Gender Dimension of Adaptation to Climate Change as Linked to Water-Energy-Food Nexus in Mecha Area, North-Westeren Ethiopia

Meseret Zewdu

A Dissertation Submitted to Centre for Environment and Development Studies, College of Development Studies

Presented in the Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Development Studies (Environment and Development Studies)

Addis Ababa University
Addis Ababa, Ethiopia
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DISSERTATION APPROVAL

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

This is to certify that the thesis prepared by "Meseret Zewdu" entitled: ***Gender Dimension of Adaptation to Climate Change as Linked to Water-Energy-Food Nexus in Mecha Area, North-Western Ethiopia*** submitted in fulfilment of the requirement for the degree of Doctor of Philosophy in Development studies (Environment and Development) complies with the regulation of the university and meet the accepted standards with respect to originality and Quality.

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Declaration

I, the undersigned, declare that this thesis is my original work and has never been presented in this or any other University for the award of a degree or otherwise. All the references and materials used for the thesis have been fully acknowledged.

Name: - Meseret Zewdu

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Date of submission: - 5/30/2020

Place: - Addis Ababa

This dissertation has been submitted for examination with my approval as University supervisor.

Supervisor name: - _____

Signature: - _____

Date: - _____

Supervisor name: - _____

Signature: - _____

Date: - _____

List of Original Papers

The following papers are extracted from the dissertation. Some of them were submitted to journals and others prepared as a manuscript to be submitted for publication.

1. Zewdu M., and Simane B, (2019). Local Spatiotemporal Climate Analysis: Temperature and Rainfall Variability in Mecha Area, North-Western Ethiopia, International Journal of Scientific Research in Multidisciplinary Studies Vol.5, Issue.12, pp.56-65.
2. Zewdu M., Simane B., and Alamirew B., (2020). Gender Dimension of Households' Vulnerability to Climate Variability in Mecha area, North-Western Ethiopia
3. Zewdu M., Simane B., and Alamirew B., (2020). Gender Dimension of Farmers' Adaptation to Climate Change in Mecha Area, North-Western Ethiopia
4. Zewdu M., Simane B., and Alamirew B., (2020). Understanding Gender Dimension of Water- Energy-Food Nexus and Climate Change Effects in Mecha Area, North-Western Ethiopia

Gender Dimension of Adaptation to Climate Change as Linked to Water-Energy-Food Nexus in Mecha Area, North-Westeren Ethiopia

Abstract

Ethiopia is suffering from climate extremes in the form of frequent flood and drought. Men and women experienced the impact of climate change differently, specifically in poor countries like Ethiopia. The link between the adverse effects of climate change and gender inequality is inextricable. Gender inequality aggravates vulnerability to climate change and decreases adaptive capacity because of poor access to vital resources including water, energy and food. This problem calls a need to investigate the gender dimension of vulnerability and adaptation to climate change as linked to water-energy-food nexus. The objectives of the study are to analyze spatiotemporal climate variability to assess gender dimension of households' vulnerability and adaptation to climate change and determinant factors to adopt adaptation technologies, and to explore gender dimension of climate change effects as linked to water-energy-food nexus in Mecha area, North-western Ethiopia. Using a household survey, quantitative data were collected from 416 randomly selected respondents and qualitative data were collected via in-depth and key informant interviews and focus group discussions. The research used inverse distance weighted interpolation tool, multinomial logit model and qualitative system dynamic approach: causal loop diagram to analyze the data. The research used statistical techniques such as means, frequencies, standard deviations, principal component analysis, t-test and one way between groups ANOVA. Findings reveal that warming trends of annual minimum and maximum temperature increased at a rate of 0.11 ^{0}C and 0.08 ^{0}C per decade, respectively. The mean annual and seasonal rainfall distribution shows statistically non-significant increasing trends. The results reveal that the vulnerability level of female-headed households is higher than male-headed households in the irrigation area. The findings further reveal that female-headed household' vulnerability level without irrigation was less than female-headed households with irrigation. Vulnerability level of male-headed households in the upper stream was more than male-headed households in the lower stream. Findings also showed that male and female farmers are different in undertaking adaptation options: more male farmers undertake adaptation options than female farmers. Further, findings reveal household heads' age, farming experience, land size and access to extension services have a significant effect for male-headed households wherea use of credit services and climate information have positively associated with female-headed households' selection of adaptation options. The last findings show that labour restriction, limited control over land and low income are major drivers that determined female-headed households' less access to water, energy and food. Climate-induced problems perpetuate female-headed households' limited access to productive resources. The results imply a need to introduce development strategies with a focus on female household heads for capacity building in different dimensions. Findings also suggest the need to gender-inclusive climate change policies with a wide range of institutional and technological support, particularly for the poorer and female household heads.

***Key words**: gender; household head; spatiotemporal variability; vulnerability; adaptation options; water-energy-food nexus*

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DEDICATION

This thesis is dedicated to one of my daughters, Meklit Zelalem

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List of Acronyms

ANOVA – Analysis of Variance
ARSDPPO - Amhara Regional State Disaster Prevention and Preparedness Office
CEDAW- Convention on the Elimination of all Forms of Discrimination Against Women
COP- Conference of Parties
CRGE – Climate Resilient Green Economy
CSA – Central Statistical Agency
EFCCC - Environment, Forest and Climate Change Commission
FDRE – Federal Democratic Republic of Ethiopia
FHH - Female-headed Household
FPE – Feminist Political Ecology
GAD – Gender And Development
GDP – Gross Domestic Product
GIS – Geographic Information System
IDW – Inverse Distance Weighted
IFAD – International Fund for Agriculture Development
IPCC - Intergovernmental Panel on Climate Change
MHH - Male-headed Household
MoWR – Ministry of Water Resources
MWFEO – Mecha Wereda Finance and Economics Office
NAPA – National Adaptation Program of Action
NCCF - National Climate Change Forum)
NMA - National Metrology Agency
PCA – Principal Component Analysis
TLU – Tropical Livestock Unit
UNEP - United Nations Environment Program
UNFCCC - United Nations Framework Convention on Climate Change
WED – Women Environment and Development
WEF - Water, Energy and Food
WHO - World Health Organization
WID – Women in Development

1. Introduction

1.1. Background of the Study

Changes in climate affect environmental systems on all continents and across the oceans (IPCC, 2007). Extensive poverty confined coping capacity and highly variable climate have made Africa one of the most vulnerable regions to climate change in the world (IPCC, 2014) though it has been the least responsible for contributing to climate variation (Alexander et al., 2011). Mubila et al. (2011) also noted that climate change represents one of the most challenging threats for all residing in Africa because of the sensitivity and fragility of its natural environment, and its excessive dependence on environment-based livelihoods, along with agriculture. Among the risks the continent faces: reductions in agricultural productivity, food security, and expanded water pressure resulted in accelerated exposure to disease and other health dangers to human health (Parry et al. 2007).

Ethiopia is among the ten countries that ranked most vulnerable to climate change in Africa mainly due to its dependence on natural resources (Vincent 2004). As such, the country has experienced each warm and cool years over the last 55(1951-2005) years: the recent years are the warmest in comparison to the past years. The temperature has been increasing by about 0.37 ^{0}C every ten years. The average rainfall of the country showed a top level of inter-annual variability (NMA 2007). The observed changes in the two parameters of climate have affected the livelihoods of the people, especially farm families. Further, the country is vulnerable to climate change because of its low adaptive potential and larger dependence on agriculture sector (Zeray & Demie, 2015) which relies upon climatic situations (IPCC, 2007). In addition, agriculture is sensitive to climate-precipitated water pressure which perpetuates the existing problems along with declining agricultural outputs, poverty and food insecurity that have an effect on smallholder farmers including female-headed households (Brown et al. 2012). Nevertheless, agriculture contributes plenty for the Ethiopian economy: makes up 52 per cent of the country's GDP, over 85 per cent of the foreign exchange profits, and about 80 per cent of employment (CSA, 2004).

Scientists projected climate change to reduce renewable surface water and groundwater sources considerably in most subtropical location; and to pose dangers to consuming water quality because of interacting factors: elevated temperature; and pollutant loadings from

intense rainfall; extended concentration of pollutants in the course of droughts; and disruption of remedy centres at some point of floods (Portmann et al., 2013). Unfavourable results of climate change on natural resources including growing water stress and decline in crop production enhance the vulnerability of many rural communities. Hence, these all negative results of the change in access to water and food are higher among the poor households who are living in environmentally vulnerable areas (Roehr, 2007).

There are considerable gender dimensions to climate change risks, adaptation, and vulnerability (Adger et al., 2007; IPCC, 2012). Gender dimensions of vulnerability derive from differential access to the social and environmental assets essential for adaptation. In many rural economies, natural, and useful resource-based livelihoods, women have poorer access than men to fundamental rights: economic assets, land, education, health, and others. In addition, drivers of gender disparity stem from social exclusion from decision-making approaches and labour markets, making women in specifically less capable of address and adapt to climate change effects (Rijkers and Costa, 2012; IPCC, 2014). Considering gender differences in vulnerability and adaptation can enable gender-touchy responses, decreasing the vulnerability of women and men (Alston, 2013). Assessment of adaptation funding that is not sensitive to gender dimensions and other drivers of gender inequalities reinforcing existing vulnerabilities (Arora-Jonsson, 2011).

There is a broad consensus around the need for policies focused to men and women whose livelihoods depend on weather-sensitive natural assets. Attention to gender, and particularly to rural women, is more and more valuable to debates on responses to climate change primarily based on the assumption they are more susceptible to climate shocks and stressors than men and their extra dependence on natural assets for fulfilling the food security desires of themselves and their dependants. Gender disparity made women politically and economically marginalized, hence less capable to influence policy process than men. In addition, regular emphasis on the value of women's knowledge and abilities should build up through their work (IFAD, 2009; Okali & Naess, 2013).

Otzelberger (2011) referred to that of a growing knowledge of climate change and gender not only requiring scientific solutions but also social, political, monetary, and gender-responsive solutions. The effects and perceptions of climate change vary at the local level, and additionally they vary among females and males and girls and boys. Together with both men and women in decision-making on climate change adaptation, and understanding the reasons

for and implications of their unique roles, responsibilities, and abilities is, therefore, definitely important for poverty decline and gender equality and successful climate-resilient development.

Adaptation has now emerged as an urgent policy priority, prompting movement both within and outside the climate change debates (Parry et al. 2005). Adaptation to climate change eases the unfavourable effects via a wide-range of system-specific moves (Fussel and Klein, 2002). Various institutional, monetary, social, and cultural elements constrain the planning and implementation of adaptation alternatives and potentially lessen their effectiveness. Adaptation planning and implementation might also require extensive inputs of know-how and human, social, and financial capital. Cultural traits which include age, gender, and sense of area affect risk perception, entitlements to resources, and choices about adaptation. Entitlements to resources can extend the variety of adaptation options that can help overcome the negative effects of climate change. The entitlements of actors to financial assets influence adaptive potential, however, women's entitlement to resources is poor (Devereux, 2001; Adger et al., 2007; IPCC, 2014).

Changing through the years, technology, access to economic resources and information, appropriate institutional offerings, social network, academic level, equity and political power are determinant factors that shape a households' adaptive capacity (Smith et al., 2000; Brooks et al., 2005). Adaptive capacity may fluctuate from one place and community to any other (Smit and Wandel, 2006) and it is dynamic in terms of scales, for instance, socioeconomic procedures influence the ability to respond to destructive impacts of climate change at the household level. Gender differentiated adaptive potential to climate change additionally exist between female- and male-headed households because of their different access to productive assets (Habtezion, 2013). Therefore, there is the need to provide a comprehensive understanding of the way different access to resources affect adaptive potential through an expression of the various adaptive strategies of households and groups that could use to reply to the unfavourable impacts of climate change.

1.2. Problem Statement

Change in weather patterns is affecting water resources in terms of quantity and quality in many parts of the world. Dire consequences of climate change on crop production have been more common than good consequences. Climate-related extremes, such as heat waves,

droughts, floods, and cyclones, reveal significant vulnerability and exposure for households. Climate-associated hazards aggravate other stressors, often with terrible results for livelihoods, specifically for people dwelling in poverty (IPCC, 2014). Studies projected that demand for water, energy and food will increase; and the supply side has been affecting by climate change (Allouche et al., 2014). Misselhorn et al. (2012) and Hertel, et al. (2010) reported that unfavourable impacts of climate change will have implications on human livelihood, particularly on agriculture resulting in a decrease in crop yield. The burden will be higher on the poorest people in their access to food. In addition, (Dubois et al., 2014) claimed that climate change has unfavourable effects on water resource, which is an essential component for agriculture. Agriculture dependent countries like Ethiopia will face a substantial challenge in access to water, energy and food resources without effective adaptation strategies to the changes in climate.

Climate extremes in the form of common flood and drought have been stricken Ethiopia (Di Falco, et al., 2008). The country is specifically at risk of climate change, given its massive reliance on rain-fed agriculture (Trocaire, 2014). The uneven distribution of rainfall and temperature has a terrible effect on crop yields at some stage in the growing seasons resulted in food shortages, farmers' poverty and in gender-differentiated vulnerability (Taye et al., 2010). In the Amhara region which includes the study area, drought and flood are the two climate occasions though the extent varies from district to district. The Regional Food Security and Disaster Prevention and Preparedness Bureau (FSDPPR) reported that flooding affected around 42,850 people; evacuated 12,571 households; and damaged 20,300 hectares of harvested land (UN OCHA, 2007). The households and communities in the area are vulnerable to impacts related to climate change observed within the last three decades. Low productivity and degraded natural resources affected farmers within the place. Many households in the region are facing large deficits in their basic food needs, following drastically below-average harvests. Those households are relying on humanitarian help as the principal source of food. Earnings from livestock sales are decrease than the ordinary because of poor livestock body conditions and prime supply on markets. 323 kebeles in the region are confronted with a severe water shortage because of drought (ARSDPPO, 2015).

The notion of gender and climate change is being inside the literature because the impacts and responses of climate change are not gender impartial (Skinner 2011). The link between climate change impacts and gender inequality is inextricable (WHO 2011). People

experienced unfavourable impact of climate change in unique ways in terms of their gender (IPCC, 2007). Men and women are differently suffering from climate change effects specifically in poor and growing countries which include Ethiopia. Women are the worst stricken by climate change because they are over-represented amongst the poorest people in the world. Globally, majority of the people residing in situations of poverty are women (Clancy et al., 2003).

In Ethiopia also, because of historic inequalities, women are more typically within the informal, household-level, and unpaid sectors of society resulting in higher vulnerability to climate change. They face demanding situations in accessing economic assets, taking part in labour and employment markets, and the usage of and enjoying natural resources which inhibit adapting to climate change. Further, women, especially in rural areas, suffer from poverty, which reduces their adaptive capability (EFCCC, 2018). Poor households typically face a variety of risks which are often financial, social and environmentally driven; and female-headed households are among the poorest groups. How poor households can deal with the effects of shocks and ongoing stresses depends on households' ownership and control of property: land, labour, financial capital, livestock, social networks, educational tier and so forth (Desta et al., 2006). The study area is not an exception for such form of inequalities between men- and women-headed households.

The gender dimension of access to and control over water resources and its management disrupted by climate change due to women's limitation in access to resources like labour, income, information and others which in turn affect their adaptive potential (Zwarteveen et al. 2012). Use of biomass as a domestic energy source is at the centre of climate which needs to take action to respond to climate change. In low-income countries like Ethiopia, access to modern energy sources is among the major livelihood challenges for the people living in poverty (Seager et al., 2016). In Ethiopia, 95% of the energy supply comes from biomass, primarily fuel wood (WHO, 2012). Female-headed households particularly affected by energy poverty because of their likelihood of living in poverty (UN economic and social council, 2006). Negative consequences of climate change in access to food are also gender-differentiated (FAO 2015). Incidence of food deficiency varies significantly among male- and female-headed households. Limited responses to unfavourable climate change impacts and limited access to productive resources such as land, credit/loan and institutional services generate food insufficiency in households headed by women (Gates, 2014).

Current gender disparity makes women more susceptible to climate change than men due to their inadequate access to crucial resources. Socio-cultural norms additionally influence their susceptibility to the change because of the gendered division of labour, mobility and participation in political and economic decision making (Adger et al., 2007; IPCC, 2014). Female-headed households have limited access to resources (Arora-Jonsson, 2011) leading to higher vulnerability to climate change effects and confined adaptive capacity (Adger et al., 2007; Aguliar, 2009). Gender disparity is the disadvantaged position of women which aggravated vulnerability to climate change with greater difficulty in coping with adverse impacts (Dankelman, 2008). Further, climate change risks vary between male- and female-headed farm households because of gender disparity that leads to differences in their degrees of adaptive capacity, though their exposure to climate extremes is comparable within a similar geographical location (Ahmed, 2012).

Women are more likely than men to work in the agriculture sector susceptible to climate change (Mubila et al., 2011). They are highly involved in agricultural activities and they are on the front-lines of the negative effects of any change in the climate. Women in poorer countries accounted for a minimum of 40% of the agricultural labour force. As an example, Ethiopian women accounted for 46% of the agricultural labour force (Vincent 2004) since most of them are engaged within the agricultural area (Debela, 2017). Women's competencies to work with the changing environment are essential to their satisfactory of lifestyles and to the survival in their communities. However, they are poorly equipped to make important adaptation strategies (Alexander et al., 2011).

Overall, gender and climate change have a vicious circle of worsening inequalities and influences (Aguliar, 2009). On the one hand, climate change slows progress towards gender equality and poses a challenge to poverty lessening efforts; on the other hand, gender inequality can further worsen the results of climate change because of uneven access to vital assets to respond to the unfavourable effects. As a result, gender is being taken into consideration as an important element and integrated into climate change adaptation policies to make sure the success and sustainability of development (Akintomide, 2009).

In Ethiopia, plentiful studies on vulnerability and adaptation to climate change examined based on spatial (agro-ecology) difference at a household level with little emphasis on the gender dimension (e.g. Deressa et al., 2008; Legesse et al., 2012; Tesso et al., 2012; Hadgu et al., 2015; Amare and Simane, 2017; Belay et al., 2017; Alemayehu & Bewket, 2016; and

Simane et al. 2016). These studies used female-headed households as an indicator in their vulnerability index considering a higher number of female-headed households increase vulnerability to climate change, and used these households as a determinant factor associated with decisions on adaptation options to climate change negatively.

Therefore, we argue that vulnerability and adaptation to climate change and the link with access to water-energy-food resources should be examined in terms of gender across male- and female-headed households separately to fill the existing knowledge gap because: 1) Gender relations determine the benefits that women and men can derive from natural resources (Watson, 2006). Female- and male-headed households felt negative climate change risks in a different way because of their unequal access to productive resources (Habtezion, 2013). Gender analysis emphasize on understanding the relationship among men and women in terms of roles, duties, access to and control over resources, power, benefit sharing and participation in decision-making at all levels (March et.al. 2005; Angula, 2008). As a result, the notion of vulnerability and adaptation to climate change is social issues critical for policy making and program intervention (Angula, 2008), 2) Male and female household heads have exceptional priorities and needs for adaptation because of gender-differentiated influences of climate change, 3) Gender-disaggregated information enhances development of gender-touchy climate change adaptation strategies, and 4) Gender disaggregated information on vulnerability, adaptation strategies and access to water energy and food resources also are crucial for triumphant implementation of policy interventions in response to climate change. Finally, empirical studies and pieces of literature concerning the link between female-headed households and unfavorable climate change effects are inadequate.

1.3. Objective of the Study

In line with our argument and response to the above-stated problems, the overall aim of this study is to examine gender dimension of vulnerability and adaptation to climate change as linked to water-energy-food nexus in Mecha area, Northwest Ethiopia. The specific objectives of the research are to:

1. analyze spatiotemporal variability of temperature and rainfall over the study area,
2. assess the gender dimension of households' vulnerability to climate change,
3. identify the gender dimension of adaptation strategies to climate change and determinant factors for adoption of adaptation options, and

4. explore the gender dimension of climate change effects as linked to water-energy-food nexus

1.4. Research Questions

The following fundamental questions guided this study.

1. What are trends, anomalies and spatial distribution of temperature and rainfall over the study area?
2. What are gender-differentiated exposure, sensitivity and adaptive capacity profile of households?
3. What are the different perceptions and adaptation options of climate change among male and female household heads?
4. What are the different factors determine male and female household heads' decision on the choice of adaptation options? and
5. What are gender-differentiated accesses to water-energy-food resources of households as linked to climate change effects?

1.5. Significance of the Study

This study provides empirical proof related to perception on climate situations, spatial and temporal variation of temperature and rainfall, vulnerability and adaptation to climate change, and climatic outcomes on resources to direct informed policymaking. The study presents scientific and gender-disaggregated knowledge to expand gender-sensitive rules, adaptation strategies and packages as well as to have gender-specific interventions. The study also offers knowledge on how gender inequality enhances households' vulnerability to climate change, decrease adaptive capacities of households and inhibits climate change responses. Besides, the outcomes of this study facilitate the question of gender equality in climate change policy dialogues and have implications on the way to better deal with other forms of social inequalities. The research also offers clue and serves as a reference for students and researchers who would like to pursue further studies from a brand new perspective and outlook of the link between vulnerability and adaptation to climate change, gender and water-energy-food nexus at the household level.

1.6. Scope and Limitation of the study

This study describes the inextricable linkage between gender inequality and vulnerability and adaptation to adverse effects of climate change, underlying factors and the role of resource ownership in reducing vulnerability, in increasing adaptive capacity as well as in access to

water, energy and food at the household level. This study is limited in investigating households' adaptation and vulnerability to climate change effects by gender without considering spatial differences. However, the climatic shocks facing all households in the study area are not the same by type and magnitude given elevation of the study area. Findings in chapter three confirm the existence of statistically significant spatial variation in temperature and rainfall. The other limitation of this study is the use of climate data from 1983 to 2014 six years back from 2020 that may create questions to associate with socio-economic data. National metrology of Ethiopia was asked to provide us rainfall and temperature data for 30 years back to 2017, however the institution was able provide us 32 years data for the above mentioned period. It was challenging to get empirical findings on female-headed households' access to resources, their vulnerability, and adaptation strategies in detail because most of the studies on gender-focused on intra-household assessments rather than assessments between male- and female-headed households, Further, the study used cross-sectional data which tries to capture a specific point in time; and may not be satisfactory to generate adequate information across time and within different contexts.

1.7. General Research Methodology

1.7.1. Description of the study area

The study was conducted in Mecha district, Amhara National Regional State, Ethiopia (Figure 1). Mecha district is situated at 500 km northwest of Addis Ababa, the capital of Ethiopia and 35km to the west of Bahir Dar, the capital of Amhara region. The total population of Mecha district is 375,716: 323,315 in rural areas and 52401 in urban areas. The study area lies between the coordinates 110 24' 62'' N latitude and 37º 08' 97'' E longitudes and has an area coverage of 156 027 ha. It is also situated at an elevation ranging from 1795 to 3268 meter above sea level (MWFEO 2015).

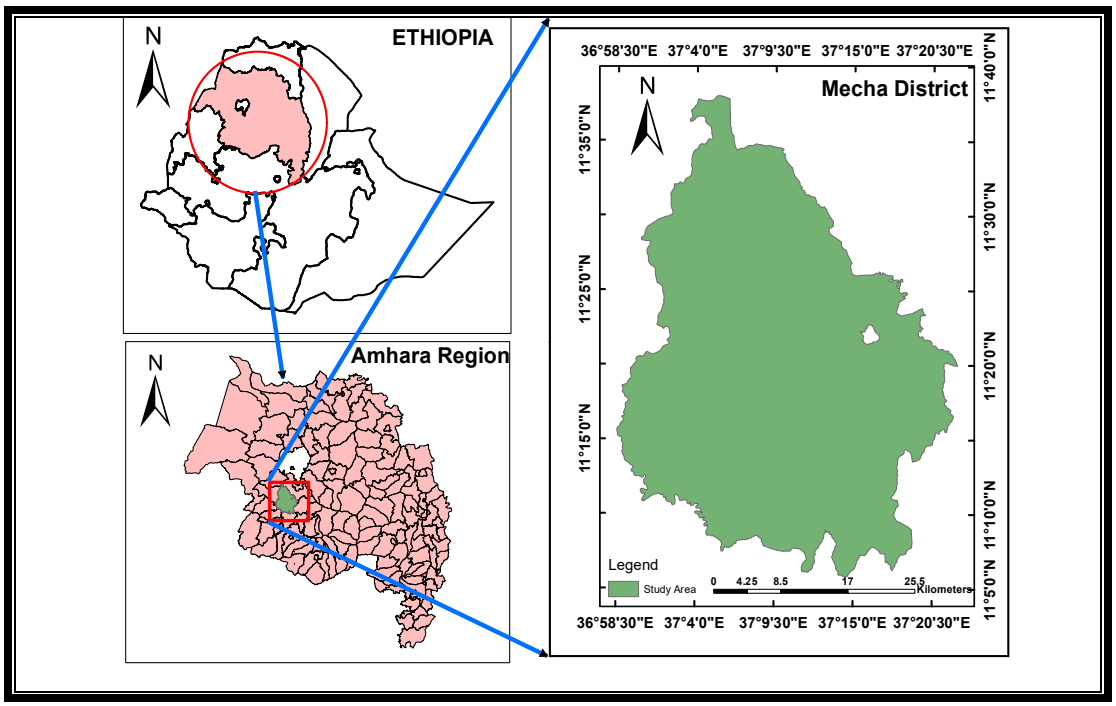


Figure 1: Location map of the study area, Mecha district (authors own construction)

As a result of this elevation difference, variables such as climate, vegetation and soils show a discrepancy. The study area exhibit two major traditional climatic zones: the Dega (2300-3200 MASL) and Woynadega (1500-2300) MASL (MWFEO 2015; Bewket, 2009). Woynadega climatic area has a cool to warm semi-humid weather, with average annual temperatures greater than 20 ^{0}C. The Dega area has a cool and humid climate with a mean annual temperature ranging from 10 ^{0}C to 20 ^{0}C (Alemayehu et al., 210). Frequent flooding and severe erosion are major problems in the area, especially in the upper stream**.** In the study area, erosion rate as high as 1.66 Mg km-2yr-1are reported (MOWR, 2005).

