the country compared with the north. Most of the land in the Tigray Regional State is covered by cropland but also large portions are bare land (Figure 3.2). According to CSA (2008), out of the total area of 54,569.25 km^2 of the Regional State, 1.3 million ha is farmland of which 1 million ha of land has been cultivated. According to Beddington et al. (2012), forest areas in Ethiopia are declining by 1% each year and the annual wood fuel consumption of the country by 2008 was close to 100,000 m^3.

[2] Natural resources officer, district office,

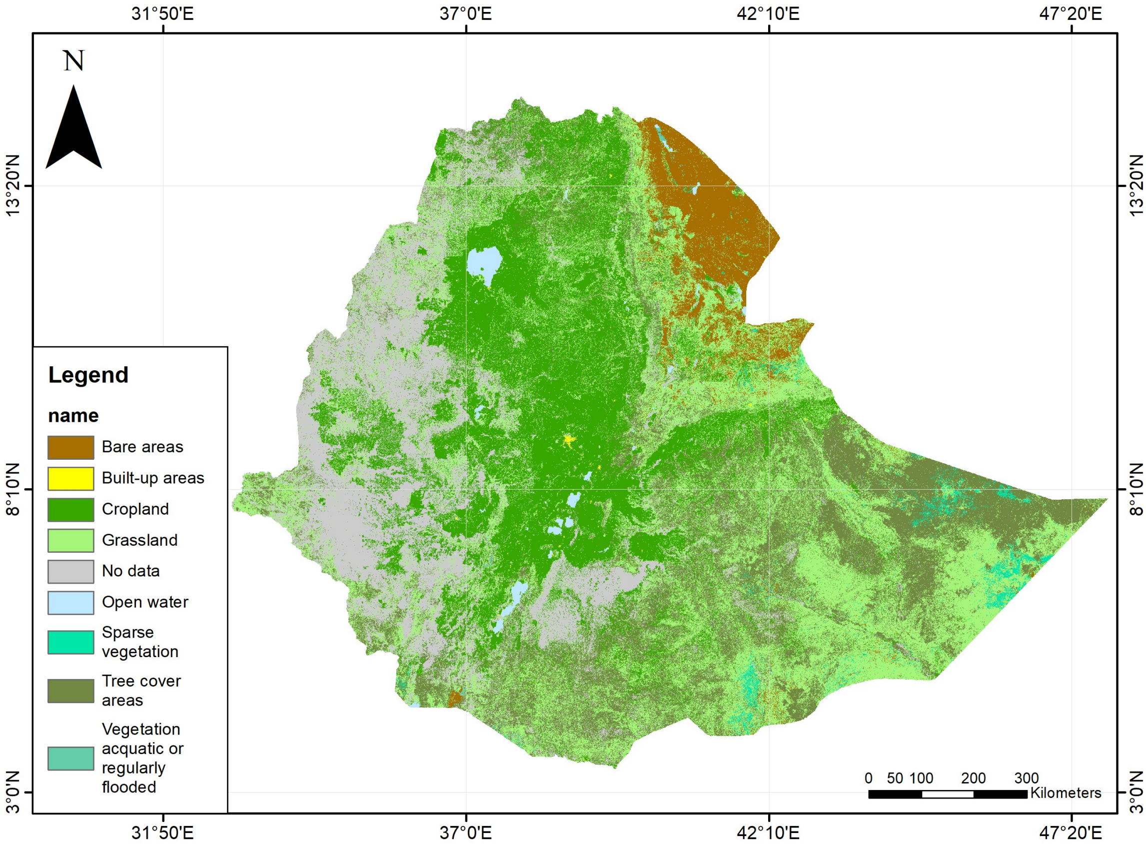

Figure 3.2: Vegetation map of Ethiopia
Source: Debebe T[3]

3.2.3 Land use and resources

The economic base of Kolla Temben District is fully dependent on rain fed mixed subsistence farming system. According to the District Agriculture Office Report (2016) from the district total of 157,000 hectares of land, 31,021 hectares are cultivated, 105,909 hectares are non-cultivable, 12,502 hectares are closures, and the rest are grazing land, woodlots shrubs and trees(Daniel Gebremedihne[4], pers. comm.).

The mean landholding of the District is one ha per household. The livestock sector in Kolla Temben District plays an important as a livelihood base for the majority of the communities and the major farming systems for the District. The types of animals and their population size in the District are; 113,779 cattle, 195,233 goats, 11,300 sheep, 133,273 poultry and 8,981

[3] Officer, National Map Works
[4] Officer, Agriculture and Rural development department of Kolla Temben District,

donkeys. Also, the district is known for bee keeping and has 11,552 traditional and 2,435 modern hives (CSA, 2007).

3.2.4 Topography and drainage

Tigray Regional State is found in northern part of the country and shares borders with north Sudan, Eritrea, Amhara Regional State and the Afar Regional States of the country to the eastern part (Figure 3.3). Tigray Regional State is highly mountainous, with steep hills as in Erope District, which makes it very difficult for large scale irrigation practices with exception of the southern and western zones.

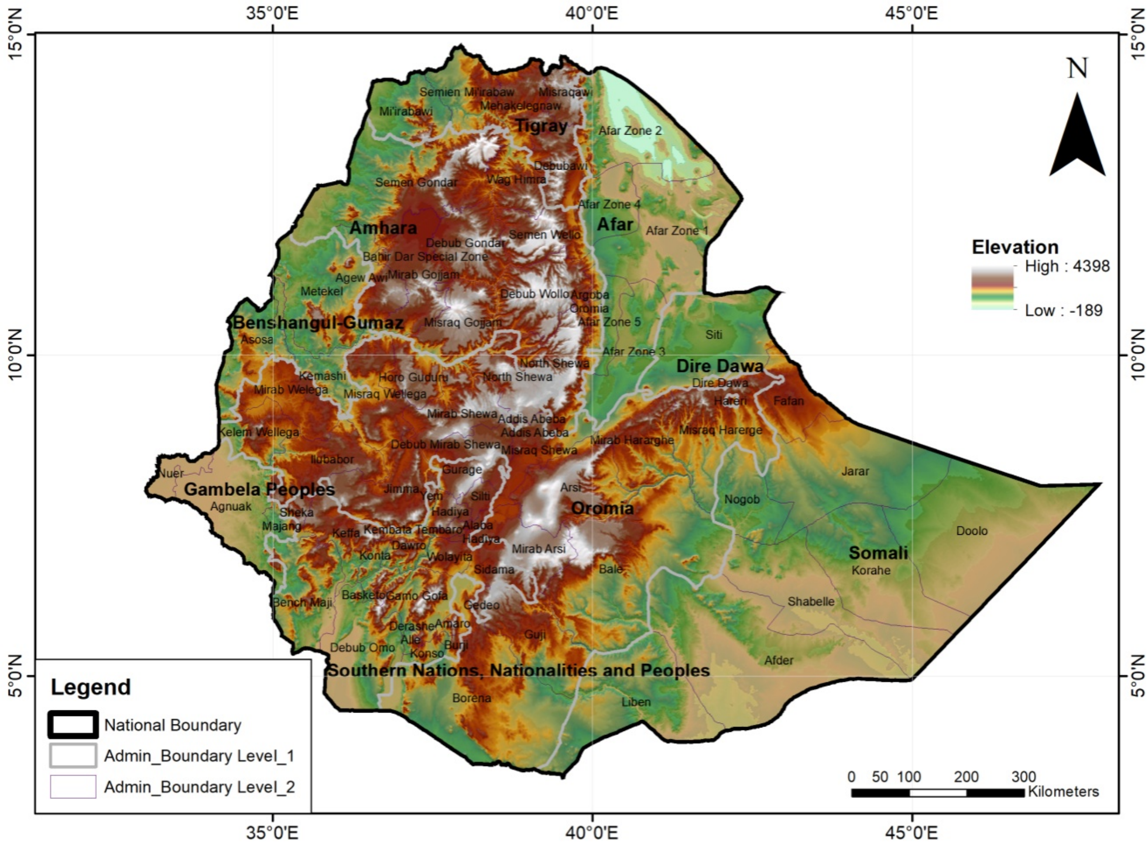

Figure 3.3: Topographic map of Ethiopia
(Source: Debebe T[5])

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[5]Officer, National Map Works

3.2.5 Water resources

According to the Regional State Bureau for Water Resources Office the coverage of water supply of the region is the lowest level in Ethiopia. The major source of portable water for the region is mainly from groundwater which is extracted from hand dug wells, shallow wells drilled up to 60 metres depth, developed springs, and deep drilled water wells. Surface water is not much used for domestic water supply in the Regional State and only two towns, namely, Adwa and Axum, are currently using surface water supply. The major river in the Tigray Regional State is the Tekeze River which has one hydro power dam near the Kolla Temben District that has electric power generating capacity of 300 megawatt(Abrha, Tesfay[6], pers. comm.). This river is one of the major rivers of the Tigray Regional State which the government of the Federal Republic of Ethiopia is considering for further utilisation as the area is arid and water stress is a chronic problem in the Tigray Regional State. Women and girls are consequently vulnerable to the impacts of climate change as they are responsible for water collection(Abrha, Tesfay[7], pers. comm.).

3.2.6 Biophysical vulnerability

The main biotic constraints on agricultural production in Ethiopia are drought, low soil fertility and water logging (MoA, 2011). This diversity and very complex topography makes the area more vulnerable to different climate change related hazards like flash floods, winds and landslides. This also makes the area very difficult for large scale irrigation practices.

3.3 Socio-economic setting

3.3.1 Political and administrative setting`

Tigray Regional State is the place where the first black decisive victory over white domination took place 130 years ago. It is also the home of the 'Axum civilizations' and the home of the first black African general 'General Alulu Abanega' who was the commander of the 'Adwa' battle against colonization. The Tigray People's Liberty Front (TPLF) is the ruling party of the Regional States following the fall of the Ethiopia military junta in 1991.

[6] Agriculture Officer in the Kolla Temben Agriculture department
[7] Agriculture Officer in the Kolla Temben Agriculture department

TPLF (Tigray people's Liberation Front) is the founder of the EPRDF (Ethiopian People's Revolutionary Democratic Party) which is the current ruling party of the country. Tigray is administratively divided into seven zones (including Mekelle City Zone), 47 Districts (12 urban and 35 rural) and 763 Kebelles (702 rural and 61 urban). Kolla Temben District is subdivided into 27 Kebelle administration areas (Abraham, Assefa[8]).

3.3.2 Economic setting

According to the Tigray Regional State Office for Planning and Finance, the gross domestic product (GDP) of Tigray Regional State is derived from Agriculture (39.4%), industry (19.6 %) service sector (41%) and the remaining 1% is miscellaneous. According to the National Meteorological Agency of Ethiopia (NMA) (2007), drought and floods and rising temperatures are identified as potential risks to agriculture and food security (Deressa, 2007). Climate change impacts are expected to negatively affect Ethiopia's economy (World Bank, 2006). Crop production is the basis for subsistence farmers in Ethiopia and covers more than 95% of cultivated land (Deressa, 2007). Ethiopia is the top in Africa and the tenth in the world in livestock population (Deressa, 2007 and Shapiro et al., 2015).

3.3.3 Social setting

The Tigray Regional State total human population size is 4,314,456 of which 2,124,853(49.2%) are male and the remaining, 2,189,603 (50.8%) are female based on the last census that was conducted in 2007. The Tigray Regional State population that lives in urban areas is 842,723 (398,072 male and 444,651 female) while those living in the rural areas is 3,474,733 (1,726,781 male and 1,744,952 female). The young population under 15 years of age has declined from 49.8 % in 1984 to 45% in 2007, and the working age group of 15-64 years of age has increased from 50.2% in 1984 to 51.9% in 2007, while those aged 65 years and above have remained more or less constant at 3.4% and 3.2% in 1994 and 2007, respectively(CSA, 2007).According to the CSA (2007) Population and Housing Statistical Report, the Ethiopian population grew at a rate of 2.6%in the years 1994 to 2007 while that of

[8] District Administration Officer, Kolla Temben District

Tigray Regional State population is estimated at 2.5% annually, which is very close to the national growth rate of 2.6.%.

The literacy level of the country is 39.8% while that of in Tigray Regional State is estimated at 45.4%. According to CSA (2007), the country has 103,283 (83,614 male and 19,669 female) people with a first degree, 24,394 (18,696 male and 5,425 female) with Master's degree and 19,667 with PhD degrees of which 78.10% are male and the rest (21.89%) are female.

The Agricultural Extension system of the country has a central and regional administrative structure. The core institutions established to support the rural people are Agricultural Technical Colleges and Farmer Training Centres (FTCs). At each Kebelle of the country, there is one Farmers Training Centre (FTC). The ATVET (Agricultural Technical Vocational Education and Training) are responsible for training of experts in the field of agriculture. These experts have commitment to work with farmers at each Kebelle after the completion of training. FTCs are the centres for training and demonstrations. The country has deployed 4 development agents (DAs) at each Kebelle. Furthermore, to deliver more technically sound services to farmers, Research-Extension-Farmer Linkage Councils have been established to oversee the technology generation, packaging and dissemination of services throughout the country (MoA, 2010).

3.3.4 Health setting

According to the Regional Bureau of Health, Tigray State has 15 hospitals (categorized as one regional hospital, one referral hospital, 6 zone hospitals and 7 district hospitals) and 209 health centres with 572 health posts. The Regional State has female health extension professionals with a minimum of diploma in health science and they are responsible for delivering health services for each household at the village level and reporting any cases to the Ministry of Health through the Regional State Health Office.

3.3.5 Regulatory framework

The Tigray Regional State has a constitution which was ratified in June 1995 after the fall of the military regime of Ethiopia in 1991. Agricultural extension services have an economic role of improving agricultural production and productivity; and a political goal of mobilizing farmers for election). The Agricultural policy of the country has two goals, improving productivity and facilitating political control which is assumed as vital to secure votes at the grassroots level (Kassahun, 2012). According to Belay (2003), the weak research and agricultural extension linkages, less appropriate policies to small holders' situation and the involvement of agricultural extension workers in activities outside of their professional duties are among the root causes to the ineffectiveness of the agricultural extension services.

3.3.6 Socio economic vulnerability

In Ethiopia, over 95%of sources of energy are from biomass, particularly wood which contributes to greenhouse gas emission (NMA, 2007). Agriculture is the means of employment for 85% of the people and contributes about 90% to the export earnings (MoA, 2011). The low level of technology utilization by farmers and the outbreak of weeds, insects and disease are affecting agricultural productivity of the country (MoA, 2011). Declining farm size, degradation of land and frequent occurrences of drought are challenging the country's economy, and tenure insecurity is also affecting productivity and production of the country (MoA, 2011). Climate change is expected to worsen the situation and its adverse impact will be more in low-income countries (ADB, 2011). The poorest and least paid workers are those who are mostly impacted by the adverse effects of climate change (ILO, 2008).

3.4 Conceptual framework

This framework helps to easily understand how household's levels of vulnerability to impacts on food production and income are interrelated in this study. The linkages between household's levels of social vulnerability, settlement vulnerability, biophysical vulnerability, water vulnerability and their relationship to food production and income levels are hypothesised in shown in Figure 3.4. Household's vulnerability level was determined by their livelihood base sensitivity, exposures and household's adaptive capacity levels to climate change impacts. Household's level of vulnerability to climate change impacts, sensitivity to changing climate, exposures and adaptive capacity are very important components for the smooth function of the food production and its outcome, food security. Household's adaptive capacity to climate change impact is influenced by asset possessions, total income, land ownership, access to social services and dependency burden. The impacts of climate change and variability push households to different types and levels of vulnerability which impact on food production and its outcome, food security. Thus, households with low adaptive capacity and high sensitivity to climate change impacts would be less productive, have less access to food and be highly dependent on food aid. Further, households with low adaptive capacity to climate change impacts have high dependency burden, produce less, and have least access to food.

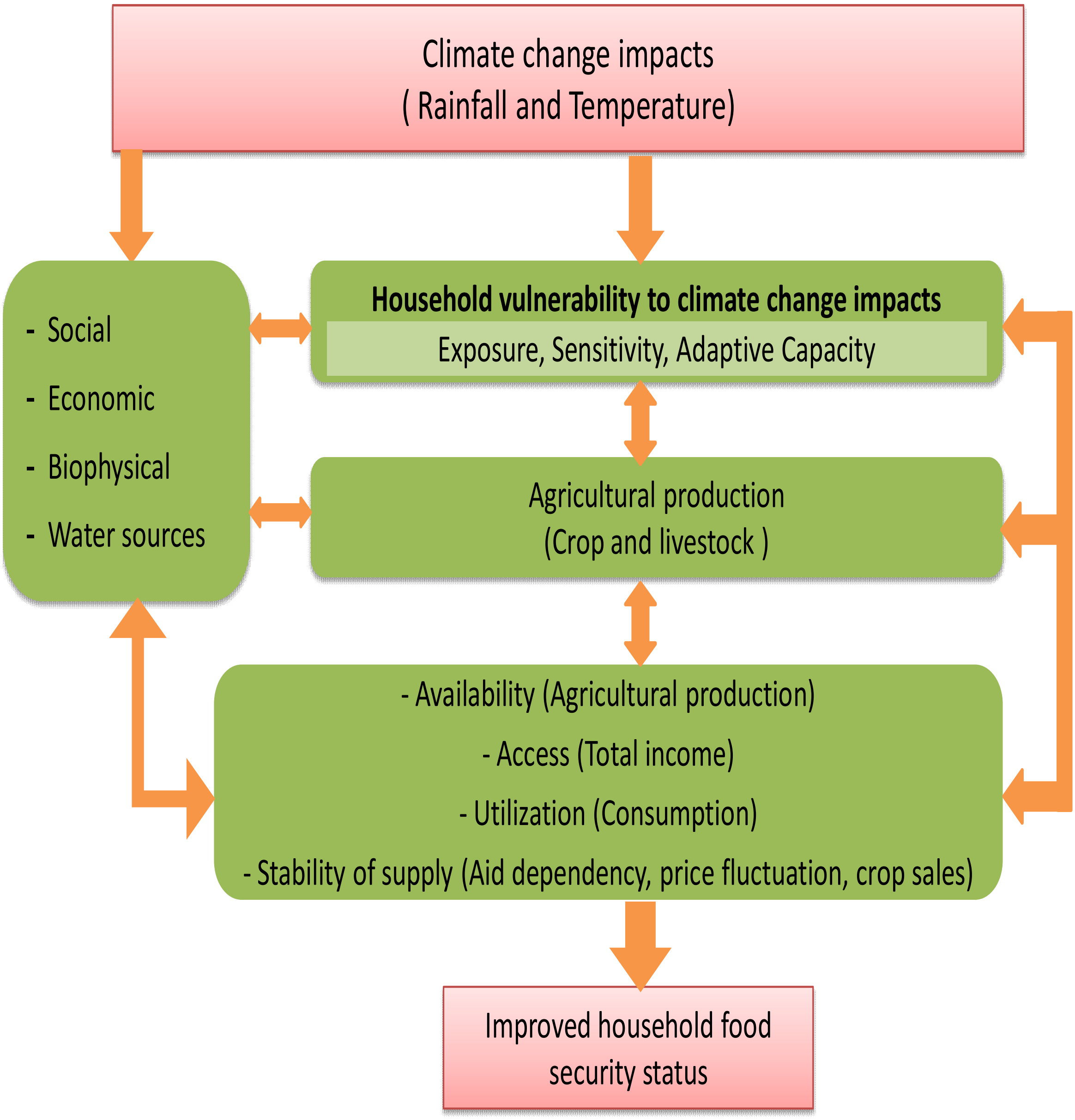

Figure 3.4: Conceptual framework of the study (Source: Author, 2016)

3.5 Methods

3.5.1 Objective 1: Establish the relationship between farmer households vulnerability to climate change impacts on agricultural production and income

3.5.1.1 Desktop studies and secondary data collection

In this study, previous researches on farmer households' vulnerability to climate change impacts on agricultural and livestock production and incomes were assessed. Climate data was retrieved from the Ethiopian Meteorological Agency, and covers the period 1983 to 2013. The data were in the form of monthly averages for both temperature (T_{max} and T_{min}) and rainfall.

3.5.1.2 Field studies

(a) Indicator Identification

Indicators for exposure, sensitivity and adaptive capacity (Table 3.1) of farmers' households were identified from the literature review as well as through consultation with farmers, agricultural extension workers and technocrats working in the study area. The indicators were then used to develop the final version of the questionnaire which was pre-tested and refined before being used to collect data from 400 households from Kolla Temben District, North Ethiopia.

Table 3.1: Vulnerability indicator variables and Likert scales. Hh = household. Farmland "difficulty level" relates to the topography, where steep slopes are more difficult to farm than level land.

Categories	Cluster	Variables	Likert scales
Household's exposure level to climate change impacts	Biophysical	Flash flood clarity incidents	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
	Biophysical	Landslide incidents	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5

	Biophysical	Extreme temperature events	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
	Biophysical	Wind extreme events	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
	Biophysical	House damage by intense rainfall	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
	Biophysical	Farmland's exposure to flood	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
	Biophysical	Farmland difficulty level for farming practices	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
	Biophysical	Soil fertility status	Very low = 5, Low = 4, Medium = 3, High = 2 , Very high = 1
	Biophysical	Waterborne diseases incidents because of contamination by floods	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
Household's sensitivity to impacts of climate change	Socio-economic	Types of agricultural practices?	Agriculture without irrigation/fully rain dependent =2, with same irrigation supplement = 1, Agriculture fully dependent on irrigation = 0
	Socio-economic	Sources of energy for cooking energy source	Electric or Kerosene = 0, wood fuel or/and charcoal = 1, Exclusively depend on wood fuel = 2
	Socio-economic	Sources of water for domestic use	Piped water = 0, Spring water = 1, access to both sources = 2
	Socio-economic	Sources of household's livelihood	Fully Agriculture = 3. Agriculture and safety net program = 2, Agriculture and non-farm activities = 1
	Socio-economic	Household assets in Ethiopia Birr (ETB)	<14,863 = 0, ≥14863-16,332.20 = 1, 16333-190,300 = 2
Household's Adaptive capacity to climate change	Socio-economic	Household land size hectare in ha	No land = 0, <.25 ha = 1, ≥.25- 0.5 ha = 2, >.05ha-1 ha = 3, >1ha-1.5 ha = 4, >1.5ha = 5
	Socio-economic	How many times hhs getting	Not all = 0, 1-2 times a year = 1, monthly = 2, Weekly =

impacts		agricultural extension services in year	3, Daily = 4
	Socio-economic	No of family member has attended or attending school	Three and above = 3, Two family = 2, One family member = 1, None = 0
	Health	No of family members have terminal illness?	Three and above = 0 two family = 1, one family member = 2, None = 3
	Health	No of family member has physical disability	Three and above family members = 0, two family members = 1, one family member = 2 None = 3
	Socio-economic	No of family members under working age group as local standard?	Three and above family members = 0, two family members = 1 one family member = 2,None = 3
	Socio-economic	Frequencies hh visited by development agent and health extension workers in a year	Not all = 0, 1-2 times a year = 1, monthly = 2, weekly = 3, Daily = 4.
	Socio-economic	Hh residence distance from public transport	<-5 km = 4, 5-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residence distance from education	<-5 km = 4, 5-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residence distance from Kebelle centre	<-5 km = 4, 5-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residence distance from health station	<-5 km = 4, 5-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residence distance from universal rural road access program (URAP)	<-5 km = 4, 5-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residence distance from market centre	<-5 km = 4, 5-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residence distance from agricultural extension station	<-5 km = 4, 5-10 km = 3, >10 km <15 = 2, >15 Km = 1

Source: Fieldwork,2016/2017

(b) Household Survey

To determine household's vulnerability to climate change impacts, data on the farmer household's exposure, sensitivity and adaptive capacity to climate change impacts were collected from 400 households in Kolla Temben District, Northern Ethiopia. The sample size was determined as explained below, and the data collection instruments used in this study were structured and semi structured questionnaires.

To calculate the sample size, the total population and the number of households were obtained from the Kolla Temben District Finance and Economic Development office. The formula used to calculate the sample size was from Yamane (1967):

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

Where:

n –calculated sample size

N –total number of households in Kolla Temben District

e –Level of precision

The total number of households in Kolla Temben District is 28,907 and the required sample size for the survey study according to the formula is 395 households but the researcher has used 400 households for the study.

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

$$\frac{28907}{1+28907(0.05x0.05)}$$

n = 394.54 households

The multistage sampling technique was applied to select the specific 400 households for the survey. In the first stage, four Kebelles (Kebelle - administration unit) was selected using simple random sampling techniques out of the given 27 Kebelles in the District. After this, 400 households were selected from the lists of households in the four Kebelles (Newi, Awetbekalsi, Atakility and Begasheka) through the systematic random sampling techniques. The sample interval was calculated using total number of households divided by total sample size for each Kebelle. From the list of farmers in each Kebelle, a random start was selected between the households listed in number one and the interval number. The sampling interval was repeatedly added to select the subsequent households up to all the required 400 households in all Kebelle were selected for the administration of questionnaires and interview. The total number of households in each of the Kebelles was: Newi 1325, Awetbekalsi 1130, Atakility 1679 and Begasheka 1373. This translated to the following number of household samples per Kebelle-Newi 96, Awetbekalsi 82, Atakility 122 and Begasheka 100 (Table 3.2).

Table 3.2: No of sampled Kebelles in Kolla Temben District with its proportionality to size.

No	Kebelle	Total no of households	Household sample	Sex of sample households	
				Male	Female
1	Newi	1325 (24%)	96 (24%)	66	30
2	Awetbekalsi	1130(20.5%)	82 (20.5%)	70	12
3	Atakility	1679 (30.5%)	122 (30.5%)	90	32
4	Begasheka	1373 (25%)	100 (25%)	64	36
5	Total	5507	400 (100%)	290 (72.5%)	110 (27.5%)

Sources: Fieldwork, 2016/2017

A simple random sampling technique was used to select households from each Kebelle (Newi 96 households, Awetbekalsi 82 households, Atakility 122 households and Begasheka 100 households) for interview. Figure 3.6 shows the location of the study area and the sample points from where the sampled households were taken for interview.

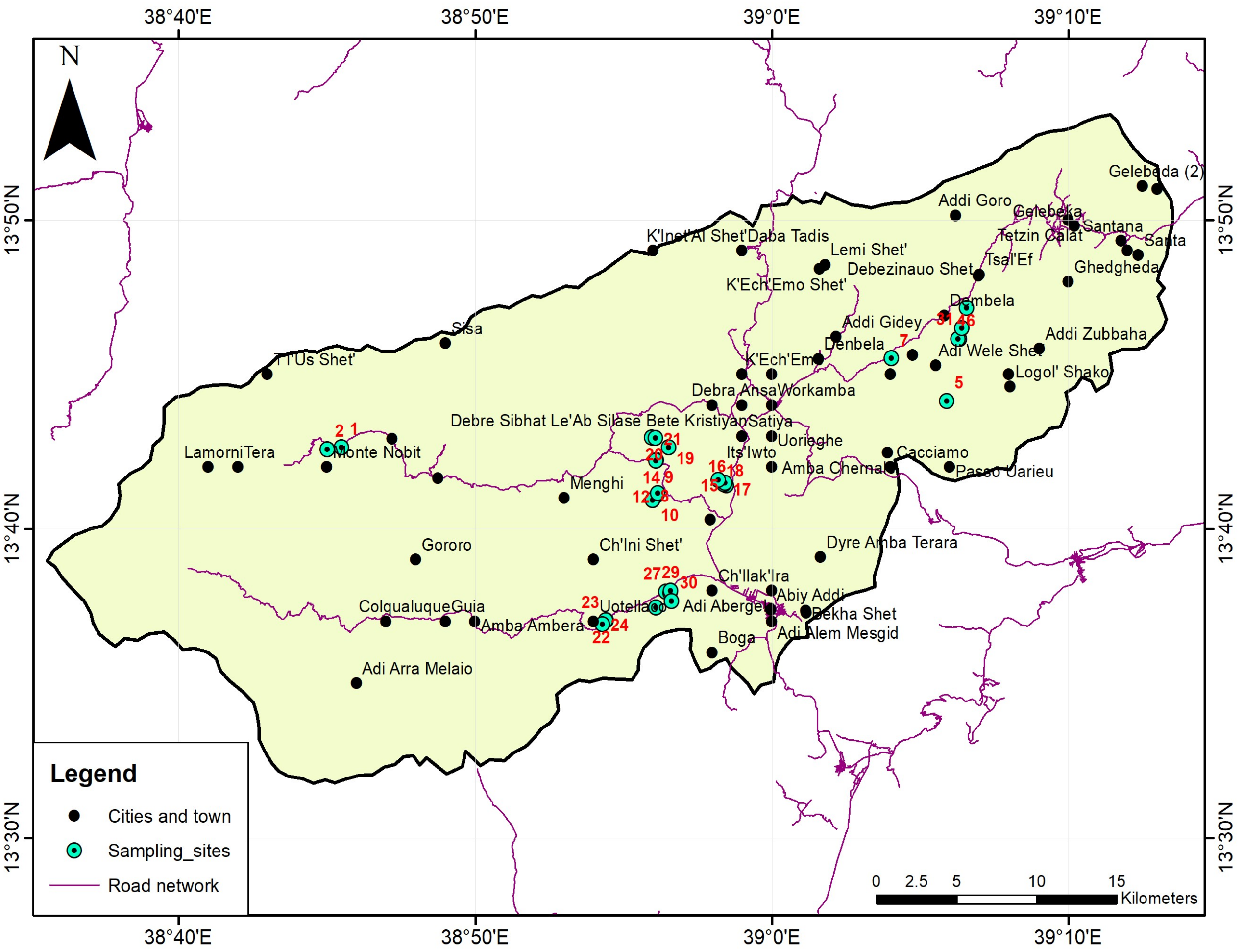

Figure 3.5:Map of the sampled households in Kolla Temben District, Ethiopia
Source: Author, 2016

(c) Focus Group Discussions

Focus group discussions were held with a total of 40 people, selected with the help of the Kebelle administrators and development agents, during the period April to September 2016. The data collected from focus group discussion (FGDs) from all the four Kebelles (Newi 10 households, Awetbekalsi 10 households, Atakility 10 households and Begasheka 10 households) were focused on climate change and variability in relation to agricultural production including factors that affect agricultural production, main causes for household's high vulnerability to climate change impacts and possible solutions to address these challenges. The participants to the FGDs were selected based on roles of gender and household heads, education levels and farming experiences (Table 3.3).

Table 3.3: Profiles of focus group discussion participants. F – female; M - male

Attributes	FGD1	FGD2	FGD3	FGD4
Name of Kebelle	Newi	Atakility	Begasheka	Awetbekalsi
Age	50-65	50-65	50-65	50-65
Education	1-12 grade	1-12 grade	1-12grade	1-12 grade
Farming experiences	30-45 years	30-45 years	30-45 years	30-45 years
No of farmers	10	10	10	10
	(5 F, 5 M)	(5 F, 5 M)	(5 F, 5 M)	(5 F, 5 M)
Kebelle Administrator	1	1	1	1
Development agent	1	1	1	1

Source: Fieldwork 2016/2017

(d) Key Informant Interviews

Key informant interviews (KII) were conducted with 24 persons comprising development agents deployed by the government to provide agricultural extension services to farmers and community leaders who were believed to be knowledgeable on climate change and food production issues in the district (Table 3.4). They were selected with the help of the Kebelle

Table 3.4:Profiles of Key informant discussion participants. F – female; M – male

Attributes	KII 1	KII 2	KII 3	KII 4
Name of Kebelle	Newi	Atakility	Begasheka	Awetbekalsi
Age	50-65	50-65	50-65	50-65
Education	5-12 grade	5-12 grade	5-12 grade	5-12 grade
Farming experiences	30-45 years	30-45 years	30-45 years	30-45 years
No of farmers	4	4	4	4
	(2M, 2 F)	(2M, 2 F)	(2M, 2 F)	(2 M, 2 F)
Kebelle administrator	1	1	1	1
Development agent	1	1	1	1

Source: Fieldwork 2016/2017

administrators and development agents and their level of education, farming experiences and age were taken into consideration The interviews took place during the period April to September 2016. The KII were focused on rainfall and temperature trends, agricultural production levels, farmer's level of exposure to climatic shocks and stresses; and the capacity of the households to cope.

3.5.1.3 Data analysis

(a) Demographic Characteristics of Households Surveyed

Demographic data (sex, age and education of farmer households) were analysed using descriptive statistics (mean, standard deviation, frequency and percentages).

(b) Climate Change Trend Analysis

Climate change trends for mean annual maximum and minimum temperatures, as well as for rainfall in Kolla Temben District, Northern Ethiopia, were determined by a simple trend analysis, a simple analysis technique which focuses only on one climate variable (Chiew and Siriwarden, 2005). Trend analysis is designed to facilitate statistical testing for trend and change in time series data (Chiew and Siriwrdena, 2005). The researcher used the TAMSAT satellite gridded climate data records for 31 years (1983-2013) for temperature and 32 years (1983-2014) for rainfall. The gridded climate data was taken from 250 grid cell points with 4.5 km^2 resolution in Kolla Temben District. The monthly mean temperature and rainfall time series plots were calculated using exploratory data analysis (EDA) techniques to observe outliers and the extreme climate events of each month for the past three decades (1983-2013).

The researcher used the Minitab version 16 statistical computer software to examine the linear trends and time series plot for temperature (T_{max}, T_{min}) and total rainfall for the past three decades. Annual mean temperature and rainfall was calculated by taking the monthly average records and divided by 12 months. Mean on the maximum and minimum temperatures, as well as mean annual rainfall and total annual rainfall were assessed for the past three decades (1983 - 2013) and coefficient of variation (CV) was also calculated using Abdi (2010) formula ($CV = \frac{S \times 100}{M}$) to see extent and trends of variability. On the other hand, the mean monthly minimum temperature was assessed for the past three decades (1983- 2013) for each month. The monthly average and seasonal total rainfall was assessed for the past three decades (1983- 2014).

(c) Overall Household Vulnerability Level to Climate Change Impacts

Data on all the indicators for household vulnerability level were collected and indexed for ease of analysis and interpretations. All indexed results for household's vulnerability level were statistically tested to establish the associations between household's vulnerability level to climate change impacts and agricultural production and total income. The overall household's vulnerability level to climate change impacts was calculated using the IPCC (2012) definition and as applied by Opiyo et al. (2014), Nkondze and Masuku (2014) and Bobadoye (2016) using the indicators in Table 3.1. It can be expressed as follows:

Household vulnerability = Adaptive capacity – (exposure + sensitivity)...........Equation (2)

$$Vi = (A_1X_{1J} + A_2X_{2J} + \ldots + AnXnj) - (A_1Y_{1j} + A_2Y_{2j} + \ldots\ldots\ldots AnYnj) \quad \text{.............} \textit{Equation (3)}$$

Where:

Vi = Vulnerability index

X = Indicators for adaptive capacity

Y = Indicators for exposure and sensitivity

J = Variables

A = First component score of each variable.

The household's vulnerability index was then calculated using the indicators (Table 3.1) for adaptive capacity, exposure and sensitivity; and quantified through Likert scales (Boone and Boone, 2012). This was used to determine household's vulnerability to climate change impacts in the Kolla Temben District. Finally, a household's vulnerability level to climate change impacts was classified into one of three groups (low vulnerability, medium vulnerability, high vulnerability) (Peris et al., 2002) based on the mean value of Vi (24.7) and its standard deviation (16.9), respectively. These three vulnerability categories of households were coded in the SPSS software as: 1 = High, 2 = Medium and 3 = Low to ease the statistical and crosstabs analysis of the data. This categorization was based on the principle that households with higher adaptive capacity are less vulnerable and *vice versa*.

(d) Establish Relationship Between Farmers Households Vulnerability to Climate Change Impacts on Agricultural Production and Total Income

The relationship between household vulnerability level to impacts of climate change, agricultural production and household's total income were also tested. The vulnerability indicators used in the analysis and their assigned weighted values are presented in Table 3.1. Multiple regression analysis examines a relationship between multiple independent variables with a dependent variable (Ghani and Ahmad, 2010). The researcher used multiple regression analysis to analyse the relationship between the dependent variables (household's vulnerability to climate change impacts) on a continues scale with the independent variables (agricultural crop production in Kg, household's total income in ETB (Ethiopia Birr), household's total livestock ownership in TLU (Tropical Livestock Unit) (Appendix 'A') and household's food consumption in ETB (Ethiopia Birr), household's annual food consumption in Kg from aid and household's total annual crop sales in Kg (Kilograms). Multicollinearity test was done before the multiple regression analysis was underway to examine for multicollinearity of variables through variance inflation factors (VIF) which could inflate the coefficients (Appendix 'B'). VIF values above 10 are taken as a multicollinearity problem (Neter et al., 1996). Accordingly, multicollinearity problem was not found that demands to removal of any variables from multiple regression analysis. Therefore, all variables were included in the multiple regressions for analysis. Stata Version 10 computer software was used to run the VIF for multicollinearity test.

Five Likert scales were used to examine intensity of the household's vulnerability. Likert scales were used to produce composed score for households characteristics (Boone and Boone, 2012). The indexed vulnerability values (adaptive capacity, sensitivity and exposure) were used to determine a household's vulnerability and statistically test the relationships between household vulnerability level to climate change impacts and households total agricultural production. The detail explanations of all indicators and Likert scales are indicated in Table 3.1 above. The most impacted crops (focusing on maize, teff, sorghum, millet and beans) and livestock types (focusing on cattle, sheep, goats and poultry) in Kolla Temben were analysed in using frequencies (Freq) and percentages (%). Similarly, the vulnerability level of households to climate change impacts in Kolla Temben District was analysed using descriptive statistics frequencies (Freq) and percentages (%).

3.5.1.4 Data analysis techniques

Grounded theory (GT) and content analysis techniques were used to analyse data from key informant interviews (KII) and focus group discussions (Strauss & Corbin, 1998). In focus group discussion, most of researchers use text to examine what participants stated in group discussions (Krueger, 1994). In analysing focus group discussion (FGDs), the group is the unit of the analysis (Morgan, 1997). Content analysis uses to analyse qualitative data from focus group discussion (FGDs) and help to determine the main concepts mentioned in the focus group discussion (Leech and Onwuegbuzie, 2008). Hence, the researcher has used the content analysis techniques to analyse data from FGDs. The group was the unit of the analysis.

The key informant interviews were analysed using grounded theory and some quotes were also included to represent direct voices by key the informants**.** In the analysis of the KII three themes were identified; rainfall and temperature trends, factors affecting agricultural production and farmers level of exposures to shocks and capacity to cope.

3.5.2 Objective 2: Assessment of farmers' perceptions on climate change impacts, adaptation strategies and their implications on agricultural Production

3.5.2.1 Desktop studies

Literature on farmers' perception to climate change impacts and adaption strategies practiced were reviewed to provide background information. This was complemented by field studies as described below.

3.5.2.2 Field Studies

Data on famers' perceptions to climate change impacts and adaptation strategies were collected from 400 sample households (3.5.1.2 b) through structured and semi structured interviews. Focus group discussion and key informant interviews were conducted in four Kebelles (Tables 3.3 and 3.4) on changes in rainfall and temperature patterns in the past three decades and their impacts on agricultural production. The focus of the group discussions and key informant interviews were; farmers' perceptions to temperature and rainfall changes, community socio-economic activities and events and the adaptation strategies practiced in District, factors that affect households ability to adapt to climate change impacts, and recommendations for improvement.

A. Perceptions

Data on farmers' perceptions to climate change impacts were collected from sampled households in Kolla Temben District (3.5.1.2) through structured and semi-structured interview schedules. Data on farmers' perceptions on changes on rainfall characteristics (rainfall amount, rainfall duration, onset of rain, cessation of rain, frequency of rain duration, intensity of humidity, duration of humidity and dry season temperature characteristics (duration of high temperature, intensity of high temperature, duration of sunny time, intensity of sunny time and frequency of occurrences of excessive heat). Other aspects considered were changes in wind characteristics (speed of wind, pattern of wind/wind direction and the frequency of occurrences of high wind speed) and changes in hazard characteristics (intensity of soil erosion, intensity of flood, incident of water born disease, frequency of malaria incident, frequency of occurrences of drought, incidents of heavy rain, incidents of conflicts and trends of migration). These were collected and classified into three groups (1 = Increase, 2 = Decrease,3 = No change) (Peris et al., 2002).

B. Adaptation strategies

During the fieldwork, 12 types of adaptation strategies were identified as detailed in Table 3.5. Farmers adaptation strategies to climate change impacts were collected from 400 households through questionnaires and coded as follows: '0' or "No" for those who did not apply the particular adaptation strategies and '1' or "Yes" for those who did (Table 3.5).

Table 3.5:List of adaptation strategies practiced in Kolla Temben District

List of adaptation strategies practiced in the district	Farmers responses No ('0')	Yes ('1')
Households using different planting dates		
Households diversify farm activities		
Household changed from livestock to crop production		

Households using irrigation facility
Household practicing soil conservations
Households using drainage
Households using increased cultivated land
Household using short gestation crops varieties
Household use flood tolerant crops
Households used drought tolerant crop varieties
Households used disease and pest resistant crop varieties
Households used water harvest practices as adaptation strategies

Sources: Fieldwork, 2016

Focus group discussions with 40 households in all the four Kebelle were conducted as detailed in section 3.5.1.2 above and their profiles presented in Table 3.3. The FGDs focused on the factors that affect farmer adaptation strategies and suggested solutions to strengthen the household resilience. In addition, key informant interview with 18 individuals with different backgrounds (Table 3.4) was conducted. The main focus of the key informant interviews was to examine in depth the adaptation strategies mostly practiced in agricultural production in the district and to identify the solution to best adapt to rainfall decrease, temperature increase and variability in Kolla Temben District. This fieldwork was conducted from the first week of January to mid-March2017.

3.5.2.3 Data analysis

One of the vital concepts in the areas of climate change science is the adaptation strategy which helps to moderate impacts and reduce vulnerability to climate change impacts. Perception is a prerequisite for adaptation. Adapting to climate change impacts depends on how farmers perceive changes (Tripathi and Mishra, 2017). Therefore, the researcher assessed the farmers' perceptions to climate change impacts before investigating the adaptation strategies applied in the agriculture. Famers' perception to the changing climate and its impacts was assessed to examine their level of understanding of the climate system.

This was done to examine the consistency between trend analysis results and household's perceptions. The possible responses on perceived changes for temperature and rainfall characteristics were classified as follows: 1 = Increase, 2 = decrease, 3 = No change. These classifications were used in the analysis and interpretation of the results (Peris et al., 2002). Household's perceived changes and actual observed changes were examined for consistency with the observed trends. This was used to establish a household's perceived changes and the actual climate change trends in Kolla Temben District.

Adaptation can be autonomous or planned. Autonomous adaptation is a strategy that can be initiated by individual households based on the level of understanding they may have on the changes. Autonomous adaptation is a bottom up and real world based approach whereas planned adaptation is an adaptation which is centralized, policy intervention and top-down based approach (IPCC, 2014). Adaptation strategies are important to reduce vulnerability and household's adaptation decisions depend on the level of understanding of the changes that are occurring. Identifying and comparing adaptation options are important to reduce vulnerability to climate change impacts (Reed et al., 2013). This study was therefore mainly focused on the adaptations strategies which are practiced by individual households (bottom up approach) to respond to perceived changes in their agricultural activities. Household's existing adaptation strategies to actual climate impacts was also examined to investigate the consistency between adaptation strategies and change trends. The adaptation strategies practiced by farmers in response to the actual impacts of climate change was statistically tested to detect whether their adaptation decision had significant impacts on the agricultural production. Dummy or categorical variables were changed into numeric data using 0 and 1 to transform the data into a format that can be easily analysed by multiple regression analysis (Agresti & Finlay, 2009). Multiple regression analysis was used to examine the association between household's adaptation choices and agricultural production (household's total income from crop production, household's total food consumption in Kg, household's total crop production in Kg, household's total consumption from own harvest in Kg and household's total crop sales in Kg). The justification given to use multiple regression has been indicated in section 3.5.1.3 of this chapter.

Data FGDs and KII were analysed using the contents and ground theory themes analysis techniques (section 3.3.1.3 'd'). The focus group discussion was to identify the types of adaptation strategies practiced by farmers in the Kolla Temben District and to select the best adaptation strategies for the areas and that would positively contribute to improved agricultural production in the district. The contents identified during the focus group discussion in Kolla Temben District were; types of adaptation strategies necessary for improved agricultural production, factors that affect farmer adaptation strategies and suggested solutions. Data from the key informant interviews was analysed in the context of two themes; adaptation strategies in crop and livestock production, and the possible adaptation options for decrease and increase in rainfall variability.

3.5.3 Objective 3: Examination of the implications of the farmers' adaptive capacity on household's food security status and interventions

3.5.3.1 Desktop studies

Information from literature on the areas of farmer's adaptive capacity to climate change impacts, food security and agricultural production were collected. This information was used to support the survey findings.

3.5.3.2 Field studies

This field worked was designed to determine household's adaptive capacity and to assess its impacts of on food security status and to identify the possible area specific factors affecting food security. To determine household's adaptive capacity to climate change impacts, data on household's adaptive capacity indicators were collected in Likert scales (Table 3.1) from 400 the sampled farmer households' (section 3.5.1.2 'b'). Data on household's total expenditure on food and family sizes were collected (section 3.5.1.2 'b') using questionnaires.

Farmer households assets, land ownership, access to services and dependency burden, factors affecting farmers ability to access enough food, areas of interventions, and suggested recommendations to address climate impacts and farmers immediate needs to overcome climate impacts were collected from farmer households (section 3.5.1.2 'b') through questionnaires. This fieldwork was conducted from January to February 2017.

In this research, focus group discussions and key informant interviews was also conducted to cross check and enrich the findings on adaptive capacity, food security and possible interventions (section 3.5.2.3). To determine household food security status, data on household total food consumption and total food expenditure in ETB covering a 12-

monthperiod was collected from Kolla Temben District. The sample size and sampling techniques for all the focus group discussion and key informant discussions have been presented in section 3.5.2.3. The fieldwork was done between October and December 2016.

3.5.3.3 Data analysis

‘Pearson correlation measures the strength of association between two variables. The correlation coefficient varies + 1 to -1, which +1 indicates strong association between the two variables and 0 indicate a weak relationship. The sign and + indicate for positive and negative relationship’ respectively (Benesty et al., 2009). T-test was used to examine the significance of differences between the two populations (Kanji, 2006).

Chi-square test was used to test relationships between two categorical variables and Pearson correlation test was used to test associations of two or more quantitative and continuous variables (Mchugh, 2013). The chi square test was used to examine the significance of the association between household’s adaptive capacity level to climate change impacts (low, medium and high) and household’s food security status (food secure and food insecure households).

The main indicators used in this study to assess household’s adaptive levels to climate change impacts were household’s asset ownership (livestock ownership, money and fixed assets valued in Ethiopia Birr (ETB), land ownership categorized into five classes on the Likert scale (No land = 0, <.25 ha = 1, ≥.25 ha to 0.5 ha = 2, >0.5 ha to1 ha = 3, >1ha to1.5 ha = 4, >1.5ha = 5) and a similar scaling was applied to “access to public services” (see Table 3.1). Thereafter, the total scored scale values by each household were calculated based on the actual scores as references to the assigned values (Table 3.1). All these indicators were used to index household’s adaptive capacity level to climate change impacts in Kolla Temben District. Households that scored less than the mean values of total scores were categorized as having low adaptive capacity and those that scored in the range above the mean value to the “mean plus one standard deviation” were categorized as having medium adaptive capacity (Peris et al., 2002). Households which had a score greater than the “mean plus one standard deviation” were taken as having high adaptive capacity (Peris et al., 2002). The relationship between household’s adaptive capacity to climate change impacts and food security status was tested for association. Inferential statistics (mean and standard deviation) was used to see the mean differences in adaptive capacity scores for the food secure and food insecure households. Area specific interventions were identified through participatory approach. The indicators used to investigate vulnerability level and relationships established to examine household adaptive capacity to climate change impact are stated in Table 3.1.

3.5.3.4 Food security and adaptive capacity to climate change impacts.

Household's food security status was determined using the standard of 225 kg of cereal per person per year (EHNRI, 1997). To determine the minimum food expenditure needed to attain 225 Kg of cereals, the average cereal price of the areas, which was found to be 8.68 ETB per Kg, was taken and used to calculate the threshold. Accordingly, the threshold for food security was found to be 1952.30 ETB (8.68 * 225) per person (Appendix 'C'). Based on the 1952.30 ETB as threshold, households were categorized into two, namely; food secure and food insecure. Households with food consumption expenditure less than the threshold (1952.30) were categorized as food insecure households and those with a score of food expenditure greater or equal to the threshold (1952.30 ETB) were categorized as food secure households. Similar approaches have been used in Kenya (Amwata et al., 2015b) and in Malawi (Kakota et al., 2015).

Farmers adaptive capacity to climate change impacts were calculated and categorised into three classes (low, medium and high) using the methods indicated in Chapter 3, sections3.5.1.2 and 3.5.1.3. The relationship between household's adaptive capacity level and food security status was then tested using chi-square test and the independent t- test to examine its significance level.

Grounded theory and content analysis techniques was used to analyse data from key informant interviews and focus group discussions (section 3.5.1.3 "d"). The contents used in the focus group discussion analysis were; food security situation and perceptions, factors affecting food security, needed interventions and households adaptive capacity, and needed interventions to improve adaptive capacity. In the analysis of the key informant interviews(KIIs), two themes were identified; food security situation and the factors underlying household food insecurity.

CHAPTER 4: FARMERS'HOUSEHOLD VULNERABILITYTO CLIMATE CHANGE IMPACTS AND THEIR INFLUENCE ON AGRICULTURAL PRODUCTION AND INCOME

4.1 Introduction

This chapter mainly focuses on climate changes in Kolla Temben District and farmers' household's vulnerability levels to impacts of climate change and their influence on agricultural production and total income (objective 1). The chapter presents the demographic characteristics of the households, analyses the baseline and current climate trends which are important to determine the farmers vulnerability levels to climate change impacts and its effects on agricultural production and income. Results from focus group discussions and key informant interviews are also presented to enrich and cross-check results from climate trend analysis and surveys.

4.2 Results

4.2.1 Demographic Characteristics of Household Survey Participants

4.2.1.1 Sex of the respondents

The sex composition of the sampled famer households was 27.5 % female and 72.3 % male. Majority of the sample households were male head households but significant number of female of headed households were also in the sample (Table 4.1).

Table 4.1: Sex of respondents

Sex	Frequency	(%)
Female	110	27.5
Male	289	72.3
Total	399	99.8
No response	1	0.3
Total	400	100.0

Source: fieldwork 2016/2017

4.2.1.2 Age of the respondents

The minimum and maximum age of the sampled households were 30 and 85 years, respectively. The age group distribution of the sample households was; 30-40 (18%), 41-51 (34.8%), 52-63 (32.3%), 64-74 (12%) and 75-85 (3%) years. The majority of the sample households (67.1%) were in the age groups of 41-51 and 52-63 years (Table 4.2).