Mecha district is a foundation for Koga watershed which is located in Tana sub-basin, Eastern part of the Blue Nile. The rivers draining Koga watershed begin from Mount Wezem and flow into Gilgel Abay, which finally drains into Lake Tana. The high run-off and associated sediment flow from the upper part of this watershed have serious consequences on the downstream users and water bodies (e.g. Lake Tana and reservoirs developed for irrigation). The watershed exhibits an elevation range of 1890-3200 meter above sea level (Alemayehu et al., 2009).

In response to increasing demand for food and contrastingly declining agricultural production in the study area, the Ethiopian government constructed Koga dam in Koga watershed to irrigate 7,000 ha land. The Koga irrigation project is found between 1892- 2043 masl altitude with UTM coordinates of N 1,255,000, N 1,270,000, E 290,000 and E 300,000. The project area covers a total size of about 10,000 ha (MoWR 2005).

Land use of the study area is dominated by traditional subsistence peasant farming on individual holdings (Mekonen & Kebede 2011). Agriculture is the mainstay of livelihood in the study area. Crop and livestock production are fully integrated and thus the production system can be referred to as a mixed farming system. Traditionally, rain-fed production of cereals, dominated by barley, wheat, teff, millet, noug and maize are the chief crops in this area. In the study area, livestock plays an increasingly important role in the household budget. Crop residue and extensive grazing in the low-lying areas are the major contributors to livestock feed resource. Livestock provides meat, milk, energy. Manure fulfils an important role through nutrient cycling between and within farms, which enables the continued use of smallholder farms. Farmers usually have cattle, sheep, goat, mule, and donkey (Mekonen & Kebede 2011; Befkadu et al., 2010).

1.7.2. Research Methods and Materials

1.7.3. Research Approach

To accomplish the study objectives, we used mixed research methods. As Cresswel (2012) & Johnson et al. (2007) noted mixed methods research approach is utilized because it can be a means for seeking convergence across qualitative and quantitative methods through triangulation of data sources. Further, this approach is a procedure for collecting, analyzing, and “mixing” or integrating both quantitative and qualitative data at some stage of the research process within a single study to gain a better understanding of the research problem

(Ivankova et al., 2006). Onwuegbuzie and Combs (2011) claimed that the principal reason to use mixed research approach is to understanding complex phenomena.

1.7.4. Research Paradigm Usage

Creswell, (2009) presents four schools of thought regarding research paradigms about knowledge claims: post-positivism, constructivism, and advocacy/participatory, and pragmatism, which are representing the beliefs of most researchers; and he suggests pragmatism as the philosophical paradigm for mixed research approach. However, Frels et al. (2012) recommends the use of multiple research paradigm and argue that a single paradigm is not appropriate for mixed research with qualitative and quantitative research designs; rather, different paradigms are relevant for different mixed research designs. The author added the use of multiple paradigms in a single mixed research study yields a greater understanding of the underlying phenomenon. Therefore, for this study, we applied social constructivism, advocacy/participatory, and pragmatism to conceptualize the problem from different perspectives and social contexts**.** Details of the paradigms explained below.

Social Constructivism

Social constructivism emphasizes how social people identify, perform, and reproduce social actions; and they come to share an inter-subjective understanding of specific life experiences (Schwandt, 2007; Onwuegbuzie, 2011). Assumptions identified in this paradigm hold that individuals seek understanding of the world in which they live and work. They develop subjective meanings, negotiated socially and historically, toward certain objects or things. The meanings and interpretations are not simply imprinted on individuals but formed through interaction with others and through historical and cultural norms that operate in individuals‘lives. Thus, constructivist researchers focus on the specific contexts in which people live and work to understand the socio-cultural settings of the participants. The researcher‘s goal is to interpret the connotations others have about the world. For this study, selection of social constructivism as a theoretical framework was relevant because gender setting represents a social constructed roles, responsibilities and identities of men and women that lead to inequality with unique life experiences (Moser 1993).

Advocacy/Participatory

The participatory approach is advocated by another group of researchers as a research paradigm. This philosophical paradigm criticized post-positivist assumptions’ structural laws

and theories that did not fit marginalized individuals or groups or did not adequately address issues of social justice historically; and constructivists' failure to consider an action agenda to help marginalized people. This worldview holds that an inquiry needs to be intertwined with politics and a political agenda." Thus, the research should contain an action agenda for a modification that may improve the lives of the participants, the institutions in which individuals work or live and the researcher's life. Researchers in this paradigm should address social issues pertinent at the time such as empowerment, inequality, oppression, domination, suppression, and alienation. This research also assumes that the inquirer will proceed collaboratively further to not marginalize the participants because of the inquiry. In this sense, the participants may help design questions, collect data, analyze information, or receive rewards for participating in the research (Creswell, 2012).

Moreover, participatory research insists on an alternative position regarding the purpose of knowledge creation. The purpose of participatory research is not merely to describe and interpret social reality, but to radically change it, and the intent is to transform reality "with" rather than "for" oppressed people. Participatory research also includes an educational component to assist people to further develop skills in collecting, analyzing, and utilizing information. The educational process is potentially liberating as it provides a way for people to develop an increasingly critical understanding of social problems (Maguire, 1987). Selecting this paradigm for this study is pertinent because this theoretical debate put inequality and oppression for the marginalized group at its centre. Gender inequality is one form of inequality and oppression; and women are among the marginalized groups (Maguire, 19877, Tong, 2009, Moser, 1993). The focus of this study is on the gender aspect, particularly men and women-headed households, of climate change-related problems.

Pragmatism

For pragmatists, instead of methods being important, the problem is most important, and researchers use all approaches to understand the problem. Similarly, mixed methods researchers look to diverse approaches to gather and analyze data rather than using to only one-way: quantitative or qualitative. Therefore, pragmatism applies to mixed methods research in that pragmatist researchers have freedom of choice; they do not see the world as an absolute unity; for them, truth works at the time; and they have believed in an external world independent of the mind as well as that logged in the mind. Furthermore, mixed methods researchers are free to choose the methods, techniques and procedures of research

that best meet their needs and purposes; they look too many approaches for collecting and analyzing data rather than subscribing to only one way; they include a theoretical lens reflective of social justice and political aims; and they use quantitative and qualitative data because they work to provide the best understanding of a research problem (Cresswell, 2012). For this study, we applied pragmatism research paradigm as it uses for mixed research approach.

1.7.5. Sampling Design and Sample Size

This study used four-stages of sampling techniques to select *the research area, villages and sample household heads*. Primarily, we choose the research area purposively because of the title: to study access to WEF resources and to see the nexus between the resources at the household level using Koga irrigation development scheme as a case, and its suitability for the researchers' understanding of the language, Amharic, with the subjects and familiarity with the community; second, we select Abiot fana and Rim Kebeles in the upper stream and Kudmi and Enguti kebeles in the lower stream using a cluster sampling method to capturespatial variations; third, we picked households using a stratified sampling technique based on the gender of household heads to recognize (1) gender-differentiated perception on rainfall and temperature variability, (2) vulnerability to climate change differences among male- and female-headed households; (3) gender-differentiated adaptation strategies and determinant factors on households' decision on adaptation options; and (4) gender-based access to WEF resources and associated factors; and fourth, we select the surveyed households using a stratified simple random sampling method of probability proportional to the size technique.

Simplified formula (equation 1) provided by Kothari (2004) is used to determine the required sample size at 95% confidence level, 5% variability and 5% level of precision. Finally, from the total male-headed (31,241) and female-headed (17,639) households, we select 416 households (224 in the upper stream: 133 male-headed and 91 female-headed and 192 in the lower stream: 133 male-headed and 59 female-headed) to be included in the analysis.

$$n = \frac{z^2.p.q.N}{e^2(N-1)+z^2.p.q} \quad \text{----------} \quad (1)$$

Based on the formula provided by Kothari (2009), for the strata male and female household heads, the method of proportional to the sizes of the strata was utilized.

$$\text{pi} = \frac{\text{Ni}}{\text{N}} \text{ ---------- (2)}$$

Pi represents the proportion of population included in stratum I, N represents the total population, and Ni represents the number of elements selected from stratum I.

$$\text{p1(MH)} = \frac{\text{N1}}{\text{N}} = \frac{31241}{48918}$$

$$\text{p2}(FH) = \frac{\text{N2}}{\text{N}} = \frac{17639}{48918}$$

For the strata of male and female household heads N_1 and N_2 are the total number of the household heads respectively whereas n_1 and n_2 are sample size.

$$\text{Ni} = \text{n} * \text{pi} \text{ ---------- (3)}$$

$$\text{n1 (MH)} = \text{n} * \text{p1} = 416 * \frac{31241}{48918} = 265.7 \approx 266$$

$$\text{n2 (FH)} = \text{n} * \text{p2} = 416 * \frac{17677}{48918} = 150.3 \approx 150$$

$$\text{n} = \text{n1} + \text{n2} = 150 + 266 = 416$$

For households in the upper and lower stream,

$$\text{pi} = \frac{\text{Ni}}{\text{N}} \text{ ---------- (4)}$$

$$\text{p1(upper)} = \frac{\text{N1}}{\text{N}} = \frac{2594(\text{HHs in the upper stream})}{4870 \text{ (total HHs in the upper and lower stream)}}$$

$$\text{p2 (lower)} = \frac{\text{N2}}{\text{N}} = \frac{2276 \text{ (HHs in the lower stream)}}{4870(\text{total HHs in the upper and lower stream})}$$

$$\text{ni} = \text{n} * \text{pi} \text{ ---------- (5)}$$

$$\text{n1 (upper)} = \text{n} * \text{p1} = 416 * \frac{2594}{4870} = 221.6 \approx 222$$

$$\text{n2(lower)} = \text{n} * \text{p2} = 416 * \frac{2276}{4870} = 194.4 \approx 194$$

$$\text{n} = \text{n1} + \text{n2} = 222 + 194 = 416$$

For male-headed households in the upper and lower stream

$$\text{pi} = \frac{\text{Ni}}{\text{N}} \text{ ---------- (6)}$$

$$\text{p1(MHupper)} = \frac{\text{N1}}{\text{N}} = \frac{1667 \text{ (MHHs in the upper stream)}}{3340 \text{ (total MHHs)}}$$

$$\text{p2(MHlower)} = \frac{\text{N2}}{\text{N}} = \frac{1673 \text{ (MHHs in the lower stream)}}{3340 \text{ (total MHHs)}}$$

$$\text{ni} = \text{n} * \text{pi} \text{ ---------- (7)}$$

$$\text{n1} = \text{MHn} * \text{p1up} = 266 * \frac{1667}{3340} = 132.76 \approx 133$$

$$n2 = MHn * p2low = 266 * \frac{1673}{3340} = 133.24 \approx 133$$

For female-headed households in the upper and lower stream,

$$pi = \frac{Ni}{N} \text{ ---------- (9)}$$

$$p1(FHupper) = \frac{N1}{N} = \frac{927\ (\text{FHHs in the upper stream})}{1530\ (\text{total FHHs})}$$

$$p2(FHlower) = \frac{N2}{N} = \frac{603\ (\text{FHHs in the upper stream})}{1530\ (\text{total FHHs})}$$

$$ni = n * pi \text{ ---------- (10)}$$

$$n1up = FHn * p1up = 150 * \frac{927}{1530} = 90.88 \approx 91$$

$$n2low = FHn * p2low = 150 * \frac{603}{1530} = 59.12 \approx 59$$

$$FHn = n1 + n2 = 91 + 59 = 150$$

Hereunder, Table 1 indicates spatial and gender based categorization of the population along with the sample sizes for each category.

Table 1: Sample size by location and gender of household heads

Stream	Households	Population	Sample
Upper	Male-headed	1667	133
	Female-headed	927	91
	Sub-total	2594	224
Lower	Male-headed	1673	133
	Female-headed	603	59
	Sub-total	2276	192

1.7.6. Methods of Data Collection and Data Sources

In response to the research questions and the stated objectives, this study used appropriate data collection instruments that fit a purpose. A primary data source, a household survey was conducted in the study area to collect information required for the study. Based on the information obtained from literature, a semi-structured questionnaire was designed to gather quantitative information. The survey questionnaire containing issues associated with households' adaptive capacity, exposure and sensitivity of climate change; households' perception on the variability of temperature and rainfall; adaptation strategies undertaken and

the determinant factors; and access to water, energy and food at the household level. The questions were developed based on a thorough and extensive review of related literature, reports, and researches.

The questionnaire was first prepared in English and then translated into Amharic (the local language) to make the questions easily comprehensible by the respondents. Before the actual data collection, the questionnaire was pilot tested and verified on small numbers of respondents outside the research site of the study area to make the essential correction and to maintain its validity. The information was gathered after all the necessary improvements to the questions have been made. The questionnaire was administered by trained enumerators under the supervision of the researcher. The filled questionnaires were checked right on the spot in each day next to the fieldwork; and all the questionnaires were filled successfully.

We used in-depth interview, key informant interview and focus group discussion (FGDs) to explore the problems from the views of participants (Cresswell, 2012) (Annex 1.2). The interview and FGD's guide involved issues related to access to productive resources; access to water, energy, and food in particular; and climate-induced problems that affect resource access.

To make the research more reliable and valid and to support the information gathered through primary data sources, secondary data were collected via reviewing and analyzing the literature and documents such as written documents, published and unpublished, online materials from reliable websites, policy and legal documents, and relevant documents from Amhara region, and *Wereda* offices, especially from Mecha district. Finally, the data collected through quantitative and qualitative methods were cross-checked and triangulated with secondary sources to increase the validity and reliability of the study findings. Hereunder, Figure 2 describes the outline of the data analysis method in each theme of the thesis even though methods of data analysis presented in each chapter separately.

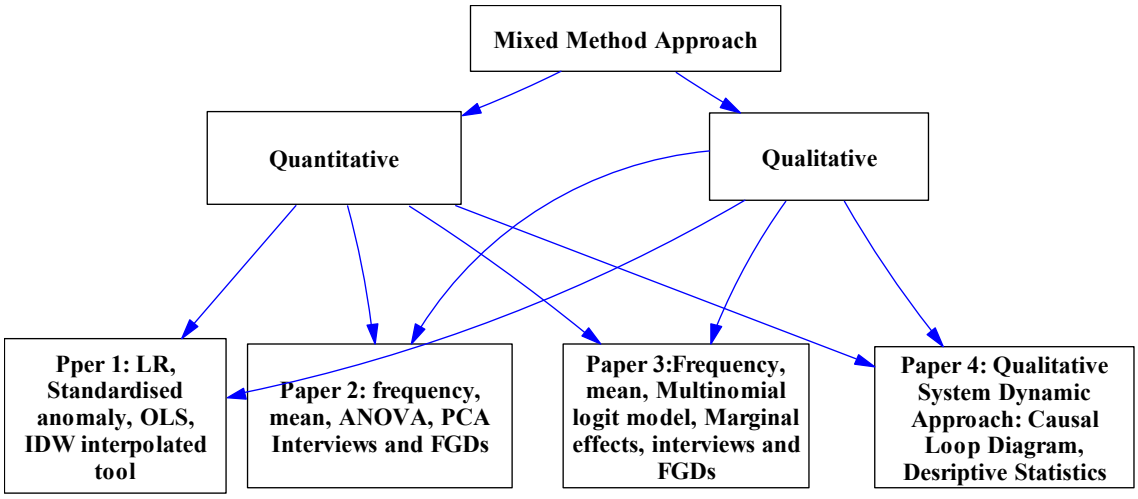


Figure 2: General description of the research approach

1.8. Organization of the Thesis

This thesis is organized into seven chapters. Next to this introductory chapter, chapter two reviews relevant literature concerning the association between gender with climate change and variability; gender and vulnerability and adaptation to unfavourable impacts of climate change; and linkages between gender, climate change and access to water, energy and food resources. Chapter three presents long-term spatial and temporal analysis of temperature and rainfall at the annual and seasonal time frame. Chapter four provides a spatial and gender-based assessment of households' vulnerability to climate change and variability. In chapter five male and female farmers' perception of the changes in climatic indicators; main adaptation options used, and factors that determine their choice of specific adaptation strategy are evaluated. Chapter six presents gender-differentiated access to water energy and food resources at household level and climate change effects on their access to these resources. Chapter seven concludes the main findings of the preceding chapters; and illustrates policy implications and issues for further research.

2. Review of Related Literature

2.1. Conceptual and Theoretical Frameworks

2.1.1. Conceptualization of Terms

Gender: The concept of gender has been embedded in a sexual division of labour in primitive society. Scientists studying several critical gender distinctions noted that variations between men and women deeply rooted to the days whilst men were hunters and women were caretaker of children close to camp. These diverse roles and settings pushed men and women to generate unique brain structures (Hopkin, 2009).

For this research, we use the definition of gender by Moser (1993) as "the social facet of culture, religion, and classes that condition the way in which masculine and feminine roles and status are constructed and defined in each society. It refers to the social differences and relations between men and women which are learned, differs among societies and cultures, and change over time". Gender relations are dynamic and converting over time in response to various socioeconomic and ideological circumstances.

Climate Change: IPCC (2007) define climate change as "*a change in the climate's state that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.*" This definition used to climate change throughout the thesis.

Climate variability: "*climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or variations in natural or anthropogenic external forcing (external variability)*" (IPCC, 2007).

Climate change can be because of natural internal processes or external forcing which is attributed directly or circuitously to human activity (IPCC, 2007; UNFCCC, 1992). However, the concept of climate change is familiar with the public commonly called anthropogenic global warming. The prime focus of this concept is man-made greenhouse gases, mostly carbon dioxide (CO2), are the primary reason for the global warming that took place during the past 50 years. Bast (2010) provides the following additional concepts, about the reasons,

that shed mild on a few factors of climate change regardless of the anthropogenic global warming concept.

Planetary motion: Natural gravitational and magnetic oscillations of the solar system may explain planetary motion: global warming of the latter part of the twentieth century brought on the planet's motion through space. These oscillations modulate solar variations which then drive change in the climate. Earth's orbit around the sun takes the shape of an ellipse, not a circle, with the planet passing farther away from the sun at one end of the orbit than at the alternative end. The closest approach of the planet to the sun is referred to as "perihelion" and the farthest approach as "aphelion."

Solar Variability: Solar variability accounts for maximum or all of the warming in the overdue twentieth century and could dominate climate in the twenty-first century apart from man-made greenhouse gas emissions. The energetic blending of gases on the near-surface of the sun denoted via modifications in the variety of sunspots causes changes in the radiant energy emitted by the sun. Furthermore, the sun's influence is ten times as crucial as CO2 in influencing global temperatures. These events cause an outflowing of charged particles called "solar wind" that reaches Earth and its environment. Solar wind affects galactic cosmic rays, which in flip have an effect on cloud formation. Changes in cloud formation are linked to variations in sea surface temperatures and wind patterns resulting in increasing near-surface air temperatures and global warming.

Vulnerability: Definitions of vulnerability vary extensively along with different scholars. Kelly and Adger (2000) declare that vulnerability is the "*inability of individuals or social groupings to respond to, in the sense of cope with, recover from, or adapt to, any external stress placed on their livelihoods and well-being.* Mubila et al. (2011) noted that human vulnerability to an environmental problem refers to people's exposure to risks, coupled with their capacity to anticipate and respond, whether adapting to their setting or by shifting to less affected regions.

Vulnerability to climate change: This thesis uses a definition of (IPCC, 2007) vulnerability to climate change as "the degree to which a system is susceptible to, or unable to cope with, unfavourable effects of climate change such as climate variability and extremes. Vulnerability is a function of the character, extent, and rate of climate variation to which a systems' exposure, its sensitivity, and its adaptive capacity". Exposure is the nature and

degree to which a system is exposed to considerable climatic variations. Sensitivity is the level to which a system is affected, either unfavourably or beneficially, by climate-related stimuli. Adaptive capacity is the capability of a system to regulate to climate change (including climate variability and extremes), to moderate potential risks, to take benefit of opportunities, or to cope with the effects (IPCC, 2001, Smit et al. 2000, Smit and Pilifosova, 2003).

To conceptualize best, it is important to mention the two interpretations of vulnerability to climate change: as an endpoint and as a starting point. As a starting point, vulnerability is a trait or state generated by many environmental and social processes but aggravated by climate change (Füssel and Klein, 2006; Kelly and Adger 2000). Vulnerability provides a way of understanding how the impacts of climate change could be distributed, primarily to recognize how vulnerability can be reduced, i.e., the focus is on adaptive capacity and solutions. As an endpoint, vulnerability is sighted as a residual of climate change impacts minus adaptation. It serves as a way of defining the extent of the climate problem and providing input into policy decisions regarding the cost of climate change versus costs related to adaptation efforts (Kelly and Adger 2000).

Adaptation: Smit and Wandel (2006) define adaptation within the context of human dimensions of global change as "a process, action or final results in a system (household, community, group, sector, country) to better deal with, manipulate or regulate to some changing condition, pressure, risk or opportunity." Another definition of adaptation is likewise provided by Brooks (2003) as ''changes in a system's behaviour and characteristics that improve its capability to cope with external tensions.''

Adaptation to climate change: in the climate context, Pielke (1998) defines adaptations as the ''adjustments in individuals, groups and institutional behaviour to reduce society's vulnerability to the changing climate.'' However, this thesis follows the concept of adaptation to climate change as the process by which stakeholders lessen the unfavourable results of climate on their livelihoods. It entails modifications in the way of life, behaviour and financial structure aimed at decreasing the vulnerability of a system to climate change, growing its sustainability (Smith et al., 2000); and the concept in IPCC fifth assessment report (2014), adaptation to climate change as "the course of adjustment to actual or anticipated climatic stimuli and its results. In human structures, adaptation seeks to slight or keep away from harm or make the most beneficial possibilities. In some natural systems,

human intervention may additionally facilitate adjustments to expected climate and its outcomes".

Smit et al. (2000); Smit & Wandel (2006) and IPCC (2001) described that various styles of adaptations are prominent based on their timing, and their spontaneity: *Anticipatory Adaptation*—adaptation options that takes place previous to effects of climate change are, also known as proactive adaptation; *Autonomous Adaptation*—adaptation that does not represent a conscious response to climatic stimuli other than caused via ecological modifications in natural structures and via market or welfare changes in human systems, additionally called spontaneous adaptation; *Planned Adaptation*— it is the result of a deliberate policy choice, based on a recognition that situations have changed and that movement is required to go back to, maintain, or obtain a desired circumstance; *Private Adaptation*— it is initiated and applied through individuals, households or non-public businesses, private adaptation is common inside the actor's rational self-interest; *Public Adaptation*—its initiation and implementation is with the aid of governments at all ranges. Public adaptation is regularly directed at communal needs; and *Reactive Adaptation*—adaptation undertake following the discovery of climate change effects.

Climate Change and WEF nexus: negative consequences of climate change affect water, energy, and food resources. On the one hand**, a**griculture and water are at the same time among the most climate-vulnerable sectors, subject to impacts such as further drying of already water-scarce regions, loss of glacier water storage, the effects of more (severe) excessive occasions, and location-specific changes in crop productivity. Food and electricity production are liable to drought as illustrated through the current food crisis within the Horn of Africa and numerous incidences of reduced hydropower production in response to drought. On the other hand, energy and food production and provisioning are essential drivers of climate change. Electricity and heat production alone contributes 27% of worldwide greenhouse gas emissions; agriculture contributes 15%, and land-use change and forestry contribute 14% (Water Resource Institute, 2005; Hoff, 2011).

2.1.2. Theoretical Frameworks

The approach to Women, Environment and Development (WED) gives attention to the way to assist women to harm by environmental destruction. This perspective tied to a feminist movement rooted in the ideology, feminism. Feminism as a socio-political movement has taken numerous forms and is theorized from unique perspectives to address the unequal

power relationship between men and women. Diverse feminist theories were developed and present diverse perspectives on a way to best increase and protect women's rights for balanced outcomes in social, economic and political aspects (Tong, 2009).

The notion of gender and climate change has been a major area of concern to specific feminist theories and their movements. Among them, ecofeminism, feminist political ecology and feminist intersectional theory are associated with this study. As groundwork, those theories are crucial to conceptualize gender and environmental change. The theories are important mainly to comprehend gender and climate change: the root causes of vulnerability to climate change obstacles, to respond to unfavourable impacts of climate change and associated factors with access to WEF resources from a gender perspective.

2.1.2.1. Eco-feminism

With introducing the women's movement, particularly in the latter half of the 20th century, many organizations had explored the links between development and women's issues. The publication of Ester Boserup's book, Women's Role in Economic Development, had profound effects upon the feminist theory in relation to development models (Mellor, 1997). The theory of Women in Development (WID) was hence created to encourage women to take part in economic activities and in the development process (Flangan, 2013).

In the 1980s, the focus of women's role in development shifted to a more socialist perspective and Gender and Development (GAD) theory acknowledged women's productive and reproductive tasks and even questioned the existing power structures leading to oppression (Sturgeon, 1997). Under this paradigm, both men and women were welcomed as agents of change. Parallel to these theories, more holistic ideologies have emerged with environmental concerns. Women, Environment and Development (WED), which was also known as eco-feminism, particularly claimed the correlation between the oppression of women and the environment (Manion, 2002).

The shift from women as individuals to gender as a system structuring power relations has been an essential improvement in feminist responses to climate change (Gaard, 2005). Consequently, throughout the 1980s and early 1990s, the discourse of eco-feminism was predominant to explain the relationship between women's oppression and environmental degradation mainly caused by male dominance (Manion, 2002; Tong, 2009). One of the

common arguments of the eco-feminist is the emphasis on women as the primary victims of environmental degradation (Arora-Jonsson, 2011).