Table 4.2: Age of the respondents in years

Respondent age groups in years	Frequency	(%)
30- 40	72	18.0
41- 51	139	34.8
52-63	129	32.3
64-74	48	12.0
75-85	12	3.0
Total	400	100.0

Source: fieldwork 2016/2017

4.2.1.3 Education level of the sample households

A majority of sampled farmer households (51%) had no formal education. The educational levels of the sample farmer households were; only reading and writing (16.5%), grade 1-4 (16.8%), grade 5-8 (13.3%) and 9-12 grades (1.8%). This shows that most of farmers in Kolla Temben District had no formal education (Table 4.3).

Table 4.3: Educational levels of the respondents

	Sample households education level	Frequency	(%)
	No formal educational	204	51.0
	Reading and writing	66	16.5
	1-4 Grade	67	16.8
	5-8 Grade	53	13.3
	9-12 Grade	7	1.8
	Total	397	99.3
	No response	3	0.8
Total		400	100.0

Source: fieldwork 2016/2017

4.2.1.4 Livelihood

Table 4.4 shows that 85.5% of the households surveyed in Kolla Temben District were fully dependent on agriculture; about 9%relied on agriculture and government safety net program,4.5% on agriculture non-farm activities while 0.8% didn't respond. Therefore, the main means of livelihood for most households in Kolla Temben District is agriculture.

Table 4.4: Households livelihood bases

	Practices	Frequency	(%)
	Fully Agriculture	343	85.8
	Agriculture and government safety net program	36	9.0
	Agriculture and non-farm activities	18	4.5
	Total	397	99.3
	No response	3	0.8
Total		400	100.0

Source: Fieldwork, 2016/17

4.2.2 Climate change and impacts in Kolla Temben District

4.2.2.1 Annual and monthly mean maximum temperatures

The linear trend line (Figure 4.1) shows that there has been an increase of annual mean maximum temperature (T_{max})in the range of 0.09°C per year in Kolla Temben District from 1983 to 2014 (Figure 4.1). September 1986 was the month with the lowest monthly mean maximum temperature over the 31-year period, while the warmest month was May 2013. The months of April, May and June were found to be the hottest months in the 31-year record (Figure 4.2). August, September and October had the lowest maximum monthly mean temperature records in the three decades (Figure 4.2). This shows that Kolla Temben District has been impacted by both rising temperatures and high extreme temperature events (Table 4.5) with the month of May having the largest temperature variability range of about 6°C, while September had the least range of 3°C for the period 1983 to 2013(Figure 4.2).

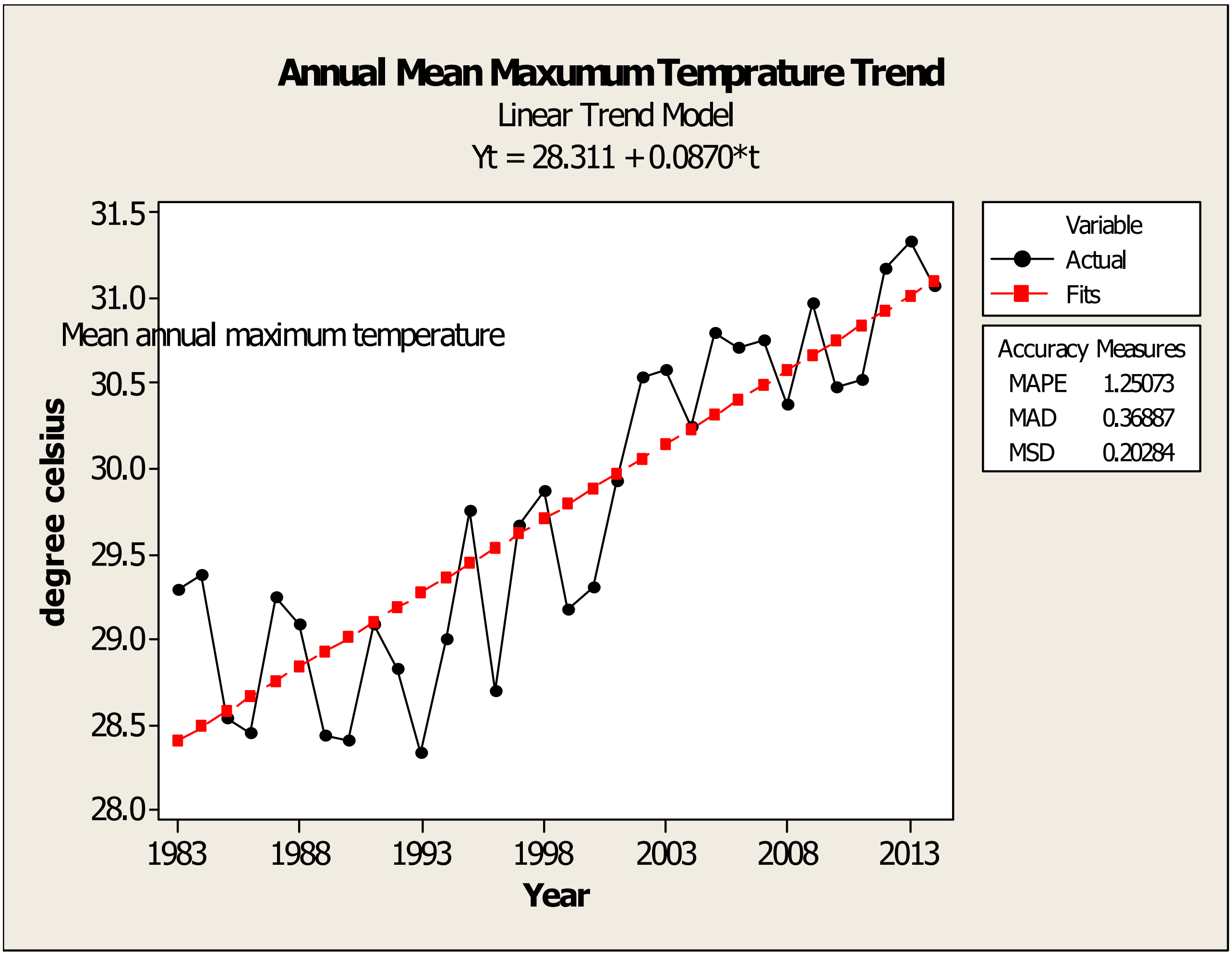

Figure 4.1: Trend of mean annual T_{max} in Kolla Temben District for 1983-2013. MAPE - Mean Absolute Percentage Error, MAD - Mean Absolute Deviation, MSD -Mean Squared Deviation (Source: Ethiopia met (TAMSAT Satellite), 2017)

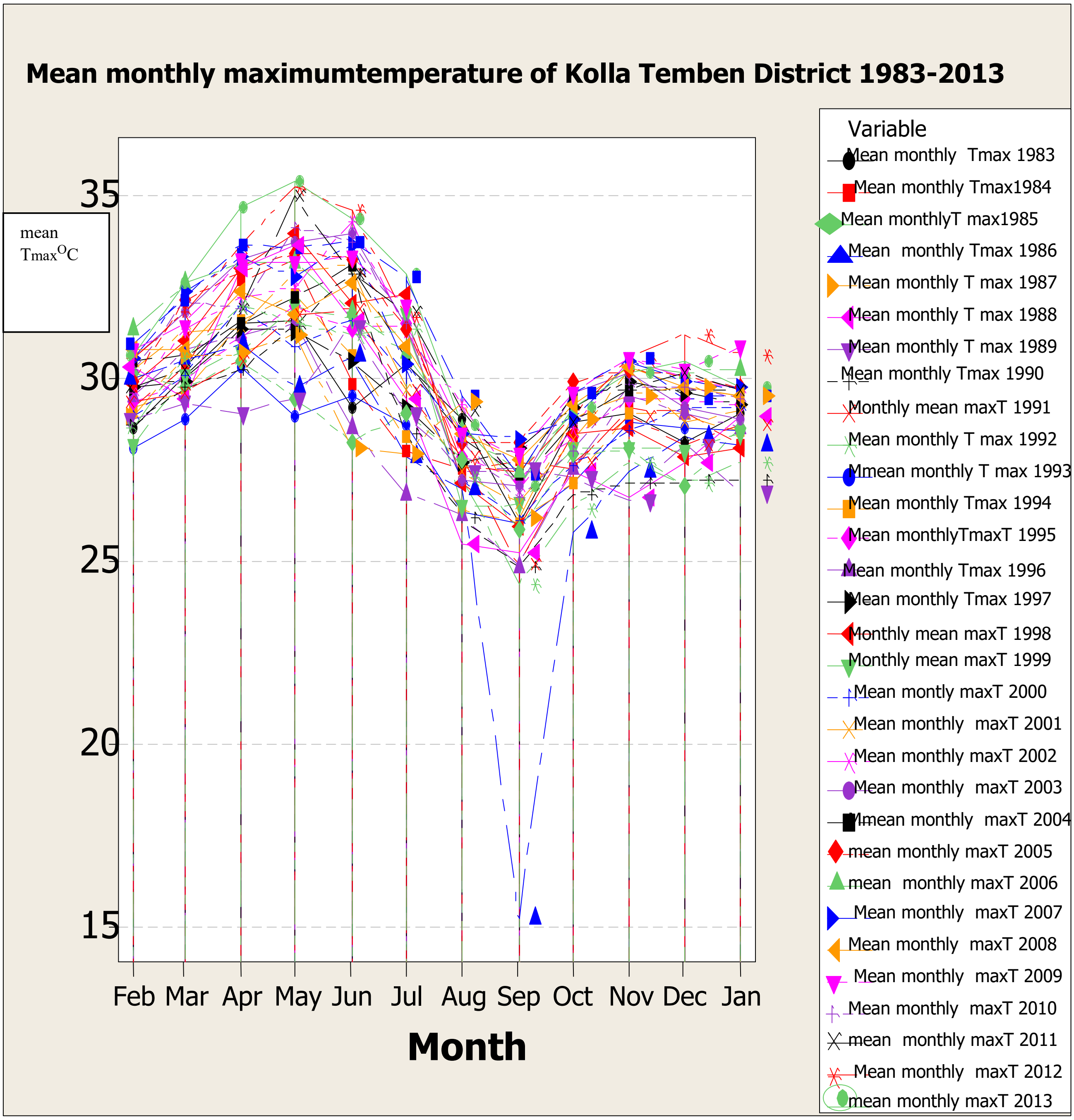

Figure 4.2: Mean monthly T_{max} variation based on year to year monthly values in Kolla Temben District for the years 1983 to 2013 (Source: Ethiopia Met (TAMSAT Satellite), 2017)

4.2.2.2 Annual and monthly mean minimum temperatures

The trend analysis shows that mean annual minimum temperature has increased at 0.04°C per year over the period 1983 to 2013 with frequent occurrences of extreme minimum temperature events (Figure 4.3). January 2009 was the coldest month in the record, at less than 9 °C. June, July and August were the months with highest mean monthly minimum temperatures within 31 years' time (1983-2013) (Figure 4.3). The temperature trend analysis showed that minimum temperature has increased in Kolla Temben District.

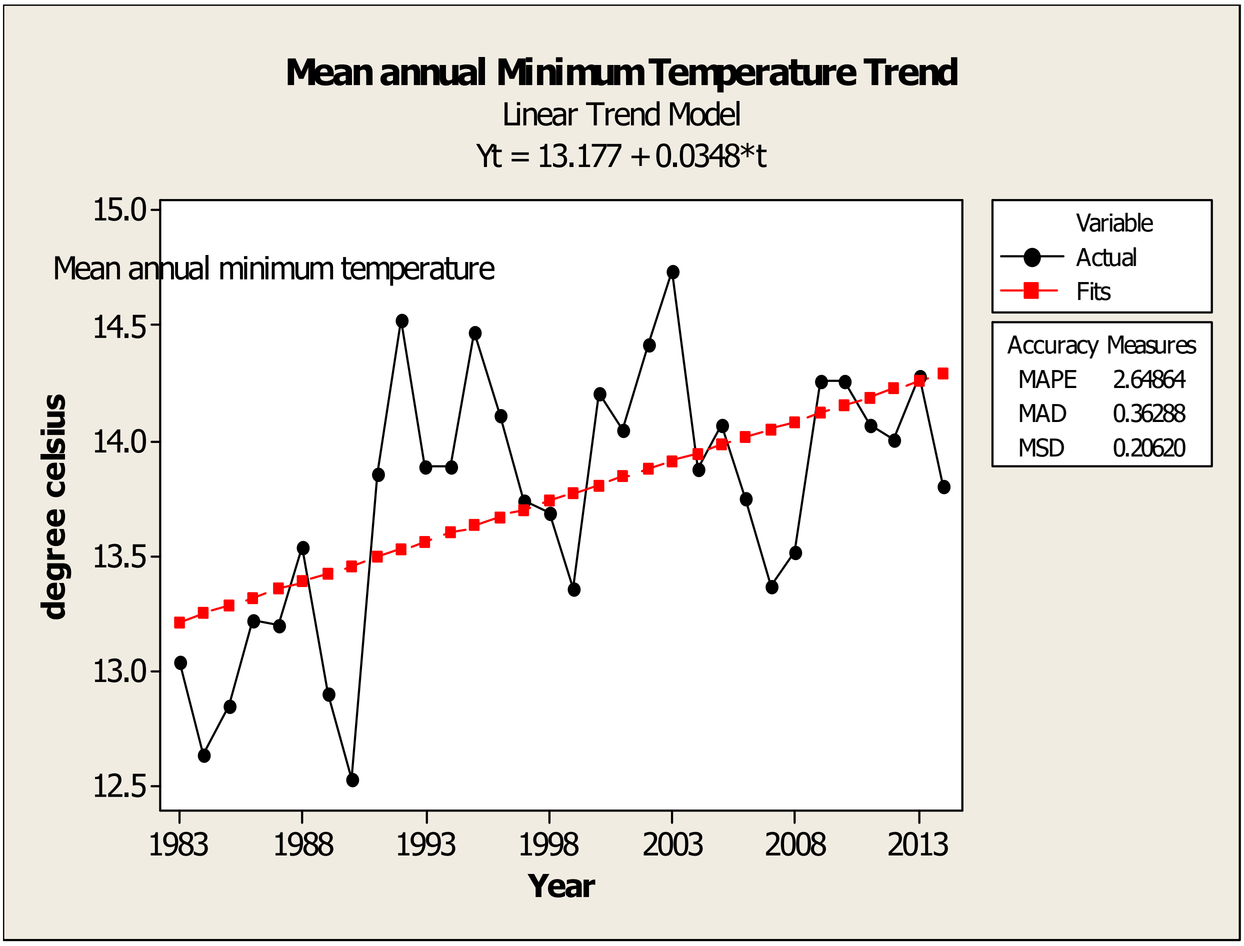

Figure 4.3: Trend of mean annual T_{min} in Kolla Temben District for 1983-2013. MAPE - Mean Absolute %age Error, MAD - Mean Absolute Deviation, MSD - Mean Squared Deviation (Source: Ethiopia met (TAMSAT Satellite), 2017)

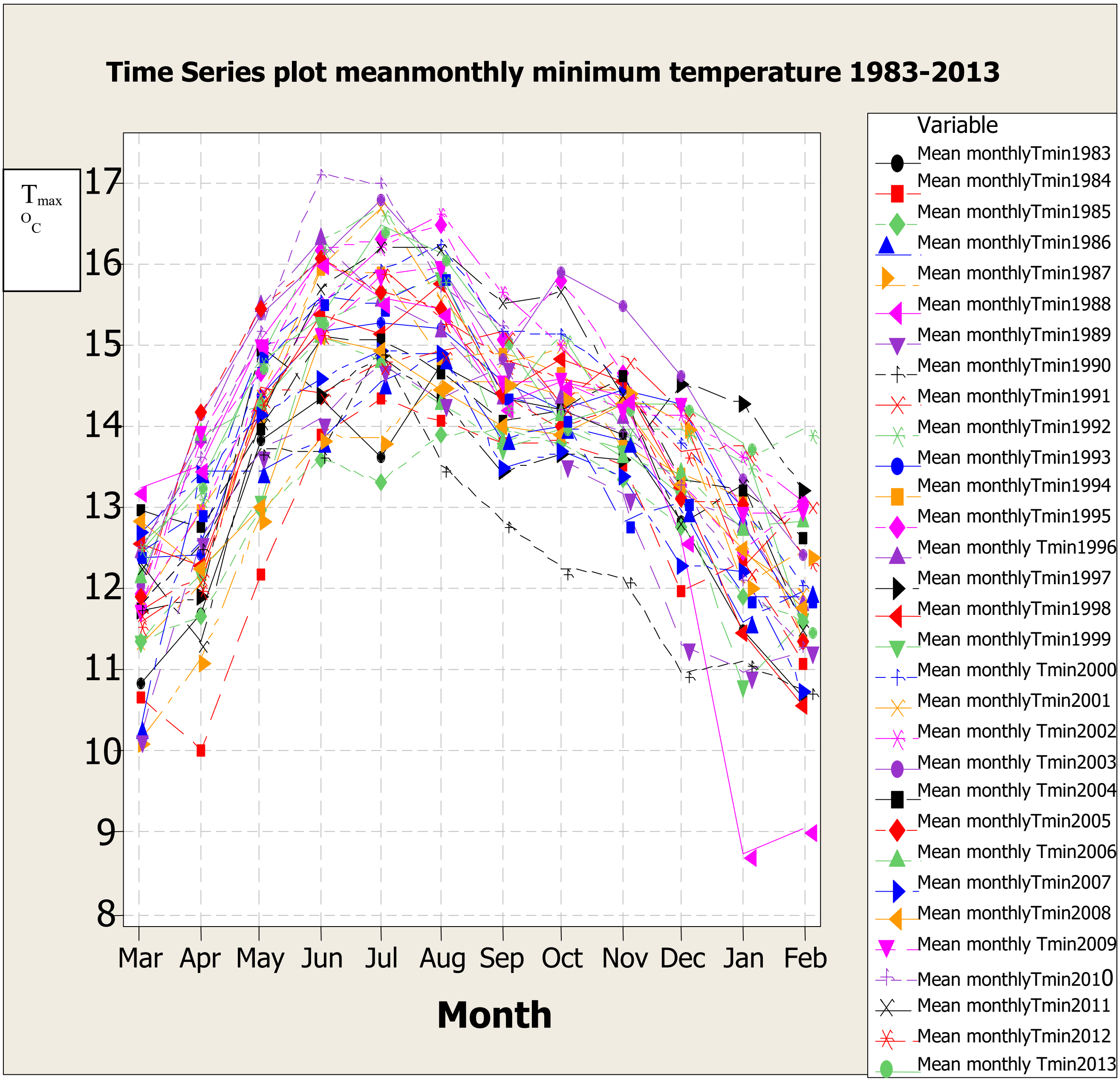

Figure 4.4: Mean monthly T_{min} variation based on year to year monthly values in Kolla Temben District for the years 1983 to 2013 (Source: Ethiopia Met (TAMSAT Satellite), 2017)

4.2.2.3 Annual and monthly mean rainfall

The linear trend analysis results revealed that annual mean rainfall in Kolla Temben District has decreased by 0.06 mm per year over the period 1983 to 2014 (Figure 4.5). There was highly variability of annual mean rainfall in the past three decades (1983-2014) in Kolla Temben District (Table 4.5). The month October 1998 was found to be the month with extremely high rainfall records in past three decades. Months that had no rainfall in the past three decades (1983-2014) was reported in March, April, May, July, December, January and February (Figure 4.6). This shows that there is high variability of monthly rainfall in Kola Temben District. This implies that the agricultural sector in Kolla Temben District is under an intense pressure of high rainfall variability and decrease.

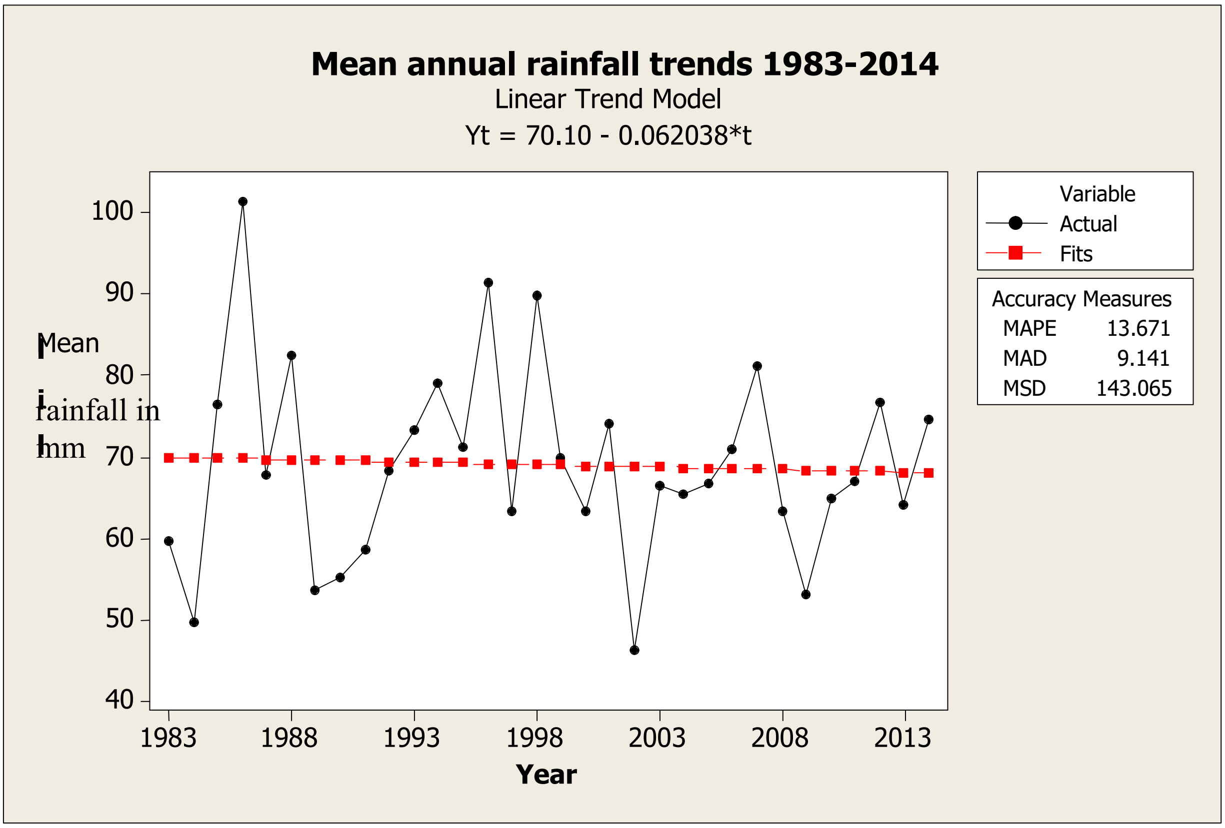

Figure 4.5: Mean annual rainfall trends of Kolla Temben District for 1983-2014 and forecasts(Source: Ethiopia Met (TAMSAT Satellite), 2017)

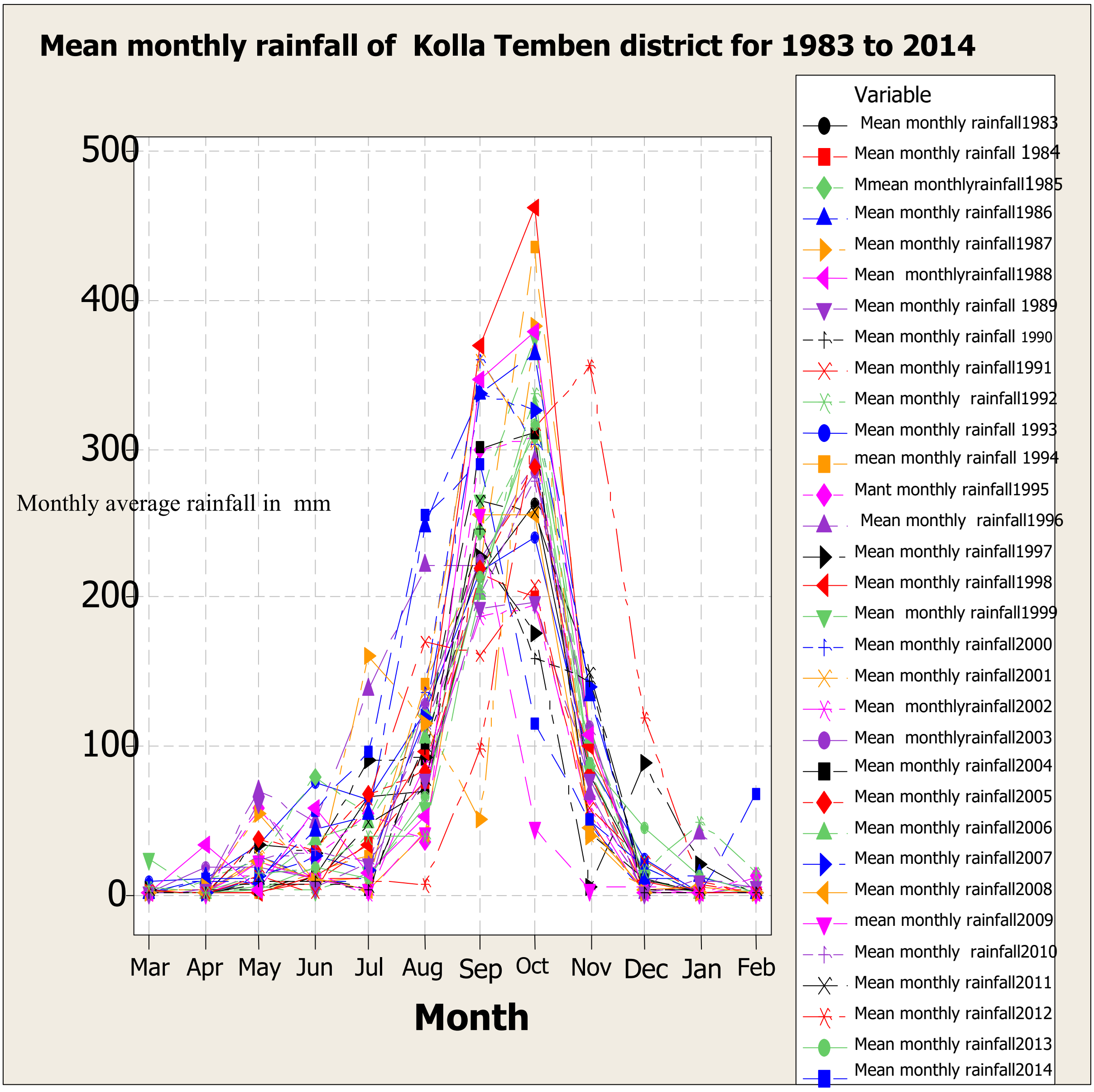

Figure 4.6: Monthly time series plot for average total rainfall of the Kolla Temben District for 1983 -2014(Source: Ethiopia Met (TAMSAT Satellite), 2017)

4.2.2.4 Temperature and rainfall coefficient of variation (CV)

The coefficient of variations for minimum and maximum temperature was 0.464 (46.4%)and 0.411(41.10%), respectively; whereas the coefficient of variation for rainfall was 0.403(40.3%) (Table 4.5). This shows the extent of temperature and rainfall variability over the past three decades (1983-2013) in Kolla Temben District.

Table 4.5: Mean annual temperature (T_{min} & T_{max}) and rainfall coefficient of variation (CV)

Attributes	T_{min} (ºC)	T_{max} (ºC)	Total rainfall (mm)
Mean	14.56	28.84	69.06
Standard deviation	6.75	11.85	27.83
Coefficient of Variation (CV)	0.464	0.411	0.403

Source: Fieldwork, 2017

4.2.2.5 Mean annual maximum and minimum temperature (T_{max} and T_{min}) variability trend

The variability trend plot shows that mean annual maximum and minimum temperature variability was on decreasing trend in the past the past three decades (1983-2013) (Figure 4.7 and 4.8). This shows that temperature variability was in decreasing trend in Kolla Temben District.

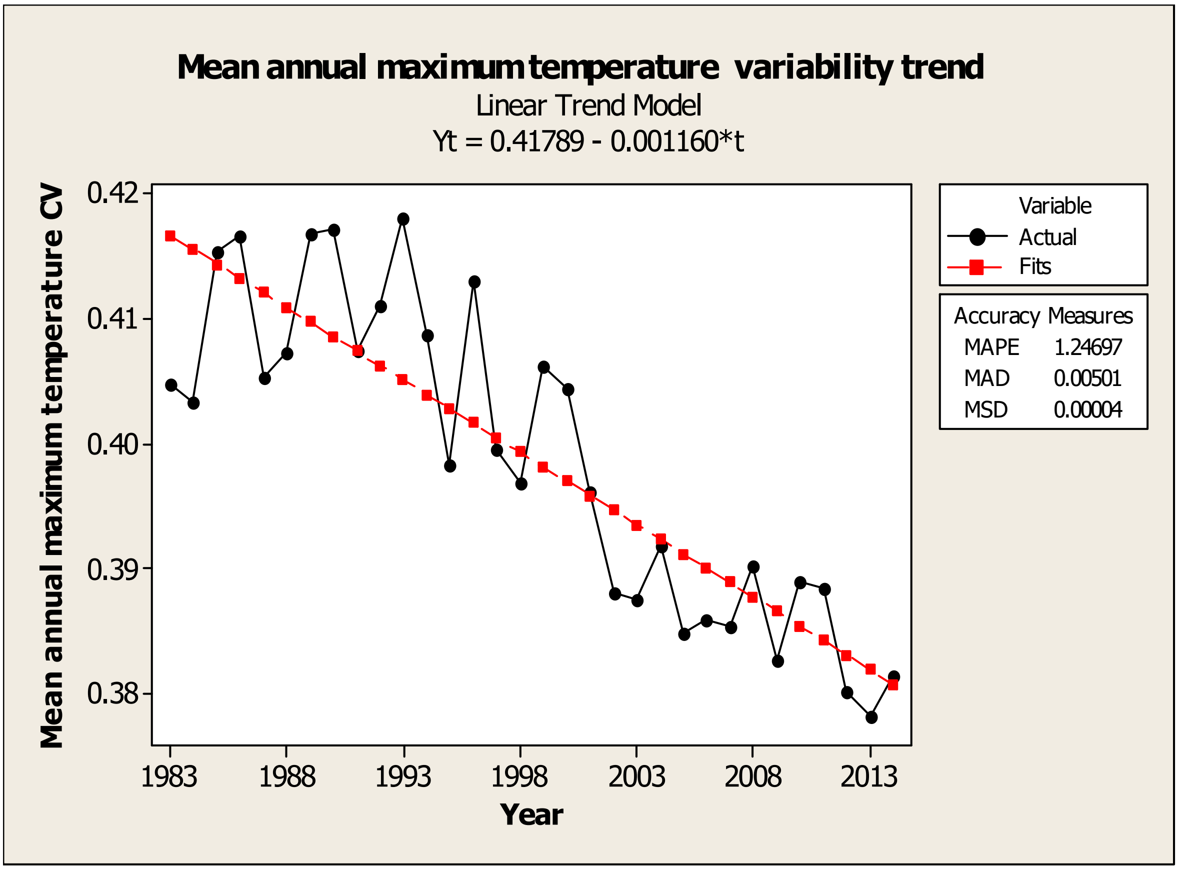

Figure 4.7 Mean annual maximum temperature variability trend variability
(Source: Ethiopia Met (TAMSAT Satellite), 2017)

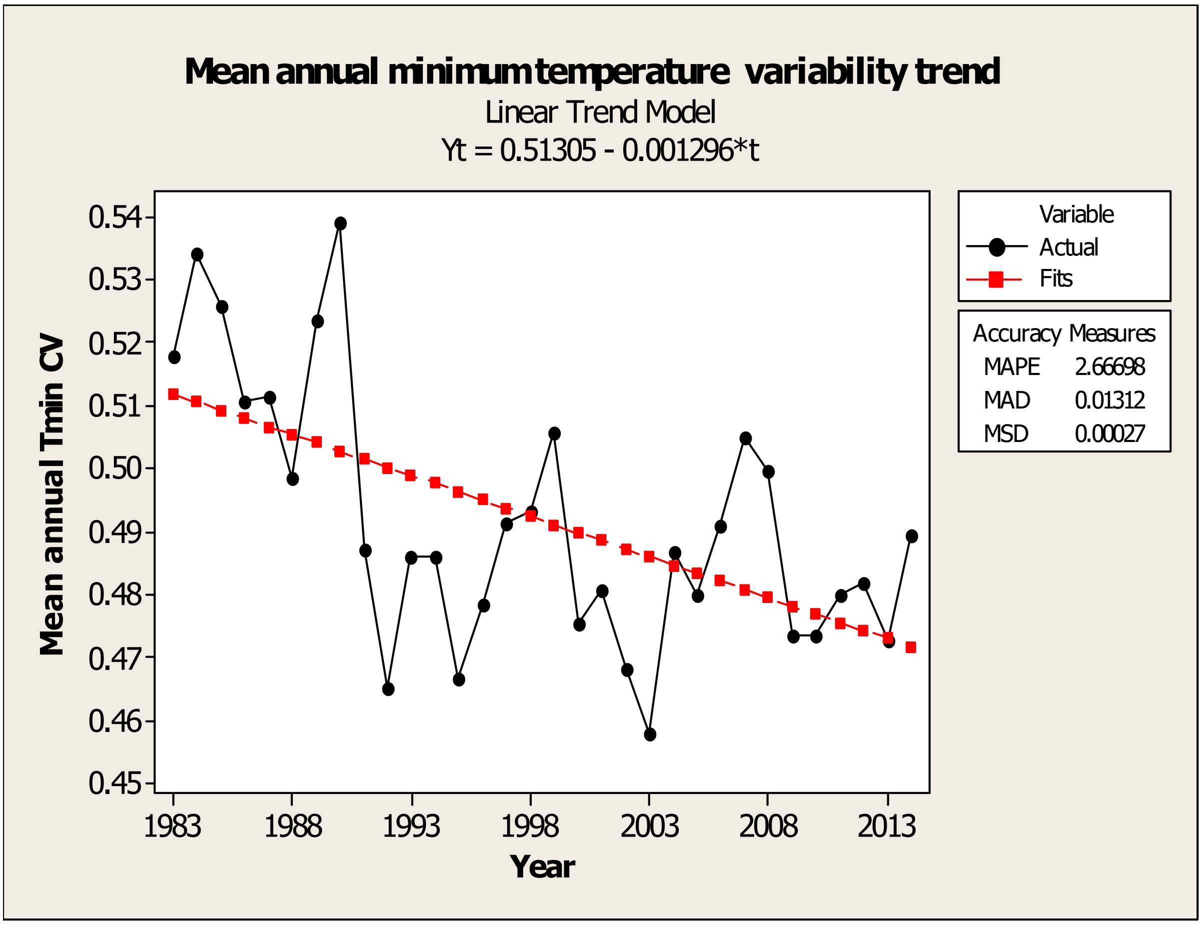

Figure 4.8:Mean annual minimum temperature variability trend (1983-2013)
(Source: Ethiopia Met (TAMSAT Satellite), 2017)

4.2.2.6 Mean annual rainfall variability trend

The variability trend plot analysis result revealed that rainfall variability there was in decreasing trend in Kolla Temben District but the rainfall variability is insignificant (Figure 4.9). This implies that mean annual rainfall has decreased continuously (Figure 4.5) with decreasing variability trends (Figure 4.9) in Kolla Temben District in the past three decades (1983-2013).

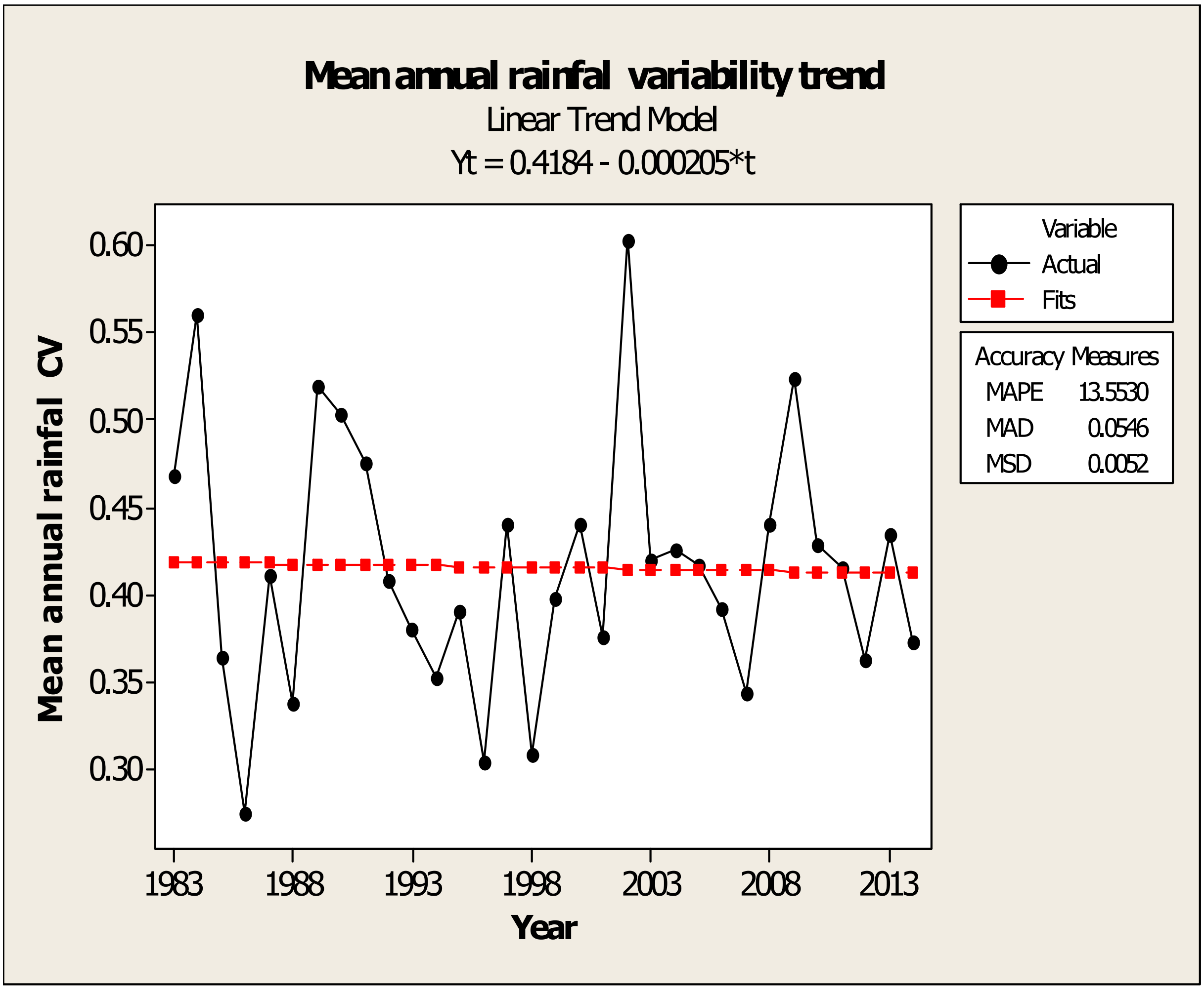

Figure 4.9: Mean annual total rainfall variability trend

(Source: Ethiopia Met (TAMSAT Satellite), 2017)

4.2.3 Farmer Households vulnerability to climate change impacts

The households were categorised into three depending on their vulnerability levels, namely; high, medium and low. The majority of households (47.5%) fall in the category of high vulnerability to climate change impact whereas 39.3% and 13.3% households fell within medium and low levels categories, respectively (Table 4.6). This shows that the majority of households (47.5%) in Kolla Temben District are highly vulnerable to climate change impacts.

Table 4.6: Household levels of vulnerability to impacts of climate change. Frequency refers to the number of respondents.

Vulnerability level	Frequency	(%)
High	190	47.5
Medium	157	39.3
Low	53	13.3
Total	400	100.0

Source: fieldwork, 2016/17

4.2.4 Relationship between household vulnerability, agricultural production and total income

Table 4.7 shows that there was no interaction between independent variables. The variance inflation factor (VIF) was found less than 10, which implies there was no significant correlation between independent variables (Table 4.7).

Table 4.7: Interaction between independent variables

Interactions between Independent	Variables in variance inflation factor (VIF)
1. Total annual crop production in Kg	1.072
2. Total income in ETB	1.100
3. Total livestock ownership in TLU	1.159
4. Total annual food consumption in Birr	2.061
5. Food consumptions per adult equivalent	1.912
6. Total annual crop sales in Kg	1.008
7. Total annual food consumption in kg from aid	1.077

Source: fieldwork, 2016/17)

Seven (7) independent variables were included in the multiple linear regression model analysis (Table 4.8). The results showed that the model was significant at $p \leq 0.002$ and the variables included in the model explained only 42% of its relationship to the dependent variable.

Only three (3) out of the seven variables were found to be significant at P≤0.05 with a F-Value of 3.391 and Adjusted R^2 of 0.42. Household total crop production in Kg (Kilo grams), household's livestock ownership in TLU (tropical livestock unit) and total crop sales had a negative association with vulnerability levels to climate change impact. This implies that with increase total crop production, livestock herd sizes and increased crop sales the lower the vulnerability to the impacts of climate change.

Table4.8: Multiple regression results of vulnerability to climate change impacts on agricultural production (B- unstandardized slops – extent of changes, Beta- standardize slops (Standard deviation), Constant-predictors)

Multiple regression	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	21.412	2.247		9.530	.000	16.995	25.830
Household total crop production in Kg	-.003	.002	-0.091	1.751	.001*	.000	.006
Household total income in ETB	-006	.000	-0.004	.008	.936	.000	.000
Households livestock ownership in TLU	-.769	.355	0.116	2.164	.031*	.070	1.468
Household total food consumption in ETB	-005	.000	-0.004	.060	.952	-.001	.001
Food consumptions per adult equivalent ETB	-.001	.002	-0.041	-.589	.556	-.004	.002
Household total annual crop sales in Kg	-.008	.002	-0.170	-3.389	.001*	-.013	-.003
Household annual food consumption in Kg from aid	.001	.002	0.024	.462	.645	-.003	.004

*Significant at P≤0.05, Adjusted R Square= 0.42, R Square=0.59, F-value=3.391, P=0.002 (Source: fieldwork, 2016/17)

4.2.5. The crops most impacted by climate change in Kolla Temben District

4.2.5.1 The crops most impacted by climate change and variability

A majority of farmers (49.5%) listed maize as the crop that is most impacted by the impacts of climate change and variability while 21%of farmers listed sorghum. Further, 17.5%, 2.8%, and 6.8% reported teff, millet and beans, respectively, as the most negatively impacted crops (Table 4.9).

Table 4.9: The crops most impacted by climate change and variability in Kolla Temben District. Frequency means the number of respondents.

Crop types	Frequency	(%)
Maize	198	49.5
Teff	70	17.5
Sorghum	84	21.0
Millet	11	2.8
Bean	27	6.8
Total	390	97.5
No response	10	2.5
Total	400	100.0

Sources: fieldwork, 2016/2017

4.2.5.2 Climate change impacts on livestock species in Kolla Temben District

A majority of farmers (48.3%) reported that, among the livestock that they own (cows, sheep, goats, and poultry), milking cows were the most impacted by climate change in Kolla Temben District. In addition, about 20% of the households reported that climate change and variability had negatively impacted on the livestock health in the District. Also, about 19.5% of the households reported the most affected to be goats and sheep (Table 4.10). This shows that the livestock sector in general and milking cows in particular are sensitive to impacts of climate change and variability in Kolla Temben District.

Table 4.10: The most impacted livestock by climate change and variability in Kolla Temben District. Frequency means the number of respondents.

List of Livestock types	Frequency	Percent (%)
Sheep and Goats	78	19.5
Milking Cows	193	48.3
All types of Cows(milking and non-milking)	38	9.5
Poultry (Chicken)	6	1.5
The health aspects of all types of Livestock (sheep, goats, cows and poultry)	80	20.0
Total	395	98.8
No response	5	1.3
Total		100.0

Source: fieldwork, 2016/2017

4.2.6 Major causes of household's vulnerability to climate change impacts

The climatic and non-climatic factors that were reported in this study as being the major causes of household's vulnerability to climate change impacts were 12 (temperature increase; declining of rainfall in amount, duration and intensity; temperature increases and rainfall decrease; less awareness on the issue of climate change; large family size; high birth rate; deforestation, small land ownership; deforestation, large family size; soil fertility problem, and high fertilizer prices).

A majority of households responses to the open-ended question on the root causes for households vulnerability in Kolla Temben District were; decrease in rainfall (27.3%), deforestation (25%) and God (14%) (Table 4.11). This shows that climate and non-climate factors have contributed to high vulnerability level to climate change impacts in Kolla Temben District.

Table 4.11: Household's responses on major causes for household's Vulnerability to climate change impacts. Frequency means the number of respondents.

Characteristics	Frequency	Percent (%)
Temperature increase	5	1.3
Declining of rainfall in amount, duration and intensity	109	27.3
Temperature increase and rainfall decrease	17	4.3
Less awareness on the issue of climate change	8	2.0
Large family size	14	3.5
High birth rate	3	0.8
Low soil fertility	5	1.3
Deforestation	100	25.0
Small farmland ownership status	18	4.5
Deforestation, low soil fertility, large family size, high fertilizer prices	18	4.5
Temperature increase, rainfall decrease and small farmland ownership	46	11.5
God	56	14.0
Total	399	99.8
No response	1	0.3
Total	400	100.0

Source: fieldwork 2016/17

4.2.7 Results from focus group discussion and key informant interview

4.2.7.1 Focus group discussion results

During the focus groups discussions, almost all farmers in the four Kebelles (Newi, Atakility, Awetbekalsi and Begasheka) of the Kolla Temben District mentioned that rainfall variability, temperature increase and low soil fertility have affected agricultural production and total income negatively (Table 4.12).The participants in all the four Kebelles reported rainfall decrease, small land size ownership and large family sizes as the major factors that affect agricultural production and total income. However, the participants from Newi and Atakility Kebelles stated that steep topography and frequent flood occurrences were the key factors that negatively their affect agricultural production and total income (Table 4.12).

All focus group discussion (FGD) participants mentioned that household's large family size, small farmland ownership status, less access to education and Agricultural Extension services were the major causes for defencelessness (high vulnerability) of households in Kolla Temben District. They suggested more access to irrigation, agricultural fertilizers and improved varieties of crops as potentially effective interventions to reduce the household's vulnerability level to climate change impacts and increase household total agricultural production (Table 4.12). This shows that area-specific and demand driven solutions are important to address household's vulnerability level to climate impacts and improve agricultural production in Kolla Temben District.

Table 4.12: Focus group discussions (FGDs) results

***Guiding open ended questions forwarded by facilitator(Researcher) to the FGD (focus group discussion)* participants**	***Concepts stated by the FGD (focus group discussion) participants (40) in four Kebelles Kolla Temben District, North Ethiopia***			
	Newi Kebelle (10)	***Atakility Kebelle (10)***	***Begasheka Kebelle(10)***	***Awetbekalsi Kebelle (10)***
How do you see the issues of climate variability and change in relation to agricultural production and total income in your Kebelle?	Rainfall variability, temperature increase and low soil fertility are affecting agricultural production and total income	Rainfall variability and low soil fertility are affecting agricultural production and income from livestock production	Rainfall variability, temperature increase, low soil fertility is affecting agricultural production and income	Rainfall variability and low soil fertility are affecting agricultural production and income
What are the major factors affecting the total production and income of households in this Kebelle?	Rainfall decrease, Small land ownership, large family size and low soil fertility, steep topography and flood	Rainfall decrease, Small farmland ownership, steep topography and flood	Rainfall decrease and small farmland ownership	Rainfall decrease and small farmland ownership

What are the causes for defencelessness (Vulnerability) in this Kebelle?	Large family size, small farmland size, less access to education and Agricultural Extension, and rainfall based agriculture	Large family size, small farmland size, less access to education and Agricultural Extension, and rainfall based agriculture	Large family size, small farmland size, less access to education and Agricultural Extension, and rainfall based agriculture	Large family size, small farmland size, less access to education and Agricultural Extension ,and rainfall based agriculture
What solution do you recommend to solve the problems in your Kebelle?	Improve access to irrigation, fertilizers and improved varieties of crops	More access to livestock feed, irrigation, fertilizers and improved varieties of crops	Improve access to irrigation, fertilizers and improved varieties of crops	Improve access to irrigation, fertilizers and improved varieties of crops

Sources: fieldwork 2016/2017

4.2.7.2 Key informant interview results

From the 16 key informants interview results, three themes were discussed. These themes were rainfall and temperature trends, factors affecting agricultural production and farmer's level of exposures to shocks and capacity to cope as discussed below.

A. Rainfall and temperature changes and agricultural production

All participants of the KII (Key informants interview) said that the decline in rainfall and increase in temperature had negatively affected their agricultural production. One participant from Begasheka Kebelle said '*the issue of rainfall is becoming very hard, my life is getting* *worse as result of rainfall decrease; Rainfall started in July and stopped in the first week of September. Long time ago, rain started in May and lasted to September but this time rainfall duration is getting shorter. It only lasts for two months and this makes my agricultural practices difficult. How can I survive in such a situation and feed my family*''? This shows that the impacts of climate change in Kolla Temben District is a reality and famers in the district lac the capacity to cope with these impacts.

All participants of the key informants interview (KII) stated that new pest infestations were becoming common on their farms, and they also lacked access to effective pesticides to control them. As stated by one participant from Newi Kebelle "Temperature *is increasing very rapidly and also we are experiencing very hot days in May and very cold one in October and November. Our sources of water for livestock and human consumption are getting dry and we are forced to travel long distance to access water. Our livestock have been affected by new animal diseases and the milk production is decreasing with some changes in its natural tastes. We need more help and technical advises from government bodies and experts. I am not aware why the taste of the milk is changing and the new insects and pests are coming to my farm*''.

Another farmer from Awetbekalsi Kebelle said "*Getting enough food at this time is difficult. I am now almost dependant on food aid from government and aid agencies to feed my family. Rainfall is decreasing and the rainy period is getting too short to produce more food. Temperature for the months February, March and May are getting hotter than usual and exposing my household to malaria incidents*''. This suggests that rainfall has decreased significantly in Kolla Temben District and the agricultural production in the district has been negatively affected. It also reveals that increasing temperature has created conducive environment for malaria epidemics in Kolla Temben District. This also shows that farmers have observed a new phenomenon (changes in the taste of their cow's milk, infestation of new insects and pests). This also confirmed that more empirical research is important to know if such phenomena (changes in the taste of cow's milk, infestation of new insects and pests) observed in Kolla Temben are related with the changing climate in the study area. more research is needed in the district to identify their root causes.