An eco-feminist, Manion (2002), argues that as resources scarcer, environmental issues tend to deal with oppressed populations. It is those oppressed people who suffer more with the consequences of ecological damage. Mies et al (1993); Mellor (1997) and Manion (2002) claimed that certain ecologically damaging issues including climate change have more of a harmful effect on women than on men, particularly as women have a tendency to be more involved in household management. As household managers, women are the first to suffer while access to sustainable livelihoods is unbalanced: when the water becomes not potable, the food stores dry up, the trees disappear, and the land becomes weak because of unfavourable changes in climate (Momsen, 1995).

2.1.2.2. Feminist Political Ecology

The notion of feminist political ecology (FPE) emerged from political ecology's concern in the mid-1990s. It was characterized as a framework for bringing 'a feminist perspective to political ecology' (Rocheleau et al., 1996). Political ecology (PE) came to the forefront of human geography in the 1980s. It is an analytical approach that questions the process of power that defines people's unequal and differentiated access to and control over resources at local, regional, and global scales (Castree and Braun, 2001). FPE claim for gender equality and social justice in environmental change and draws from the fundamental political and analytical character of feminism: power and difference. Sundberg (2017) conceptualize feminist political ecology as a subfield that brings feminist theory, objectives, and practices to political ecology; and located gender as a crucial variable in relation to class, race, and other relevant dimensions of political-ecological existence in constituting access to, control over, and know-how on natural resources and in shaping environmental relations.

FPE was built insights from women's involvement in local environmental struggles and social movements; and they claim that disasters placed gender and other styles of social inequality into stark help (Wisner et al., 2004; Bankoff et al., 2004). Popular gender, climate change and catastrophe discourses these days revolve around a focused feminine subject, especially the poor rural women of the South who are negatively affected by climate change. This same thinking argues that women are powerful agents of change and their full participation is crucial to the success of adaptation and mitigation packages, and hence, it is

important that women and gender experts take part in all decisions associated with climate change (Röhr et al., 2008).

Enarson and Morrow (1998) argued that gendered vulnerability to disasters and climate risk does not derive from a single factor such as 'being a woman', but vulnerability instead shows historically and culturally specific patterns of practices, processes and power relations that cause some groups or persons more underprivileged than others. FPE emphasizes the need to recognize the differentiated vulnerable positions among women and men that do not easily fit into the singular and undifferentiated category of 'disaster victim' in popular discourse (Hyndman, 2008; Cupples, 2007; and Arora-Jonsson, 2011; Resurrección, 2017).

Feminist political ecologists (Dianne Rocheleau, Barbara Thomas-Slayter, and Esther Wangari), in their book 'Feminist Political Ecology', focus in opening up three new concerns for consideration related to gender and climate change: (1) environmental knowledge and practices in terms of gender: the involvement of women in adaptation to climate change (2) gender-specific rights to natural resources and unequal vulnerability to environmental change: gender-differentiated, unequal access to resources and vulnerability to climate change and (3) gender-based environmental activism and organizations: the involvement of women in the design and implementation of climate change policies and adaptation programs from international to local levels (Sundberg, 2017).

In general, FPE provides a framework for rethinking the connections between environment and society, by moving away from a singular focus on human and the environment to the gender-specific impacts of climate change (Arora-Jonsson, 2011). FPE usefully put to look not only at how climate change has gender-specific impacts, but also how knowledge, policies and practices that combine around climate change adaptation bring gendered effects (Arora-Jonsson 2011; Bee et al. 2013; Tschakert 2013).

2.1.2.3. Feminist Intersectional Theory

The underlying idea on feminist intersectional theory, a feminist sociological concept introduced by Crenshaw (1991), is not new. Different feminist theories introduced gender from a different perspective and identify the root causes of women's oppression in unique aspects. For instance, patriarchy in radical feminism, class in Marxist feminism, and race in black feminism were identified as root causes of women's oppression (Tong, 2009). The

intersectional theory has grown within these feminist theories and is grounded in a feminist understanding of power and knowledge production (Kaijser & Kronsell, 2014). Davis (2008) defines intersectionality as the interaction between gender and other categories of difference in individual lives, social practices, institutional arrangements, and cultural ideologies and the outcomes of these interactions in terms of power. Further, it is an approach to understanding intra-group difference and the existence of multiple axes of identity that govern an individual's or group's relationship to power (Osborne, 2015 in Chaplin et al., 2019),

The intersectional theory emphasizes the constant renegotiation of power relations and how individuals and groups can experience both power and oppression simultaneously. Social groups are neither homogenous nor static, and intersectional approaches recognize this complexity by taking historical, social, cultural and political contexts into account. This approach offers a way to understand and respond to different factors and enhance awareness of people's needs, interests, capacities and experiences, which in turn help in targeting policies and programs (Chaplin et al., 2019). Keeping in mind the bigger picture, identifying power patterns under social categorizations, an intersectional analysis see how these factors are reinforced or challenged in light of climate change (Kaijser & Kronsell, 2014).

The responsibility and decision-making power of individuals and groups associated with climate change can be attributed to social structures based on characteristics which include gender, socio-economic status, ethnicity, nationality, health, sexual orientation, age, and location. Furthermore, the effects of climate change and strategies for adaptation are determined by using such type of social structures because climate change debate is recognized from the social aspect in general and gender perspective in particular. From an intersectional understanding, how individuals relate to climate change relies upon their positions in context-specific power structures based on social categorizations (Kaijser & Kronsell, 2014).

Intersectional approaches help to apprehend the differentiated and root causes of vulnerability and resilience; and the perspectives upon what elements are relevant in a particular setting (Kaijser & Kronsell, 2014). Hankivsky (2014) noted that people's vulnerability to climate change or how they experience adaptation strategies is the end result of several factors along with decision making, power, and responsibilities and roles. Conversely, Chaplin et al. (2019) claimed that climate-precipitated risks jeopardize existing inequalities: those who face the greatest levels of risk and require the highest levels of resilience are often groups with the

highest inequality and barriers to having access to their rights in everyday life. This frequently includes women, people with disabilities, children, older persons, minority and others who are contextually marginalized. Marginalized people are less likely to displace and to afford to live somewhere else, and had poorer prospects if displaced because of weather extremes (Elmhirst, 2015).

To conclude, even though the theories do not have any defined set of strategies for searching clear understandings of vulnerability and resilience regarding climate change and natural hazards, they are essential to comprehend how different groups, male and female-headed households associate differently to climate change, because of their situations in power structures: gender inequality primarily based on the local context on socialization. In addition, the theories are vital to look at the intersection of gender and vulnerability, adaptation to climate change and access to natural resources together with water, energy and food with factors like gender inequality, gender-differentiated access to critical assets and decision-making power, social norms, and institutional offerings.

2.2. Gender in Climate change Policies and Legal documents

In this thesis, diverse policies and legal documents are revised at an international and national level because it is far essential using those documents as a foundation to explain historical backgrounds of gender and climate change; to acknowledge whether gender is considered in the development and climate change discourses, and to verify how the problem is severe, and researches are important.

The view of gender in climate change policy has recently emerged. It is better to begin this comparison with the broad base of gender and environment. Women have been considered as best environmental managers and have been started to be portrayed in policies designed to preserve the environment in the 1990s (Jackson, 1993; Okali & Naess, 2013). Women, environment and development have been the next step with the strategy to involve knowledgeable and resourceful women, and of even seating them at the forefront of environmental policy (Leach and Green, 1995). Consequently, gender relations with the environment are observed to emerge from the social context inspired by Gender and Development (GAD) discourse and practice. Following gender and environment, gender in climate change policy become emerged throughout the late 1990s with increasing interest in

adaptation to adverse impacts of climate change. The argument about climate change impacts can exacerbate current inequalities' started out to emerge after 2000 (Okali & Naess, 2013).

The UN's Intergovernmental Panel on Climate Change became set up in 1988, however, the reference became made to gender in 2001 with confined appearance and discussion of what this might suggest for policy. The word gender appears in the context of statements about sex-differentiated levels of vulnerability as a consequence of the 'feminization of poverty'; women in disasters; and using gender analysis to map social vulnerability (IPCC, 2011). Similarly, in the UNFCCC documents, the drawing up of National Adaptation Programs of Action (NAPAs) calls to national governments to follow-up on worldwide level consensus on gender, or women. The program targeted the most vulnerable locations and people as a key strategy. Fourth assessment report (IPCC, 2007) identifies Africa as the most vulnerable region and the poor inclusive of women as the most susceptible people.

2.2.1. International Level

Worldwide, several conventions and declarations provide a legal foundation on gender, environment and development in general and on gender and climate change in particular in which Ethiopia is among the signatory nation parties. Most of the agreements recall gender and oblige states to undertake measures against discriminatory practices and movements. The Constitution of Federal Democratic Republic of Ethiopia (Constitution, FDRE, 1995), under article 9, verifies that "all global agreements ratified by Ethiopia are an integral part of the law of the land." The government of Ethiopia took part in different international conventions; signed and ratified diverse protocols listed below. This shows that the country has taken the legally binding documents into consideration as part and parcel of the constitution.

Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) is the first global treaty expressly recognizing women's human rights. The assertion of CEDAW's committee, at the forty-fourth session of the subsidiary body for implementation in 2009, calls on states parties to include gender equality as an overarching guiding principle within the UNFCCC agreement expected at the 15th conference of parties (COP) in Copenhagen. In addition, the committee stated, "*Climate change has gender-specific unfavourable effects. However, women are not just helpless sufferers of climate change – they are effective agents of change and their management is vital. All stakeholders need to ensure that climate change and disaster risk reduction measures are gender-responsive to*

local knowledge systems and respect human rights. Women's right to take part in all levels of decision-making should be assured *in climate change policies and programs*." (UN Human Rights, 2009)

Agenda 21, which establishes a base for sustainable development, was adopted at the United Nations Conference on Environment and Development, in Río de Janeiro in 1992. It includes a separate section (chapter 24) entitled "global action for women towards sustainable development", which calls upon governments to make the essential constitutional, directorial, cultural, social and economic changes to eliminate all barriers to women's full involvement in sustainable development and in public life. It additionally requires the adoption of measures to translate its objectives into obvious strategies. This is to be performed through government policies, nationwide guidelines and plans to make certain equity in all aspects of society, along with women's "key involvement" in decision making and environmental management (Aguilar, 2009).

Beijing Declaration and Platform for Action: At the fourth international conference on women, held in Beijing in 1995, clearly defined the link between gender, the environment and sustainable development. Chapter K of the Platform for Action makes specific orientation to the environment with strategic goals and act as central themes, which include the poverty that affects many women; the need for women to take part energetically in making-decisions about their surroundings at all levels; and integration of the gender aspect in sustainable development policies and programs. This perspective has later appeared in a number of global meetings that further explored the relationship between gender and climate change (Larson, 1996).

In 2014, a conference of Parties (COP20) in Lima, Peru, the UNFCCC called for an action plan to develop a two-year program on gender (the Lima Work Program on Gender). This work program involves mapping of decisions and conclusions on gender and climate change adaptation, to recognize areas of progress, potential gaps, and areas where further support and extra collaboration are needed. The program also notes gender-responsive climate policy still requires additional strengthening in all activities associated with adaptation and mitigation and decision-making on the realization of climate policies. Because of this preliminary work, the UNFCCC Paris Agreement in 2015 formally identified the intersection of climate change and gender equality, empowerment of women, and recognition in their rights (Glemarec et al., 2016).

The UNFCCC COP21 Paris Agreement in December 2015, 195 nations adopted the first worldwide, legally binding global climate agreement. Governments agreed to a broad goal of "holding the increase in the global mean temperature to well under 2°C above pre-industrial levels and to pursue efforts to limit an increase in temperature, recognizing that this would significantly reduce the risks and unfavourable effects of climate change." The agreement additionally mandates gender-responsive adaptation actions and capacity-building actions. In article 7.5, "parties recognize that adaptation strategies should follow local knowledge, gender-responsive, inclusive and expressed approach with a view to mainstream adaptation into pertinent socioeconomic and environmental policies and actions". Article 11.2 states "…Capacity-building should be guided by lessons learned and should be a powerful, and iterative procedure that is participatory, cross-cutting and gender-responsive" (Rhodes, 2016; Glemarec et al., 2016).

2.2.2. National Level

Apart from being a signatory of main conventions on climate change, environment and development that merge gender, the Ethiopian Government has additionally expressed its commitment to women's involvement in environmental policies by taking various actions. The following are actions and implementation measures taken to date:

The environmental policy of Ethiopia become authorised in 1997 and is the primary key document that captured environmental sustainable development principles. The policy aims to enhance and increase the health and quality of life of all Ethiopians and to endorse sustainable social and economic development via the sound management and use of natural, man-made and cultural resources and the environment as a whole (FDRE 1997). The document considered social and gender concerns as a cross-sectoral environmental policy with four objectives to: "1) make certain that formal and casual training in environmental and resource management include methods and tools for evaluation and removal of inequalities; 2) make environmental consciousness and public schooling programs which include both men and women in all perspectives of society; 3) focus on all policies, programs and projects to impact evaluations in order to maximize equality for the socially disadvantaged groups; and 4) facilitate the involvement of women across all sections of society in all aspects of environment and resource management."

Ethiopia has recently set up nationwide climate-change forum and community network on climate change and has submitted both a national adaptation program of action (NAPA) and

appropriate mitigation action plan to the UNFCCC (Gebreegziabher et al., 2011). In efforts to address the shock of climate change, the Government of Ethiopia has prepared NAPA with the primary goal of identifying and promoting actions that address immediate needs for adapting to undesirable impacts of climate change. Eleven priority projects mentioned in the NAPA which focus in the areas of capacity building in human and institutions, strengthening natural resource management through community participation, enhancing irrigation agriculture and water harvesting, improving early warning systems and increasing consciousness (NMA, 2007). The document, submitted to UNFCCC, gives no attention to the integration of gender in the priority projects but mention gender as an integral part of all development activities (Ababa, 2007).

In 2009, Ethiopia's Environment, Forest and Climate Change Commission (EFCCC) has undertaken a targeted gender analysis to inform adaptation of decision-making with recognition to the integration of gender to realizing an effective and sustainable adaptation program. In the document, three main issues are identified that must be taken into consideration in the application of NAPA. Gender differences in adaptation needs, opportunities and capacities; 2) Equal involvement and influence in adaptation decision-making procedures; and 3) Equal access to monetary resources and other advantages resulting from adaptation investments (EFCCC, 2009).

Authorities of Ethiopia additionally developed a strategy called Climate Resilient Green Economy (CRGE) in 2011 to reduce GHG emissions and unsustainable use of natural resources and to achieve middle-income status by 2025 in line with green economy development. The strategy initiative follows a sector-based approach and has four pillars: agriculture, forestry, power and transport. In this strategy, gender is considered only in one pillar, power even though its integration is smaller. Initiative 2 rural energy and efficient stoves state "use of biomass, the primary source of rural domestic energy and the second largest contributor to GHG emissions, can be reduced with efficient stoves. Use of efficient stoves increases rural household income by 10%, creating an industry worth USD 15 million in gross value added (GVA), reducing GHG emissions by 50 Mt CO2e8 by 2030, and improve health and gender equality." This indicates that the use of efficient stove reduces indoor air pollution causing respiratory disease that affects mainly women and girls (Duflo et al., 2008).

In general, use and management of natural resources considerably vary among women and men, and degradation of natural resources affects them differently, these patterns of disadvantage reinforce the involvement of women in adaptation policies of climate change (FAO, 2014). Adaptation is triumphant if it reduces the vulnerability of poor people to existing climate variability, while also building potentials to anticipate and react to changes in climate as well as encouraging sustainable development (IPCC, 2001; Roehr, 2007). Besides, adaptation requires the development of human power, improving institutional structures, and sound management of the public economy and natural assets (Adger et al., 2003). Therefore, mainstreaming climate change issues into national development policies ensures uniformity between the needs of adaptation and poverty eradication (Roehr, 2007).

To conclude, the international and national legal documents, discussed above, are valuable for gender concerns into climate change policies and programs and help to shift the issue of gender and climate change in Ethiopia from the focus on different impacts of climate change on men and women to the importance of considering women as an agent to respond to adverse impacts of climate change. Therefore, one can conclude that gender equality is essential to the successful initiation, implementation, monitoring and evaluation of climate change policies; and programs. These documents additionally facilitate gender equality via consideration of women in adaptation actions relevant for this study.

2.3. Linking Gender with Vulnerability to Climate Change

Vulnerability is context-specific and what makes one area or community vulnerable may be exclusive for others. Vulnerability additionally varies across different households, male- and female-headed, and in terms of the extreme climate, occasions experienced. There are determinants of vulnerability which includes developmental factors that are likely to influence the susceptibility of a particular place or community even in various socioeconomic contexts (Brooks et al., 2005; Deressa, 2010). The dynamic nature of the vulnerability is one of its key features that may change as the end result of variations in the natural and cultural socioeconomic traits of a particular area or population (Cutter et al., 2009; Smit and Wandel, 2006).

Given men's and women's unique roles and responsibilities at the household and community levels, impacts of climate change affect them differently. Women are more exposed and vulnerable to climate change because of their higher dependence on natural resources and livelihoods which are more likely to be affected by climate variability and change, and their

limited access to vital productive resources to cope with. Cultural norms associated with gender restrict the capability of women to make quick decisions to move to safer places in disaster situations until it is too late (Nellemann et al., 2011 and Habtezion, 2013). Furthermore, Habtezion (2013) reported that lack of information, legal restrictions and the absence of effective influence in decision-making from the household through the community, national, regional and international levels contribute to their disproportionate vulnerability.

Women themselves are not homogenous groups but different in influence, attitude and in contributing to climate change, to how they are affected by it and which possibilities they posses to adapt to climate change. Gender differentiated impacts of climate change on men and women is not only based on their respective roles and responsibilities but also their location. For instance, the situation of women in the global South differs significantly from the situation in the global North. While women in the South are more affected by climate change and less capable to adapt the adverse impacts and the reverse is true for women in the North (Hemmati, 2007). Women tend to be more vulnerable to climate change and face greater challenges than men in adapting to adverse impacts in the global south because: 1) Structural inequality: poverty contributes directly to vulnerability, for instance, the poor are often unable to access the technology needed to adjust their livelihoods to a severe change in climatic conditions (Mearns et al. 2010). 2) De facto and de jure discrimination: the economic marginalization of women let them to fewer assets and a more inadequate resource base than men to respond to the effects of climate change (Archambault and Zoomers, 2015). 3) socio-cultural barriers: gender-differentiated impacts of climate change are attributable to gender-differentiated powers, roles and responsibilities of men and women at the household and community levels. These spatial gendered characters also often lead to increased vulnerability to climate change for women (Hemmati, 2007).

Women and men have diverse experiences with the impacts of climate change in their respective households and they have unique gender interests, practical and strategic, and perspectives which are important for adaptation to climate change (Dazé & Dekens, 2017). On the one hand, their practical interests focus on the most immediate necessities such as water, shelter, food, income and health care within specific situations. On the other hand, their strategic interests focus on the relative status of women and men within society. These interests vary in the social context and are related to roles and expectations, as well as to

gender divisions of labour, resources and power. Strategic interests may include gaining legal rights, closing wage gaps, and protection from domestic violence, and increased decision making. Considering these interests precipitate implementation of climate change adaptation policies and programs (Moser, 1993).

2.4. Linking Gender with Adaptation to Climate Change

Given the impacts of climate change on livelihoods, response efforts to address them contain two options: adaptation and mitigation (Maddison, 2007). Adaptation is the concern of this study to identify gender-differentiated adaptation options and associated factors. Adaptation is widely recognized as one of two main response options to reduce exposure and vulnerability while also increasing capacity to resist or recover from the potential adverse impacts of climate extremes and events (Field et al., 2012). It refers to the ability of individuals, societies and systems to cope with multi-scalar processes (Dodman and Mitlin, 2013) and to evaluate information on present and future climate change in relation to planned policies, practices and infrastructure (Füssel, 2007).

Because of the unique experiences in adaptation capacities and opportunities, men and women also differ in their informational needs and may differ as well in their preferred outlets for receiving information about adaptation (Glatzel, 2015). Women may be restricted from participating in adaptation because of prevailing beliefs and social norms that inhibit them to speak in public resulting underrepresentation in decision-making processes relevant to adaptation though they are intended beneficiaries (Napa gender).

Human relationships with environmental change are two ways: social forces exert pressures on environments to be changed, and environmental changes can shape human relationships. Likewise, gender norms and environmental changes affect each other: environmental changes including climate change precipitate the existing gender inequality due to its higher impact on women, and the existing gender inequality jeopardizes adaptation to the adverse impacts of climate change due to limited access to and control over resources among women. Gender-differentiated vulnerability resulting from climate change and poverty is associated with to access to and control over natural resources as well as access to basic services such as loans and credit, agricultural extension, market information, safe and affordable energy, and water and sanitation (Seager et al., 2016).

Climate change impacts can worsen traditional gender disparities; adaptation efforts offer opportunities to advance gender equality and women's empowerment. Gender-responsive climate change responses will contribute to the reduction of gender inequality and will increase people's resilience to climate change (Habtezion, 2013). Adaptation and adaptive capacities are often considered as core characteristics of a successful strategy to deal with shocks and stressors such as natural hazards or creeping environmental changes in the long run and building resilience is seen as a core task in this context. Adaptation strategies for climate change will be more effective if made in a decision-making process in which all the affected parties (men and women) are involved. It is thus important to identify gender-responsive strategies to respond to the environmental and humanitarian crises caused by climate change (Aguilar, 2009). As Bee (2011), claimed women can be positive agents of change and contribute to resilient livelihood strategies and natural disasters and times of stress can provide women with a unique opportunity to challenge and change their gender status in society.

2.5. Gender and Climate Change Implications on WEF resources

Globally food production systems are under stress and are unsustainable in their present form (FAO 2015). Climate change undermines efforts to produce high-quality nutritious food. While climate change affects everyone, its impacts on food security are not gender-neutral. Women are at higher risk of being undernourished than men; during periods of food scarcity, they eat less than men in terms of both quality and quantity (Habtezion 2012; Seager et al., 2016). At the household level, the prevalence and nature of food shortage have a considerable variation across male- and female-headed households. Households headed by women are particularly affected by food scarcity because of inadequate responses of climate change impacts and limited access to productive resources such as land, credit/loan and institutional services (Gates, 2014).

Access to water was considered as a physical resource determined by the hydrological cycle and physical infrastructure, however, there is also "hydro-social cycle" (Linton and Budds 2014; Seager et al., 2016). Hydro-social cycle reflects the social aspect of water. The concept directs attention to how water is produced and the social power and equity relations in how it is used and distributed. It describes the socio-natural processes by which water and society: access, provision and use of men and women at household and farm level. Access to and

control over water, and its management are shaped by social factors including gender and every stage in the hydro-social cycle involves different demands, risks and benefits for women and men (Joshi 2015; Zwarteveen et al. 2012; Seager et al. 2009; Sultana 2007 in Seager et al., 2016). The gendered dimensions of both the hydrological and hydro-social cycles will be disrupted by climate change (UNFCCC, 2016)

Energy production and consumption are among the most powerful sectors of the global economy and key drivers of livelihoods and environmental conditions. Fossil fuel burning is the largest source of greenhouse gas emissions, the main cause of global climate change (US EPA, 2016). Energy use is at the centre of global climate debates and urgent to take action to respond to climate change (Seager et al., 2016). Energy poverty is deeper in low-income countries and accessing modern energy services is a major livelihood challenge for the poorest people. It is even more difficult for poor women to access basic energy financing than for poor men. Energy resources are divided inequitably in terms of gender. Men's and women's respective roles, identities and underlying power dynamics affect the way they access and use energy and participate in decisions and investments (Seager et al., 2016).

Women in rural areas are especially vulnerable as they are highly dependent on local natural resources for their livelihood. The poor women, charged with securing water, food and fuel, for both cooking and heating, face the greatest challenges (Yared, 2014). Climate change can significantly impact on the availability of energy sources for cooking. Poor women can be faced with carrying heavy loads of fuel wood over longer distances (Pettengell 2010).

Biomass fuel such as wood, charcoal, dung and crop residues remains the principal energy source of Ethiopia. About 95% of the country's energy supply comes from biomass, mainly fuel wood (77%), dung (8%), crop residues (9%) and charcoal (1%). Rural poor households often use these energy sources for cooking, heating and lighting causing indoor air pollution resulting in acute respiratory illness. Over 70, 000 Ethiopians die every year due to indoor air pollution (WHO, 2012). Energy poverty particularly affects women because of their greater likelihood of living in poverty majority of which are female-headed households (UN economic and social council, 2006).

In line with the theories and pieces of literature explained in the sections above, the following conceptual framework (Figure 3) was constructed for this thesis. These different theoretical and conceptual reviews have given useful insights into the core areas of this thesis. The

framework showed that how the subject of gender inequality interlocked with the four core areas of the thesis.