B. Factors that affect agricultural production and income

All participants of the KII mentioned that low soil fertility, continuous decline of rainfall, steep topography, ownership of small land sizes and limited access to irrigation and agricultural fertilizers were the major factors that affected agricultural production and total income**.** One participant from the Awetbekalsi Kebelle stated that '*The land size I own is less than a hectare and its fertility is also decreasing continuously but my family is getting bigger. I have no idea how I could feed this large family*'. One participates from Newi. Kebelle also said *'Many years ago, the rainfall, soil fertility, weather condition and agricultural production were good. Feeding a family was not a challenge but nowadays everything has changed. I can't even feed my family for more than 5 months. My family is fully dependent on food aid. The rainfall is not in my side. I have no irrigation facility. Life becomes too difficult*'. This clearly shows that most of farmers in Kolla Temben District have adversely been affected by climate change impacts on the agriculture sector.

C. Farmer's level of exposures to climate related shocks and capacity to cope

The third theme found from the KII in Kolla Temben District was farmer's level of exposure to climate related shocks and capacity to cope. All participants from the four Kebelles (Newi, Atakility, Awetbekalsi and Begasheka) said that farmers were highly exposed to flood, heavy rain, landslides and food insecurity. They also reported that famers' capacity to cope with climate related shocks were very low and all support requested from the local and central government have not been delivered. One participant from Atakility Kebelle said that '*flood is damaging the farmland I have and as a result productivity is decreasing. Food insecurity is a big challenge to my family and I have no means to cope with such challenges except to ask the government for food aid*'. This shows that farmers in Kolla Temben District are highly impacted by climate change and their capacity to cope with the adverse impact is very low, compounding their high food insecurity status.

4.2.7 Discussion

It has been noted that the climate change and variability variables that negatively affect crops are maximum temperature, rainfall and relative humidity (Ali et al., 2017). This study assessed two of these three climate variables, namely, temperature and rainfall. During the period 1983 to 2013, the mean annual T_{max} increased by 2.88ºC and mean annual T_{min} by 1.28ºC. These increases are in tandem with the observed combined land and ocean average global warming of 0.85ºC for the period 1880 to 2012 (Pachauri and Meyer, 2014), but the rate of increase is much higher for the study region than the global average and in agreement with the prediction of Hulme et al. (2001) that Africa will on average warm by 2 to 6ºC within 100 years' time and the prediction of IPCC (2014) that global mean surface temperature will increase by 3.7 to 4.8 by 2100 compared with pre-industrial level.

These temperature increases are accompanied by extreme higher temperature event in May and extreme low temperature event in September. These extreme climate events may exacerbate impacts on those most vulnerable farmers. Decreasing variability has been noted in the analysis of the mean annual variability trend plot of temperature (Figure 4.7 and Figure 4.8) and rainfall (Figure 4.9) accompanied by decrease of mean annual total rainfall (Figure 4.5) and increase of mean annual temperature (T_{max} and T_{max}) (Figure 4.1 and Figure 4.3) in Kolla Temben District. In addition, while Hulme et al. (2001) noted a mean temperature range (DTR) declined of 0.05°C to 1°C in Sudan and Ethiopia but a localised study by Amogne et al. (2018)in Woleka Busine, North Central Ethiopia reported that T_{max} and T_{min} had increased by 0.06°C and 0.03°C per decade respectively.

Addisu et al. (2015) reported December and January as the months with high variations of mean monthly temperature of about 1.2 ºC in Lake Tana Sub-Basin of Ethiopia, while the more localised dataset from Kolla Temben District suggests that such a decline may not reflect the reality on the ground as some of the mean monthly temperature ranges have been shown to be as large at 6ºC for the month of May in the period 1983 to 2013.

It has previously been noted that rainfall in the eastern, southern and southwest parts of Ethiopia were declining in the periods of June to September, 1982-2002 (Yilma and Zanke, 2004), and this is consistent with the results of this study, where rainfall has been declining at a rate of 0.06 mm per year for past three decades (1983-2014). Southern Ethiopia has experienced rainfall deficiency in 1999, 2000,2004,2007,2008,2009 and 2011(Funk et. al.,2014), and such deficits are expected to continue as the variability in the region decreases (Figure 4.9, Figure 4.7 and Figure 4.8). Seager et al. (2010) and Niang et al. (2014) report precipitation increase for southeastern part of Ethiopia. IPCC (2013) projected for 'gradual increase of global precipitation' by 21st century. Few et al. (2015) projected that mean annual rainfall will increase by 7% in East Africa by 2080 to 2090, but this is not in tandem with the actual records from the Kolla Temben District, suggesting that climate models for the Ethiopia region may not be capturing extreme climate variability well enough, perhaps because of the country's steep topographical gradient. This is supported by the report of Few et al. (2015) that 'topographic influence' on climate models are ''not well understood''. This study result is in agreement with localised report of Souverijns et al. (2016) that precipitation has decreased in northwestern Ethiopia over the last decades.

Luxon and Pius (2012) reported that extreme climate events in Sub-Saharan Africa will be severe. According to Nkondze and Masuku (2014) who reported that the number of family members in sickness, those with many dependants, large family sizes and less livestock ownership status adversely influence a household's level of vulnerability to climate change impacts. Opiyo et al. (2014) reported on farmers' vulnerability in Kenya that 27% of them are highly vulnerable, 44% moderately vulnerable, and 29% least vulnerable but in Kolla Temben District 47.5% households was found to be highly vulnerability to climate change impacts and only 13.3% and 39.3% were found in the low and medium vulnerability categories (Table 4.6). This study supports the findings of Nkondze and Masuku (2014) who reported that livestock ownership status influence household's vulnerability levels. Similarly, Godber and Wall (2014) revealed that climate vulnerability will affect livestock production in sub Saharan Africa. Findings from Kolla Temben District support the above conclusion that household vulnerability level to climate change impact has negative relationships with households total crop production, total income, total livestock size ownership, total annual crop sales (Table 4.8). This is also in agreement with the views of Moore et al. (2012) and Kotir (2010) that vulnerability to climate change impacts can affect crop yields negatively in Sub-Saharan Africa.

Monirul (2014) reported that income, agricultural activities and agricultural land has impacts on household's vulnerability to climate change; those findings are supported by the outcomes of this study that shows that there is negative relationship between household's vulnerability level to climate change impacts and household's total crop production and livestock size in Kolla Temben (Table 4.8). Similar findings have been reported by Hoffmann (2010) who noted that climate change impacts have differential impacts on meat, milk and eggs production. Mader et al. (2009) also reported that milk production can decline by 1% to 7% based on location. This is in agreement with this study's finding that the most negatively impacted livestock were the milking cows. Goats and sheep were among the livestock negatively impacted by climate change and variability. Poultry was found to be the least impacted livestock by climate change and variability (Table 4.10). Further, Adu et al. (2018) reported that maize growing farmers are the most adversely impacted by climate change. This is in agreement with this study finding that maize is the most negatively impacted crop type while millet and beans are the least impacted crop types by the impacts of climate change and variability in Kolla Temben District (Table 4.9).

Oo et al. (2018) revealed that farmer's adaptation measures help to reduce vulnerability to climate change impacts and improve resilient to climate change. IPCC (2018) report that 'Populations are disproportionately' vulnerable to climate change impacts and area specific intervention is needed to moderate impacts and reduce vulnerability. This is in support with this study results that more access to irrigation facilities, agricultural fertilizers and improved varieties of crops are the areas of intervention that can reduce a household's vulnerability to climate change impacts and improve its agricultural production (Table 4.12).

4.2.8 Conclusion

From this study, a majority of farmers have no access to formal education and their livelihood bases are mainly dependent on rainfed agriculture which is very sensitive to climate change and variability.

Temperature is increasing more than global climate models projected for the region. The rate of temperature rise is more than double compared with what it was over the past one hundred years. Rainfall decrease has negatively impacted agricultural production and the availability of animal feeds, and this is in line with farmers observations that the frequency of occurrence of heavy rainfall and drought, malaria incidents, and migration trends are increasing. This study has established that impacts of climate change on subsistence farmers are very severe. Most of the subsistence farmers are classified as being highly vulnerable to climate change impacts, and such impacts negatively affect their total crop production, total crop sales and total livestock ownership status, which are already low to begin with. Households with lower vulnerability to climate change impact have significantly higher total income, livestock ownership status and agricultural production compared to those with higher level of vulnerability.

More research work is still needed to ascertain the vulnerability of agriculture to the impacts of climate change on subsistence farmers taking into consideration the indigenous knowledge. Smallholder farmers are becoming more vulnerable to climate change impacts and area-specific adaptation strategies are needed to reduce household's vulnerability and improve adaptive capacity. Hence, farmer's perception is a prerequisite to consider for them to appropriately respond to area-specific climate impacts through adaptation.

CHAPTER 5: FARMERS' PERCEPTIONS ON CLIMATE CHANGE IMPACTS, ADAPTATION STRATEGIES AND THEIR IMPLICATIONS ON AGRICULTURAL PRODUCTION

5.1 Introduction

Adapting to climate change impacts is very important to reduce vulnerability and enhance adaptive capacity. Adaptation can be top down, where it is centralised and policy driven or bottom up where it is real problem based and demand driven (IPCC, 2014). This chapter focuses on the latter, specifying the climate extreme events experienced by the farmers and adaptation strategies they have adopted to mitigate these events in Kolla Temben District. This chapter is divided into six sections. The first section deals with the types of adaptation strategies practised by farmers in response to climate change impacts. Second, the influence of the various adaptation options adopted by the farmers and their influence on the farmers total agricultural production. The third and fourth sections consolidate the findings from focus group discussions and key informant interviews and lastly, the remaining two sections deal with the discussions of the results and conclusions derived from the main findings of this study.

5.2 Results

5.2.1 Farmers' perceptions on climate change impacts

5.2.1.1 Predominant climate events in Kolla Temben District

Perception is a prerequisite for farmers to decide on the types of adaptation strategies to use to respond to climate change impacts. Adaptation decisions depend on perceived changes. Therefore, this section mainly focuses on farmers understanding of the chronology of the occurrence of the climate extreme events, temperature and rainfall trends in the district. Household's perceived and actual changes in rainfall and temperature trends were examined and compared to the agricultural data on the district records to investigate farmers understanding and response to these changes.

The climate extreme events that have occurred in the study area include changes in rainfall patterns, longer dry season spells, higher temperatures and increased frequency of the droughts. For instance: about 84.5% households reported that they had experienced changes in rainy periods (late start and early offset); 85.3% of the respondents noted that there has been a change in the length of the dry seasons (in the past, there was long rainy and short dry period but now there is long dry season and short rainy period); stronger winds were indicated by 76.3% of the respondents; 81.8% acknowledged that it was getting warmer; and about 68.5% reported more frequent occurrences of drought; (in the past 30 years, drought was occurring once in 5 to 10 years and shorter but now they are experiencing drought annually and it lasts longer) (Table 5.1).

Table 5.1:The climate extreme events experienced in Kolla Temben District over the past 30 years (1983-2013). Frequency relates to (1) the number of respondents – no brackets and (2) percentage - brackets.

Type of climate change and variability phenomenon	Farmers observation and responses compared to (1983-2013		Total	No response
	Yes Frequency	No Frequency	Frequency.	Frequency
Change in rainy periods (decreased amount and shorten duration)	338 (84.5)*	56(14.0)	394(98.5)	6(1.5)
Longer dry season periods	341(85.3)	54(13.5)	395(98.8)	5(1.3)
Presence of strong winds	305(76.3)	87(21.8)	392(98)	8(2.0)
Warmer temperature	327(81.8)	62(15.5)	389	11(2.8)
Increased frequency in the occurrence of drought	274(68.5)	103(25.8)	377(94.3)	23(5.8)

*Figures in brackets are percentages. Source: fieldwork (2016/17)

5.2.1.2 Households perceptions on rainfall characteristics

The results in Table 5.2 show the characteristics of rainfall in terms of the amount, duration, onset of rain, frequency of the rainy season, intensity of rain, humidity, duration of humidity and dry season. About 52.7% farmers reported an increase in early cessation of rainfall with one month while 68.5% reported an increase in dry season periods for two months. Majority of farmers (85-72.3%) reported declining precipitation, change in precipitation duration from 4 months to two and half months, and change in early onset of rain by one month, high intensity and long duration of humidity while 2.6 and 9.5 % of farmers reported that they had not made any observable changes in rainfall characteristics (changes in rainfall amount and frequency of rainy days in a month) over the past three decades (1983-2013) (Table 5.2).

Table5.2: Household observation and perceived change in rainfall characteristics compared to the past three decades (1983-2013) and above in Kolla Temben District

Rainfall characteristics	Households perceptions and responses on changes in rainfall characteristics in the past 30 years			Total households that responded	Total households with non-responses
	Increase	Decrease	No change	Total	No response
	Frequency	Frequency	Frequency	Frequency	Frequency
Changes in rainfall amount	36 (9)*	340(85)	31(2.6)	397(99.3)	3(0.8)
Changes in rainfall duration	30(7.5)	334(83.5)	27(6.8)	391(97.8)	9(2.3)
Changes in early onset of rain	38(9.5)	329(82.3)	27(6.8)	394(98.5)	6(1.5)
Changes in early cessation of rain	211(52.7)	154(38.5)	28(7.0)	393(98.3)	7(1.8)
Changes in the frequency of shorten rainy time(few rainy days in a month)	262(65.5)	97(24.3)	38(9.5)	397(99.3)	3(0.8)
Intensity of humidity	71(17.8)	294(73.5)	30(7.5)	395(98.8)	5(1.3)
Duration of humidity	85(21.3)	289(72.3)	22(5.5)	396(99.0)	4(1.0)
Dry season time duration	274(68.5)	93(23.3)	28(7.0)	395(98.8)	5(1.3)

*Figures in brackets are percentages. Source: fieldwork (2016/17)

5.2.1.3 Household's perception to temperature characteristics

The results in Table 5.3 focus on the attributes of temperature, namely: duration of high temperature, intensity of high temperature, duration of sunny time, intensity of sunny time, and frequency of occurrences of excessive heat. A majority of households reported that they observed an increasing trend in the following: duration and intensity of high temperatures, each at 81.5%, duration of sunny time (74.8%), and intensity of sunny time (76.3%) whereas only 9.0 -15.5% of the respondents reported a decreasing trend in these attributes (Table 5.3).

The field study report revealed that only 9% and 11.5% farmers perceived that duration and intensity of high temperature decreased, respectively. Only 8.5% of farmers reported no change in the duration of high temperature and sunny time.

Table 5.3: Households' perceptions on temperature attributes

Temperature attributes	Household's perceptions and responses on temperature changes for the past 30 years			Total households that responded to each characteristics	Total households non responses to each characteristic
	Increase	Decrease	No change	Total	No response
	Frequency	Frequency	Frequency	Frequency	Frequency
Duration of high temperatures	326 (81.5)*	36 (9.0)	34 (8.5)	396 (99)	4 (1)
Intensity of high temperatures	326(81.5)	46 (11.5)	24 (6.0)	396(99)	4 (1)
Duration of sunny times	299 (74.8)	62 (15.5)	34 (8.5)	395 (8.8)	5 (1.3)
Intensity of sunny times	305 (76.3)	62 (15.5)	25 (6.3)	392 (98)	8 (2.0)
Frequency of occurrences of excessive heat	158 (39.5)	205 (51.3)	33 (8.3)	396 (99)	4(1)

*Figures in Brackets are percentages; Source: fieldwork (2016/17)

5.2.1.4 Household's perception to wind characteristics changes

The results in Table 5.4 focus on the main characteristics of wind in terms of change in speed and change in the pattern (wind direction and the frequency of occurrences of high wind speed). From Table 5.4, majority of households reported increasing trends in: the speed of wind (65.8%), change in pattern and direction of wind (57.55%) and the frequency of occurrences of high wind speed (70.3%). The result in Table 5.4 also shows that 10% and 23.8% farmers perceived that there was decrease of wind speed and patterns and only 22.8% and 17.8% reported no changes in wind speed and pattern, respectively. This shows that there is change in wind characteristics (wind direction, frequency of occurrences of high wind speed, speed and pattern of wind) in Kolla Temben District.

Table 5.4: Household's perceptions on wind changes

wind characteristics	Households perceptions and responses on changes in wind characteristics for the past 30 years			Total households that responded to each characteristic	Total households non responses to each characteristic
	Increase	Decrease	No change	Total	No response
	Frequency	Frequency	Frequency	Frequency	Frequency
Change in speed of wind	263(65.8)*	40(10.0)	91(22.8)	394(98.5	6(1.5)
Change in the pattern of wind/wind direction/	230(57.5)	95(23.8)	71(17.8)	396(99.0)	4(1.0)
The frequency of occurrences of high wind speed	281(70.3)	83(20.8)	32(8.0)	396(99.0)	4(1.0)

*Figures in brackets are percentages. Source: fieldwork (2016/17)

5.2.1.5 Households perception on changes in the characteristics of climate hazards

Climate related hazards were perceived to have eight (8) characteristics, namely; changes in: intensity of soil erosion, intensity of flood, incidence of water-borne diseases, frequency of malaria incidences, frequency of droughts, incidences of heavy rain, incidences of conflicts and trends of human migration. A majority of the respondents (61.3 % and 60.3%) reported an increasing trend in incidences of water borne diseases and frequency of malaria incidences, respectively, and 53.5% reported an increase in the intensity of soil erosion which negatively affected farmers agricultural production (Table 5.5). This shows that water borne diseases and malaria incidents are increasing and farmers are under stress of illness which constrains them from investing more time in agriculture.

Table 5.5: Household perception on climate hazard trends

Hazard characteristics	Households perceptions and responses on climate related hazard characteristics in the past 30 years			Total households that responded to each characteristic	Total households non responses to each characteristics
	Increase	Decrease	No change	Total	No response
	Frequency	Frequency	Frequency	Frequency	Frequency
Changes in intensity of soil erosion	214(53.5)*	161(40.3)	21(5.3)	396(99.0)	4(1)
Changes in the intensity of floods	163(40.8)	188(47.0)	44(11)	395(98.8)	5(1.3)
Changes in the incidences of water borne diseases	245(61.3)	76(19.0)	75(18.8)	396(99.0)	4(1.0)
Changes in the frequency of malaria incidences	241(60.3)	112(28.0)	44(11)	397(99.3)	3(0.8)
Changes in the frequency of droughts	127(31.8)	247(61.8)	22(5.5)	396(99.0)	4(1.0)
Changes in the incidences of heavy rain (floods)	97(24.3)	279(69.8)	18(4.5)	394(98.5)	6(1.5)
Changes in the incidences of conflicts	150(37.5)	192(48.0)	52(13)	394(98.5)	6(1.5)
Changes in the trends of migration	112(28.0)	246(61.5)	37(9.3)	395(98.8)	5(1.3)

*Figures in brackets are percentages. Source: fieldwork (2016/17)

5.2.1.6 Farmers access to climate information

A majority of farmers (66.3%) had no access to climate information while only 31.3 % of the farmers had access to climate information. Farmers with access to climate information produced an average of 621 Kg as annual total crop harvest (Maize, Teff, Millet, Sorghum and Barely) while those farmers with no access to climate information produced an average of 511 Kg of total annual crop harvest which was 110 Kg less compared with those with access to climate information (Table 5.6). This shows that access to climate information contributes positively to agricultural production in Kolla Temben District.

Table 5.6: Farmers access to climate information and average crop production (Maize, Sorghum, Teff, Millet, Nug, and Adanguare) compared with those don't

Farmers access to climate information	Frequency & (%)	Farmer's annual average total annual crop production in Kg
Yes	125 (31.3) *	621
No	265 (66.3)	511
No response	10 (2.5)	
Total	400 (100.0)	

*Figures in brackets are percentages. Source: fieldwork (2016/17)

5.2.2 Adaptation strategies to climate change impacts in agriculture

5.2.2.1 Types of farmer's adaptation strategies in agriculture

The farmers practising agriculture in the study area was found using different types of adaptation strategies as shown in Table 5.7. The adaptation strategies practised were: planting of different varieties of crops (98.8%), use of different planting dates (87.5 %), diversification of farm activities (75.5%), shift from livestock to crops (23.5 %), use of short gestation crops (51.3%), use of flood-tolerant crop varieties (53.5 %), use of disease or/and pest resistant crop varieties (66.8%), and water harvesting practices (62.5%). Each strategy was considered independently depending on the number of farmers utilising it. The most preferred adaptation option was use of different planting dates, followed by use of drought tolerant varieties and diversification of farm activities while the least adopted were practising of soil conservation, shift from livestock to crop production and use of irrigation facility in a descending order.

Table 5.7: Household's adaptation strategies in agriculture (crops) sector

Local adaptation strategies to climate change impacts	Households status in using these adaptation strategies in response to climate change impacts		Total households that responded	Total households non responses
	No	Yes	Freq.	Freq
	Freq	Freq		

Drought tolerant crop varieties	89(22.3)*	302(75.5)	391(97.8)	9(2.3)
Use different planting dates	45(11.3)	350(87.5)	395(98.8)	5(1.3)
Diversifying farm activities	89(22.3)	302(75.5)	391(97.8)	9(2.3)
Shifting from livestock to crop production	300(75.0)	95(23.8)	395(98.8)	5(1.3)
Using irrigation facility	331(82.8)	64(16.0)	395(98.8)	5(1.3)
Practicing soil conservations	294(73.5)	101(25.3)	395(98.8)	5(1.3)
Use drainage	102(25.5)	291(72.8)	393(98.3)	7(1.8)
Use of short gestation crops	191(47.8)	205(51.3)	396(99.0)	4(1.0)
Use of flood tolerant crops	182(45.5)	214(53.5)	396(99.0)	4(1.0)
Use of disease or/and pest resistant crop varieties	129(32.3)	267(66.8)	396(99.0)	4(1.0)
Water harvesting practices	145(36.3)	250(62.5)	395(98.8)	5(1.3)
Increase in cultivated land	110(27.5)	286(71.5)	396(99)	4(1)

*Figures in brackets are percentages. Source: fieldwork (2016/17)

5.2.2.2 Farmer's adaptation strategies and crop production

First, multicollinearity test was carried out to ensure no variables included in the model were highly correlated. One way to estimate multicollinearity is the variance inflation factor (VIF), which assesses how much the variance of an estimated regression coefficient increases when predictors are correlated. If no factors are correlated, the VIFs will all be 1. If the variance inflation factor (VIF) is equal to 1 there is no multicollinearity among regressors, but if the VIF is greater than 1, the regressors may be moderately correlated. A VIF between 5 and 10 indicates high correlation that may be problematic (Lewis-Beck, C., & Lewis-Beck (2015). Table 5.8 shows that there was low interaction between independent variables. The variance inflation factor (VIF) was found less than 10, which implies there was no significant correlation between independent variables (Table 5.8). The Multiple Linear Regression Model was significant at $P \leq 0.05$, explained 41% of the variation in the model and had an F-Value of 0.018 as shown in Table 5.9.

Table 5.8: Interactions of independent variables

Independent Variables	Independent variables interaction /Variance Inflation Factors (VIF)
Planting dates as adaptation strategies to changing climate	1.124
Diversify farm activities as adaptations to changing climate	1.155
Change from livestock to crop production as adaptation strategies to climate change	1.434
Irrigation as adaptation strategies to climate change	1.522
Soil conservations as adaptation strategies to climate change	1.342
Use of drainage as adaptation strategies to climate change	1.300
increasing cultivated land as adaptation strategies to climate change	1.207
Short gestation crops as adaptation strategies to climate change	1.150
Flood tolerant crops as adaptation strategies to climate change	1.161
Drought tolerant crop as adaptation strategies to climate change	1.216
Disease and pest resistant varieties as adaptation strategies to changing climate	1.095
Water harvest practices as adaptation strategies to climate change	1.210

Source: fieldwork, 2016/17

The relationship between farmer's adaptation strategies and crop production (in Kg per year) was tested using multiple regressions as outlined in section 3.5.2.3 in Chapter 3. Table 5.9 revealed that use of different planting dates, irrigation and drought tolerant crops were found with significant impacts on total crop production:

Table 5.9: Multiple regression results of household's adaptation strategies and annual total crop production (2015) (B- unstandardized slopes – extent of changes, Beta- standardize slops (Standard deviation), Constant-predictors)

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound

(Constant)	395.886	145.482		2.721	0.007	109.796	681.977
Households use of different planting dates	80.562	92.497	0.047	0.871	**0.038**	-101.334	262.457
Households diversify farm activities	131.608	70.577	0.103	1.865	0.063	-7.183	270.398
Household changed from livestock to crop production	106.105	77.394	-0.084	-1.371	0.171	-258.300	46.090
Households using irrigation	227.664	90.770	0.159	2.508	**0.013**	49.164	406.164
Household practicing soil conservations	-81.437	72.727	-0.066	-1.120	0.264	-224.455	61.580
Households use drainage	79.740	71.335	0.065	1.118	0.264	-60.541	220.021
Households increase in cultivated land	6.667	66.872	0.006	0.100	0.921	-124.838	138.171
Use of short gestation crops	106.543	58.844	0.099	1.811	0.05	-9.174	222.260
Household use flood tolerant crops as adaptation strategies to climate change	42.210	59.256	0.039	0.712	0.477	-74.317	158.738
Use of drought tolerant crops	-9.054	66.391	0.008	0.136	**0.048**	-139.611	121.504
Use of disease or pest resistant crop varieties	-20.326	61.117	0.018	-0.333	0.740	-140.513	99.861
Water harvesting practices	-40.208	62.466	0.036	-0.644	0.520	-163.048	82.632

Sig. – significance (p ≤0.05 –in bold). Adjusted R Square= 0.41, R Square=0.53, F-value=0.018
Source: fieldwork, 2016/17,

Use of irrigation, planting date adjustment and short gestation and drought tolerant crop varieties were the most effective adaptation strategies for improvement of crop production in Kolla Temben District (Table 5.9). The results show that farmers' adaptation decisions have significant impacts on crop production in Kolla Temben District.

5.2.3 Findings from focus group discussion

5.2.3. 1. Farmers perceptions to climate change impacts

The FGD participants in all the four Kebelles (Newi, Atakility, Begasheka and Awetbekalsi) presented five climate related events in the study area namely; changes in rainfall amounts, changes in temperature, changes in frequency of occurrences of extreme temperature, changes in rainfall variability and impacts on agricultural production (Table 5.10).

All FGD participants perceived that rainfall amount had decreased in the past three decades (between 1983 and 2013 years) with more variability. Also, temperature had increased with more extreme hot days in February, May and April (Table 5.10). The months of April, May and June were found to be the hottest months in the last three decades (Figure 4.2). Rainfall decrease had negatively affected agricultural production and the availability of livestock feeds. Further, temperature increase had exacerbated malaria incidents (Table 5.10).

Table 5.10: Responses from the focus group discussion on farmers' perception to climate change impacts

FGD questions to participants	Concepts stated by the FGD (focus group discussion) participants (40) in the four Kebelles on perception to climate changes and impacts. There were 10 participants in each group.			
	Newi	Atakility	Begasheka	Awetbekalsi
How have the rainfall and temperature of this area been over time?	Rainfall has decreased with more variability but temperature has increased with more extreme hot days in February, May and April	Rainfall has decreased with more variability but temperature has increased with more extreme hot days in May and April		

How have changes in rainfall and temperature affected agriculture in this area	Rainfall is affecting agricultural production and hot temperature is exposing people to malaria and some pests	Rainfall is affecting agricultural production and temperature increase is exposing crops and livestock to new infestation of insects and some pests	Rainfall is affecting agricultural production and availability of feeds for livestock	Rainfall is affecting agricultural production

Source: Fieldwork, 2016/17

5.2.3.2 Farmers adaptation strategies to climate change impacts

The focus group discussion participants in all the four *Kebelles*[9] (Newi, Atakility, Begasheka and Awetbekalsi) mentioned in common that the use of improved varieties of crops is the best adaptation strategy. For the Newi Kebelle, it was noted that the availability of more animal feeds stores, access to animal feeds, and limits to household's livestock ownership were the most appropriate adaptation strategies to climate change impacts. This difference was because of the topographical and biophysical differences of the study area. On the other hand, in the Atakility Kebelle, the use of improved crops varieties that takes a shorter time to mature and the availability of seeds were reported as the best adaptation strategies to climate change impacts in the agriculture sector (Table 5.11). In most of the four Kebelles (Newi, Atakility, Begasheka and Awetbekalsi Kebelles), it was reported that limited access to inputs such as fertilizers due to high costs and lack of irrigation were the major constraints to a households ability to adapt to climate change. The suggested solutions to improve household's adaptation strategies to climate impacts in the agriculture were: improved households access to irrigation, availability of improved crop varieties, improved access to agricultural inputs, and improved soil fertility (Table 5.11) andis consistent with the survey results in Table 5.7.

[9] Administration units

Table 5.11: Results from focus group discussion on adaptation

FGD guiding questions	Concepts stated by the FGD (focus group discussion) participants (40) in four Kebelles			
	Newi (10)	Atakility (10)	Begasheka (10)	Awetbekalsi (10)
What are the best adaptation strategies in crop and livestock production low rainfall decrease and high temperature?	Use of improved varieties of crops, store more animal feeds, availability of animal feeds and limiting of household livestock ownership	Use of improved varieties of crops that need short time to mature and availability of livestock feeds	Use of improved varieties of crops	Use of improved crop varieties
What are the factors that affect households ability to adapt climate change impacts (rainfall decrease and temperature increases)?	Less access and high price of agricultural fertilizers, financial constraints to purchase inputs, no access to irrigation			
What do you recommended to be done for an effective adoption and implementation of the adaptation strategies (in the Agriculture/ Livestock, crops /and human health etc.)?	Improve access to irrigation, improved varieties of crops and agricultural inputs, improve soil fertility	Improve access to irrigation, improved access to varieties of crops and agricultural inputs, improve soil fertility	Improved access to improved varieties of crops and agricultural inputs and improved soil fertility	Improved access to improved varieties of crops and agricultural inputs and improved soil fertility

Source: Fieldwork, 2016/17

5.2.4 Findings from key informant interviews

5.2.4.1 Key informant interviews results on farmers perceptions to climate change impacts

A. Perceptions on rainfall and temperature changes and its impacts

During the key informant interviews, two themes were identified, namely; rainfall decrease and temperature increase and their impacts on agricultural production and availability of feeds for livestock.

All the key informants perceived that rainfall had increased over the past three decades (from 1983 to 2013 years) and was characterised by a late start and early cessation. This negatively impacted on agricultural production and availability of feeds for livestock. One participant from Newi Kebelle said and I quote *"Many years ago rainfall would start in March and end in September but nowadays the rainfall starts in the last week of June and goes up to the end of August. The rain period has become very short to cultivate crops which need long rainy periods. Further, rainfall is highly fluctuating with time. This fluctuation of rainfall is negatively affecting the growth potential of the planted crop seeds"*. The participants from New Kebelle reported that temperature has increased very rapidly. This temperature increase has impacted on the volume of water in the river they use for home and livestock consumption. All the key informants reported that temperature had increased and rainfall had decreased in Kolla Temben District over the past three decades.

5.2.4.2 Key informant interviews results on farmers adaptation to climate change impacts

The key informant interview results identified improved varieties of crops, introduction of new varieties of animal feeds (like Alfalfa) and soil and conservation practice as the most adopted adaptation strategies in Kolla Temben District. The solutions suggested by all the key informants to best adapt to the continuous decrease and variability of rainfall were to use crop varieties that were resistant to droughts, floods, pest and insect infestations, and water stress. They also suggested using crop varieties that need a shorter time to mature, improvement of farmer's access to irrigation and agricultural fertilizers at affordable prices and introduction of rotation agriculture practices. They also suggested that policy direction is important to moderate climate impacts. One key informant from Newi Kebelle said and quoted *"rainfall is decreasing and rainy period is becoming shorter but the crop varieties we are still using is* *the one we were using many years ago which needs very long rainy period to mature. We are really in a big challenge. How can we shorten the time duration our crops need to get mature or increase the rainy periods? The issue of rainfall is a big issue for all of us who fully depend on rainfall based agriculture to feed ourselves."* This shows that rainfall decrease and short rainy period is a big challenge for crop production in Kolla Temben District. This also stated that the use of improved varieties of crops, improved access to irrigation and availability of agricultural fertilizers at affordable prices are the best adaptation strategies (interventions) to improve agricultural production in Kolla Temben District.

5.3 Discussion

5.3.1 Rainfall and temperature changes: farmer household perceptions and instrumental data

The results in Table 5.1 showed that 84.5% of farmers perceived changes in the rainfall period and 85.3% experienced longer dry seasons in Kolla Temben District. and the instrumental climate data that showed that there was an increasing temperature trend (Figure 4.1) and a change in the frequency and magnitudes of extremely high and low rainfall events with decreasing trend of mean annual rainfall over the past three decades (Figure 4.5). This is in tandem with the perceptions of farmers in the wider context of the eastern Africa region that rainfall was generally decreasing and temperature was rising. For example, Gebre et al. (2013) revealed that farmers in North Ethiopia well perceived rainfall trend changes. Further, the Rao et al. (2011) study in Kenya revealed that 34% and 45% of farmers perceived that the rain seasons had shortened and rainfall amounts had also declined. In the same country, Ovuka and Lindqvist (2016) reported that majority of farmers in Murang'a District perceived that rainfall had decreased over the past 40 years. For instance, Evelyn et al. (2017) revealed that 74% and 100% of farmers in Mikuyuni and Kaveta villages of Kenya noticed a decrease in the average annual rainfall over the last two decades. This was associated with a perceived temperature increase by 60% of the farmers. Also, Osbahr et al. (2011) reported that 48% of farmers in Uganda perceived rainfall season changes over the past 20 years. Msafiri and Xinhua et al. (2017) findings in Tanzania report that 60% farmers perceive temperature increase.

Although the climatic contexts are not the same, similar perceptions are noted in other parts of Africa, reflecting that global warming is changing, rainfall patterns and amounts (decreasing), raising temperatures, and impacting agricultural production in similar ways in much of the continent. For example, Ayanlade et al. (2017) revealed that 67% of farmers in Southern Nigeria have noticed a rainfall decrease over the past 30 years. Similar findings have been reported by Mensa et al. (2012), who reported that 92% farmers perceive temperature increases while 87%perceived decrease in precipitation. Ayanlade et al. (2017) confirmed that smallholder farmers' perceptions to climate change impacts are consistent with climate trend analysis results. Kalinda (2011) reported that farmers in Zambia perceived temperature has increased in the past decades.

A study conducted by Howe et al. (2013) in 89 countries revealed that greater than 60% respondents perceive that temperature got warmer. This is consistent with the results of this study. Teskey et al. (2015) projected that global heat waves would be doubled by 2020, and the findings of this study support this global outlook, in that a majority of households in Kolla Temben District (81.8%; Table 5.1) reported that there are more frequent occurrences of extreme temperature events (extreme hot and cold) compared to years ago, and that the duration of hot periods had increased (Table 5.3). The changes were associated with farmer perceptions on changes in wind patterns and characteristics as well (wind speed, and frequency of occurrences of high wind speed) which were perceived by 65.8% as generally increasing over the past 30 years. Thus, the finding farmers' perceptions about climate changes are consistent with the observed instrumental climate data for Kolla Temben District, and in the wider eastern Africa region, suggests that the climate has changed significantly enough to be discernible by those who have stayed in the area for several years.

5.3.2Other climate-related farmer perceptions

Nordas and Gleditsch (2007) reported that there is no clear knowledge on the relationship between climate change and conflict. Recently, Abela et al. (2019) reported that the impacts of climate on conflict incidents are time bound and context specific. This supports the results that the frequency of incidents of conflict was perceived by the majority of households having decreased over the past 30 years (Table 5.5).

A majority of households perceived that the frequency of incidents of migration have decreased over the past 30 years (Table 5.5). Direct policy interventions by the government was mentioned in a group discussion as a major reason for the decreasing trends of migration and for the moderated impacts of drought at household level (Table 5.11) and section 5.2.3.2). Policy orientation and actions are likely to influence the extent to which climate impacts affect people and their livelihoods (Table 5.11 and section 5.2.3.2). This finding is supported by Luxon and Pius (2012) in Sub-Saharan Africa, who established that policy has a role in exacerbating climate impacts. This revealed that policy direction has a very important role in moderating the adverse impacts of climate change.

The household survey results revealed that increase of diseases also had a negative impact on the smallholder farmers, limiting their ability to be more productive in agriculture (Table 5.9). This is in agreement with other research findings that have shown that climate change exacerbate disease incidents and this negatively affect farmers agricultural production (e.g. Patz and Olson, 2006; Patz and Reisen, 2001; Ebi and Nealon, 2016; Wu et al., 2016).

In the East Africa region, rainfall decrease and temperature increase has contributed to severe food insecurity and malnutrition (Funk et al., 2014). This supports the field study results that temperature increases and frequent extreme temperature events exacerbated food insecurity (Table 5.5). Hyandye et al. (2018) revealed that warmer temperature will reduce underground water availability which farmers use for irrigation and will lead East Africa to large reduction in agricultural production. This is in agreement with results of Table 5.5 that impacts of climate change have negatively affected agricultural production, and rainfall amount.

5.3.3Farmer households access to climate information

This study established that farmers with access to climate information have higher crop production compared with those without (Table 5.6). In support, Amwata et al. (2018) established that household's access to climate change related information was very important for farmers to make sound decisions on adaptation to climate change impacts Also, climate information needs to take two forms in order to help farmers understand more the probabilistic nature of forecasted products and also to assist farmers on the way to respond effectively in decision making (Nidumolu et. al., 2018). However, climate information on its own is not sufficient but should be more accurate and be availed two months before onset of rainfall to allow farmers utilize the information effectively to improve the agricultural production (Amegnaglo et al., 2017).

5.3.4 Farmer household adaptation strategies

Ali and Erenstein (2017) reported farmers adaptation strategies in the agriculture as sowing time adjustment (22%), drought tolerant crops varieties (15%) and shifting to new types of crops (25%). This is in agreement with this field study results that the most practiced adaptation strategies in agriculture in Kola Temben District were; use of different crop varieties change in planting dates, diversification of farm activities, production shift from livestock keeping to crop production and *vice versa*, irrigation, use of pest resistant crops varieties, and water harvesting practices. This shows that farmers are using different types of adaptation strategies to mitigate the impacts of climate change.

Diversification of farm activities, shift from livestock to crops, increase of cultivated land, use of short gestation crop and flood tolerant varieties adaptation strategies are the most recommended adaptation strategies to improve agricultural production (Table 5.9). This is in agreement with the results that switching from crops to livestock or livestock to crop is one of the important adaptation strategies for smallholder farmers (Hassan& Nhemachena, 2008). Elum et al. (2017) reported that drought- tolerant varieties were the most common adaptation strategies to climate change impacts. This supports that the use of crop varieties that resist to drought and insect and pest infestations is important to moderate the adverse impacts of climate change on crop yields (cf. Elum et al. 2017; Shrestha et al. 2018; Ahmed et al.,2019; Etten et al., 2019) (Table 5.11). This is in agreement with Okonya et al. (2013) who identified 'storing of food, household's income diversification, digging drainage channels, planting trees with high-yielding, use of early-maturing, drought and disease tolerant and pest-resistant varieties of crops, planting at onset of rains and increased use of pesticides as the most used adaptation strategies by smallholder. Table 5.8 identify *planting dates* adjustment*, diversify farm activities, shift from livestock rearing to crops, use of irrigation, drainage practices, increase cultivated land, short gestation crop varieties and flood tolerant as* the adaptation strategies with real positive impacts on crop production. This also supports the findings of this study that availability of animal feeds and limits a household's livestock size ownership, crop varieties that can resist drought, flood, pests and insects, water stress and crop varieties that need shorter time to get matured, rotation agriculture are the most appropriate adaptation strategies to climate change impacts (Table 5.11). This shows that production diversification to include both livestock and crops is one of the effective adaptation strategies that farmers should use to respond to climate impacts. This also revealed that climate change impact becomes the major determinants for the types of agricultural practices farmers should choose. Farmers agricultural practices has also started to be shaped by the climate impacts their villages received.

Aydinalp and Cresser (2008) revealed that use of different crop varieties, water harvesting practices and change in plating schedules are important to reduce negative impacts and improve crop production. Recently, Kidist et al. (2018) reported that adaptation strategies practiced by farmers can reduce negative impacts and take advantages of changes to improve production. These are in agreement with this study result that households who used drought and flood tolerant, disease and pests resistant varieties of crops and use of different planting dates had significant positive impacts on their total annual income from crops in ETB, total annual food consumption from own harvest in Kg, total annual crop sales in Kg, and total annual crop production in Kg (Table 5.9). In support, Elum et al. (2017) also reported that drought-tolerant varieties as the most common adaptation strategies to climate change impacts. Farmer households that used drought tolerant crops as an adaptation strategy to climate change impacts had higher total income than the farmers households that did not.

Crop varieties that can resist extreme temperature are needed to sustain crop production and to feed the ever increasing world population (Southworth et al., 2000). This support the findings, shown in Table 5.9, that farmer's adaptation decisions are one of the determinant factors that affect farmer household's total income from agriculture. Lane and Jarvis (2007) revealed that crop varieties that can tolerant climate stress (drought, flood and extreme temperature) and resist pests and diseases is important to sustain crop production. This is tandem with results of this study that use of a crop variety that can resist pests and disease as adaptation to climate change impacts had positive impacts on total crop production (Table 5.9). Crop varieties that can resist extreme temperature are needed to sustain crop production and to feed the ever increasing world population (Southworth et al., 2000). This supports the results that adaptation strategies that fit the specific impacts are very important to sustain productivity of the agriculture sector and to feed the fast growing population. These makes clear that adaptations strategies that are initiated by farmers are the most successful and technically sound strategies that well address area specific problems, needs and demands.

Crop yield is more sensitive to precipitation than temperature (Kange et al., 2009). Earlier planting and irrigation can increase yields by 11 to 38% (Moradi et al., 2013). This supports the results that households who used irrigation as adaptation strategies had positive significant association with household's food consumption in Kg, total crop production in Kg, total income from crop production (Table 5.9). Households with more access to irrigation facilities had higher annual crop production compare with those do not. Irrigation support can increase crop production even in the time of severe climate impacts (Kange et al., 2009). Mwaura et al. (2017) suggested for the urgent need of water harvesting technologies in Kenya to improve agricultural production. The use of irrigation as an adaptation strategy to climate change impact has significant positive effect on agricultural production (Moradi et al., 2013). This is in support with results of Table 5.10 that irrigation that is the most appropriate adaptation strategy to climate change impacts.

Adjustments of sowing dates are most recommended adaptation strategy in the agriculture (Muller et al., 2014). This supports the results that managing the date to plant crops has positive contribution to the increments of annual total crop production. This also revealed that planting date adjustment has significant impacts on improving crop production. These are with agreement of the results of this field study that adjustment in planting dates had positive contribution to crop production (Table 5.9). This also substantiate that the agriculture sector is demanding human intervention through adaptation to overcome climate change impacts and sustain production.

5.4 Conclusion

Temperature increase, high frequencies of occurrences of drought and strong winds are becoming common in rural areas. Early cessation of rain, the frequency of shorter rainy period and dry season duration is in the increasing trends. Most of farmers perceived that rainfall is in decreasing trend and early cessation of rainfall is becoming a big challenge for agricultural production. Farmers have well perceived the changes that have happened in their villages as results of climate change impact. A majority of farmers perceive that rainfall is decreasing whereas temperature (T_{max} and T_{min}) has been increased significantly in the past three decades. Rainfall decrease has negatively impacted agricultural production and the availability of animal feeds.

Farmers alleged that the frequency of occurrence of heavy rainfall and drought, malaria incidents, and migration trends are increasing. The incidents of malaria and water borne diseases are increasing. Most of households' perceptions on temperature change trends are consistent with recent research findings but still lacking the understanding on the long term consequences of the speedy changing climate on their livelihood bases and health status.

Limited access to climate information and high prices of agricultural fertilizers, financial constraints to purchase inputs and no access to irrigation are the major constraints that affect household's ability to adapt to climate change impacts in agriculture. Access to climate information helps farmers to make sound decisions on adaptation in the agricultural production. Farmers with better access to climate information have higher agricultural production compared to those with no access.

Adaptation strategies have significant impacts on agricultural production and total income. The commonly used adaption strategies in the agriculture sector are; crop varieties that can resist diseases and pests; water harvesting practices; shift from animal husbandry to farming and more irrigation. Most effective adaption strategies are irrigation, planting date adjustment, drought tolerant and short gestation crop varieties. The soundness of farmer's decisions on adaptation determines the growth potential of agricultural production in arid and semi-arid areas. Agricultural production is under the risk of rainfall fluctuations and unpredictable changes.

Effective adaptation strategies are important in the current ever changing climate to improve household's food security status and adaptive capacity to through improving agricultural production. Hence, the next chapter will examine farmer's food security status and its relation to adaptive capacity to climate change impacts and possible area specific interventions to improve food security.

CHAPTER 6: IMPLICATIONS OF THE FARMERS ADAPTIVE CAPACITY ON HOUSEHOLDS' FOOD SECURITY STATUS AND RESILIENCE BUILDING

6.1 Introduction

This chapter focuses on investigating the interactions between households adaptive capacity to climate change impacts, food security and the possible interventions for enhancing resilience (Objective 3). This chapter present results on household's adaptive capacity and its interaction with socio-economic factors such as dependency, land ownership, access to social services and factors that affect households' ability to access food.

6.2 Results

6.2.1 Household adaptive capacity levels to climate change impacts

The household adaptive capacity levels to climate change impacts were determined and categorised into low, medium and high classes using the method outlined in Table 3.1 and section 3.5.1.2 'b' of Chapter 3. The study shows that the households adaptive capacity levels (section 3.5.3.3) to climate change impacts in Kolla Temben District were as follows: 52.3% (low adaptive capacity), 34.0% (medium adaptive capacity) and 13.8% (high adaptive capacity) to climate change impacts (Table 6.1). This implies that the majority of households in Kolla Temben District were very susceptible to climate change impacts.

Table 6.1: Households adaptive capacity to climate change impacts by category. Frequency is number of respondents.

Households adaptive capacity level categories	Frequency
Low	209 (52.3)*
Medium	136 (34.0)
High	55 (13.8)
Total	400 (100)

* Figures in brackets are percentages. Source: Fieldwork, 2016/17

6.2.2 Household's adaptive capacity indicators (health and dependency status)

Farmer household's dependency status was assessed using questionnaires as indicated in chapter 3, section 3.5.3.2. This study revealed that only 29.8% of the households had no household member under working age group as per local standard (below 14 years' age) (Table 6.2). Further, the study revealed that, of the households with three or more members, 46.4% had either terminal illness, disability status and/or were under the working age group (Table 6.2). The majority of households in the area had large size of family members under the working age group.

Table 6.2: Situation of the household's family members

Health and dependency characteristics	Household member situation				Total
	≥3 household members	Two household members	One household	None	
	Frequency	Frequency	Frequency	Frequency	Frequency
Household members with terminal illness	3(0.8)*	5(1.3)	32(8.0)	360(90.0)	400(100.0)
Household members with disability	3(0.8)	0	18(4.5)	379(94.8)	400(100.0)
Household members under working age group	177(44.3)	70(17.5)	33(8.3)	119(29.8)	399(99.8)

*Figures in brackets are percentages. Source: Fieldwork, 2016/17

6.2.3 Households adaptive capacity indicators (land ownership status)

Households land ownership status was reported using a Likert scale (0 hectare, less than 0.25 hectare, 0.26 - 0.50 hectare, >0.5 - 1.50 hectare and greater than 1.50 hectare) as indicted in the method chapters, Table 3.1 to examine households land ownerships. The majority of households in Kolla Temben District owned land between 0.26 to 1.5 hectares. Only 1.3% of households had land sizes greater than 1.5 hectare while about 3 % did not own land (Table 6.3) while the majority (41.5%) of farmers in Kolla Temben District own land sizes between 0.26 and 0.5 hectares.

Table 6.3: Household land ownership status

Number of household member at each categories	Frequency
No land	12(3.0)*
Less than or equal to 0.25 hectare	54(13.5)
≥0.26to ≤0.5	166(41.6)
≥0.56 to ≤1 hectare	122(30.5)
≥1.01 to ≤1.5 hectare	40(10.0)
≥1.5 hectare	5(1.3)
Total	399(99.8)
No response	1(0.3)
Total	400(100)

*Figures in brackets are percentages. Source: fieldwork, 2016/17

6.2.4 Households access to Agricultural Extension services to enhance adaptive capacity

Farmer household's access to agricultural was assessed using the methods in section 3.5.1.2. Access to Agricultural Extension was categorised into five, namely; not at all, 1-2 times a year, monthly, weekly, and daily as shown in Table 6.4. Table 6.4 shows that about 24.5% of the households had no access to agricultural extension while a majority of the households (61.3%) had access to agricultural extension services at least 1-2 times a year.

Table 6.4: Household's access to Agricultural Extension services situation and adaptive capacity

Number of times a household accesses agricultural extension services	Frequency	Low adaptive capacity	Medium adaptive capacity	High adaptive capacity
Not at all	98(24.5)*	75(35.88)	18(13.24)	5(9.09)
1-2 times a year	245(61.3)	124(59.33)	47(34.56)	3(5.46)
Monthly	46(11.5)	7(3.35)	71(52.20)	46(83.64)
Weekly	9(2.3)	3(1.44)	0	0
Daily	1(0.3)	0	0	1(0.3)
Total	399(99.8)			
No response	1(0.3)	0	0	0

Total	400(100)	209 (52.3)	136 (34.0)	55(13.8)

*Figures in brackets are percentages. Source: Fieldwork, 2016/17

6.2.5 Summary statistics for households adaptive capacity to climate change impacts and household's food security status

Inferential statistics (mean and standard deviation) was used to estimate the mean differences of the food secure and food insecure households as indicated in Table 3.1 and section 3.5.3.3. Food secure households had 3.04 score of mean in adaptive capacity to climate change impacts compare with food insecure households (Table 6.5).

Table 6.5: Statistical report of household adaptive capacity to climate change impacts and households food security

Capacity	Household food security status	No	Mean	Std. Deviation	Std. Error Mean
Household adaptive capacity to climate change impacts	Food Secure	68	56.65	12.33	1.50
	Food Insecure	331	53.61	10.77	0.59

No- Number- Mean- Mean of the food secure and food insecure farmers. Source: Fieldwork, 2016/17

6.2.5.1 Factors that affect farmers ability to access food

Factors that affect farmers' ability to access food are categorized into two as land and related production factors (small land size holding, soil fertility problem, insects and pests, weeds and high price of fertilizers) and weather-related factors (rainfall, frosts, winds, drought). The factors reported by households to influence their access to enough food (minimum daily calorific value) were; small land holdings (9%), rainfall amounts (20%), insect and pests infestation (2.3%), weeds (0.08%), low soil fertility (4.5%), changes in rainy seasons (1%), high prices of fertilizer (0.8%), rainfall, frosts, winds, weeds, pests and insects (23.5%), small land holding, decline of soil fertility, high price fertilizer and drought (7%) and the rest, 23% of households said small farmland holding and rainfall as the major factors that affect their ability to access food (Table 6.6). This clearly shows that farmers ability to access to food in Kolla Temben District is influenced both by climatic and none climatic factors.