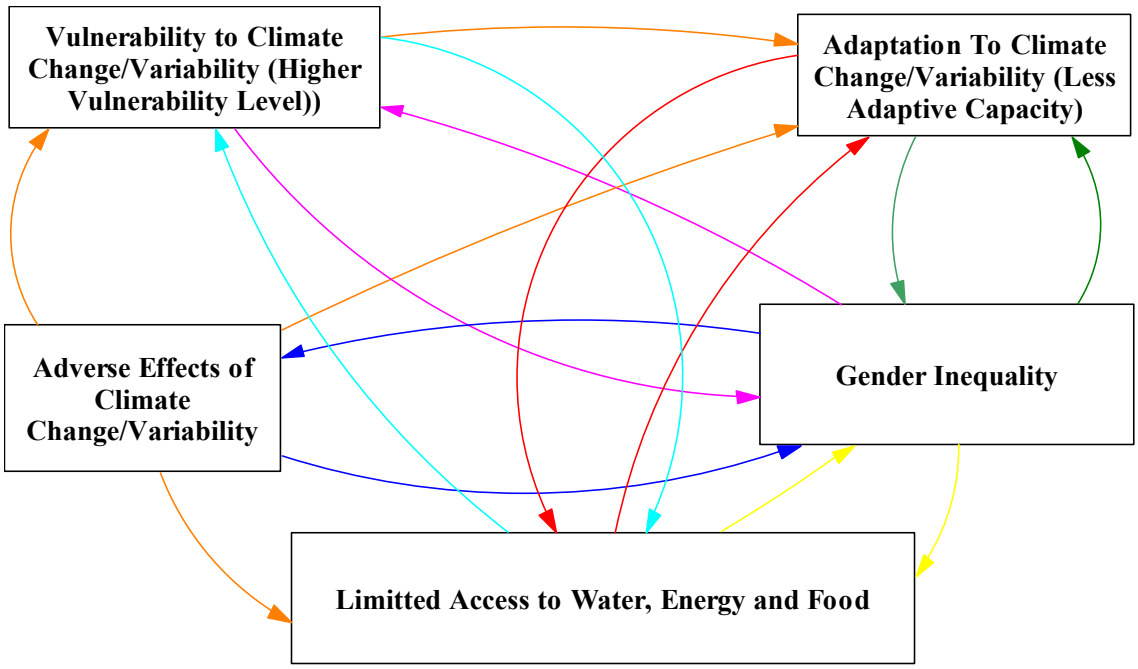


Figure 3: Conceptual Framework of the Study (source: Author's own construction 2020)

3. LOCAL SPATIOTEMPORAL CLIMATE ANALYSIS: TEMPERATURE AND RAINFALL VARIABILITY IN MECHA DISTRICT, NORTHWEST ETHIOPIA

3.1. Abstract

Assessment of climatic factors like temperature and rainfall can improve the effectiveness of agricultural activities such as planting and irrigation via responses to unfavourable impacts. This study aims to analyse the spatiotemporal variation of rainfall and temperature at seasonal and annual timescales where such kind of detail analysis does not exist. We used gridded monthly rainfall and temperature data constructed to 154 points at a 10×10 km resolution from 1983 to 2014. Linear regression, standardized anomalies, inverse distance weighted interpolation tools and ordinary least squares are employed to analyse temporal and spatial variation. Findings reveal that annual minimum and maximum temperature significantly increased at a rate of 0.11^{o}C and 0.08^{o}C per decade respectively. Seasonal warming trends for maximum temperature were significant in the winter and spring seasons ($p = 0.05$) whereas ($p = 0.01$) in winter and autumn for minimum temperature. Adjusted R-square values of the ordinary least squares method resulted in spatial relationships for annual rainfall, minimum and maximum temperature are 0.41, 0.44 and 0.68 respectively. The mean annual and seasonal rainfall distribution shows statistically non-significant increasing trends. These results call a need to develop local level and context specific climate change adaptation strategies.

Key Words: trend, spatial variability, temporal variability, climate factors

3.2. Introduction

The long term rise in the average of the earth's surface is one of the most series issues confronting human today. Extreme weather events, notably drought, flood and tropical storms, are also threaten development gains across different sectors in rural areas (Brown et al. 2012). Ethiopia is a country with a very diverse climate patterns that are highly variable and unpredictable. The average annual minimum and maximum temperature over Ethiopia has been increasing and the rainfall patterns are highly variable (NMA 2001). Droughts and floods additionally are the two frequently occurring climate extreme situations in the country (NMA, 2007).

In low-income countries like Ethiopia, climate is the primary determinant of agricultural productivity. Since Ethiopia is dependent on rain-fed agriculture and has limited resources to adapt to climate changes (Apata et al. 2009; Trocaire 2014; NCCF 2009), long-term changes in temperature and rainfall decrease net revenues from agricultural production with corresponding negative effects on food security (Bewket 2009; Deressa et al.2010; UNDP 2011; Alemayehu & Bewket 2017). Variations in climatic factors and the frequency and severity of extreme events like droughts, floods, and windstorms affect the productions of crop (Masika 2002). Temperature and rainfall patterns also impact the availability of water for agricultural activities, including irrigation (Döll 2002).

In the Amhara regional state of Ethiopia, where the study area is located, unfavourable effects of climate change and variability affects the community that are heavily engaged in agricultural activities, susceptible to changes in climate (NCCF, 2009; Abel et al., 2015). Studies show that crop-pest, livestock epidemic, hailstorm, drought, and flood are the most frequently occurring climate-related hazards in the region (Misganaw et al. 2014).

Previous studies on rainfall reported high variability of annual and seasonal rainfall with a non-significant trend in the north (Hadgu et al. 2013; Gebreselassie & Moges 2015); in the south-western (Eshetu et al. 2016); and in the north-western (Bewket & Conway 2007; Ayalew et al. 2012) parts of Ethiopia. NMA (2001) reported a decreasing trend of annual rainfall in the north and southwest parts; and an increasing trend of annual rainfall in the central part of the country.

Studies on the temperature, in contrast, reported significant warming trends in the minimum and maximum temperatures (NMA 2007; Taye & Zewdu 2012; Mengistu et al. 2013; Alemayehu & Bewket 2017). For instance, Mengistu et al. (2013) observed a significant warming trend of temperature over most parts of the Blue Nile river basin in all seasons. At annual time scale, maximum and minimum temperatures increased in over 33% of the Basin at a rate of 0.1 and 0.15^{o}C per decade, respectively; however, the western part (12%) of the Basin experienced declining trends in annual and seasonal time scales.

The main livelihood of the people in the study area depends on agricultural activities including irrigation: the most vulnerable activities to climate change impacts because of its dependence on temperature and rainfall (Döll 2002; Deschênes & Greenstone 2007). The variation of rainfall and temperature would additionally impact the water demand for agriculture (Lee & Huang 2014). Assessment of environmental factors like temperature and rainfall can improve the effectiveness of agricultural activities. In the study area, detail spatial and temporal analysis of the two climate indicators does not exist so far. Therefore, this study aims to analyze spatiotemporal variability and trends of rainfall and temperature in *Mecha* district between the period 1983 to 2014 to inform the farmers, agricultural development planners and other concerned bodies. Further, the study is valuable for development of local adaptation strategies to future climate change and variability; and water resource managers to decide on the irrigation practices.

3.3. Research Methods and Materials

Gridded monthly rainfall, minimum and maximum temperature data were constructed to 154 points on 10×10km resolution. The data obtained from the National Meteorological Agency (NMA) of Ethiopia for the period from1983-2014 were utilized. Temporal and spatial analyses were made on annual and seasonal rainfall, minimum and maximum temperature using different methods below.

As Bewket & Conway (2007) and Alemayehu and Bewket (2017) noted, in Ethiopia there are three rainfall seasons: Kiremt from June–September, Belg from March-May and Bega from October- February, therefore, we analyzed rainfall based on these three seasons. For temperature; winter from December–February, spring from March-May, autumn from September–November, and summer from June-August (Mengistu et al. 2013) were analyzed. The data were framed using the above seasonal calendar for rainfall and temperature.

The gridded data were input into Geographic Information Systems (GIS) as point data to model the spatial relationship of rainfall and temperature data. This study used Geo-statistical techniques using an Inverse Distance Weighted (IDW) to predict the map of the spatial distribution of the two climate data sets. IDW tool is an exact local interpolator that used the measured sampled values surrounding the prediction location to predict a value for any non-sampled location, based on the assumption that things close to one another are more alike than those that are farther apart (Bostan & Akyürek 2012 and Esri 1995-2016).

Global interpolator spatial statistics tool _Ordinary Least Squares (OLS) _ was used to model spatial relationships: dependent variable's relationships of explanatory variables associated with geographic features such as latitude, longitude, and altitude; and to measure how strong those relationships are. Before the OLS regression application, we constructed a scatter plot matrix (appendix I) between variables to see the relationship strength of dependent and independent variables (Esri 1995-2016). We used Robust Probabilities (Robust Pr) to determine coefficient significance, and the Joint F and Wald Statistic determine overall model significance (appendix II). R-square values are used to assess model performance, with the values for r^2 range from 0.0 to 1.0 (Esri 1995-2016).

We applied the following regression equation to the independent variables to best predict the dependent variables, similar to studies by Bostan & Akyürek (2012) and Vicente-Serrano et al. (2003).

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 \pm ------ \beta nXn + \mathcal{E} ---------- (1)$$

Where Y is dependent variable, the Xs are explanatory variables, β is regression coefficients and Ɛ is a random error term or residuals.

For temporal trend analysis of rainfall and minimum and maximum temperature, linear regression was employed to each of 154 points using the equation (2) below. The standard Z score was used to calculate anomalies of rainfall and temperature (equation 3). The same equations (2 & 3) were utilized by (Bewket & Conway 2007; Mengistu et al. 2013; and Alemayehu & Bewket 2017)

$$Y = mx + b ---------- (2)$$

Where Y is the dependent variable, m is the slope, x is the independent variable and b is the intercept.

$$Z = \frac{X - \mu}{\delta} \quad (3)$$

Where Z is a standardized anomaly; x is the value of a particular year; μ is long term mean annual record over a period of observation and δ is the standard deviation of annual rainfall over the period of observation.

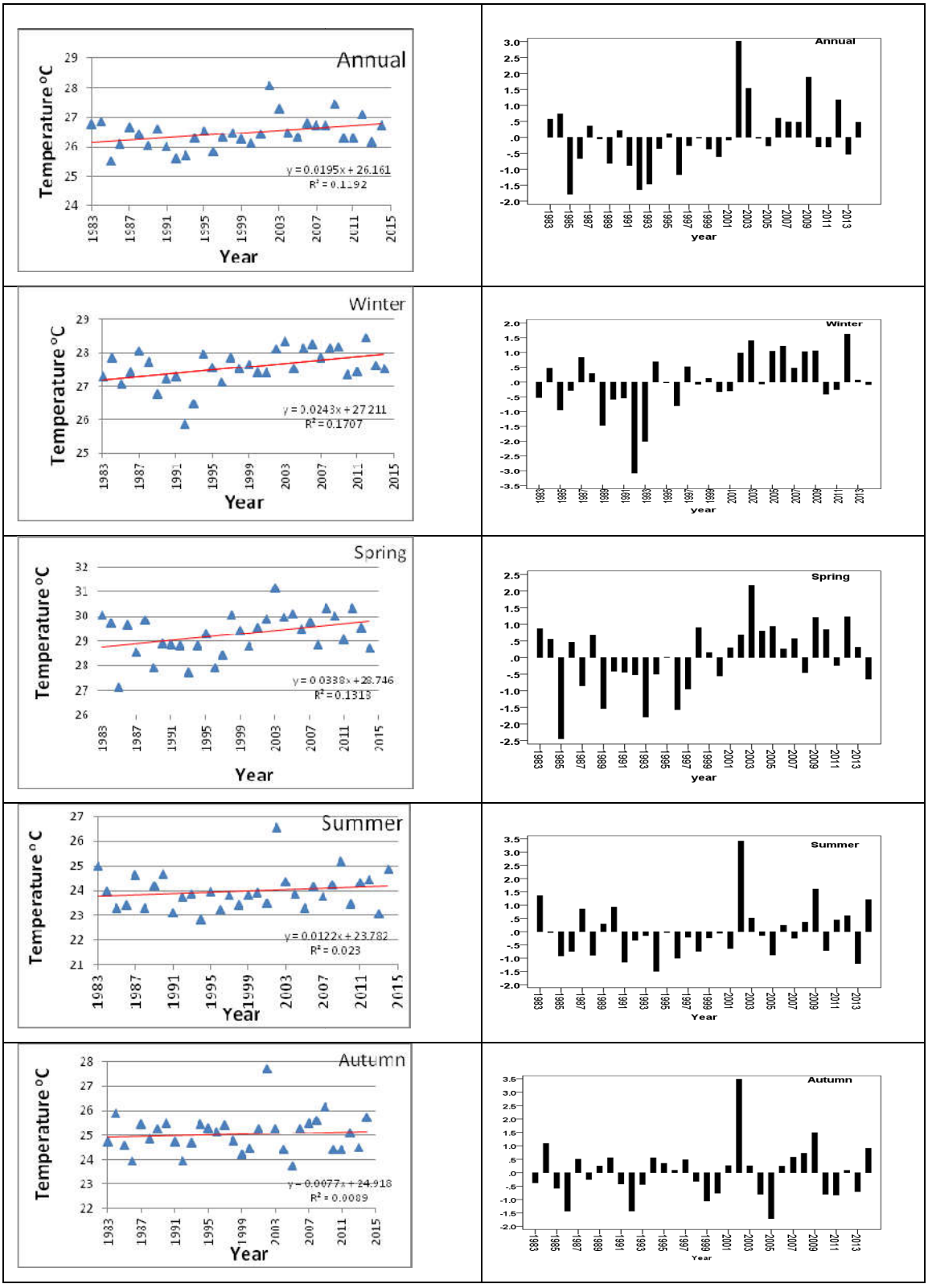
3.4. Results and Discussion

Temporal and Spatial Variation of Maximum Temperature

Table 2 pointed out the temporal variation of maximum temperature at annual and seasonal time scale over the study area for the period 1983-2014. The findings showed that an average annual maximum temperature of the study area is 26.5^{o}C and increased by 0.08^{o}C per decade. Monthly mean value varies from 23.1^{o}C in July to 29.9^{o}C in March. The warming trends in the winter and spring seasons were significant (p=.05) whereas non-significant increasing trends were recorded for annual and the rest two seasons. Other studies of climate variability in Ethiopia, for instance, Conway et al. (2004) in Addis Ababa; Mengistu et al. (2013) in the upper Blue Nile basin; Asfaw et al. (2018) in Weleka sub-basin; Alemayehu & Bewket (2017) in the central Highlands of Ethiopia; and NMA (2007); and Jury & Funk (2013) for the whole country reported warming trends of maximum temperature with substantial variation at different spatial scales and period. Omondi,et al. (2013) also reported comparable warming trends in the horn of Africa from 1961 to 2010.

The inter-annual variability of maximum temperature (Table 2) showed that the existence of hot, moderate and cold years from 1983 to 2014. Inter-annual variation of annual maximum temperature showed negative anomalies for most of the years from 1985 to 2001. This result coincides with a study by Alemayehu and Bewket (2017) in the annual maximum temperature of Efratana Gidim. The last decade is warmer than the first two decades in the annual winter and spring maximum temperatures, whereas great anomalies observed in summer and autumn. Analogous maximum temperature anomalies reported in other studies by NMA (2001, 2007); Taye and Zewdu (2012); Tesso et al. (2012) and Mesngistu et al. (2013).

Table 2: Temporal variability of annual and seasonal maximum temperature: **left (trend) and right (anomaly) from 1983 to 2014 (constructed by the authors)**



Inverse distance weighted (IDW) interpolation results presented in Figure 4 point out decadal spatial increasing trends in average annual maximum temperature: 22.7 to 27.31°C, 22.9 to 27.6°C and 23.2 to 27.8°C for the first, second and third decades respectively.

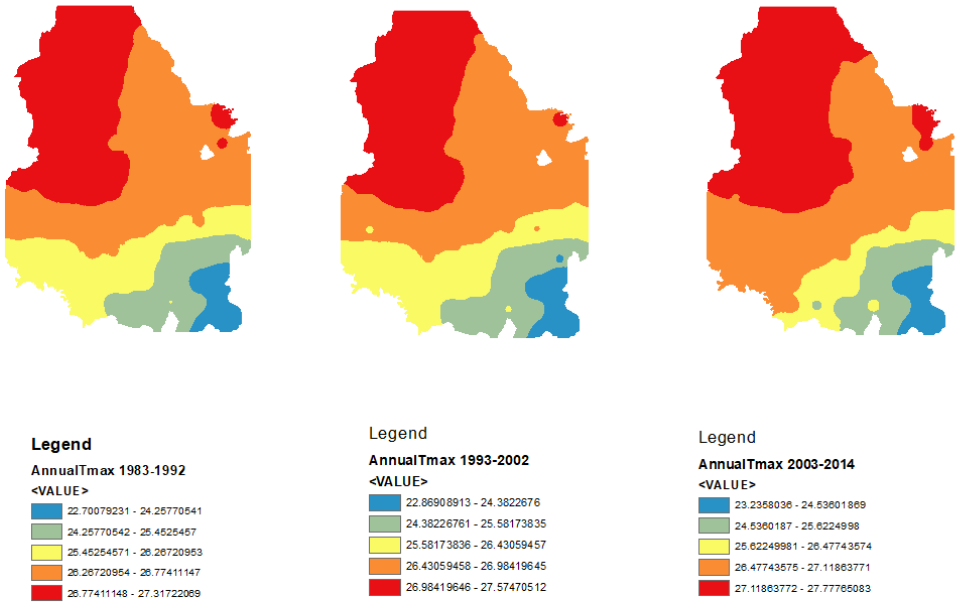


Figure 4: Spatial interpolated map of mean annual maximum temperature per decade (source: constructed by the author)

Figure 5 shows the annual and seasonal spatial variation of maximum temperature in the study area, depending on the Geo statistical analyst tools: the IDW result. The result showed that the mean annual maximum temperature varies spatially from 23°C in the south-eastern parts of the study area to 27.5°C in the north and north-western parts during 1983-2014. OLS results, for annual data, point out that the coefficient of variation is significant ($p < 0.01$) and the adjusted R2 value is 0.68 (see appendix II/a). Seasonally, it varies spatially from 23.3 to 28.9°C; 25.7 to 30.6°C; 20.4 to 25.2°C; and 21.6 to 26°C for winter, spring, summer and autumn respectively. The area has experienced almost similar spatial warmer and cooler trends with annual maximum temperatures during winter and spring. Warmer areas observed during summer and autumn in the north half of the area, and cooler areas located similarly

with the annual and the other two seasons for the recorded period. Based on spatial statistics, OLS results, the coefficient of variation is significant for all seasons ($p<0.010$; and adjusted R2 values are 0.69, 0.55, 0.52 0.49 for winter, spring, summer, and autumn, respectively.

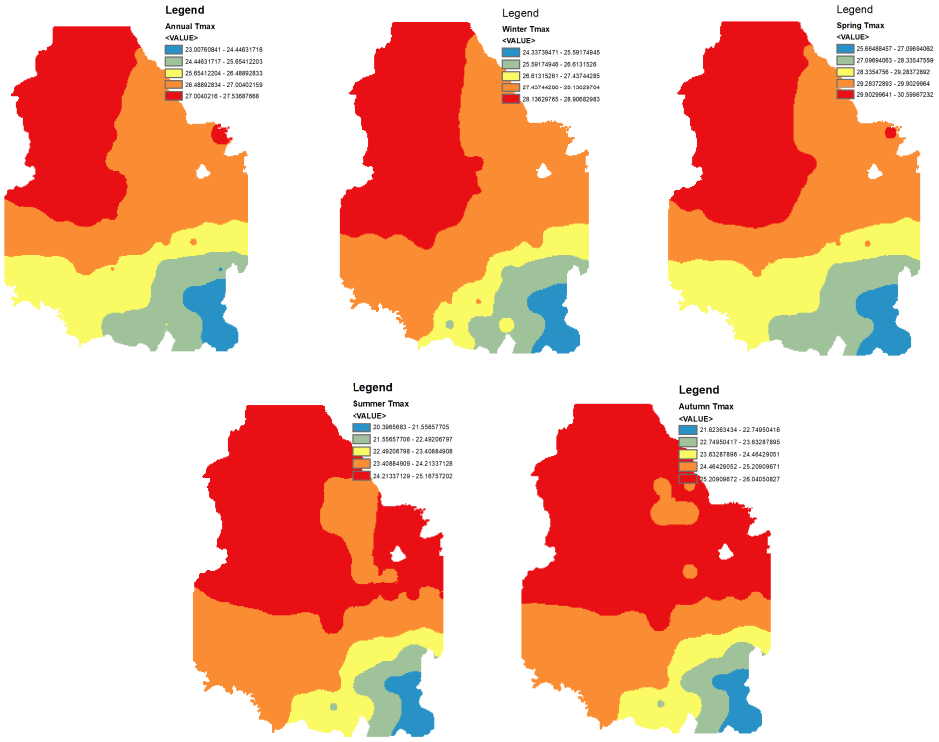
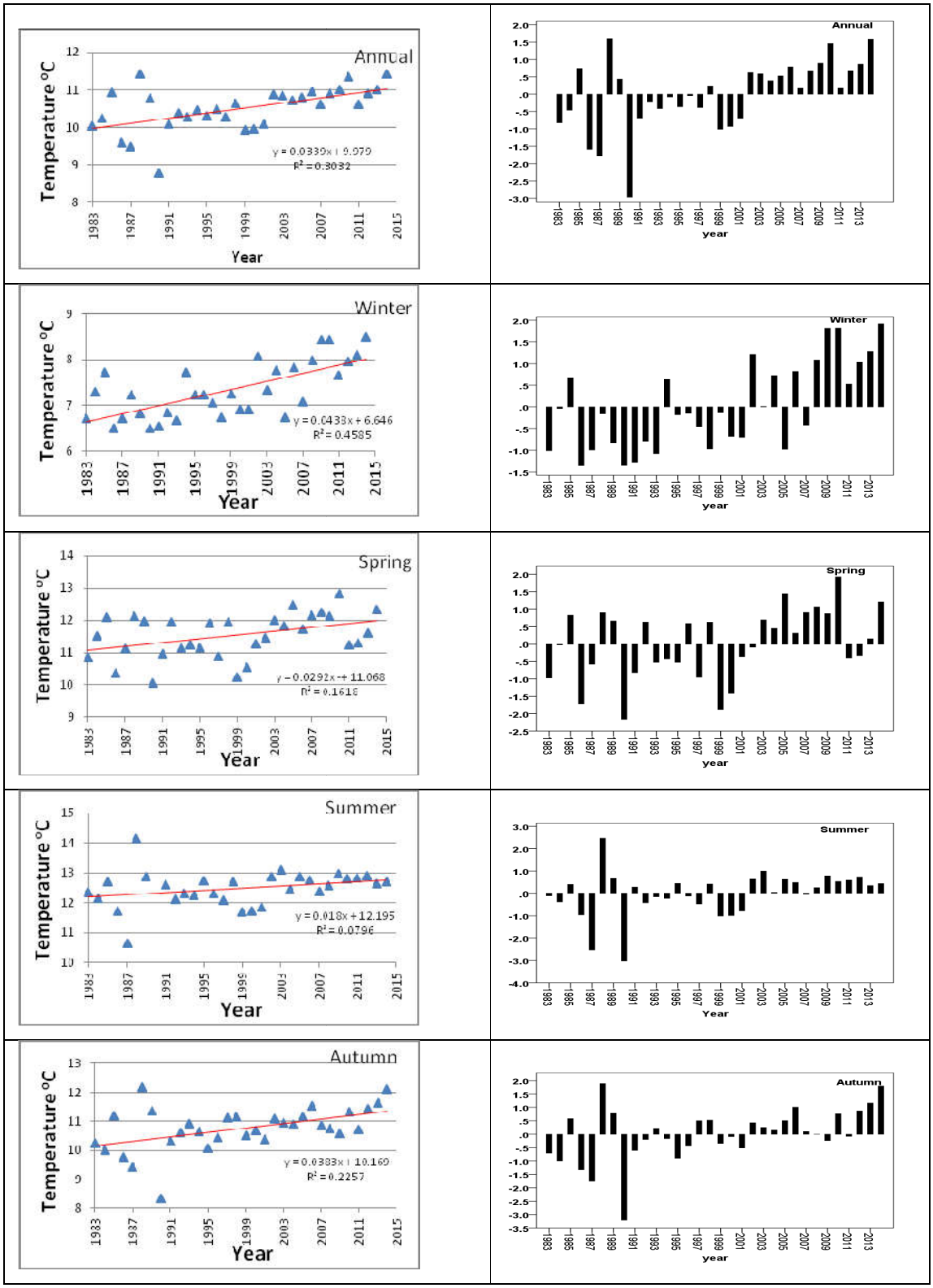


Figure 5 Annual and seasonal spatial interpolated map of maximum temperature from 1983-2014 (source: author's own work)

Temporal and Spatial Variation of Minimum Temperature

Table 3 presents the annual and seasonal temporal variation of the minimum temperature in the study area. The study revealed that the average annual minimum temperature of the study area is 10.5^{o}C and significantly increased by 0.11^{o}C per decade. The monthly mean value varies from 6.7^{o}C in January to 12.7^{o}C in May. The result shows significant warming trends of annual minimum temperature ($p = 0.01$). Seasonally, the warming trends of winter and autumn are significant ($p=0.01$) whereas spring and summer are significant at ($p=0.05$) levels. Other researchers reported similar warming trends in minimum temperature in different places and periods. In Addis Ababa, Conway et al. (2004) reported increased trends in annual minimum temperature of 0.4^{o}C per decade from 1951 to 2002. In the upper Blue Nile basin, Mengistu et al. (2013) also found that minimum temperatures increased at a higher rate than the maximum temperatures during winter, summer, autumn and the annual time scale.

Table 3: Temporal Variability of Annual and Seasonal Minimum Temperature: **trend (left) and anomaly (right) from 1983 to 2014 (constructed by the authors)**



Other studies also found increasing trends of minimum temperature: Alemayehu & Bewket (2017); NMA (2007); Asfaw et al. (2017).

The inter-annual variation of minimum temperature presented in Table 3 shows that the area has experienced both warm and cold years in the observed period. The results revealed annual minimum temperature shows positive anomalies from 2002 to 2014. In winter, we observed negative anomalies in the 1980s and 1990s, except in 1994 and 1995. The last decade is warmer than the first two decades for the recorded period consistently. Other studies_ NMA (2001, 2007); Taye and Zewdu (2012); Alemayehu and Bewket (2017); Tesso et al. (2012) and Mesngistu et al. (2013) also reported similar minimum temperature anomalies with different spatial scale and temporal variation.

IDW interpolated results in Figure 6 shows decadal spatial increasing trends in average annual minimum temperature. Consistent with the temporal trends, results depict the last decade was the warmest (9.0 to 11.5^{o}C) compared with the first (8.2 to 11^{o}C) and the second (8.3 to 11.1^{o}C) decades.