Table 6.6: Factors that affect farmer's ability to access enough food and build resilience

Category	Factors	Frequency
	Small land size holdings	36(9.0)*
	Insects and pests	9(2.3)
Land and related production factors	Weeds	3(0.8)
	Soil fertility	18(4.5)
	High prices of fertilizers	3(0.8)
	Small land holdings, decline in soil fertility, high fertilizer prices and drought	28(7.0)
	Small farmland holding and low rainfall	92(23.0)
Weather-related factors	Rainfall amounts	80(20.0)
	Changes in the rainy seasons	4(1.0)
	Rain fall, frosts, winds, weeds, pests and insects	94(23.5)
	Drought	28(7.0)
	Total	395(98.8)
	No response	5(1.3)
	Total	400(100)

* Figures in brackets are percentages. Source: fieldwork, 2016/17

6.2.5.2 Households food security status and levels of adaptive capacity to climate change impacts

Household's food security status was examined using the method indicated in chapter 3, section 3.5.3.4 and adaptive capacity was assessed using the indictors in Table 3.1. In this study, out of 331 food insecure households, 180 households (54.38%) had low adaptive capacity, 115 (34.74%) medium and 36 (10.88%) had high adaptive to climate change impacts. Majority of households (54.38%) with low adaptive capacity to climate change impacts were found to be food insecure. Only 28 households (13.46%) were reported to be food secure with low adaptive capacity to climate change impacts. Table 6.7 revealed that only 21 households (15.44%) out of 136 households with medium level adaptive capacity to climate change impact were found to be food insecure (Table 6.7). Thus, households with low adaptive capacity to climate change were also the most food insecure. This implies that household's adaptive capacity to climate change impacts influences households' food security status in Kolla Temben District.

Table 6.7: Household food security status and household climate adaptive level

Status		household climate adaptive level			Total
		Low	Medium	High	
Household food security status	Food insecure	180 (86.53)	115 (84.56)	36 (65.45)	331 (82.7)
	Food secure	28 (13.46)	21 (15.44)	19 (34.54)	68(17.0)
Total		208	136	5	399 (99.8)

*Figures in brackets are percentages; Source: fieldwork, 2016/17

6.2.5.3 Relationship between household's adaptive capacity level to climate change impacts and household's food security status

Chi-square test shows that there was significant relationship between household's adaptive capacity to climate change impacts and household's food security status in Kolla Temben District (Table 6.8). A household's capacity to adapt to climate change impacts is lower when the food insecurity is higher.

Table 6.8 Chi-square tests of household' adaptive level to climate change impacts and household's food security status

	Value	Degrees of freedom	Asymptotic significant (2-sided)
Pearson Chi-Square	14.051[a]	2	.001
Likelihood Ratio	12.045	2	.002
Linear-by-Linear Association	10.067	1	.002
N of Valid Cases	399		

Source: fieldwork, 2016/17

6.2.6 Interventions suggested to build resilience

Building resilience to climate change impact is one of the most important areas of interventions to reduce the vulnerability of the households. Since climate change impacts are disproportionally distributed, local specific intervention is curial to effectively address impacts at local level. Hence, this research established the location specific interventions and farmer's immediate needs to build resilience in Kolla Temben District. Responses were therefore clustered in different types of) analysis themes as per the farmers' recommendations, namely; to build resilient, constraints they faced to build more resilient livelihoods, immediate needs to ease resilient building and; suggested actions to be taken by farmers themselves, district administrator, experts, Kebelle development agent and policy directions) to ease analysis and interpretations.

6.2.6.1 Farmers' recommendations

Farmers' recommendations were reported in two areas; *agricultural aspects* including reforestation and availability of agricultural inputs; and *services delivery*, which includes emergency aid by government, access to pumped water and good governance. Recommendations suggested by farmers to enhance resilience include: reforestation (41.8%), "God is the only solution" (13%), delivery of emergency aid by government (10.5 %), access to pumped water (7.5%), access to early maturing and drought resistant seeds (6%),availability of agricultural inputs (4.5%), reforestation, emergency aid support, early matured and drought resistant seeds, access to pumped water, good governance at Kebelle level (4.3%), redistribution of land (3%), good supply of effective pesticides and insecticides (2.8%), and effective pesticides (2.8%) (Table 6.9). About 3% of the respondents reported that there was no need for action.

Table 6.9: Recommendation made by farmers to address climate change impact challenges

Recommended actions by farmers	Frequency
1. Reforestation practices	167 (41.8)*
2. God is the only solutions	52 (13)
3. Emergency aid by government	42 (10.5)
4. Access to pumped water	30(7.5)

5. Access to early matured and drought resistant crop seeds	24(6.0)
6. Availability of agricultural inputs	18(4.5)
7. Good governance	17(4.3)
8. No need of actions	12(3.0)
9. Redistributions of land	12(3.0)
10. Good supply of effective pesticides and insecticides	11(2.8)
11. Reforestation, emergency aid support, early maturing and drought resistant seeds, access to pumped water and effective pesticides	11(2.8)
Total	396(99.0)
No action	4(1.0)
Total	400(100)

*Figures in brackets are percentages; Source: fieldwork, 2016/17

6.2.6.2 Farmers' responses on major constrains to build resilience

Households' responses on constraints in building resilience for adverse impacts of climate were captured in six categories as shown in Table 6.10. Reasons associated with government accounted for 33%, government and community at 44.9%, poor Kebelle administrations at 2.5%, poor leadership at 13%, and God at 5.5%. This shows that majority of farmers in Kolla Temben District believe that services from government body is important to moderate the adverse impacts of climate change impacts.

Table 6.10: Farmers' responses on the root causes of the current situation of climate change related impacts at household level

Farmers' Responses	Frequency
Government and community	166(41.50)*
Poor government services	132(33.0)
Poor leadership	52(13.0)
God	22(5.5)
Community	12(3.0)
Poor Kebelle Administrations	10(2.5)
Total	396(99.0)

No response	4(1.0)
Total	400(100)

*Figures in brackets are percentages; Source: fieldwork, 2016/17

6.2.6.3 Farmers needs to overcome the impacts of climate change and build resilience

Households reported the need to overcome the challenges of climate change impacts through skill development, input access and good governance (Table 6.11). Results in Table 6.11 shows that smallholder farmer households in Kolla Temben District have good capability to identify the actions to be taken in the short term (aid and access to portable water) and in the long term (reforestation practices) to manage the impacts of climate change at household level.

Table 6.11: Household needs to overcome the climate change impact and build resilience

Households Needs	Frequency
Improving households food security status	90 (22.5)*
Food aid and fair distributions of aid	74 (18.5)
Availability of cheap fertilizer	43(10.8
Relocation	36(9.0)
Pumped water for drinking	26(6.5)
Reforestation practices	26(6.5)
New skills on how to improve productivity with the current challenges	22(5.5)
Good Governance and Justice	18(4.5)
More job opportunities	17(4.3)
Availability of insecticide and pesticide	16(4.0)
Improving productivity, food security and fair distributions of aid	11(2.8)
Drought resistance varieties of crops	3(0.8)
Availability of water for livestock	5(1.3)
Total	387(96.8)
No response	13(3.2)
Total	400(100)

*Figures in brackets are percentages; Source: fieldwork, 2016/17

6.2.6.4 Suggested actions for all farmers in the district by the sample smallholder farmers to overcome climate impacts and build resilience

Several suggestions on enhancing farmer resilience were made in the areas of agricultural practices, namely; improving land management practices, use of appropriate fertilizers, reforestation, irrigation, household's awareness including the fear to challenge government and ask for their rights, control family sizes, improve productivity and accept the consultation given by agricultural experts as shown in Table 6.12. About 17.5% of the households recommended the need to improve land management practices while 10.8% recommended the need for appropriate practices of fertilizer applications. Majority of famers (48.5%) suggest investing more time in improving productivity and accepting the direction given by government and experts to improve resilience to tackle challenges.

Table 6.12: Actions suggested by sample farmers to tackle the challenges in the District

Suggested intervention	Frequency
1. Farmers in the district should work hard to improve productivity and should also accept the direction given by government and experts	194 (48.5%)*
2. Improve land management practices	69(17.5)
3. Appropriate practices of fertilizer applications	43(10.8)
4. More reforestation	33(8.3)
5. Fear to challenge government should improved	13(3.3)
6. Irrigation facility should be practiced by farmers to cope with rainfall related problem	12(3)
7. Control family size	10(2.5)
8. Improve land management, appropriate applications of fertilizer, reforestation, Controlling family size, use of irrigation	2(0.5)
9. Awareness	1(3.0)
Total	377(94.3)
No response	23(5.8)
Total	400(100)

Figures in brackets are percentages; Source: fieldwork, 2016/17

6.2.6.5 Suggested actions by farmers targeting experts to build resilience

Experts were requested to provide more technical training to farmers (16.5%) to overcome climate impacts and to improve resilience. Majority of farmers (40%) mooted for effective delivery of services to enhance resilience (Table 6.13). This shows that the farmer households recognised that the technical competency of experts and effective delivery of services by them are important in Kolla Temben District to tackle the impacts of climate change on small-holder farms.

Table 6.13: Actions suggested to be taken by experts at District level to enhance resilient at Kebelle level

Suggested actions for experts	Frequency
▪ Effective delivery of service	160(40.0)*
▪ Working hard	93(23.3)
▪ Should provide technical training	66(16.5)
▪ There should be effective monitoring and evaluating mechanisms	55(13.8)
▪ All report developed by experts should be real reflections of farmers	8(2.0)
Total	382(95.5)
No response	18(4.5)
Total	400(100)

*Figures in brackets are percentages; Source: fieldwork, 2016/17

6.2.6.6 Suggested actions for District administrator to overcome current climate impacts situations and build resilience

A majority of the farmers (74%) mooted for participatory decision and effective administration system and promoting of good governance to enhance resilience (Table 6.14). This shows that the role of District Administrator in building households' resilience to climate change impacts is very crucial in Kolla Temben District (Table 6.14). This also revealed that climate change impacts at household level can be exacerbated if the services delivery system and governance strategies are not effective to facilitate the enhancement of household's adaptive capacity to climate change impacts.

Table 6.14: Suggested actions to be taken by District administrators to build resilience

Suggested actions to be taken by District administrators to build resilience	Frequency
1. Increased direct contact with the community	136(34)*
2. They should promote good governances at Kebelle level	104(26)
3. Should provide effective services	56(14)
4. Doing well and no suggestion on it	52(13)
5. Report should be verified	9(2.3)
6. Control/address bribe practices	9(2.3)
7. They should be solve the problem we are facing	9(2.3)
8. Effective monitoring system	4(1.0)
9. Report should be verified, practice should be addressed, administrator should have direct contact with community	1(1.0)
Total	380(95.0)
No response	20(5.0)
Total	400 (100)

*Figures in brackets are percentages; Source: fieldwork, 2016/17

6.2.6.7 Suggested actions for Kebelle development agents to overcome current climate impacts situations and build resilience

Most of the farmers (65%) recommended for participatory agricultural extension services delivery system to improve household's adaptive capacity to climate impacts (Table 6.15). This shows that farmers in Kolla Temben District are not adequately getting the needed agricultural extension support to improve their adaptive capacity to climate change impacts.

Table 6.15: Recommended actions to be taken by development agents

Suggested action to be taken by development agents	Frequency
1. Effective delivery of Agricultural Extension Services	224(56)*
2. They should not force farmer to buy fertilizers	63(14.8)
3. They are doing well and no suggestion on it	53(13.3)
4. Use participatory approach when provide inputs	36(9.0)
5. DA should be well trained and skilled to guide farmers	16(4.0)

6.None	1(0.3)
7.Total	393(98.3)
8.No response	7(1.8)
10. Total	400 (100)

*Figures in brackets are percentages. Source: fieldwork, 2016/17

6.2.6.8 Suggested actions for government to overcome current climate impacts and build resilience

Actions recommended to government include: fertilizer price decrease (12.5%), monitor the implementation of programs (20.3%), empower young people (2%), design policy to diversify sources of incomes (9.3%), improving the survival rate of planted trees and to introduce effective monitor mechanisms (4.3%), devise ways to ensure farmers benefit more from protected and forest areas(4.8%), provide water and agricultural inputs (6.3%), no action (6.8%), timely supply of effective pesticides and insecticides (1.8%), and promote good governance and justice at Kebelle level (28.5%) (Table 6.16). This shows that government policy change is very important to enhance resilience in Kolla Temben District.

Table 6.16: Recommended solutions to be taken by government to address climate change impacts and build household resilience

Suggested solutions by farmers to tackle climate change impacts	Frequency
1. Government should promote good governance and justice at Kebelle level	114 (28.5)*
2. Government body should be monitor implementations of programs	81(20.3)
3. Fertilizer price adjustments	50(12.5)
4. Design policy to diversify sources of incomes	37(9.3)
5. No recommendation to government	27(6.8)
6. Provide water and agricultural inputs	25(6.3)
7. Protected forest area should benefit the society	19(4.8)
8. Improvement of the survival rate of planted trees and effective monitoring mechanisms	17(4.3)
9. Empower young people	8(2.0)

10. Timely supply of effective pesticides and insecticides	7(1.8)
11. None	2(0.5)
Total	387(96.8)
No response	13(3.3)
Total	400(100)

*Figures in brackets are percentages. Source: fieldwork, 2016/17

6.2.7 Findings from focus group discussion

Four focus group discussions were held in each of the four Kebelles namely Newi, Atakility, Begasheka and Awetbekalsi. Participants from the Atakility Kebelle defined food security as "producing enough crops to feed a family" (Table 6.17).

Participants in all Kebelles (Newi, Atakility, Begasheka and Awetbekalsi) mentioned that low soil fertility, shorter period of rainfall and less access to agricultural fertilizers were the factors that negatively affected households food security status. Focus group discussion participants from Awetbekalsi also mentioned infestations of insets and pests and limited access to improved varieties of crops as the major factors that negatively affected households' food security in Kolla Temben District (Table 6.17).

Most of the focus group discussion (FGD) participants suggested controlling family size, improving crop productivity and more access to clean water as the best solutions to improve household's food security status and adaptive capacity to climate change impacts. All participants of the focus group discussion (FGD) in all the four Kebelles (Newi, Atakility, Begasheka and Awetbekalsi) agreed that the adaptive capacities of farmers in Kolla Temben District were too low to enable them overcome climate impacts. The solutions suggested by the focus group discussion (FGD) participants from the Atakility Kebelle to address the impact of climate change were: controlling the family size, improving access to irrigation and crop production. Participants from Begasheka Kebelle suggested more food aid, reforestation and improved access to education as the critical solutions to improving food security, adaptive capacity to climate change impacts and building resilience. The participants from Awetbekalsi Kebelle had suggested the need for more access to irrigation facilities and improved varieties of crops as the only solutions to improving their household food security status. This confirms that there is no universal solution that can apply in all Kebelles to improve household's food security status and adaptive capacity to climate change impacts. This also substantiates the need for more location specific research works to address climate change impacts effectively.

Table. 6.17: Focus group discussion results

Guiding open ended questions used by the Researcher to facilitate FGD sessions	Concepts stated by the FGD (focus group discussion) participants (40) in four Kebelle			
	Newi Kebelle (10)	*Atakility Kebelle (10)*	*Begasheka Kebelle (10)*	*Awetbekalsi Kebelle (10)*
What does food security mean to you and how do you see the food security situation of your community in your Kebelle?	Food security means getting enough food and feeding family for 12 months. Most of famers in our Kebelle couldn't feed themselves	Food security means producing enough crops to feed family. Most of farmers in our Kebelle depend on aid to feed their family when drought has occurred which is a nowadays occurring on annual base.	Food security means producing enough food crops and rainfall is affected household food security in our Kebelle	Food security means getting enough food and feeding family for 12 months. Most of famers in our Kebelle couldn't feed themselves
What are the factors affect food security in your Kebelle and what should do to improve food security	Low soil fertility, shorten period of rainfall, less access to agricultural fertilizers	Low soil fertility, shorten period of rainfall, limited access to agricultural fertilizers, small land ownership	Low soil fertility, shorten period of rainfall, limited access to agricultural fertilizers, small land ownership	Low soil fertility, shorten period of rainfall, limited access to agricultural fertilizers, small land ownership, infestation of insects and pests,

in your Kebelle?				no access to improved varieties of crop seeds
How do you see the coping capacity and what should do to improve households' adaptive capacity to shocks and food security in your Kebelle?	Low capacity to cope any shocks and the solution is controlling family size and improve crop productivity relocation and access to clean water for home consumption	Low capacity to cope any shocks and the solution is controlling family size, access to irrigation and improve crop productivity	low capacity to cope any shocks and the solution is more aid, reforestation practices and improve access to education	Low capacity to cope any shocks and the solution is improve access to irrigation facilities and improved varieties of crop seeds

Source: Fieldwork, 2016/2017

6.2.8 Findings from key informant interviews

The key informant interview results were presented in two themes, namely; food security situation and, factors that affect households' access to food and the possible solutions.

A. Food security situation

All the key informants stated that the food security situation in the Kolla Temben District is getting worse and most of the farmers were not in a position to feed their families continually throughout the year. Nowadays, food aid is becoming very important in feeding the families in Kolla Temben District. One key informant from New Kebelle said and quoted" my *grandfather had no problem to feed his family. At that time, we had no problem as a family to feed ourselves from own farm production. We were in a good condition but at current times even feeding our own families from own production is becoming very difficult and challenging"*. Other participants from Begasheka Kebelle said and I quote *'nowadays the only option we have to feed our family is to look for food aid from the central government or to migrate to other places to look for daily labour'*.

B. Factors affecting farmers' access to food and the suggested possible solutions

All the key informants (KI)stated that large family size, low soil fertility, rainfall fluctuation, shorter of rainfall period, and farmland topography as factors that affect farmer's ability to get access to enough food to feed their families. One participant from Atakility Kebelle said and I quote *'many years ago my family size was small in size, farmland fertility status and rainfall situation were good. I had no problem to feed my family but nowadays, the soil fertility status of my farmland is very poor, agricultural fertilizers are very expensive, our families are getting large in size but the farmland size we possessed is still the same as it was many years ago'*. The solutions suggested by the key informant interview participants were; improve soil fertility, control family size, more access to irrigation, availability of improved varieties of crops at Kebelle level and improve farmer's farmland size.

6.3 Discussion

6.3.1 Household adaptive capacity and food security

Razak and Kruse, (2017) revealed that majority of farming households in Sub-Saharan Africa have low adaptive capacity to climate change impacts. This supports the findings of this study which shows that 52.3% of the households interviewed had low adaptive capacity, 34% had medium capacity, while only 13% had high adaptive capacity. Razak and Kruse (2017) also reported that economic resources, access to technology and level of awareness to climate change impacts have significant impacts on farmer's adaptive capacity but Table 6.17 revealed that family size, crop productivity, access to water, irrigation and crop varieties had impacts on famers adaptive capacity to climate change impacts. This was because of farmers differences in livelihood bases, location specific indicators of adaptive capacity and disproportional distributed climate impacts. This is in agreement with this result that most of the developmental activities undertaken in Kolla Temben District were contributing less than what is expected to improve household's adaptive capacity to climate change impacts (Table 6.1). This study also makes it obvious that if the current development policy continues without transformation to incorporate climate-resilience aspects in agriculture and food production, then, many households could be affected severely by climate related hazards. This is in agreement with the result of Campbell et al. (2016) that interventions and adaptation is most relevant to those most vulnerable and with less adaptive capacity to climate impacts.

Dependency ratio, family size and incidents of illness are the main indicators of food insecurity (Haddad and Kennedy, 1994). Titus and Adetokunbo (2007) also revealed that food insecurity incidence is influenced by the age of household head, family size and dependency ratio. This is in concurrence with the results of this study that households with more family members, more terminal illness cases, and higher dependency burden have less adaptive capacity to climate change impacts and are more food insecure (Table 6.2). This shows that household's family member profiles influence food security status and adaptive capacity to climate change impacts.

Further, Mamo and Ayele (2003) reported the average farmland ownership in Libokemkem District of Northern Ethiopia is 0.81 and 1.02 ha for female and male headed households respectively. Later, Kidane et al. (2005) reported that food secure households had 1.5 ha more compare with food insecure households in Oromiya Regional State, Ethiopia but failed to see its implication to adaptive capacity to climate impacts. Recent findings by Antwi-Agyei et al. (2015) revealed that more access to farmland is vital to improve farmers' adaptive capacity to climate impacts in Sub-Saharan Africa. This supports the current field study result indicated in Table 6.3where the majority of the households (41.5%) in the District were found with small farmland holding status (between 0.26 and 0.50 hectares). This shows that small farmland ownership is one of the factors that affect household's adaptive capacity and food security.

Wheeler and Von (2013) reported that climate change and variability will exacerbate food insecurity in vulnerable communities. This supports the results from Table 6.5, Table 6.7 and Table 6.8 that the higher the adaptive capacity to climate impact and the higher the probability of a household being food secure. This is consistent with the findings of Hoffmann et al. (2009) that farmers' awareness positively influences food security. Babatunde et.al. (2007) revealed that household income and family size, educational level of head of households and total production are the major determinants for household's food security. This is in tandem with this finding that controlling family size and improve crop productivity are the best solutions to improve household's food security and to build adaptive capacity to climate change impacts (Table 6.17 and section 5.2.8). Recent findings by Wossen et al. (2018) suggested improving farmer access to credit and subsidies of agricultural fertilizers to moderate adverse impacts of climate change on agricultural production. This is in agreement with the results from the focus group discussion and key informant interview (Table 6.17 and section 6.2.8 ‘b’) that rainfall variability, low adaptive capacity to climate change impacts, limited access to agricultural inputs (fertilizer and improved varieties of crop) pests and insect infestation have negatively affected farmer households food security. This confirmed that households food security is under the stress of climatic and non-climate factors. This also shows that the issue of climate change has changed the conventional discourses of taking the problems of food security as production and consumption to include adaptive capacity to climate change impacts. This substantiate that food security was influenced by the adaptive capacity and affirmed that concentrating solely on input supply, production and market was not the right direction to improve household food security.

6.3.2 Agricultural Extension

Harvey et al. (2014) reported that revitalizing farmer agricultural extension services is very important to address households’ vulnerability level to climate change impacts. This supports the results of this field study that households that had access to agricultural extension services had higher adaptive capacity compared to those who had no access (Table 6.15). Prokopy et al. (2015) reported that agricultural extension services have critical role in educating farmers how to effectively adapt climate change impacts. Molua al. (2010) noted that the performance and governance of agricultural extension services are important to overcome climate challenges. This is in tandem with findings of this field study that majority of households (40%) recommended the need for improved agricultural extension services delivery system to moderate climate impacts (Table 6.13). Households were expected to utilize all information and technical advices provided by extension agents to improve their productivity. A majority of households (56%) said that the agricultural extension services provided to them were not consistent with their actual needs (Table 6.15). The field study also revealed that households were forced to buy chemical fertilizers directly channelled from the government a top -down approach (Table 6.15). This clearly shows that development agents in the study were not working according to the basic principles of the agricultural extension services and the needs of households (Table 6.15). This make clear that access to agricultural extension delivery in the area is low even though the country has deployed tens of thousands of development agents in each village administrations across the country to provide free and effective agricultural extension services at household level (Table 6.4).

Ali et al. (2017) revealed that temperature increase, rainfall decrease and relative humidity greatly impacts on crop yields and farmers access to food negatively but to failed consider household's farmland size and solely focused on environmental factors. Table 6.17 revealed that limited access to agricultural fertilizer and improved varieties of crop have negatively affected household food security (Table 6.17). Table 6.6 reported that the major factors that restricted farmers ability to access food were; rainfall fluctuation, small farmland holding, rainfall decreasing; and frost incidences, high wind speed, weeds, pests and insect infestation (Table 6.6). This shows that farmers ability to access food determined both by climate and non-climate factors.

Singh et al. (2013) suggested water harvesting practices as the best solution to achieve food security. Rosegrant and Cline (2003) also reported that crop yields have impacted by less investment in research and infrastructure and water scarcity but Table 6.17 reports that rainfall fluctuations, limited access to irrigation and improved varieties of crops have negatively impacted agricultural production and household's food security status (Table 6.17). This shows that limited access to irrigation and improved varieties of crops agricultural production negatively affected agricultural production and food security.

6.3.3 Resilience building

Bene et al. (2016) reported that policy makers and donors are more interested in resilience and adaptive capacity building than address food insecurity. Moloney and Funfgeld (2015) revealed that weak institution and governance at the local level negatively affect household adaptive capacity to climate change impacts but Table 6.17 revealed that big family size, less crop productivity, less access to education and water, no irrigation, deforestation and less to education are the factors that affect households adaptive capacity to climate impacts and food security. This was because of the differences in farmer's livelihood base and the types of impacts received. This is in agreement with results of this field study that the severity of climate impacts determined not only by the extent of the impacts but also by institutional strengths at grass root level (Kebelle level) (Table 6.16). This also supports the result of Table 6.9 that the impacts of climate change at household level were worsening because of government mismanagement practices. Also, the focus group discussions results in Table 6.17 uniquely reported that low soil fertility, limited access to agricultural fertilizers, small farmland ownership and limited access to improved varieties of crops are the factors negatively affected food security.