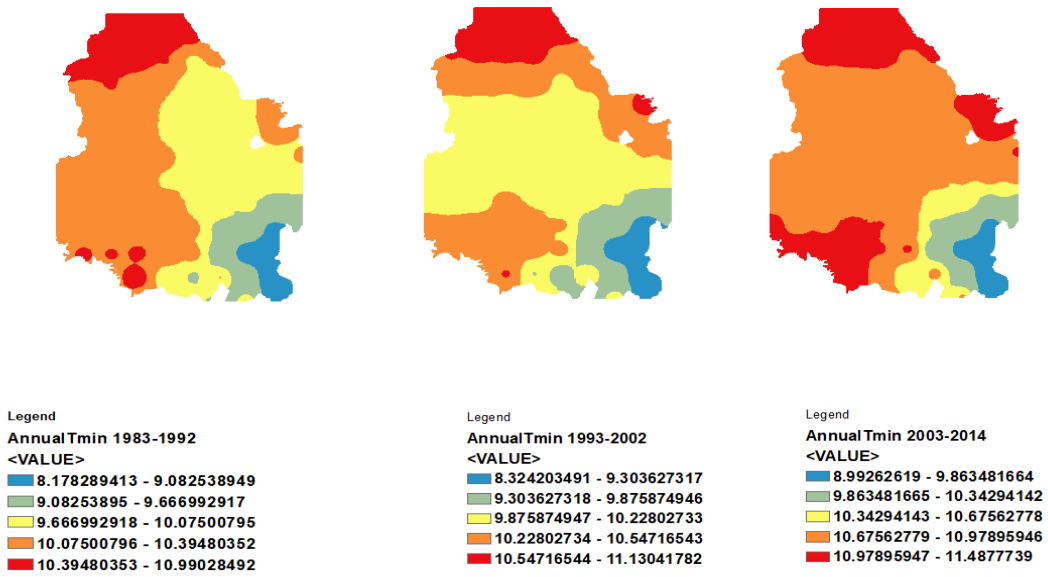


Figure 6: Spatial interpolated map of mean annual maximum temperature per decade (source: constructed by the author)

Figure 7 shows annual and seasonal spatial variation of minimum temperature in the area based on IDW interpolator technique for the period 1983-2014. Mean annual minimum temperature varies spatially from the 8.5°C, the cold temperate area in the south-eastern to 11.2°C the hot temperate area in the north parts of the area. OLS results showed that the coefficient of variation is significant: $p < 0.01$ and the adjusted R^2 value is 0.44 (see appendix II/b). We observe considerable seasonal spatial variation of minimum temperature compared to the maximum temperature. It varies from 6.2 to 7.9°C; 9.7 to 12.1°C; 9.9 to 13.4°C; and 8.4 to 11.7°C for winter, spring, summer and autumn, respectively. The area has experienced consistent hotter temperate in the north and colder temperate in the south-eastern parts in all seasons during the recorded period. The spatial statistical results revealed a significant coefficient of variation $p<0.01$ in all seasons; and adjusted R^2 values for winter, spring, summer and autumn are 0.36, 0.27, 0.39 and 0.45 respectively.

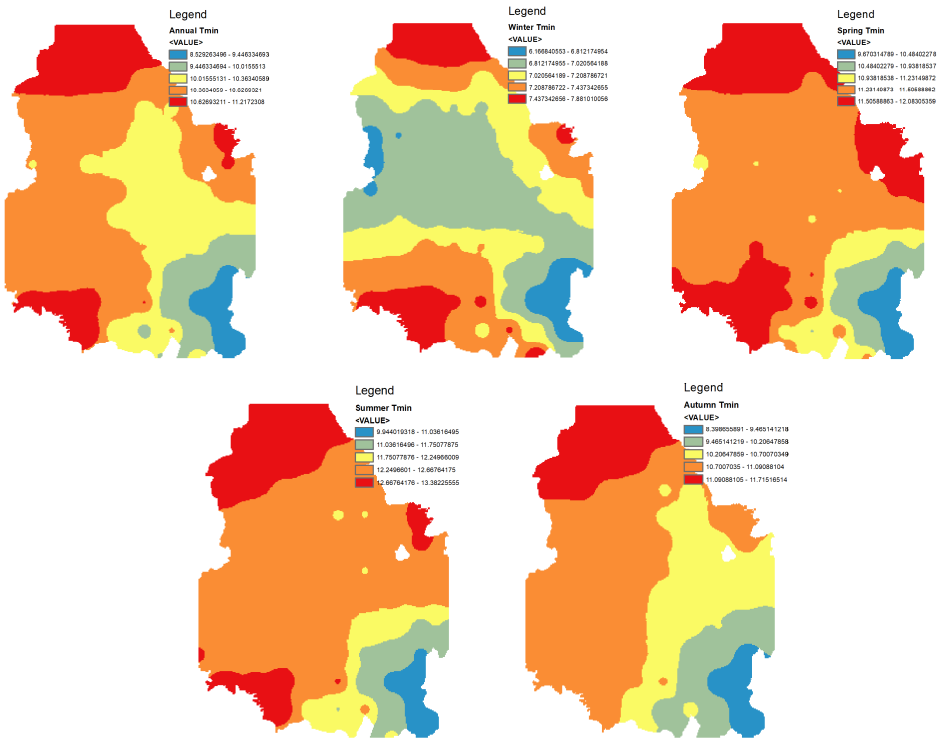


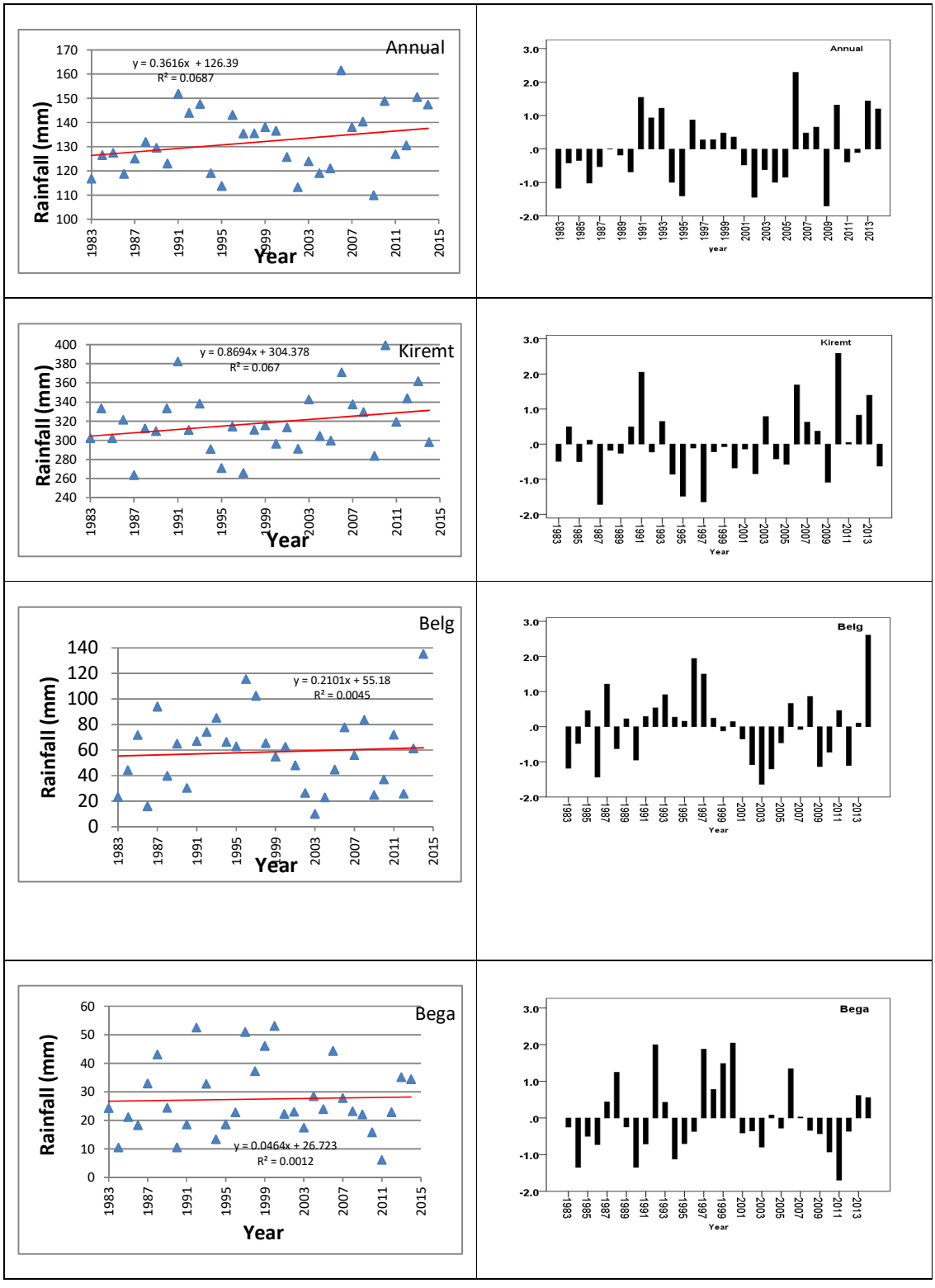
Figure 7: Annual and seasonal spatial interpolated map of minimum temperature from 1983-2014 **(source: constructed by the author)**

Temporal and Spatial Variation of Rainfall

Table 4 presents the temporal variation of rainfall in annual and seasonal time scale over the study area. Findings show the total annual rainfall distribution varies from 1319.8- 1939.7mm for the recorded period. Seasonal total rainfall varies from 1054.8-1597.3mm in kiremt (June-September); 30.4-405.6mm in Belg (March-May); 30.7-265.5mm in Bega (October-February). Results additionally show the annual and seasonal rainfall shows statistically non-significant increasing trends. Mengistu et al. (2007) reported similar results except a decline trend for spring in the Blue Nile river basin; Alemayehu & Bewket (2017) found a statistically non-significant increasing trend of Kiremt rainfall in Efratana Gidim and significant increasing trend in Menz Gera Meder, central highlands of Ethiopia. Eshetu et al. (2016) reported similar non significant increasing trend in Gatira, southwestern Ethiopia. Gedefaw et al. (2018) observed an increasing trend of annual rainfall in Amhara region specifically in Gondar, Bahir Dar and Motta.

Inter-annual variation of annual rainfall displayed in Table 4 indicates negative anomalies for most of 1980s and positive anomalies for the last decade. This result is consistent with a study by Ayalew et al. (2012) in the Amhara region, location of our study area. Seasonal rainfall variability has shown negative and positive anomalies in the 1990's for Kiremit (June-September) and Belg (March-May) seasons, respectively. The driest and wettest years are 2009 and 2006, respectively. The area has experienced both wet and dry years with moderate inter-annual rainfall variation. The result is in line with Alemayehu & Bewket (2017) in the central highlands of Ethiopia; and Bewket and Conway (2007) and Ayalew et al. (2012) in the Amhara region.

Table 4: Temporal Variability of Annual and Seasonal Rainfall: **trend (left) and anomaly (right) from 1983 to 2014 (source: constructed by the authors)**



The IDW interpolated decadal spatial map of rainfall distribution given in Figure 8 shows increasing trends in average annual minimum rainfall: 109.4, 111.1 and 113.4mm for the first, second and third decades respectively. The result additionally shows the highest spatial rainfall amount was recorded during the second decade: 179.9mm compared with 166.0mm for the first and 176.2mm for the third decade

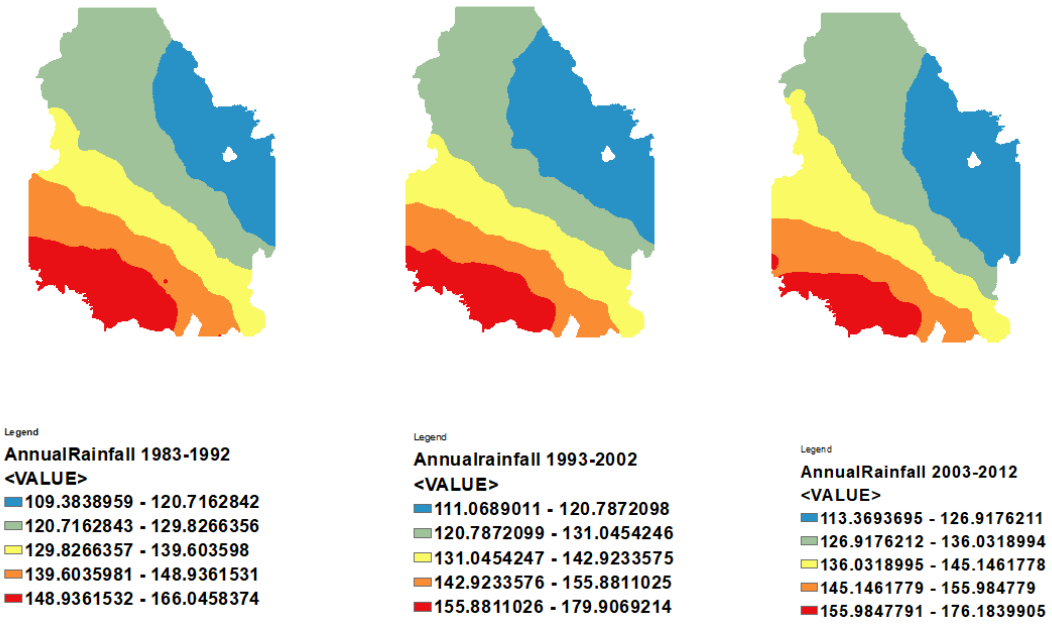


Figure 8: Spatial interpolated map of mean annual rainfall per decade (source: constructed by the author)

Figure 9 points out the annual and seasonal spatial variability of rainfall distribution. The spatial distribution of mean annual rainfall varies from 111.81mm in the eastern part of the area to174.18mm in the south-western part. The annual spatial statistics showed that robust pr is significant ($p<0.01$) with the adjusted R-square values (R^2 is 0.41) (see appendix II/c). Seasonal spatial mean rainfall distribution varies from 263.75-396.21mm in Kermit, similar location with an annual rainfall; 40.22 mm in the north and north-eastern areas to 95.94 in south and south-western areas; and 27.34mm in the north to 51.81mm in the south parts of the area. The spatial statistical result showed that robust pr is significant $p<0.05$ in Kiremt and Belg seasons with R^2 values of 0.32 and 0.17 respectively.

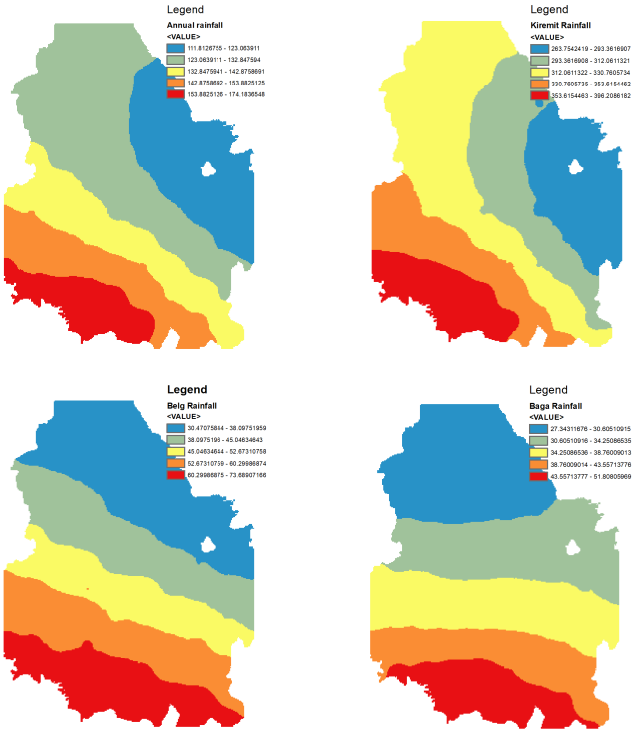


Figure 9 Annual and seasonal spatial interpolated map of rainfall from 1983-2014 **(source: constructed by the author)**

3.5. Conclusion

The main purpose of this study was to provide analysis on spatial and temporal variability in rainfall and temperature at annual and seasonal time scales. The study analyzed rainfall, minimum and maximum temperature using meteorological satellite data constructed to 154 points at a 10×10 km resolution from 1983 to 2014. Based on the analysis using different statistical methods, we found that the study area experienced spatiotemporal changes in temperature and rainfall for the evaluated period. The study indicated significant warming trends of minimum temperature at annual and seasonal time scale and maximum temperature in winter and spring seasons. Spatially, north and north-western parts of the area have experienced warmer temperatures compared with the south-eastern, the cooler area. The last decade of the observed period for minimum temperature was warmer than the first two decades in annual and seasonal time frame. We observed consistent spatial warming trends in the north and south-eastern parts of the area, at annual and seasonal time scales respectively. Regarding rainfall, statistically non-significant increasing trends with moderate inter-annual rainfall variability were observed at annual and seasonal time scales over the study area. The area has experienced the highest rainfall distribution in the annual time scale and the kiremt

season in the southwest; and in Belg and Bega seasons in the south. These results call a need for planning of local adaptation strategies to prevent unfavourable impacts of temperature and rainfall variability on agriculture and water resources.

4. GENDER DIMENSION OF HOUSEHOLDS' VULNERABILITY TO CLIMATE CHANGE IN MECHA DISTRICT, NORTHWEST ETHIOPIA

4.1. Abstract

Climate change impacts affect the well-being of the poor with limited access to resources that increase their level of exposure and decrease their coping ability. In Ethiopia, female-headed households have limited access to and control over key resources than male-headed households. This problem calls a need to study gender differentiated vulnerability to climate change to facilitate decisions, to focus on the most vulnerable groups and to provide gender-disaggregated information for development of local adaptation strategies. Data was collected from 416 randomly selected respondents using a household survey. The data was analysed looking at means, frequencies, standard deviations t-test and one way between groups ANOVA. Six sets of vulnerability indices were constructed using principal component analysis (PCA). The study revealed that vulnerability level of female-headed households (V^1=0.52) is higher than male-headed households (V= 1.23) in the irrigation area. The findings further reveal that female-headed household' vulnerability level (V=0.87) residing without the irrigation area was less than that of female-headed households (V=0.52) living in the irrigation area. Vulnerability level of male-headed households (V=1.04) in the upper stream was more than male-headed households (V=1.23) in the lower stream. However, one way between groups analysis of variance with post-hoc tests indicated that there is no significant vulnerability difference between all household groups: female- and male-headed households in the upper and lower stream. With respect to aggregated households across gender, female-headed households have relatively higher vulnerability level (V=1.28) than male-headed households (V=1.32). The results from independent sample t-test indicate significant mean difference between aggregated male- and female-headed households with respect to land size, livestock size, off-farm income, saving, irrigated land, water and food insufficient months and total yields. Findings suggest the formulation of gender-sensitive policy to increases female farmers' access to resources to reduce their vulnerability so as to build their adaptive capacity and to share the benefit of irrigation starting from the design of such a scheme.

Key words*:* female-headed households, access to resources, climate variability, and principal component analysis

[1] The lower 'V' values the higher vulnerability level and the higher 'V' values the lower vulnerability level.

4.2. Introduction

In Ethiopia, larger dependence on climate-sensitive production systems mainly agriculture, exposed the rural households to the changes in climate and related hazards (NCCF, 2009; Abel et al., 2015). Studies showed that climate-associated risks have been occurring frequently throughout the country (Misganaw et al. 2014). In Amhara Regional state of Ethiopia, regular flooding damaged crop land of farm households resulted in land degradation which in turn increases vulnerability of the households (ARSDPPO, 2015).

The intergovernmental panel on climate change (IPCC) highlighted that differences in vulnerability and exposure arise from non-climatic factors and multidimensional inequalities shape differential risks. Vulnerability to climate change may damage or harm a group of people who are marginalized and susceptible to adverse effects of climate change and also to some adaptation responses. Interlocking social processes like gender causes vulnerability as well as exposure to climate change that aggravate inequalities in socioeconomic status and income (IPCC, 2014).

Most of the key areas of unfavourable consequences of climate change are strongly associated with gender inequality issues. Because of gender differences in property rights, access to information and in cultural, social and economic roles, natural disasters are likely to affect men and women in a different way. Climate change is likely to deepen the gender dimensions of vulnerability, especially among female-headed households (Brown et al., 2012) and expected to jeopardize women's livelihoods by reducing economic opportunities, especially for female-headed households (Dodman, 2010).

Impacts of climate change are anticipated to disproportionately affect the welfare of the poor in rural areas, such as female-headed households and others with limited access to land, modern agricultural inputs, infrastructure, and education (IPCC 2014 p.19). In Ethiopia, female-headed households are poorer than male-headed households (Muleta & Deressa, 2014) caused by different levels of access to and control over key resources that leads to gender inequality which can be heightened by climate-related risks (Trocaire, 2014). Similarly, in Amhara region, limited access to productive resources and socio-cultural practices made female-headed households more vulnerable to the effects of climate change and unable to respond to its effects (Atinkut et al., 2018) as the poorest households are likely to suffer the most from climate change risks (Bewket et al. 2015).

Households in the same geographic location and within the same environment, face different vulnerability levels since vulnerability does not only depend on the system's sensitivity and exposure, but the adaptive capacity of the people in a system (Shah et al. 2013; Amusa et al. 2015). Analyzing gender-differentiated vulnerability enhances identifying problems related to climate-sensitive livelihoods; facilitating decisions to be focused on the most vulnerable groups; and providing gender-disaggregated information for local adaptation strategies to be set. Further, comprehension of vulnerability to changes in climate variability/change and climate extremes is important for development planners and decision-makers.

Nevertheless, previous studies in the region (e.g. Alemayehu & Bewket, 2016; Simane et al. 2016 and Amare & Simane, 2017) assessed smallholder farmers' level of vulnerability to climate change and variability across different agro ecology zone in different research sites and reported that farmers in lowland areas are the most vulnerable to climate change than farmers in highland and midland areas. In contrast, Tesso et al., (2012) reported farmers living in the highland areas were very much vulnerable to natural shocks compared to those living in the lowland area.

The above researchers analyzed farmers' spatial vulnerability differences and used female-headed households as an indicator in their vulnerability index considering a higher number of female-headed households increase vulnerability to climate change. However, it is necessary to stress that women are vulnerable not because they are "naturally weaker", but because conditions of vulnerability faced by men and women are different because of their gender. They are also capable of bettering themselves, becoming empowered, or changed. Further, women are not passive, they do not only receive help but they are active agents with different capacities to respond to the challenges posed by climate change (Aguilar, 2009). Further, Cutter et al. (2009) stated that setting female-headed households as vulnerability indicators that increase or decrease the impact of specific natural hazard events on the local population does not adequately capture groups' vulnerability. Overall, considering female-headed household as one variable does not shed light to assess the group's vulnerability to climate variability/change. Therefore, our study aims to analyze gender-differentiated vulnerability to climate variability/change between male-headed and female-headed households to identify their vulnerability level separately to develop specific adaptation strategies; to provide gender-disaggregated data for climate-associated policy makers and program developers; and

to make female-headed households the part to withstand the adverse impacts of climate change.

4.3. Research Methods and Materials

Vulnerability Analysis

There are three commonly used methods for vulnerability analysis, namely, socio-economic (political economy), biophysical (risk-hazard) and an integrated approach. The socio-economic and political status of individuals or groups is the centre for socio-economic vulnerability assessment. Individuals or some group of people in a community differ based on education, gender, wealth, health status, access to vital resources and political power, which contribute more to vulnerability difference. This method targets on recognizing the adaptive potential of the people based on their internal characteristics. One major limitation of this approach is that it does not account biophysical resources which have the potential to counteract unfavourable impacts of climate risks (Füssel 2007; Deressa et al. 2008, & Gutu et al. 2012).

The second approach, biophysical, tries to assess the level of damage caused by environmental pressure on both social and biological systems. Füssel, (2007) called this approach a risk hazard approach which is helpful to test the risks that arise from peoples' exposure to hazards of a particular type and magnitude. The major limitation of this approach is that it focuses on the assessment of biophysical factors which is not enough for sympathetic the complex nature of the vulnerability and neglects the socio-economic aspect in producing vulnerability and in adapting to climate change (OPiyo et al. 2014).

The third approach, integrated method, enables to combine assessment of both the peoples' internal characteristics and risks triggered by environmental stresses (Füssel, 2007). Füssel and Klein (2006) claimed that the IPCC definition of vulnerability to climate change as a function of adaptive capacity, sensitivity, and exposure has a comparable concept with the integrated approach to vulnerability analysis. The definition of IPCC on vulnerability implies an external character by the exposure of a system to climate variations; an internal character that comprises its sensitivity; and its adaptive capacity to these stressors. This specific theme of the thesis used the integrated concept to correct the first two approaches' limitations.

Accordingly, vulnerability indicators were framed by the IPCC explanation of vulnerability as a function of exposure, sensitivity, and adaptive capacity. Exposure encompasses all the elements of climate change, including changes in the mean, range, or variability of temperature and precipitation, and the frequency and magnitude of climate extremes that are demonstrated by the damage, hardship, and death caused by events such as droughts and floods. Human systems sensitive to climate change include mainly water resources; agriculture; and human health. Adaptive capacity with climate change impacts in human systems includes wealth, technology, information, skills, infrastructure, and institutions (IPCC, 2001). In sum, major and sub-components, presented in Table 5, were developed based on the IPCC's concept of vulnerability combined with local studies (Dechassa et al. 2016; Tesso et al., 2012; Simane et al. 2016 and Amare & Simane, 2017) in consideration of the local context. Besides, gridded monthly temperature and rainfall data on 10x10 km resolution were obtained from the National Meteorological Agency of Ethiopia for the period 1983-2014 to analyze trends and variability of temperature and rainfall.

Table 5: Vulnerability Indicators at Household Level

Vulnerability factor	Major Indicators	Sub-indicators	Functional relationship
Adaptive capacity	Wealth	Total land resources in Kada*[2]	The higher households' wealth, the lesser their vulnerability.
		Total livestock based on TLU conversion factor	
		Off-farm income in Birr*[3]	
		Savings from their income in Birr	
		Radio (yes/no)	
		Mobile phone (yes/no)	
		Hand-dug well water (yes/no)	
		Energy saving stove (yes/no)	
		Solar energy source (yes/no)	
	Agricultural Technology	Use of fertilizer (yes/no)	The more households' use of agricultural technology, the lesser their vulnerability
		Use of improved seeds (yes/no)	
		Use of pesticides (yes/no)	
	Institution and Skills information	Access to telephone services (yes/no)	The more households' access to different institutional services, the lesser their vulnerability
		Access to extension services (yes/no)	
		Access to weather information (yes/no)	
		Households with formal education (yes/no)	The more households informed and

*[2] Kada a quarter of one hectare
*[3] Birr is Ethiopian currency

			skilled, the lesser their vulnerability
Sensitivity	Infrastructure	Distance to health center in minutes for one round trip Distance to market in minutes for one round trip Distance to school in minutes for one round trip Distance to veterinary center in minutes for one round trip Distance to main road in minutes for one round trip	The longer households travel, the higher their vulnerability level
	Social network	Membership in peasant association in percent Membership in informal associations in number Number of relatives and friends to borrow in numbers	The higher households' social network, the lesser their vulnerability
	Socio-demography	Total family member in number Dependent family member <15 and >65 years old in number	The higher households' family member and dependents, the more their vulnerability level
	Water	Irrigated land in Kada Sufficient water for domestic use (yes/no) Time to collect water in minutes per day Number of water insufficient months in 2016 year	The more irrigated land, water sufficiency, smaller time to water points, and smaller water insufficient months; the less households' vulnerability.

Exposure		
Agriculture/food	Total annual production per quintal in 2016 year Diversity of crop species in number Number of food insufficient months in 2016 Natural resource conservation practices in number	The higher production and diversity of crops; smaller food insufficient months; increase in soil fertility and more natural resource conservation practices made households less vulnerable.
Health	Number of family member illness Number of days family member illness Health center uses (yes/no) Membership to health insurance enterprise (yes/no)	The number of family members' illness and more days they spend due to illness; the lesser households' use of the health center and being member in health insurance enterprise the higher their vulnerability level
Climate change	Mean STD. deviation of monthly avg. of avg. minimum daily temperature (2000-2014) for aggregate data Mean STD. deviation of monthly avg. of avg. maximum daily temperature (2000-2014) for aggregate data Mean STD deviation of monthly avg. of avg. daily precipitation (2000-2014) for aggregate data	Increase in temperature and a decrease in rainfall increases households' vulnerability
Climate extremes and damages	Drought frequency for the past 10 years in number Flood frequency for the past 10 years in Number Land damaged by flood for the last 10 years in kada	The more frequency of climate extremes and their impact on households, the more households' vulnerability.

Estimating Vulnerability

There are two types of commonly used approaches to estimate vulnerability; the econometric and the indicator approach. Hoddinott and Quisumbing provide econometric approaches to estimate the vulnerability as expected poverty, as expected utility and as uninsured exposure to risks. It is used to analyze the level of vulnerability across different social groups by employing household-level data. However, this approach is limited by 1) the use of estimations made across a single cross-section requires the strong assumption that the cross-sectional variability captures temporal variability in estimating vulnerability as expected poverty; 2) vulnerability as expected utility is probably the hardest measure to calculate; and 3) vulnerability as uninsured exposure to risk is ex-post rather than ex-ante and requires panel data (with three or more rounds) to be credibly estimated (Hoddinott and Quisumbing 2003).

The other approach, the indicator method is a means of a quantitative measure intended to be an attribute or a parameter of a system of interest using a single value (Cutter et al. 2008). It involves the selection of indicators that a researcher considers to largely account for vulnerability to climate variability even though subjectivity is considered as a shortfall in the selection of various indicators (Deressa et al. 2008). Assigning weights to the indicators is another challenge in this approach. There are two methods to assign weights; equal/average and unequal. Equal weight is based on the assumption that all indicators are equally important. However, it leads to the overweighting of some less important indicators while underweighting the important ones and it may be too arbitrary (Tesso et al., 2012; Piya et al., 2012). Assigning weights based on the expert judgment is one way of unequal weight, but this approach was criticized for being subjective and often constrained by lack of expert knowledge and agreement on the subject. (Gbetibouo, 2009). Assigning weights by principal component analysis (PCA) is another way of unequal weighting preferred to the above methods (Cutter et al., 2003). Therefore, following (Tesso et al., 2012; Dressa et al., 2008; Tsue et al., 2014; Opiyo et al., 2014; Bekele, 2013; Piya et al. 2012), this paper uses a statistical technique, PCA, to assign weights to indicators. In general, with its limitation "the usefulness of quantitative indicators for reducing complexity, measuring progress, mapping, and setting priorities make them an important tool for decision-makers" (Cutter et al., 2008).

Before running principal component analysis, descriptive and inferential analyses were carried out for all the variables under adaptive capacity, sensitivity, and exposure looking at

means, frequencies, standard deviations t-test and one way between groups ANOVA. Selected original variables were normalized using the equation given below following calculation of the life expectancy index in human development report by UNDP (2018).

$$Normalized\ value = \frac{Observed\ value - Mean}{Standard\ deviation} \text{ ---------- (1)}$$

After normalization of all the sub-components as an index, PCA was carried out for overall vulnerability indices' development to avoid subjectivity in assigning weights as all vulnerability indicators have no equal contribution to the overall vulnerability index. Factorability and appropriateness of combined data were examined based on the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity before PCA application (Table 8). As Pallent (2010) explained Bartlett's test of sphericity should be statistically significant at $p < .05$ and the Kaiser-Meyer-Olkin (KMO) value should be 0.6 or above for the factor analysis to be considered appropriate.

Six sets of vulnerability indices were constructed using similar indicators _ male-headed and female-headed households in the upper stream (MHHup and FHHup); in the lower stream (MHHLow and FHHLow); and aggregated male-headed and female-headed households (AgMHH and AgFHH) to compare similar and different gender of households in different settings and the vulnerability position between them. For each variable, the first principal component scores, which accounted for the largest possible proportion of the total variability, is computed by multiplying the case's standardized values were utilized for households' vulnerability analysis. Finally, overall vulnerability index was calculated using the following equation employed by other researchers (Tesso et al., 2012; Dressa et al., 2008; Opiyo et al., 2014; Bekele, 2013)

$$Vulnerability = Adaptive\ capacity - (Sensitivity + Exposure) \quad (2)$$

4.4. Results and Discussion

Adaptive capacity profile

Descriptive results in Table 6 indicate that female-headed households in the upper stream had the least average farm size (2.75 Kada) and livestock in TLU (1.62) while the largest mean farm size (5.56 Kada) and livestock in TLU (4.75) belong to male-headed households in the lower stream. Female-headed households in the upper stream are better in terms of average

Table 6: Descriptive Results (mean and percentage) of Vulnerability Indicators across Households

Variables	Upper stream households		Lower stream households		Aggregated households	
	Male-headed	Female-headed	Male-headed	Female-headed	Male-headed	Female-headed
Total land resources per capita	4.406	2.753	5.564	3.449	4.872	3.027
Total livestock number	4.1312	1.6234	4.7492	2.0953	4.4402	1.8090
Off-farm income	14344.89	8717.56	14939.55	4091.53	14642.22	6897.99
Saving	4893.23	2369.78	6272.93	571.19	5583.08	1662.33
Radio	45.1%	71.4%	34.6%	69.5%	39.8%	70.7%
Mobile phone	36.1%	65.9%	30.8%	55.9%	33.5%	62.0%
Hand dug well water	29.3%	73.6%	27.1%	64.4%	28.2%	70.0%
Energy saving stove	72.9%	80.2%	57.1%	76.3%	65.0%	78.7%
Solar energy source	40.6%	73.6%	14.3%	57.6%	27.4%	67.3%
Use of fertilizer	4.5%	60.4%	3.0%	40.7%	2.3%	52.7%
Use of improved seeds	4.5%	57.1%	6.8%	40.7%	2.3%	50.7%
Use of pesticides	4.5%	60.4%	5.3%	40.7%	2.3%	52.7%
Access to credit services	55.6%	74.7%	57.9%	79.7%	56.8%	76.7%
Access to telephone services	36.1%	62.6%	8.3%	44.1%	22.2%	55.3%
Access to extension services	7.5%	59.3%	3.0%	66.1%	5.3%	62.0%
Access to weather information	54.9%	65.9%	51.9%	93.2%	53.4%	76.7%
Households with formal education	63.2%	87.9%	61.7%	83.1%	62.4%	86.0%
Distance to health centre	90.89	158.02	88.65	79.66	89.77	121.33
Distance to market	95.850	85.934	101.353	75.847	98.602	81.967
Distance to school	37.52	44.66	62.56	83.05	50.04	59.76
Distance to veterinary centre	43.84	45.27	70.23	82.71	57.03	60.00
Distance to main road	45.71	62.97	68.80	82.54	57.26	70.67
Membership in peasant association	33.1%	73.6%	3.0%	81.4%	18.0%	76.7%
Membership in informal associations	3.5865	2.3297	3.6692	2.7119	3.6278	2.4800
Number of relatives and friends to borrow	3.31	1.82	4.85	2.95	4.08	2.27
Total family member	5.87	3.88	6.06	4.17	5.97	3.99
Dependent family members	3.03	1.49	3.08	2.08	3.06	1.73
Irrigated land	.353	.264	3.395	1.729	1.874	.840
Sufficient water for domestic use	26.3%	26.4%	10.5%	20.3%	18.4%	24.0%
Time to collect water	42.60	43.30	21.59	23.37	32.09	35.46
Water insufficient months	3.71	3.60	3.80	3.54	3.75	3.58
Total annual production	8.25	3.87	9.86	1.56	8.71	2.96
Diversity of crop species	2.15	1.66	2.41	2.07	2.28	1.82
Food insufficient months	3.64	2.70	3.96	3.46	3.80	3.00
Natural resource conservation practice	1.11	.48	2.53	1.41	1.82	.85
Family member sickness	.85	.85	.40	.53	.62	.72
Days family member sickness	42.00	27.98	18.35	29.80	30.18	28.69
Health center use	3.8%	0.02	.8%	6.8%	2.3%	4.0%
Membership to health insurance interprize	27.1%	40.7%	21.8%	39.0%	24.4%	40.0%
Drought frequency	54.1%	59.3%	29.3%	45.8%	41.7%	54.0%
Flood frequency	66.2%	65.9%	42.9%	42.4%	54.5%	56.7%
Land damaged due to flood	.500	.462	.132	.076	.316	.290
Decrease in rainfall	47.80%	49.50%	61.2%	50.8%	54.9%	52%
Increase in temperature	93.30%	89%	96.2%	91.5%	79.30%	80%

annual saving (2,369.8 birr) and off-farm income (8,717.6 birr) than female-headed households' saving (571.2 birr) and off-farm income (4,091.5) in the lower stream. In general, male-headed households have a higher size of land (4.9 Kada), annual income (14,642 birr), and livestock in TLU (4.4) compared with female-headed households' land (3 Kada), annual off-farm income (6,897 birr) and livestock in TLU (1.8). In line with these results, a study in Nigeria by Amusa et al. (2015) revealed male-headed households have better farm size, off-farm income, and livestock than female-headed households.

Except for female-headed households in the upper stream, most of the households in the upper and lower stream used agricultural technology such as fertilizer, improved seeds, and pesticides (Table 6). In terms of access to institutional services, male-headed households have less access to credit services by 55.6 and 57.9 percent in the upper and lower stream, respectively. Though more female-headed households have less access to all the institutional services, their less access to credit service is greater than the other services: 74.7 and 79.7 percent in the upper and lower stream, respectively. The higher percentage of less access to credit services may lead to higher vulnerability. Amusa et al. (2015) and Suhiyini et al. (2019) confirmed that female-headed households' less access to credit services contribute to their higher vulnerability to climate change compared with their counterparts' male-headed ones.

Households without access to formal education and information regarding climate variability are higher for female-headed than male-headed households (Table 6). This result agreed with the study of Flatø et al. (2016) that reported male-headed households to have higher educational levels than female-headed households. Infrastructure was measured via distance to different sectors in minutes for one round trip and female-headed households' average minutes to the sectors are greater than male-headed even though there is no big variation of average minutes of the distances across all households. However, the percentage of households travelling more than the average minutes have big variation; for instance, 58.6% of male-headed and 68.8% of female-headed households in the upper stream travel long distance to reach to the health centre and major road, respectively. Concerning social networks, female-headed households' participation in formal and informal associations is significantly lower than male-headed. Average family members and dependent family members were higher in male-headed households than female-headed households for both upper and lower stream. These results corroborate with studies by Shah et al. (2013) and

Suhiyini et al. (2019) that revealed female-headed households were more vulnerable in terms of social network and male-headed households had more dependents than female-headed households.

Exposure and Sensitivity profile

Three major indicators (water, food, health) with twelve sub-indicators were set under sensitivity. Regarding sub-indicator of sensitivity, water, the average size of irrigated land in the upper and lower stream was incomparable; 0.34 and 3.40 for male-headed households and 0.24 and 1.73 for female-headed households respectively. However, the average annual production of female-headed households (3.9 quintal) in the upper stream was greater than that of female-headed households (1.6 quintal) in the lower stream with the existence of greater size of irrigated land. Food insufficient months were also higher in the lower stream (3.5) than that of the upper stream (2.7) for female-headed households. A higher percent of female-headed households (39%) in the lower stream does not use the health centre during illness and a higher percent of male-headed households (54.1%) in the upper stream are not members to health insurance enterprises (see Table 6).

Independent sample t-test was carried out for the association between some of the continuous variables and aggregated households (Table 7). The results presented in Table 7 indicate that there is a significant mean difference between male- and female-headed households with respect to land size, livestock size, off-farm income, saving, family size, dependent family size, irrigated land, water and food insufficient months and total yield.

Table 7: Independent T-test on continuous variables and gender of household heads (source: Survey result 2017)

Variables	Male-headed household		Female-headed households		t-value	Sig.
	Mean	*SD*	*Mean*	*SD*		
Total land resources	4.985	2.9553	3.027	2.2186	7.068	.000
Total livestock number	4.4402	2.14831	1.8090	1.64313	13.006	.000
Annual off-farm income	14,642.22	18,466.063	6,897.99	11,880.088	4.624	.000
Annual saving	5,583.08	12,634.815	1,662.33	4,562.199	3.667	.000
Total family member	5.97	1.947	3.99	1.689	10.397	.000
Dependent family members	3.06	1.614	1.73	1.061	9.046	.000

Irrigated land	1.874	2.2374	.840	1.2293	5.231	.000
Time to collect water	32.09	37.357	35.46	26.037	-.978	.329
Water insufficient months	3.75	.505	3.58	.805	2.673	.008
Total annual production	9.05	9.679	2.96	3.708	7.407	.000
Food insufficient months	3.80	.591	3.00	1.043	10.003	.000
Land damaged due to flood	.316	.6895	.310	.4870	.091	.928
Days family member sickness	30.18	70.430	28.69	68.736	.208	.835
Family member sickness	.62	.816	.72	.636	-1.243	.215

Households' vulnerability to climate Change

Forty-two indicators were subjected to principal components analysis (PCA) and 15 components were extracted with eigenvalues exceeding or equal to 1. Using varimax with Kaiser Normalization, the components accounted for 81.4 % of the total variance in all of the variables with only 18.6% loss of information (see appendix IV). Table 8 presents the factorability and appropriateness of the data based on the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity.

Table 8: Kaiser-Meyer-Olkin (KMO) and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.780
Bartlett's Test of Sphericity	Approximate Chi-Square	6822.798
	Degree of freedom (df)	861
	Significance (*p*)	.000

The first loadings of PCA identified under adaptive capacity, sensitivity and exposure for each group of households are presented (see appendix IV and V). The factor scores (weights) of the first PCA were positively associated with majority of the indicators under adaptive capacity for male-headed households compared to female-headed households. Based on PCA results, Table 9 indicates female-headed households in the lower stream had lower adaptive capacity (0.739) compared to the upper stream (0.803). In contrast, male-headed households' adaptive capacity of the lower stream (1.198) was better than that of male-headed households (1.007) in the upper stream.

Table 9: Calculated IPCC contributing factors' indices across households

IPCC climate change contributing factors	Upper stream Households		Lower stream Households		Aggregated Households	
	Male-headed	Female-headed	Male-headed	Female-headed	Male-headed	Female-headed
Adaptive Capacity	1.007	.803	1.198	.739	1.095	1.089
Sensitivity	0.03	.123	-.030	-.124	.022	-.038
Exposure	-.059	-.188	.001	.341	-.251	-.143

Sensitivity and exposure are directly associated with overall vulnerability indices, i.e. the lower households' sensitivity and exposure value the lesser their vulnerability and the reverse is true for higher values. Most of the factor scores of sensitivity and exposure are negatively associated especially for households in the lower stream. Female-headed households in the upper stream are more sensitive (0.123) than male-headed households (-0.03) in the lower stream (Table 9). Households in the lower stream had a higher exposure index: (0.341) for female-headed and (0.001) for male-headed compared with households in the upper stream: (-0.188) for female-headed and (-0.059) for male-headed.

Findings presented in Figure 10 pointed out that female-headed households in the lower stream were more vulnerable in terms of adaptive capacity (0.739) and exposure (0.341); less vulnerable in terms of sensitivity (-0.124) compared with female-headed households' adaptive capacity (0.803), exposure (-0.188) and sensitivity (0.123) in the upper stream. On the other hand, male-headed households' vulnerability level in the lower stream was lower in terms of adaptive capacity (1.198) and sensitivity (-0.03) and relatively higher in terms of exposure (0.001) than male-headed households' vulnerability position in adaptive capacity (1.007) sensitivity (0.03) and exposure (-0.059) in the upper stream.

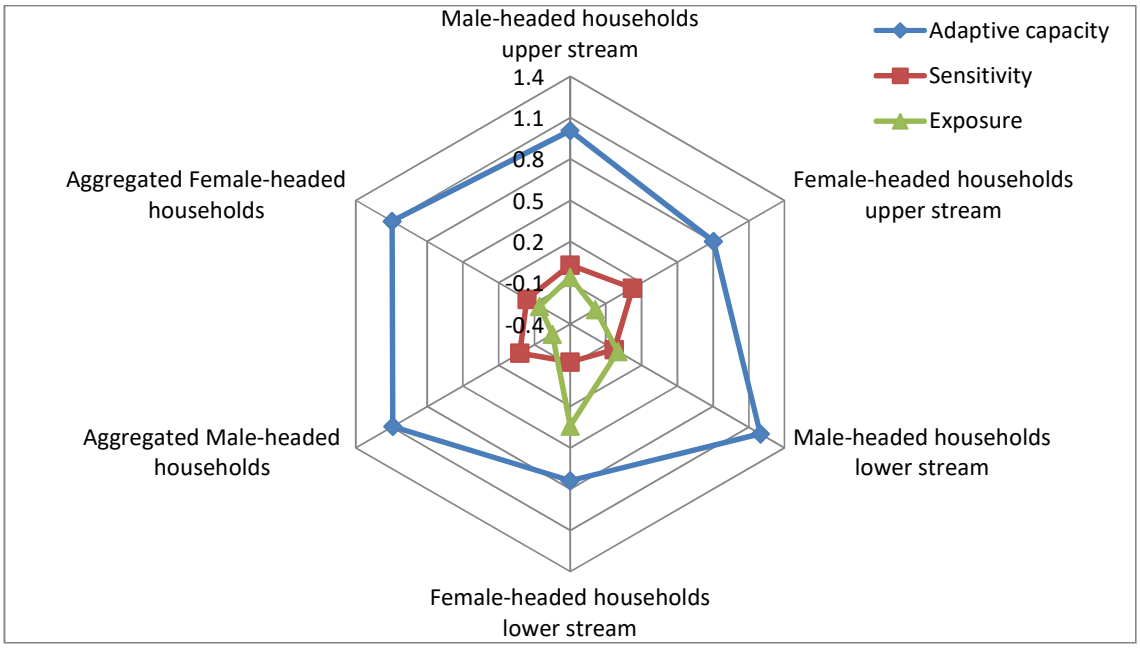


Figure 10: Spider diagram of adaptive capacity, sensitivity and exposure index for all household groups (Source: Survey result 2017)

Regarding the aggregated gender of households, Figure 10 pointed out aggregated male-headed had a higher adaptive capacity index (1.095) than female-headed households (1.089). Female-headed households have less sensitivity (-0.038) and less exposure (-0.143) indices compared with male-headed sensitivity (0.022) and exposure (-0.251). Briefly, the lesser sensitivity and exposure of female-headed households contribute to their lower vulnerability; however, their lower adaptive capacity contributes to their overall higher vulnerability (Figure 10).

The overall vulnerability of households presented in Figure 11 indicated that female-headed households in the irrigation area are the most vulnerable group, whereas male-headed households in the same area are the least vulnerable group. This result is supported by a focus group discussion of selected female-headed households and they replied;

> *"The irrigation water is useful for many farmers but we are not using. Since we are female, we lack money, we lack oxen, and we lack labor to plow. For instance, last year (2008 E.C.), my land was idle during the irrigation season. This year, I rent out for the irrigation season and I will use it for the rain season. The other discussant replied, "Female household heads have land in the irrigation area but it*

depends on the sharecropper's interest and capacity to cultivate during the irrigation season. If he is interested and capable of cultivating our land also has equal access to water to use our turn like others. But if he is afraid of expenses like seed, fertilizer, and labor; our land will remain idle until the rain season. " (FHH FGD2)

In line with our result, studies in Ghana and Zambia and in Tanzania revealed that female-headed households adopt small-scale irrigation technology lesser compared to male-headed households because of constraints (van Koppen et al. 2012; Njuki et al. 2014) including social relations, limited access to land, labor and education to adopt irrigation technology (International Fund for Agricultural Development., 2009). Further, this result showed female household heads' vulnerability level in the upper and lower steam are not similar which indicates that women are not homogenous group as intersectional theorists and feminist political ecology argued gendered vulnerability to disasters and climate risks does not derive from a single factor such as 'being a woman', but instead vulnerability indicates what factors are relevant in a particular setting with specific context (Kaijser & Kronsell, 2014; Enarson; 1998).

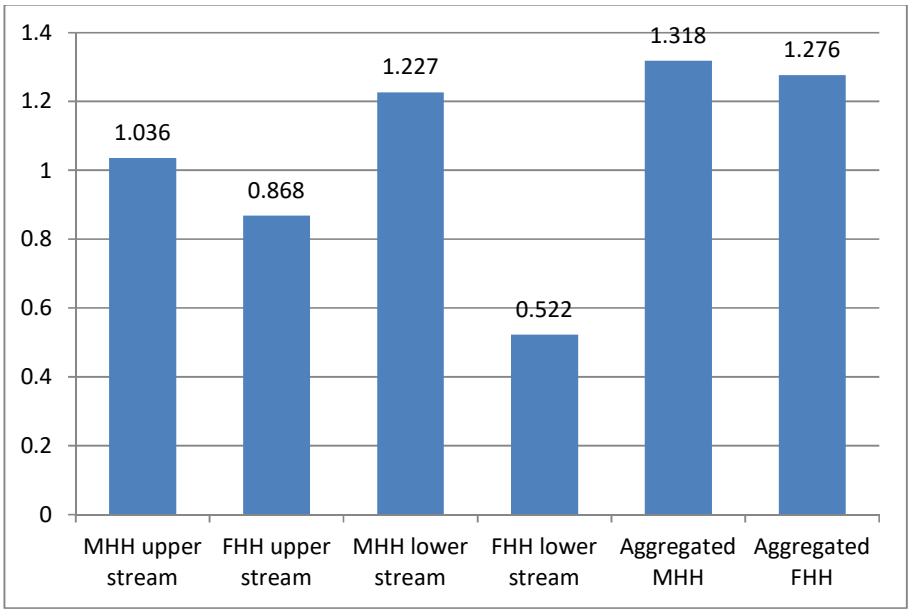


Figure 11: Households' overall vulnerability to climate variability (Source: Survey result 2017)

Our result coincides with a research by Shah, et al. (2013) among Carony and Nariva wetland communities in Trinidad and Tobago on vulnerability to climate change. The study reported that little difference in vulnerability between female and male-headed households and the former are better than the latter households in terms of housing and land tenure. Our finding is also in line with Flatø et al. (2016) study that confirmed male-headed households have a very similar vulnerability to rainfall variation as female-headed households in South Africa. An eco-feminist, Manion (2002) also claimed that ecological damaging issues including climate change have more of a detrimental effect on women than on men. In contrast, Ncube et al. (2016) reported male-headed households were regarded as highly vulnerable in Lambani province, South Africa compared with female-headed households though the difference was not significant.

4.5. Conclusion

This study focused on local-level assessment of vulnerability to climate variability across different household groups. An in-depth understanding of adaptive capacity, sensitivity, and exposure of households across gender is necessary to develop people-cantered adaptation programs. Using different vulnerability indicators, gender-based vulnerability analysis showed female-headed households in the irrigation area are the most vulnerable groups while male-headed households are the least vulnerable groups in the same area. The former had the least adaptive capacity, whereas the latter had the highest adaptive capacity. Female-headed households without irrigation were less vulnerable compared to female-headed households with irrigation. Male headed households in the upper stream were more vulnerable than male-headed households in the lower stream. Concerning aggregated households across gender in the research site, female-headed households have relatively higher vulnerability level than male-headed households. Based on the results we recommend the formulation of gender-sensitive policy to build female farmers' adaptive capacity by increasing their access to resources. Besides, attention should be given to the involvement of female-headed households to share the benefit of irrigation starting from the design of irrigation development schemes.