Brook et al. (2005) revealed that political and civil rights, good governance and literacy improve household's adaptive capacity to climate change impacts. Later, Eakin et al. (2014) reported that less effective institution can undermine adaptive capacity. This supports the results of this field study that improvement of governance at Kebelle (Village) level was seen as important and most cited (26%) by the households (Table 6.14). This is also in agreement with results of Table 6.16 that the introduction of effective monitoring systems of programs and services were found as an immediate need of 20.9% households to facilitate making villages more resilient to climate change impacts. This finding supports that of Bulkeley et al. (2009) who reported that good governance, effective monitoring and efficient institutions are fundamental to building resilience to climate change impacts. Zomer et al. (2008) revealed that reforestation helps to reduce greenhouse gas emissions and achieve sustainable agricultural development and build resilient to climate impacts. This is in agreement with results of this field study that the introduction of mass reforestation practices has recommended as an appropriate action to build climate resilient agriculture (Table 6.12). Focus group discussion results in Table 6.17 reported that controlling family size, improving productivity, access to water for drink, aid, relocation of farmers, irrigation and reforestation practices are important for resilient building. This confirms that resilient building depends on location, specific impacts, topography and households' circumstances.

Mubaya et al. (2012) revealed that less access to chemicals for crops and livestock and unavailability of improved seed varieties as major problems for farmers' level of productivity. This is in agreement with the results of this study that low soil fertility and lack of improved varieties of crops have negatively impacted farmer's total agricultural production and food security status but this study mentioned shorten period of rainfall, less access to fertilizer and small farmland size ownership as additional factors that affect production (Table 6.17).

Improving access to water for irrigation is very important to enhance the resilience of the most vulnerable rural poor and to improve food security status (Table 6.11). This is in agreement with Taylor et al. (2013) that availably of ground water will be very curial to improve food security as precipitation variability and the frequencies of drought will intensify under the ever changing climate. Earlier, Turral et al. (2011) also reported that access to water for irrigation is curial to ensure households food security but the local farmers (Table 6.17) added soil fertility, access to agricultural fertilizers and shorter gestation crop varieties as very important elements.

6.4 Conclusion

Most of farmers have low adaptive capacity to climate change impacts due to limited access to economic resources and technology and conflicting policies. Ineffective public service delivery system and less access to productive assets have exacerbated household's food insecurity. Poor health status, big family size, small farmland size, higher dependency ratio, rainfall variability, low adaptive capacity to climate change impacts, less access to agricultural inputs and insect infestations are negatively affected household food security. Household's adaptive capacity level to climate change impacts has a positive correlation with household's food security status. A household with highest adaptive capacity is likely to be more food secure.

Agricultural extension services have critical role in facilitating adaptation strategies and moderate climate impacts at household level. Agricultural extension services delivery need to be re -innovated to help farmers to improve their agricultural production in the ever changing climate. Climate change impacts accompanied with less access to agricultural extension and inputs are negatively affected households adaptive capacity to climate change impacts and food security.

Severity of climate change impacts on agriculture determined not only by the extent of the impacts on the sector but also the institutional strength at local level, low soil fertility, less access to agricultural input, irrigation, availability and access of improved varieties of crops. Resilient building is very important to moderate the adverse impacts of climate change and improve food security.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 General Conclusion

Temperature in northern Ethiopia is increasing very rapidly; more than global climate models project for the area. The pace of temperature rise in North Ethiopia is more than double compared with the rate a hundred years ago. This trend is exposing the area to various climate extreme events and makes smallholder farmers vulnerable to climate change impacts. Global climate modelling results are not enough to make conclusion on local level climate change impacts. Climate change is impacting smallholder farmer households in different degrees depend on their level of vulnerability, adaptive capacity and the adaptation strategies they used to adapt to the changing climate. Vulnerability to climate impacts is one of the major factors negatively affecting agricultural production and total income. Vulnerability to climate change has negative relationship with household's total agricultural production. The more a household is vulnerably to climate change impact, the less in agricultural production and total income. Households with lower vulnerability level to climate change impact has significant higher total income, livestock ownership status and more annual agricultural production compared to highly vulnerable households.

A majority of farmers perceive that rainfall is decreasing and temperature has increased. Farmers perceive that the frequency of occurrences of heavy rainfall, drought and malaria incidents are increasing. Smallholder households' perceptions to temperature trend change are consistent with scientific research findings except that they do not understand long term consequences of these changes on their livelihood bases and health status.

Adaptation practices are very important to sustain agricultural growth, reduce vulnerability and moderate impacts. Farmers use their own adaptation strategies to improve agricultural production. Farmers within the same location and weather condition can use different adaptation strategies. The soundness of farmer's adaptation decision determines the growth potential of total agricultural production. There is significant positive correlation between the use of adaptation strategies and increased agricultural production. All adaptation strategies no have similar contribution on enhancing agricultural production and some have no significant impact on agricultural production improvement. Short gestation crops, drought resistant crops varieties and irrigation are the most effective adaptation strategies on crop production.

The severity of food insecurity at household level has direct link with the level of vulnerability and adaptive capacity to climate change impacts. Subsistence farming communities have low adaptive capacity and a highly vulnerable group to climate variability. Households with low adaptive capacity are the most susceptible groups for food security problem. Household's adaptive capacity to climate change has a positive correlation with food security status. Household's food security status depends on household's adaptive capacity and climate variability. So concentrating efforts solely on inputs, productions and market facilities are not the right direction to improve household's food security status. The issue of climate is changing the conventional discourses of the trouble of food security from production and consumption to the new concept of adaptive capacity and reduction of vulnerability. The issues of food security are highly interrelated with household's adaptive capacity. A household with highest adaptive capacity to climate change impact has high probability to be food secure.

Implication of the findings are: climate is changing and therefore it is important that the smallscale farmers build their capacity to adapt to these changes which are already affecting their food security; farmers perceptions of change are consistent with instrumental data which indicate that the changes that have occurred have been large enough to have a discernible impact on them and they need to match the change impacts with appropriate and sustainable adaptation strategies; farmers use many adaptation strategies but do not know which ones are the best to build resilience to climate change – this study has shown that irrigation, drought resistant crop varieties, and short gestation crops are the three most effective strategies which should be accompanied by sustainable land management practices.

7.2 Recommendations

This research has suggested the following recommendations for new insights, policy strategies, practices, further study and future research needs.

1. The District and Regional State planning offices should put more emphasis on enhancing households adaptive capacity to climate change through improving family health, access to agricultural extension and education, improve farmland ownership size and reduce household dependency burden and diversify sources of livelihood to improve food security.

2. Farmers should be well trained on irrigation and water harvesting effectively use for irrigation to moderate adverse impacts of climate to improve their total agricultural production and annual incomes.

3. Adaptation preparation at Kolla Temben District and Tigray Regional State level needs a bottom up approach to address location specific adaptation needs and to respond to climate change impacts appropriately. Bottom-up adaptation strategies should be given a priority in climate policy documents as households are feeling climate impacts to varying degrees. Households in Kolla Temben District should be encouraged by the district agriculture and irrigation officers to use improved varieties of crops that can resist drought, diseases and pests and to fully participate in water harvesting practices as adaptation strategies to climate change impacts.

4. Agricultural experts and Regional State governor should sensitize and raise awareness among households on the main causes for household's vulnerability to climate change impacts.

5. Agricultural experts and Regional State governor should aware of the implications of temperature increase, rainfall decreasing, large family size, deforestation, -Soil fertility problem, high price of fertilizer, small landholding, flood, land slid and hazard problems. Other factors to consider also include: less access to education, health and water, high household's dependency burden, low household's adaptive capacity to climate change and lack of area specific adaptation options on agricultural production, total income, food consumption and food security.

6. The existing policies in place on food production should be revised to deal the with newly emerging climate change impact related challenges. Household's adaptive capacity to climate change should be improved through policy interventions that can facilitate household's access to social services, potable water and basic economic sources. Further, policies that are regulating the agriculture sector should accommodate issues like irrigation facilities, household's exposures level to flood, landslides and farmland topography status beyond production, marketing, consumptions and input supply as the

environment and the health of the climate system is very important to sustain agricultural growth.

7. Improving farmlands resilient to climate change impacts through reforestation, improvements of household's adaptive capacity to climate change impacts and effective public services delivery system are the suggested interventions by majority of farmers to address food security problems at household level.

8. More location specific research is recommended to identify the adaptation strategies most effective to increase agricultural production.

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APPENDIXES

Appendx 'A' Conversion factor (TLU).

Animal Category	TLU	Animal Category	TLU
Calf	0.25	Donkey (young)	0.35
Weaned Calf	0.34	Camel	1.25
Heifer	0.75	Sheep and Goat (adult)	0.13
Cow and Ox	1.00	Sheep and Goat (young)	0.06
Horse	1.10	Chicken	0.013
Donkey (adult)	0.70		

Appendix 'B' Multicollinearity Test (VIF)

Variables	**Multicollinearity test (VIF)**
(Constant)	
hh total annual crop production in Kg	1.072
Household Total income in ETB	1.100
households livestock owenership in TLU	1.159
houshold total annual food consumption in Birr	2.061
Food consumptions per adult equivalent	1.912
hh total annual crop sales in Kg	1.008
household annual food consumption in kg from aid	1.077

Variables	***Multicollinearity tests (VIF)***
Households using different planting dates as adaptation strategies to changing climate	1.124
Households diversify farm activities as adaptations to changing climate	1.155
Household changed from livestock to crop production as adaptation strategies to climate change	1.434
Households using irrigation facility as adaptation strategies to climate change	1.522
household practicing soil conservations as adaptation strategies to climate change	1.342
Households use drainage as adaptation strategies to climate change	1.300

households used increasing cultivated land as adaptation strategies to climate change	1.207
Household used short gestation crops as adaptation strategies to climate change	1.150
Household use flood tolerant crops as adaptation strategies to climate change	1.161
Households used drought tolerant crop as adaptation strategies to climate change	1.216
Households used disease and pest resistant varieties as adaptation strategies to changing climate	1.095
Households used water harvest practices as adaptation strategies to climate change	1.210

Appendix 'C'

Conversion factor used to compute adult equivalent (AE).

Age Group (years)	Male	Female
< 10	0.6	0.6
10 – 13	0.9	0.8
14 – 16	1.00	0.75
17 – 50	1.00	0.75
> 50	1.00	0.75

Appendix 'D'Questionnaire

1. Household head

1.1 Name of households head/optional/ ------------------------------------ 1.2Annual Land Tax in Birr______

Sex (0) Female 1) Male------. Age------ educational level; (0) No formal education, (1) Reading and writing (2)1-4 grade (3)5-8 Grade, (4) 9-12 ,5) Diploma (6) First Degree and above

2. Field worker and Kebele**.**

2.1. Name of Enumerator------------------------2.2. Name of kebelle -------------------

2.3. Date of Interview --2.4. Signature--------------------------
-

3. Brief stories of households

3.1Pleasethink of the current situations of climate vulnerability and its impacts to food production (food security, agricultural productions and annual income)
What is happening or what happened?

____
____
____
____
____
____
____
____
____
____
____
____
____

3.1.2 What is the cause of the situation you mentioned?

____
____
____
____
____

3.1.3 What is the effect of the problem in your life?

____
____
____
____
____

3.1.4 In your opinion what actions should be taken to address the issue?

____
____
____

3.1.5 What are the factors that affect your ability to access enough food?

3.1.6 For how many times these issue happening

3.1.7 Who can be responsible to these situations?

3.1.8 What is your need with this situation?

3.1.9 What actions government should have taken to address the issue

3.1.10 what are the wrong actions been taken and what actions you recommend to be corrected?

____

____

3.1.11 By the government

____

____

____

____

3.1.12 By the framers

____

____

____

____

____

3.1.13 By the DA

____

3.1.14 experts

____

____

____

3.1.15 by the district administrators

____

____

____

____

Put in descending order based on the importance in your life_____ (0. Livestock, production 1. Crop production 3. Both equally important)

Which one is most important? Put in descending order starting from the most impacting to the least

(1. Miaze 2. Teff 3. Sorghum 4. Millet 5. Bean 6. other) 1. _________2. ______3. ____4_____5__6—other

Which one is most important? Put in ascending order

(1. Cattle 2. sheep 3. goat 4. poultry) 1. ____2. _____3. ______4. __________

4. Household Vulnerability, Agricultural Production and Income

4.1 Which factors are most affecting your agricultural productions?

Put orderly starting from the most affecting you to the least influence it has --

01. Rainfall variability 02. temperature rise 03 speedy wind 04. Flood 05, Soil fertility problem, others------------

4.2. Which one is highly impacting by changing climate? Put orderly starting from the most impacted to the least

____

01, sheep and goat 07.human health

02, milking cow 08. others, specify--------------------------------

03. Cows

05. Oxen

06. Chicken

4.3. What solutions you recommend to solve these problems

____

____

____

4.5. Which one of the following is affecting your livelihood base? Put orderly starting from the most impacting you to the least

0. Flood
1. Drought
2. Rainfall starts late and ends soon
3. Low rainfall become in low in amount
4. High temperature
5. Other specify

4.6 Household family information

Please would tell us your family member (Living with you) details like age and sex

Age category (years)	No of family member at each age category	
	Male	Female
Less than 10 year old		
10-13 years		

14-16 years
17-50 years
Greater than 50 years

5. Please mark the following based on your status

Categories	Cluster	Households status twards;	Choose one
Household's exposure level to climate change impacts	Biophysical Biophysical	High flood incidents	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Landslide incidents	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Extreme temperature events	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Wind extreme events	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		House damage by intense rainfall	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Farmland's exposure to flood	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Farmland difficult for farming	Very low = 5, Low = 4, Medium = 3, High = 2 , Very high = 1
		Soil fertility status	Very low = 5, Low = 4, Medium = 3, High = 2 , Very high = 1
		Waterborne diseases because of contamination by floods	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
Household's sensitivity to climate change impacts	Socio-economic	Types of Agriculture practices?	Agriculture without irrigation/fully rain dependent =2, with same irrigation supplement = 1, Agriculture with fully depend on irrigation = 0
	Socio-economic	Sources of energy for cooking energy source	Electric or Kerosene = 0, wood fuel or charcoal = 1, Exclusively depend on wood fuel = 2

	Socio-economic	Sources of water for domestic use	Piped water = 0, Spring water = 1, both = 2
	Socio-economic	Sources of household's livelihood	Fully Agriculture = 3. Agriculture and safetynet program = 2, Agriculture and non-farm activities = 1
	Socio-economic	Household assets in Ethiopia Birr (ETB)	<14,863 = 0, ≥14863- 16,332.20 = 1, 16333-190,300 = 2
	Socio-economic	Household land size hectare in ha	0ha = 0, <.25 ha = 1, ≥.25-0.5 ha = 2, >.05ha-1 ha = 3, >1ha-1.5 ha = 4, >1.5ha = 5
Household's Adaptive capacity to climate change impacts	Socio-economic	How many times hhs getting Agricultural Extension, services in year	Not all = 0, 1-2 times a year = 1, monthly = 2, Weekly = 3, Daily = 4
	Socio-economic	No of family member has attended or attending school	Three and above = 3, Two family = 2, One family member = 1, None = 0
	Health	No of family members have terminal illness?	Three and above = 0 two family = 1 one family member and above , None = 3
	Health	No of family member has physical disability	Three and above family member = 0, two family = 1, one family member = 2 None = 3
	Socio-economic	No of family members under working age group as local standard?	Three and above = 0. two family member = 1 one family member = 2,None = 3
	Socio-economic	Frequencies hh visited by development agent and health extension workers in a year	Not all = 0, 1-2 times a year = 1, monthly = 2, weekly = 3, Daily = 4.
	Socio-economic	Hh residents distance from public transport,	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residents distance education	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-	Hh residents distance	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2,

economic	from Kebelle centre	>15 Km = 1
Socio-economic	Hh residents distance from health station	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
Socio-economic	Hh residents distance from URAP road	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
Socio-economic	Hh residents distance from market centre	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
Socio-economic	Hh residents distance from agricultural extension station	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1

6. Agricultural production and incomes

6.5.1 Crop productions and incomes from the sector

Please would you give us the total income you earn from crop sales?

Type of crop you Produced	Amount you sales in the market in Quintal		Total income obtained In Birr
	Produced	Sell	
Teff			
Maize			
Sorghum			
Millet			
Barely			
Nug			
Adanguare			
Others			

6.5.2. Livestock size and Income from the sector

Do you own livestock? 1. Yes 2. If yes, indicate the number of livestock you have and income earned

Type of livestock	Number owned (At the time of interview)	Number sold	Total income obtained In Birr
Cow			
Oxen			
Goat			
Sheep/Adult			
Sheep/Young			
Poultry			
Calf			
Weaned calf			
Donkey /Adult			
Donkey/young			
Heifer			
Camel			
Horse			
Chicken			
Others			

6.5.3 None Agricultural Income

Do you or any member of your family have off –farm/non-farm job -----1. Yes 2. No;

If yes indicator the type of work and annual income for the years 2015

Family names	Types of job	Annual income

6.5.4. Have you received any other income (such as remittances?

gift aid or other transfer in 2015 ------1. Yes 2. No;

if yes indicate the amount in ETB-------------------------

6.5.4.1. Indicated the amount of food aid your house hold received

Types of food items provided	Amount consumed in kg	Amount sold and income	
		Amount kg	Value in birr
Wheat			
Maize			
Money			
Others			

6.5.5. Household Food expenditure

6.5.5.1. Indicate the type amount of food expenditure of your family for the year 2015 (2007 E.C).

We would like to ask you about all the food that was bought for consumption and or was consumed from your own stock for past 12 months

Food type You consumed in the past 12 months	Total food consumed		Total food Consumed from own harvest		Total food Consumed from Food aid		Total food Consumed from Purchased		Total food consumed from gift /remittance	
Foods	Amount (Quintal)	Value in birr	Amoun(Quintal)	Value in birr	Amoun(Quintal)	Vale in birr	Amount (Quintal)	Value in birr	Amount (Quintal)	Value in birr
Maize										
Sorghum										
Wheat										
Teff Other										

Do your livestock? 0. No 1.YES, if yes fill the following

Asset types	No	Value in ETB	Code
How many sheep do you have?			
How many goats do you have?			
How many cattle do you have?			
How many chickens do you have?			
How many saved money do you have?			

6.6 Land ownership

Do you have land? 0. No 1. Yes, if yes please fill the following

	Codes				
How much is you Land size hectare ?encircle from the list below	0	1	2	3	4
0 ha					
0.-.25 ha					
.26-0.5 ha					
.056-1 ha					
1.01-1.5					
Greater than 1.5 ha					

7. Working with farmers for Adaptation and assessing perceptions

7.1. Have you heard about climate variability/ change before? (A). Yes ________(b). No__If yes, what is your understanding of it? ____

____

7.2 From what source(s) did you hear it from? (Tick as appropriate)

(i) Weather station (ii) Extension Agents (iii) Radio (iv) from FTC

(v)Other sources (specify): ____

7.3 The following are mostly occurring event? (Encircle)

1. There is changed rainy period these days (0. No, 1. Yes)
2. There is longer dry season these days (0. No, 1. Yes)
4. There is stronger wind these days (0. No, 1. Yes)

5. Warm temperature (0. No, 1. Yes)
6. Frequent occurrence of drought (0. No, 1. Yes)

7.4. How will you describe the present weather conditions in your areas compared with the situation about 30 and above years ago? (use x)

7.4.1 Rainfall Characteristic	Perceived Change by the farmers			
	Increase	Decrease	No Change	Others
1. How is the Rainfall Amount compare with the past 30 years and above?				
2. How is the Rainfall Intensity compare with the past 30 years and above?				
3. How is the Rainfall Pattern compare with the past 30 years and above?				
4. How is the Duration of rain compare with the past 30 years and above?				
5. How is the Early Onset of rain compare with the past 30 years and above?				
6. How is the Late cessation of rain compare with the past 30 years and above?				
7.4.2 Temperature Characteristics				
Characteristics	Increase	Decrease	No change	
1. How is the Duration of temperature compare with the past 30 years and above?				
2. How is the Intensity temperature compare with the past 30 years and above?				
7.4.3Wind Characteristics				
Characteristics	Increase	Decrease	No change	
1. How is the Speed of wind compare with the past 30 years and above?				

2. How is the Pattern of wind compare with the past 30 years and above?				
7.4.5 Relative Humidity				
Humidity in your areas	Increase	Decrease	No change	Others
1. How is the Intensity of humidity compare with the past 30 years and above?				
2. How is the Durations of humidity last compare with the past 30 years and above?				
7.4.6 Sunshine Characteristics				
Characteristics	Increase	Decrease	No change	Others
1. How is the Duration of sunny time compare with the past 30 years and above?				
2. How is the Intensity of sunny time compare with the past 30 years and above?				
7. 4.7 Hazard Characteristics	***Increase***	***Decrease***	***No change***	
Hazards and related events				
How is Soil Erosion intensity in the past 30 years compare with the past 30 years and above?				
How is the Flooding intensity compare with the past 30 years and above?				
How is the Early rainfall compare with the past 30 years and above?				
How is the Late rainfall frequency compare with the past 30 years and above?				
How is the Shorten rainy time frequencies compare with the past 30 years and above?				
How is the Long dry season compare with the past 30 years and above?				

Short dry season compare with the past 30 years and above?
How is the frequency of High-wind-speed compare with the past 30 years and above?
How is the frequency of Excessive heat compare with the past 30 years and above?
How is the Water born disease compares with the past 30 years and above?
How is the Malaria incident compare with the past 30 years and above?
How is the Drought frequency compare with the past 30 years and above?
How is the Heavy rain incidents compare with the past 30 years and above?
How is the Conflicts compare with the past 30 years and above?
How is the Migration compare with the past 30 years and above?
How is the frequency of occurrence of Conflicts for grazing compare with the past 30 years and above?
How is the Newborn baby death rate compare with the past 30 years and above?

7.5 Which of the following measures does your use to adapt to the changing?

Slno	Adaptation measures	Responses (0=No 1=Yes)
1	Did you use Planting different varieties of crops as adaptation strategies to changing climate **(0.No , 1.Yes)**	
2	Did you use Adopting different planting dates **(0.No , 1.Yes)**	
3	Did you use Diversifying from farm to non-farm activities as adaptation strategies to changing climate **(0.No , 1.Yes)**	

4	Did you use Changing from livestock to crop as adaptation strategies to changing climate**(0.No , 1.Yes)**	
5	Did you use Use of irrigation as adaptation strategies to changing climate **(0.No , 1.Yes)**	
6	Did you use Change of soil conservation technique as adaptation strategies to changing climate **(0.No , 1.Yes)**	
7	Did you use Use Drainage as adaptation strategies to changing climate **(0.No , 1.Yes)**	
8	Did you use Use Increasing hectares of land cultivated as adaptation strategies to changing climate **(0.No , 1.Yes)**	
9	Did you use of short gestation crops as adaptation strategies to changing climate **(0.No , 1.Yes)**	
10	Did you use Use of flood tolerant crops as adaptation strategies to changing climate **(0.No , 1.Yes**	
11	Did you use Use of drought tolerant crops as adaptation strategies to changing climate **(0.No , 1.Yes)**	
12	Did you use Use of disease/pest resistant varieties as adaptation strategies to changing climate **(0.No , 1.Yes)**	
13	Did you use Water harvest practices as adaptation strategies to changing climate **(0.No , 1.Yes)**	

14 If you use Other adaptation, please specify below

Which of these measures you mentioned are effective to you? (List them in order of importance/effectiveness)____

____

Appendix 'F'

Leading questions for key informant interview and group discussions

Guiding questions for Key Informant Interview and group discussion

My name is Alemu Addisu. I am a PhD student in the University of Nairobi. The main purpose of this key informant interview and focus group discussion is to collect same data on your personal experiences about your over all observations on the impact of climate change vulnerability toward food system and its outcome food security in the community. This is therefore to kindly request your kind responses on following specific questions.

Name--------------------------------Sex-----------------------Age-------------Education------------

Responsibility in the Community -----------------------Farming experience -------------

I

How do you see the issues of climate change in relation to agricultural production and annual?

1. What are the major factors affecting the Income of households in this Kebelle?
2. What is the impact of climate and weather variability in households' productions?
3. What are the areas which make agricultural most vulnerable?
4. What are the sources of vulnerability in this Kebelle?
5. What do you recommend to solve these problems?

II

1. What is food security mean to you?
2. How do you see the food security status of the community?
3. What are the factors affecting food security?
4. What needs to do to improve food security status of your kebelle
5. What are the factors that affect capacity of households to cope with any shokes?
6. What do you recommend to be done to improve household's climate households capacity and to improve food security statusthe government should do to improve hh food security?
7. What should be done by the community to improve food security?

III

1. What do you think about changing climate and households adaptation choices?
2. How do you see the change in rainfall and temperature?
3. What are the appropriate strategies to be done when rainfall start late and stop early?
4. How do you see the adaptation strategies of the community in such cases?
5. What are the best adaptation strategies in crop production with changing climate or variability like rainfall decrease and temperature increase?
6. What are the factor affecting the households to adapt climate change?
7. What are the most appropriate adaptation strategies for livestock productions in this Kebelle
8. What do you recommended to be done for an effective adaptation strategies (in the Livestock, crops, human health etc)?