5. GENDER DIMENSION OF FARMERS' ADAPTATION TO CLIMATE CHANGE IN MECHA DISTRICT, NORTHWEST ETHIOPIA

5.1. Abstract

Adaptation to Climate change impact and gender inequality inversely reinforces each other. Adaptation to adverse impacts of climate change requires households' access to resources, whereas gender inequality creates different access to and control over productive resources among male- and female-headed households. This problem calls a need to investigate various adaptation strategies undertaken by the two households and the determinant factors associated with their decision to an adaptation option to provide gender-disaggregated data for gender-based interventions and integrate gender dimension in climate change adaptation policies and programs. The aim of this specific theme of the thesis is to examine the gender dimension of farmers' perception on temperature and rainfall variability, adaptation strategies they undertook, and determinant factors of their decision on adaptation options. Data was collected from 416 randomly selected respondents using a household survey. The data were analyzed using descriptive statistics and multinomial logistic regression across four groups of households. The result found that male and female farmers' perception of temperature and rainfall is almost similar. Findings also showed that male and female farmers are different in undertaking adaptation options: more male farmers undertake adaptation options than female farmers. Further, findings reveal household heads' age, farming experience, land size and access to extension services have a significant effect for male-headed households whereas family size, livestock number, use of credit services and climate information have positively associated with female-headed households' selection of adaptation options in the upper stream. In the lower stream, Age, farming experience and total land size affect female household heads' decision on adaptation options in the upper stream but these variables had no effect for male household heads. Findings suggest the need to inform agricultural extension workers to be gender inclusive and the need to build farmers' capacity to choose effective adaptation options with a wide range of institutional, policy, and technology support, particularly for the poorer and female household heads.

Key words: Gender-responsive adaptation options, perception, decision making, household heads

5.2. Introduction

Climate change is one of the global environmental changes likely to have harmful effects on natural and human systems, economies and infrastructure. Negative effects of climate change are expected to exacerbate poverty in most developing countries including Ethiopia (IPCC, 2014). The risks associated with it call for a broad spectrum of policy responses and strategies at the local, regional and global level (Fussel and Klein, 2002; IPCC, 2007). Fifth assessment reports by IPCC (2014) noted the importance of reduction and management of impacts and risks related to climate change through adaptation. Authorities at various levels are developing adaptation plans and policies and to integrate climate-change considerations into broader development plans.

Climate change acts as a magnifying glass which exposes and can deepen existing underlying gender inequalities (Skinner, 2011). IPCC (2014) noted that difference in susceptibility to climate change arises not only from climatic factors but from inequalities in the society. Gender is one of the core areas cause inequality and a system in which female are socially, economically, culturally, politically, institutionally marginalized resulted in vulnerability to climate change and needs to adapt.

Sperling (2003) claimed that the unfavourable impacts of climate change are more severely felt by poor people and poor countries while it is a global phenomenon. Their high reliance on natural assets and confined capacity to cope with climate extremes trigger them to be more vulnerable. Female-headed households are among the poor communities, thus it is important to identify unique adaptation responses to address climate change impacts on different social groups (UN Women Watch, 2009).

In developing regions like Ethiopia, rural female-headed households are among the poorest of the poor (Nelson et al., 2011; IPCC, 2014). Carson et al., (2013) claimed that people who are least able to adapt will feel the impacts of climate change most acutely. Households led by women and men, in their respective access to resources and social roles, are affected by the effects of climate variability differently. Compared to poor men, poor women lack the resources and opportunities to cope with the devastating results of climate change. Adaptation seems to be the most efficient way for farmers to reduce these negative impacts. Moreover, addressing the challenges of climate change is required by taking action to limit climate impacts to deal with the changes (Füssel et al. 2006).

Adaptation to climate change depends on a range of conditions: from peoples' level of exposure and dependency upon weather patterns for livelihoods to varying capacities in adaptation, which are influenced by gender, power, access to and control over resources in the household, community and society (Nellemann et al., 2011). Further, Skinner (2011) explained that responses to climate change need to be grounded in an understanding of the difference between men and women at the household level and at the wider community level; and of how these relationships are affected by and influence responses to climate change.

Nabikolo et al. (2012) and Skinner (2011) noted that compared to male-headed households, female-headed households have inadequate access to and control over productive resources such as land, labour, and livestock that are often a major factor in determining the adaptation strategies a farmer can choose. Further, the lack of these resources made female-headed households more vulnerable to the effects of climate change and reduce their adaptive capacity to respond to its effects. However, the two households' exposure to climate change and its negative impacts are similar (Adger et al., 2005).

Previous studies in Ethiopia (e.g. Deressa et al., 2008; Legesse et al., 2012; Tesso et al., 2012; Hadgu et al., 2015; Amare and Simane, 2017; Belay et al., 2017) consider the gender of household heads as a predictor variable that influences the decision on the choice of adaptation options. Accordingly, it is not clear which factors are important for decisions to adaptation on adverse effects of climate change among male- and female-headed households. However, adverse effects of climate change are experienced differently by gender and it has different effects on women and men farmers because of different access to resources that are essential to cope with the change and responding to climate-related problems involves decision making (IPCC, 2014; Trocaire, 2014).

Having clear demarcations on the different perceptions male and female household heads have, adaptation options they undertake, and determinant factors that influence their decisions on adaptation options are essential for gender-based intervention. Providing gender-disaggregated data is also valuable for policymakers and strategy developers in climate change adaptation programs. Further, adoption researches that analyze based on separate gender of household heads are limited so far. Therefore, this study tried to have analysis on perception, adaptation strategies and determinant factors to undertake different adaptation options for male and female household heads separately.

In response to the above stated problem, the study specifically aims to: 1) understand gender dimension of farmers' perceptions of climatic conditions; 2) identify adaptation options female and male household heads undertaking to adverse effects of climate change; and 3) analyze key factors determining female and male household heads' choice of a particular climate adaptation strategy.

5.3. Research Methods and Materials

Data Collection Method

This study used both primary and secondary data sources. As primary data sources, we collect quantitative and qualitative data through semi-structured questionnaires and interviews respectively. Survey questionnaires and interview guides were administered to the farmers. The questions included issues related to farmers perceptions on temperature and rainfall; adaptation strategies used by the farmers and determinant factors to select adaptation options to adverse effects of climate variability and change. Besides, document review was conducted as secondary data sources. Finally, the data derived from both types of data sources were cross-checked and triangulated to make the research more reliable and valid.

Data Analysis

In order to undertake a gender disaggregated analysis, descriptive statistics (frequency, mean and crosstabs); inferential statistics (z- score and linear regression); and multinomial econometric model were employed.

Model Specification

To analyze factors that affect the decision of farmers to select adaptation strategies, multivariate model was utilized to allow the determination of the likelihood of the different adaptation options to be selected. Multinomial logit (MNL) and multinomial probit (MNP) models are the most commonly used multivariate choice models in an adoption decision study with multiple choices with unordered response categories. These models have got desirable statistical properties as the probabilities are bounded between 0 and 1. This study employed the MNL model because it is widely used in climate change adaptation studies involving multiple choices and is easier to compute than its alternative, the MNP (Onubuogu & Esiobu, 2014, Belaineh et al. 2012, and Nhemachena & Hassan, 2007).

We estimate the actual climate change adaptation behaviour of each household heads using separate dependent variables with various choices to decide the factors influencing the

farmer's choice of particular adaptation methods. As Gbetibouo, (2009) explained, any adaptation option could fall under the general framework of utility and profit maximization. A rational farmer then seeks to maximize his/her profit over a specified time horizon, and must choose among a set of adaptation options. In this model, it is expected that i^{th} farmer maximizes his/her perceived advantage from adopting a convenient j^{th} adaptation method than the advantage from other adaptation options (say, k) determined by factors x represents a number of institutional, technological, informational, and economic factors (IPCC, 2014) described in eq.(1) following the work of (Belaineh et al. 2012, and Nhemachena & Hassan, 2007), the observable utility attached to each adaptation method j=0, 1,2,…,J by farmer i can be expressed as:

$U_{ij}\ (\beta_j X_i + \varepsilon_j) > U_i k(\beta k X_i + \varepsilon k),\ k \neq j$ ---------- (1)

Where

Uij represents the perceived value by farmer iof adaptation options jand k, respectively;

Xi represents explanatory variables that influence the choice of the adaptation options;

j and k are parameters to be estimated; and

j and ε are the error terms

Each household heads face a set of discrete, mutually exclusive choices of adaptation measures are assumed to be depend on factors of x. The probability P, of using a type of adaptation methods j by a given farmer i needs to be independent from the probability of selecting another adaptation method k (Pij/Pik is independent of the remaining probabilities) expressed as:

$$P(Y = J/x) = \frac{\exp(X\beta j)}{1+\sum_{k-1}^{j}(\exp\ (X\beta k)+\varepsilon}, j = 1,2, \ldots Jn$$ ---------- (2)

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent variable, but estimates do not represent either the actual magnitude of change nor probabilities (Greene, 2000 in Belaineh et al. 2012). To interpret the effects of explanatory variables on the probabilities, marginal effects will be hence computed (equation 3). Differentiating equation 2 partially with respect to the

explanatory variables provides marginal effects of the explanatory variables given as (Greene, 2003):

$$\delta j = \frac{\partial Pj}{\partial Xk} = Pj\left(\beta jk \sum_{j=1}^{j-1} Pj\,\beta jk\right) = Pj(\beta - \dot{B}) - - - - - - - - - - - - - (3)$$

The marginal probabilities are purposes of the likelihood itself and measure the expected change in likelihood of a particular decision being made with respect to a unit change in predictor variable from the average (Greene, 2003).

Description of Model variables

Dependent Variables: The dependent variable for this study is the actual adaptation practices employed by the farmers to adapt to the adverse effects of climate variability/change.

Independent Variables: Based on the review of the literature on adaptation, institutional, technological, informational, and economic factors are hypothesized to influence households' adaptation choice in the study area. The potential explanatory variables to predict determinant factors for climate change adaptation among households are described below.

Age of the household head

Age of the household head has both positive and negative relationships with the decision to practice adaptation. Some studies found that the age of the household head captures the farming experience and affects awareness of change in temperature. Belay et al. (2017), Deressa et al. (2008) noted that as the age of the household head increases the probability of practising adaptation options increases. An empirical study by Gebrehiwot & Veen (2013) shows that a unit increase in the age of the household head increased the probability of using crop diversification, changing planting date and using irrigation as an adaptation option. This means that the likelihood of taking up climate adoption measures was higher among older farmers. On the other hand, a study by Gebreyesus (2016) showed that the age of the household head negatively associated with farmers' decision to adopt. In this study, the age of the household head is hypothesized to have both positive and negative impacts on adaptation options.

Farming experience

Farming experience of the household heads helps to recognize changes in climate its unfavourable effects. Experienced farmers would be better at distinguishing climate change from merely inter-annual variation (Maddison, 2007). Farming experience increases the likelihood of taking up adaptation strategies as experienced farmers have much knowledge and also information on changes in climatic conditions and the best crop management and livestock practices to adapt (Nhemachena & Hassan, 2007; Apata et al., 2009). Empirical studies by Komba & Muchapondwa, (2015); Belay et al., (2017) and Gbetibouo, (2009) additionally showed that the farming experience of the household head increases the likelihood of undertaking adaptation strategies due to older farmers' know-how concerning the time climate change occurred in the area; its implication on agricultural practices; and which methods work well in a specific location. Therefore, it is hypothesized that farmers' experience would influence the decision on adaptation options positively.

Educational Level

Education determines practising adaptation to climate change positively (Maddison, 2007). Gebrehiwot & Veen, (2013) noted that education increased the probability of the head of the household adapting to climate change, particularly through an increase in crop diversification, soil conservation, changing planting dates and using irrigation. Komba & Muchapondwa (2015) found that farmers with more education or in households with more educated members are more likely to pursue adaptation strategies related to climate change than are farmers with lower education levels. In this study thus, we hypothesize that the educational level of the household head has positive impacts on adaptation options.

Farm size

Empirical adoption studies reported that farm size is another factor associated with using adaptation strategies significantly and positively (Belayneh et al., 2012; Apata et al., 2009). Advancing Capacity to Support Climate Change, (ACCCA, 2010), reported that large farm size positively influenced the adoption of soil and water conservation, tree planting and use of improved varieties. Other studies by Fosu-Mensah et al., (2010) and Belay et al. (2017) indicated that farm size has a positive and significant association with most of the adaptation strategies. Further, farm size affects the adoption of new technology as large farm owners tend to adapt faster than smaller farm owners. Therefore, we hypothesized that farmers with larger farm size are more likely to undertake adaptation options.

Household Size

Household Size refers to the number of family members living in a household. The literature on adoption studies showed that household size of farmers significantly increased the probability of adaptation (Deressa et al., 2008). Increase in the household size resulted in a 6.7% increase in the probability of planting trees to adapt to the changing climate (Gebrehiwot & Veen, 2013). In contrast, household size has a negative impact on the decision to adopt any option (Sofoluwe et al., 2011). However, in this study, farm household with a larger family size is hypothesized to increase the probability of undertaking adaptation options.

Livestock Ownership in TLU

Livestock is one of the basic assets and an important component of the farming system in the Ethiopian rural economy. Gebrehiwot & Veen, (2013) describes ownership of larger livestock size increased the likelihood of adapting to climate change, particularly through an increase in crop diversification, soil conservation, planting trees and irrigation. Further, Belay et al. (2017) found that livestock production has a positive association with the adoption of adaptation strategies such as a change in the planting season, integrating crops with livestock rearing and SWC. Conversely, Amare and Simane, (2017) noted that livestock holding negatively influences households' choice of livelihood diversification strategies at 1% probability level. Therefore, a household with larger livestock is hypothesized to impact adaptation options positively and negatively.

Access to Agricultural Extension Services

Access to free extension services significantly increases the probability of taking up adaptation options. Farmers who have significant extension contacts have better chances to be aware of changing climatic conditions and the various management practices that they can use to adapt to changes in climatic conditions. Improving access to extension services for farmers has the potential to increase farmers' awareness of adaptation measures (Nhemachena & Hassan, 2007; Maddison, 2007). A study was done by Amare and Simane, (2017) indicated that farm households with extension advisory services are more likely to adopt new technologies and advance in their production. Having access to extension service increases the probability of adoption of adaptation by 22.8%. Therefore, we hypothesize access to this service has a positive relationship with employing adaptation options.

Access to credit services

Lack of credit or savings represented a barrier to adaptation (Maddison, 2007). Access to affordable credit increases financial resources of farmers and their ability to meet transaction costs associated with the various adaptation options they might want to take (Nhemachena & Hassan, 2007; Apata et al., 2009). This means that availability of credit eases farmers to buy inputs such as fertilizer, improved crop varieties and irrigation facilities. In a study conducted by Deressa et al. (2008), access to credit services was among the variables that positively and significantly influenced adaptation options to climate change. Amare and Simane, (2017) found that the influence of access to credit service on farmers' decision to invest in small-scale irrigation is significantly positive. Hence, we hypothesize that having access to credit services positively associated with adaptation practices.

Information on Climate change

Information on temperature and rainfall has a considerable and positive impact on the likelihood of using different adaptation options (Gebrehiwot & Veen, 2013). This means that being well informed about climate variability and changes has a positive impact on practice adaptation strategies (Belay et al. 2017). Better access to early warning about drought and flood before it happened has a significant and positive impact on the likelihood of using agronomic practices, and soil and water conservation (Amare and Simane, 2017). On the other hand, Deressa et al., (2008); and Legesse et al., (2012) noted that information on climate had no positive and statistically significant effect on adaptation strategies. However, we assume that having access to information on climate change increased the probability of using different adaptation options.

Soil fertility

Soil erosion resulted in decreasing soil fertility is climate change-related factor (Jalloh et al., 2013). Nelson and Stathers (2009) also reported declining soil fertility as adverse effects of climate change that leads to more frequent crop failure and increased yield variability in Tanzania. Having access to fertile land is found to be important determinants of adaptation in South Africa (Bryan et al., 2009). Moreover, Fosu-Mensah et al. (2010) noted that the soil fertility level was found to be the significant determinant of farmers' choice of adaptation measures. Therefore, decreasing soil fertility is hypothesized to be associated with adaptation options positively.

Table 10: Summary and Description of Hypothesized Variables in the Empirical Model

Model Variables	Measurement	Variable type	Expected effect
Dependent Variables			
Adaptation options to adverse effects of climate change	**0**, for not using any adaptation options; 1, for change in farming system; 2, for soil and water conservation and 3, for use of agricultural inputs	Categorical	
Independent Variables			
Age of household head	Years	Continuous	+/-
Faming experience of household head	Years	Continuous	+
Educational Level	1= household head with formal education and 0= household head without formal education	Dummy	+
Farm size	Total land size in Kada[4]	Continuous	+
Access to Extension Services	1, if yes and 0,otherwise	Dummy	+
Use of credit services	1, if yes and 0,otherwise	Dummy	+
Household Size	Family members of a household in number	Continuous	+
Livestock Ownership	Livestock size in TLU	Continuous	+/-
Information on Climate change	1, if yes and 0,otherwise	Dummy	+
Soil fertility	1, for decreasing and 0, for increasing	Dummy	+

5.4. Results and Discussion

Perception

This section briefly summarizes farmers' perception regarding the patterns of temperature and rainfall over the past 10 years. Results showed that smallholder farmers perceive climate variability/change occurring in their areas. Regarding temperature, most 84.6% of male and 78.7% of female household heads perceive that long-term temperatures are increasing (Figure 12). It is important to know whether farmers' perceptions are consistent with metrology data for verification. Accordingly, long-term changes in temperature and rainfall from 1983 to 2014 were analyzed. Results from farmers' perception are in line with trends of annual minimum and maximum temperature presented in chapter 3 which indicate that warming trends of minimum and maximum temperature were significant during the period. Coincides with our result, previous studies (e.g. Asfaw et al., 2017; Alemayehu & Bewket, 2017; Jury

[4] Kada is local measurement of land in the study area. 4 Kada is equal to 1 hectare

& Funk, 2013; and Omondi, et al., 2013) also reported warming trends of temperature with substantial variation at different spatial scales and period in Ethiopia.

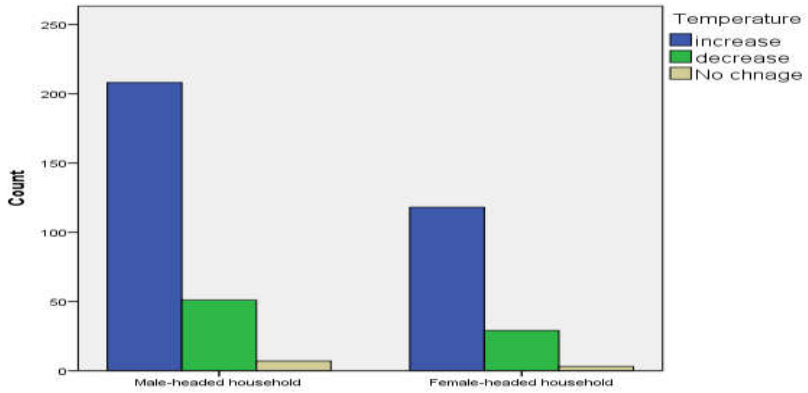


Figure 12: Gender differentiated perceptions in temperature for a decade

Results presented in Figure 13 shows that 60% of female and 65.8% of male household heads perceive rainfall patterns are increasing. In line with these results, results from gridded monthly data in chapter 3 showed an increasing trend of rainfall even though it is non-significant. Inter-annual variation of annual rainfall presented in chapter 3 additionally indicated both negative and positive anomalies for the 1980s and 1990s, however, positive rainfall anomalies were observed in the last decade: from 2005 to 2014. The high proportion of farmers noticing an increase in rainfall could be due to the considerable increase in rainfall during the last decade. Thus, farmer reports of an increase in rainfall over the past 20 years may indicate that their perceptions are influenced by more recent rainfall patterns. In short, findings indicate that both groups of households perceive the change in temperature and rainfall patterns. Other studies on rainfall, Mengistu et al. (2007) and Alemayehu & Bewket (2017) reported similar a statistically non-significant increasing trends of rainfall in the Blue Nile river basin and in the central highlands of Ethiopia, respectively.

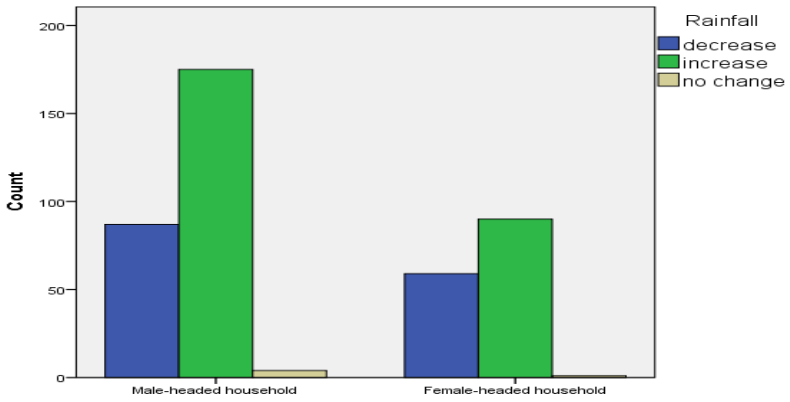


Figure 13: Gender differentiated perceptions in rainfall for a decade

3.2. Adaptation options to adverse effects of climate variability

Besides their perception of rainfall and temperature, farmers were asked about the adaptation option they have mostly used for the adverse impacts of climate variability. Adaptation practices employed by the farmers were analyzed based on the data derived from a survey of farm households across gender in the study area. Male and female household heads were asked questions concerning adaptation options they have mostly used to cope with the negative effects of climate variability and changes. Findings indicate that farmers used adaptation options which include, change in farming system, change in planting dates, crop diversification, use of agricultural inputs, planting trees, and soil and water conservation (SWC). For the ease of model analysis, the adaptation strategies identified by the farmers were combined in to four categories, including 'no adaptation' category, according to their contextual close relation. Next to no adaptation option; crop diversification and change in planting dates were grouped under change in farming system; use of agricultural inputs was set as third category and planting trees was grouped under SWC as the last category. Despite the fact that majority of female farmers perceived changes in temperature and rainfall over a decade, Table 11 indicates more (18.7) percent of female farmers did not employ adaptation strategies in comparison with 10.5 percent of male farmers.

Table 11: Adaptation options by percent

Adaptation Strategies	**Male-headed households**		**Female-headed households**	
	Freq.	Percent	Freq.	Percent
No adaptation options used	28	10.53	28	18.67

Change in farming practice	124	46.62	68	45.33
Use of agricultural inputs	38	14.29	19	12.67
Soil and water conservation	76	28.57	35	23.33

Findings presented in Table 11 showed that the most important adaptation strategies among male- and female-headed households were changing farming practice and soil and water conservation. Results also depict gender-differentiated undertaking of adaptation measures. In the same way, Hadgu et al., (2015); Belay et al., (2017); Gebrehiwot and van der Veen (2013) reported changing crop type/variety, soil and water conservation, changing in planting date, crop diversifications and tree planting as adaptation options for adverse impacts of climate change.

Determinants of adoption of adaptation options to climate variability

To estimate determinants of farmers' choice of an adaptation option, from several mutually exclusive adaptation strategies pursued in their context, to reduce adverse impacts of climate change, multinomial logistic (MNL) regression was applied for male- and female-headed households separately. In the analysis 'no adaptation option used' was used as a base category since it is essential to select the base category to test the other choices as alternatives to this option during the application of the MNL model. Multicollinearity among the explanatory variables was tested using variance inflation factor (VIF) and no problem was encountered across all household groups. Using the Hausman test, the multinomial logit model was tested for the validity of the independence of irrelevant alternatives (IIA) assumptions that states characteristics of one particular choice alternative do not impact the relative probabilities of choosing other alternatives. The test failed to reject the null hypothesis of independence of the adaptation options, suggesting that the model specification is fitting to model climate change adaptation options of smallholder farmers.

Estimated parameters of the model (MNL) were analyzed based on signs of regression coefficients to recognize the directions and their significance levels and to distinguish the effect of the predictor variable on the outcome variables. The likelihood ratio chi-square of 126.9 with a p-value < 0.01 for male-headed households and chi-square of 129.25 with a p-value < 0.01 for female-headed household indicate that the model fits significantly for both household groups. Besides, marginal effects were calculated for the two household groups to predict the probability of choosing each adaptation option at each level of a predictor variable

holding all other variables in the model at their means. Hereunder, the marginal effects with p-values are presented in Table 12.

Age and farming experience are considered as one variable in other studies based on the assumption that the more farmers get older, the more they are experienced (Deressa et al. 2008; Gebrehiwot and Van der Veen, 2013). In fact, this assumption may work for male farmers. However, our study considers these two variables separately since female farmers' farming experience may or may not have a similar direction with their age. For instance, a widowed household head would practice farming activities after the death of her husband and a single household head after spending some time with her family as a girl spends time at home with her mother. In contrast, male household heads start practicing farm activities during his childhood as a boy spends time with his father resulted in more farming experience.

Age of the Household Head

In line with the hypothesis, the result presented in Table 12 showed that the age of male household heads is negatively connected with change in farming at 10 percent significant level. A unit increase in the age of this household group decrease the probability of change in farming system by 1.1%. On the other hand, the age of female household heads has no significant association with any of the adaptation options. This finding showed that the decision on the choice of adaptation option is gender-differentiated. Further, the probability of taking up climate adoption measures among older male and female farmers is different. This may be because of biological factor: an increase in age probably limits adaptation potentials of farmers.

Findings of this study are in line with other studies on determinants of adaptation options to climate variability (Amare and Simane, 2017; Belay et a. 2017; Gebrehiwot and Van der Veen, 2013), that reveal age have negative relationship with adoption of adaptation strategies. This result is in contrary to the result that confirms an increase in the age of female farmers increases the probability of shifting planting dates (Negasi, 2016). From the intersectional theory point of view, the decision-making power of individuals in relation to climate change can be attributed to social characteristics which include age that determined strategies for adaptation. Further, the feminist in this theory claimed that how individuals relate to climate

change depends on their positions in context-specific power structures based on social categorizations which include gender (Kaijser & Kronsell, 2014).

Table 12: Marginal effects from the multinomial logit climate change adaptation model

Explanatory variables	Adaptation options					
	Change in farming system		Use of agricultural inputs		Soil and water conservation	
Male-headed Households						
	Coef.	**P Level**	**Coef.**	**P Level**	**Coef.**	**P Level**
Age	-.01111*	0.080	.005258	0.243	.005181	0.373
Farming Experience	.010523*	0.086	-.002538	0.557	-.006010	0.289
Educational Status	-.111757*	0.062	.021266	0.628	.08733	0.115
Land size	-.014194	0.251	-.007514	0.441	.01976 **	0.050
Access to extension service	.152492**	0.036	-.132314***	0.003	-.010863	0.872
Access to credit service	.083243	0.171	-.032826	0.445	-.030938	0.582
Family size	-.005699	0.728	-.003792	0.732	-.00382	0.803
Livestock size	.017997	0.229	-.004192	0.682	-.010845	0.444
Soil fertility	.074943	0.196	.124769***	0.003	-.116469**	0.031
Access to climate information	.150432***	0.009	.005148	0.899	.017092	0.749
Female-headed Households						
Age	-.008026	0.156	.004003	0.586	.000145	0.978
Farming Experience	.006943	0.234	-.002585	0.511	.002591	0.617
Educational Status	-.059826	0.494	-.063701	0.343	.026993	0.732
Land size	-.021831	0.247	-.013071	0.394	.013551	0.402
Access to extension service	-.042138	0.620	.00705	0.908	.083634	0.312
Access to credit service	.231409***	0.002	.162548**	0.022	-.014927	0.833
Family size	.03306 **	0.050	.023746	0.133	-.011277	0.607
Livestock size	.039303	0.106	-.017946	0.342	.02310 *	0.090
Soil fertility	-.20876***	0.006	.052272	0.352	.161858**	0.038
Access to climate information	.247342***	0.001	-.037902	0.458	-.01895	0.778

Farming Experience

Findings presented in Table 12 indicated that change in farming system is affected by the farming experience of male household heads. The results in the same Table showed that their farming experience was positively associated with change in farming system at 10 percent significant level. A unit increase in male household heads' farming experience significantly increases the probability of change in farming system as an adaptation option by 1.1%.

Conversely, the farming experience of female household heads was non-significantly associated with all the adaptation options. This result indicated that female household heads' age and farming experience has no direct relationship as explained before.

These results are consistent with a research finding in the Nile Basin of Ethiopia that reported farming experience influences farmers' decision on adaptation options (Deressa et al. 2008). Another research also showed male farmers are better on taking up adaptation options than female farmers (Nhemachena and Hassan, 2007). In line with our results, the intersection approach argue that people's vulnerability to climate change and how they experience adaptation strategies is the result of multiple factors including farming experience (Hankivsky, 2014). Dazé & Dekens (2017) additionally noted women and men, in their respective households, have different experiences that are important for adaptation to climate change.

Educational status

In contrary to prior expectation, results presented in Table 12 showed that educational status of male household heads is negatively and significantly associated with using change in farming practice as an adaptation strategy to unfavourable effects of climate change and variability at 10 percent significant level. The result also indicated that being educated for male household heads is more likely reduces the probability of using change in farming system as adaptation strategies by 10.1%. Consistent with this finding, Amare and Simane (2017) noted a negative association between level of education and adaptation strategy. Results additionally showed female household heads' educational status has no significant relationship in selecting all of adaptation options.

Land Size

Consistent with our hypothesis, findings in Table 12 revealed that land size has a positive relationship with SWC for male household heads at 5 percent significant level. A one-unit increase in land size significantly increases the probability of adoption of SWC by 1.4% for male household heads. This result corroborates with a study by Amare and Simane (2017) reported that land size significantly increases the likelihood of using SWC measures. This may be probably farmers having larger land size have no fear of land size reduction in the adoption of SWC measures. Gbetibouo (2009) additionally confirmed that larger land size

increase using adaptation strategies. For female-headed households, land size has no significant association with any of the adaptation options.

Access to Extension service

For male-headed households, having access to extension service was positively associated with change in farming practice and negatively associated with use of agricultural inputs at 5 per cent and 1 per cent significance level, respectively. Male household heads' having access to extension services is more likely increases the likelihood of practising change in farming practice and decreases use of agricultural inputs by 15% and 13%, respectively. This may be due to the extension services that focus on agricultural activities and its improvement rather than using agricultural inputs like fertilizer and improved seeds as adaptation options to climate change (see Table 12). Conversely, for female-headed households, having access to extension services has non-significant effect on all of the adaptation options. Seager et al. (2016) noted that gender-differentiated vulnerability resulting from climate change is related to access to and control over natural resources as well as access to basic services such as an agricultural extension services to cope with unfavourable effects.

Similar with our results, Belay et al. (2017) and Legesse et al. (2012) noted that increasing access to extension services increases the likelihood of adoption of the integrated crop-livestock farming system as adaptation option i.e. shifting from crop-based to integrated system. The result also in line with a lot of researches in Ethiopia, e.g. Amare and Simane, (2017); Belay Et al. (2017); Deressa et al. (2008), and Tesso et al. (2012) who reported that increase in access to extension service positively related with the probability of using climate change adaptation options. However, unlike the hypothesis, it has a negative influence on the probability of only one adaptation option. Belay et al. (2017) reported that agricultural extension agent is underscored among the source of information regarding climate change. This result corroborates with that of Legesse et al. (2013) who noted access to extension service decreases the probability of adoption of adaptation strategies.

Access to credit service

As the expectation, results in Table 12 showed that access to credit services is positively and significantly associated with two adaptation options: change in farming practice and use of agricultural inputs as adaptation options for female household heads. However, having access to credit services has no significant association with all of the adaptation options for male household heads. A unit increase in having access to credit services is associated with a

change in a farming practice and use of agricultural inputs at 5 percent and 1 percent significance level, respectively for this household groups. Female household heads' having access to credit service increases the probability of adoption of change in farming practice by 23.1% and the likelihood of use of agricultural inputs by 16.3%. This result coincides with that of Hadgu et al. (2015) who reported an increase in having access to credit services has a positive influence on farmers to practice irrigation as it is considered one of changing farming system. This variable also positively and significantly associated with 2.392 and 9.927 increases in the probability of crop diversification for female farmers in the upper and lower stream, respectively. This implies that having access to credit solves the cash problem and allows farmers to buy purchased inputs such as fertilizer, improved crop varieties and other facilities for adoption (Deressa et al., 2008). Consistent with this result, Gebrehiwot and Van der Veen (2013) reported increasing farmers' access to credit indeed increased the likelihood of choosing improved seeds as agricultural input by 10.6%, indicating that access to credit improved poor farmers' opportunities to make productive investments.

Household size

Similar to the prior expectation, the results presented in Table 12 showed that a larger family size has a positive and significant association with change in farming practice at 5% for female household heads and has no significant relationship to any of the adaptation option for male household heads. This may be due to female household heads' dependence on families' labour and male household heads' adoption of adaptation measures by themselves. A one-unit increase in the variable household size is associated with 3.3% increase in the likelihood of change in farming system for female-headed households. In line with our result, family size is significantly and positively related adaptation measure (Belay et al., 2017; Gebrehiwot and Van der Veen, 2013).

Livestock size in TLU

In line with the hypothesis, findings depict that livestock size is positively associated with an adaptation options for female-headed households. Larger livestock size is positively and significantly associated with soil and water conservation. A one unit increase in livestock number is more likely increases the probability of adoption of SWC 2.3% (Table 12). This means that households with larger livestock size have a good opportunity to invest in climate adaptation measures as they are a source of wealth to access inputs important for adoption (Deressa et al., 2008). Moreover, livestock ownership was among the variables that positively

affect adaptation strategies to climate change in Doba area, Ethiopia (Belayneh et al. 2012); this variable also increases the likelihood of soil and water conservation as an adaptation measure to climate variability in Tigray regional state of Ethiopia (Advancing Capacity to support Climate Change Adaptations/ACCCA, 2010). In contrast, a study (Nabikolo et al. 2012) reports that possession of animals had a negative and significant influence on female heads' decision to adapt to climate change in Eastern Uganda.

Soil fertility

Findings in this study (Table 12) showed that decrease in soil fertility is positively associated with use of agricultural inputs at 1 percent significant level and SWC at 5% significant level for male- headed households. Decrease in soil fertility is more likely increases the probability of use of agricultural inputs by 12.4% and decrease the probability of SWC by 11.6% for male household heads. For female household heads, decrease in soil fertility negatively and significantly associated with change in farming practice and positively associated with soil and water conservation. Decrease in soil decrease the likelihood of using change in farming practice by 20.9% and increase the probability of soil and water conservation by 16.2%. This indicates that low soil fertility is one of the inverse impacts of climate variability because of flooding resulted in soil erosion (Apata et al., 2009). Less fertile land caused less production compared to more fertile land. As a result, farmers are forced to use different adaptation strategies e.g. animals waste as manure (Deressa et al., 2009). Fosu-Mensah et al., (2010) reported soil fertility as the most important factor that affects farmers' perception and adaptation to climatic conditions.

Use of climate information

Findings presented in Table 12 indicated that change in farming system is affected by access to climate information for male and female household heads. The results showed that their farming experience was positively associated with change in farming system at 1 percent significant level. Having access to climate information significantly increases the probability of using change in farming practice as an adaptation option by 15% and 24.7% for male and female household heads, respectively. In the same way, studies (Deressa et al., 2009; Hadgu et al., 2015; Belay et al., 2017; Legesse et al., 2012 Amare and Simane, 2017) confirm that access to climate information significantly and positively associated with different types of adaptation options to climate change.

5.5. Conclusion

This study was analyzed in terms of gender at household-level to identify perception on temperature and rainfall variability, adaptation options to adverse effects of climate variability and determinant factors that influence the decisions farmers make in the adoption of technology. The decisions of male and female farmers are influenced by factors including household characteristics, socioeconomic and environmental resources. Based on findings from this result, we made the following conclusions.

In this study, differences in adaptation options and determinant factors on the choice of adaptation options were observed based on gender. For male-headed households, all explanatory variables have a significant effect on their choice of adaptation options except family size, livestock size and climate information. For female-headed household, age, educational status, access to extension and credit services, family size, livestock size and access to climate information have significant effect for their selection of adaptation options.

Male household heads' choice of an adaptation option is not affected by family size livestock size and access to climate information. Farming experience, total land size and access to climate information do not affect female household heads' decision on adaptation options Findings of this study suggest the need to inform agricultural extension workers to be gender inclusive, i.e. female household heads should be their target on giving pieces of training and other information equal with male household heads. Moreover, results imply the need to build farmers' capacity to choose effective adaptation options with a wide range of institutional, policy, and technology support, particularly for the poorer and female household heads.

6. GENDER DIMENSION OF WATER- ENERGY-FOOD NEXUS AND CLIMATE CHANGE IN MECHA DISTRICT, NORTHWEST ETHIOPIA

6.1. Abstract

An integrated approach to water, energy and food security has been advocated due to increasing demands of natural resources. It is important to take note of this fact, not only because men and women farmers have different needs but also they have different access to natural resources. Gender differentiated access to natural resources, including energy, land, and water is an important dimension to understand the ways that resource users and managers relate to resources and to each other. This study explores the gender aspect of water-energy-food nexus and climate change effects specifically on access to water, energy and food resources at household level. Using a qualitative system dynamic approach, the study concluded that labour restriction, limited control over land and low income are major drivers that determined female-headed households' less access to water, energy and food. Climate induced problems perpetuate households' limited access to productive resources. Research and development initiatives should introduce strategies with a focus on female household heads for capacity building in different dimensions.

Keywords: access to resources, control over resources, causal loop diagram, female-headed households

6.2. Introduction

The Bonn water-energy-food (WEF) nexus conference has advocated an integrated approach in the management of food, water, and energy security. Projections point out that demand for fresh water, energy, and food will explode over the next decades because of population growth, economic growth, and urbanization, increasing demand for food and diversified diets, climate change and natural resource scarcity (Hoff, 2011). Globally, (FAO, 2014 cited IEA 2010 & Drews et al., 2016), project the water and food demand to increase by 50% and 60% respectively by 2050 and the energy demand will also continue to grow over 40% by 2040. Developing countries, like Ethiopia, face immense problem in supplying food, water, and energy, compounded by climate change risks that require the efficient use of natural resources to cope with (IFAD, 2012).

Climate change increases the frequency of climate-related shocks, which puts pressure on food, energy and water supply. It has an effect on food accessibility food directly through decrease in quantity and quality of yield, crop failures, livestock loss, and the effects weather on agricultural practices; rising temperature affects water supply via evaporation and decreasing run-off. Changes in the frequency and intensity of rainfall lead to the increased incidence of floods and droughts resulting in food insecurity. Researchers expect climate change impacts disproportionately affected the welfare of the poor in rural areas including female-headed households and others with limited access to social, economic and physical resources (IPCC 2014; Mubila et al., 2011 and Carter & Gulati, 2014).

Speeding up access to WEF resources and integrating the poorest is one of the guiding principles of the nexus. There is significant overlap between the 1.1 billion poor people lacking sufficient access to water; close to 1 billion who are malnourished; and the 1.5 billion are lacking access to electricity (Hoff, 2011 cited Human Development Report, 2006; IFRC, 2011; IEA, n.d.). Worldwide, of the approximately 1.3 billion people living in poverty, 70% are women many of whom live in female-headed households in rural areas (Clancy et al., 2003). The poverty situation of female-headed households, in particular, is more severe, which is rooted basically in lacking vital livelihood assets (Middlebrook 2003; Clancy et al., 2003).

In analyzing resources from a gender perspective, it is important to look at the difference between access to resources and control over them. March et al. (2005) defined access as the

opportunity to make use of a resource. Control is the power to decide how resources use, manage the resources' benefit, and who enjoy the resources. Female-headed households' limited access to and control over land, a pivotal resource for accessing other goods and services, hinders their ability to access to WEF and major livestock resources (Aureli & Brelet, 2004; Panda, 2007; Parker et al., 2016; Senay, 2012; Wahaj & Hartl, 2007; World Bank, 2012). Irrigation benefits for women farmers also constrained by their limited access to key assets and opportunities (Parker et al., 2016). Investments in irrigation worldwide have focused on large-scale projects (dams, canals) benefiting rich farmers often at the cost of small and marginal farmers, including female farmers (Panda, 2007). As a result, many women farmers remain poor, vulnerable to food insecurity and marginalized (Wahaj & Hartl, 2007).

In Ethiopia, female-headed households have lesser land sizes than male-headed households: the total land area cultivated by male heads is 1.97 hectares compared with 1.18 hectares for female heads (Central statistical Agency [CSA], 2013). The Rural Socioeconomic Survey of Ethiopia (CSA, 2011-2012) confirmed that female farm managers produce 23 percent less per hectare than their male counterparts (Aguilar et al., 2014). When female-headed households have land, 70 percent of them sharecrop out their land: triggers them to lose half of the yield, and the rest rent out (Howard & Smith, 2006). This is because of their dependence on male labor and limited access to oxen to farm themselves (CSA, 2013; Mamo & Ayele, 2003; Mossa, 2010; Mulugeta, 2013).

In Ethiopia, few empirical studies carried out on the WEF security nexus at different scales and in different aspects. For instance, Al-Saidi (2017) assessed the WEF security nexus in the eastern Nile basin and introduced the resource use profiles of Egypt, Sudan, and Ethiopia in the three sectors. He summarizes common challenges to resource security, such as climate risks and land degradation. Other researchers (Guta et al., 2017; Mirzabaev et al. 2015) analyzed the nexus in developing countries including Ethiopia. The former assessed factors that determine the successes and failures of decentralized energy solutions based on case studies through the coupled lenses of energy transition and the WEF security nexus; and the results show that access to modern decentralized energy solutions has not resulted in complete energy transitions for various tradeoffs. The later test trade-offs and synergies of bio-energy within the WEF security nexus and concludes that applying the nexus perspective to analyses of bio-energy widens the scope for achieving multiple-win outcomes. Villamor,

Guta, Djanibekov & Mirzabaev (2018) also conducted intra-household assessment in Amhara and Oromia Region on management of resources in WEF nexus from a gender perspective and identify main actors and resources interlinked to the nexus.

In line with the nexus approach, experiences in Ethiopia ensure that natural resource management requires a multi-sector integration and the strong involvement of farmers to identify problems and implement solutions at the local level (Farnworth, 2013). The different access to natural resources, including energy, land, and water across gender is an important dimension that governs who uses what and in what way (Nelson, Sisto, Crowley & Villarreal 2012); and gender is one of the core areas to be included in the social system of the WEF nexus (Muiti, 2012). Further, researches on the WEF security nexus at household level has limited so far in Ethiopia. Therefore, this study explores the gender dimension WEF nexus and climate change effects with the focus on access to WEF and associated resources. The study is valuable for decision-makers and development planners in WEF sectors from a gender perspective, and researcher would use it as an insight for further investigation on WEF nexus.

In response to the stated problems above, the central questions that guided this inquiry are: How access to WEF resources is gender-differentiated? How do the causal interactions of productive resources affect female-headed households' access to WEF resources? How does climate change/variability affect access to WEF resources?

6.3. Research Methods and Materials

Sample Size

To collect essential data, we used fifteen in-depth interviews with female household heads and ten key informant interviews with focal persons in the study area including three village leaders, head of the agriculture office, head of food security office, coordinator of rural energy supply, coordinator of rural water supply, head of cooperative office, head and deputy head of women's affairs office. In addition, four FGDs with female and male household heads separately (two FGDs for each group with 6 members in a group) were conducted as prime data sources. The sample size was determined by the data saturation level.

Methods of Data collection

In response to the research questions, this study employed qualitative data collection methods such as in-depth personal interview, key informant interview and focus group discussions were conducted in order to acquire detailed information about the title in the research site. The data was recorded by the researcher through intensive note taking and tape recording with the consent of the participants.

Data Analysis

We used a qualitative system dynamics tool, a causal loop diagram, to analyze the cause-effect interactions between WEF and associated resources from a gender perspective at the household level. The system dynamics (SD) approach depends on the identification and recognition of resources, their states, and rates (Pejić-Bach & Čerić, 2007). Qualitative analysis in SD is a conceptualization of systems' problematic behavior and useful for describing the problem's root causes, and solutions. In SD, a causal loop diagram (CLD) is the fundamental qualitative modeling technique that helps graphically capture the causal relationships between interactive subsystems. The causal relationships of system variables may be positive (reinforcing) and negative (balancing) causal relationships. A positive causal relationship means an increase/decrease in one variable would increase/decrease in another variable; whereas a negative causal relationship signifies that an increase/decrease in one variable triggers a decrease/increase in other variables (Mirchi, Madani, Watkins & Ahmad, 2012).

We described key variables depending on the results from qualitative data with relevant literature (Table 13). We analyzed the qualitative data following qualitative research procedures (Cresswell, 2009). Primarily, the data collected through primary data sources prepared and organized by transcribing and translating interviews; and summarizing field notes. Next, we read all the data to have a general sense of the information and to capture its overall meaning. Third, we started the coding process to categorize the data depending on the research questions. In this stage, we have taken different activities, such as dividing sentences and paragraphs into categories; and labelling the categories with terms. Fourth, we had a detailed description of the data in the categories; making interpretation and meaning of the data. Finally, the data collected through interviews and discussions were cross-checked and triangulated with secondary sources to increase the validity and reliability of the description of causalities between variables in CLD. Based on these results, we developed causal loop diagrams and explained using Vensim system dynamics software.

6.4. Results and Discussion

Access to and Control over WEF Resources

There is a big difference between access to resources and control over resources as it is mentioned in the introductory section of this chapter. For instance, having access to land is having the opportunity to make use of the land whereas control over land is the power to decide on how the land managed and benefit from it. Results in Table 13 indicate female household heads control over land is limited since they are not ploughing themselves and using all the crops from their land. Instead they are sharing the crops from their land for the share cropper.

Hereunder, results presented in Table 13 are factors associated with access to water, energy and food resources in the study area. These results are derived from in-depth interviews, key-informant interviews and focus group discussions that are put as annex; and from other studies that are consistent with our findings. Labour restriction, lack of controlling over land and low income are found to be major drivers interlocked with female-headed households' less access to water, energy and food resources.

Table 13: Description of key variables on access to WEF and associated resources

	Variables of Causal Loop Diagram	Description depending on qualitative data and literatures	Qualitative Data Sources (annexed)	Relevant literature (reference mode)
1.	Labor dependence	Compared to male household heads, female household heads are not cultivating their land themselves due to the norm that assures ploughing is males' activity. This leads female farmers to be dependent on male labour. Labour is the main constraint female-headed households faced and left them with two alternatives: either to rent out their land or to be engaged in a sharecropping system.	Female household heads FGD1 & Key-informant village leader-1	Middlebrook, 2003; Mulugeta, 2013 and Panda, 2007
2.	Limited control over land	Female household heads have access to land; however, they are not privileged due to their dependence on male labour to plough and harvest. Female-headed households' limited control over land generates less access to other resources including water, energy and food.	Female household heads FGD 1&2	Middlebrook, 2003; Panda 2007; Parker et al., 2016 Senay, 2012 and Wahaj & Hartl, 2007
3.	Low income	In a rural area, the main means of income are agriculture. FHHs are underprivileged in the agricultural system mainly because of their dependence on male labour to cultivate and have full benefit from their land.	Female household head in-depth interview 1&2 & Key-informant: village leader-1	Clancy et al., 2003; Parker et al., 2016 Mulugeta, 2013
4.	Less access to	Most of FHHs have no hand-dug well water for domestic purpose and they do not use irrigation water since they are not managing their farm by themselves rather it	Key informant from water office & Female	Clancy et al., 2003; Wahaj & Hartl,

	water	depends on the share croppers' interest to harvest in the irrigation season	household heads FGD2	2007
5.	Less access to energy sources	In the study area, farmers dominantly used biomass for domestic use. FHHs are not using these energy sources because they lack animals to use cow dung and they are not managing their land to use crop residue and to plant trees as domestic energy source.	Female household head in-depth interview 1&2 and Female household heads FGD2	Clancy et al., 2003; World Bank, 2012
6.	Less access to food	Because of share cropping system, FHHs receive fewer major food grains, which is not enough for their annual consumption.	Female household heads FGD1	Clancy et al., 2003; Desta, Haddis & Wahaj & Hartl, 2007
7.	Land rent out	Because of FHHs' labor restriction, male farmers rented out FHHs' land with a little amount of money, which is unbalanced with the benefit from their land.	Female household heads FGD1 & Key informant village leader	CSA, 2013
8.	Share cropping	Most of the FHHs, except the few who have sons capable of farming, engaged in a share cropping system. The agreement may receive half of the crop or one third of the crop.	Female household heads FGD1 & Key informant village leader	Howard & Smith;2006 Mulugeta, 2013
9.	Less amount of crop	Not only the size of FHHs' land that contributes to their less crop amount, but also the sharecropping system that let them to share the crop from their land by half and more.	Female household heads FGD1	Aguilar et al., 2014
10.	Social norm/culture	The social norms inhibit female household heads to plough their land by oxen and to harvest as they want.	Female household heads FGD1	Mulugeta, 2013; Desta et al., 2006
11.	Loss of planting tree	FHHs' dependence on male labour resulting in a lack of planting trees used for many purposes in the study area.	Female household heads FGD1&2	Panda, 2007; Senay, 2012
12.	Loss of crop residue	FHHs rented out or share cropped their land. They can't use crop residue as animal fodder and domestic energy source.	Female household heads *FGD2 &* Female household head in-depth interview *2*	Mulugeta, 2013; Desta et al., 2006
13.	Lack of high value animals	FHHs have no enough land and fodder to rear big animals like an ox and cow. They cannot use animals' waste as an energy source; the diary product as a food source and selling animals as a means of income.	Female household head in-depth interview 2 & Female household heads FGD2	Aureli & Brelet, 2004; Mamo & Ayele, 2003; Middlebrook, 2003; Mossa 2010; Senay, 2012
14.	Lack of fuel wood	Besides using eucalyptus trees as another means of income for the farmers, they use as fuel wood. FHHs missed these opportunities because of their small land size, labour dependence and limited control over their land.	Female household head in-depth interview 2 & Female household heads FGD2	Mulugeta, 2013; Senay, 2012
15.	Loss of irrigation water use	FHHs' rent out their land or it belongs to the sharecropper. Using irrigation water depends on male farmer's interest.	Female household heads FGD 1&2	Parker et al., 2016
16.	Loss of hand-dug well	Most of FHHs have no enough income to pay for hand-dug well water and they cannot dig out for water.	Female household head in-depth interview 2 & Key informant from water office	Parker et al., 2016

17.	Less access to solar energy source	FHHs could not afford to buy a solar energy source for lighting due to their low income.	Female household head in-depth interview 1	Senay, 2012 Panda, 2007
18.	Smallest land size	FHHs have smaller land size compared with male-headed households	Key informant village leader, Document review & Female household heads FGD2	CSA 2013; Mamo & Ayele , 2003; Mossa 2010; MWRLAO, 2009; Senay, 2012
19.	Less access to dairy products	Most of FHHs have no cows. They cannot use milk and milk products like male household heads that accessed cows.	Female household heads in-depth interview 2 & Female household heads FGD2	Aureli & Brelet, 2004; Senay, 2012
20.	Climate Change/ Variability	Climate-induced problems like frost & seasonal temperature variability exacerbate FHHs' less access to WEF and associated resources.	Male household heads FGD1 & Female household heads FGD1 Field note	Flatø, Muttarak & Pelser 2016; World Bank, 2012; IPCC, 2014

Causal loop analysis on access to water, energy and food resources

Access to water

In the study area, rope-pump water, spring water, and hand-dug well are major sources of water for domestic use. Among these, farmers dominantly used hand-dug well water for cooking, sanitation, and livestock. Most of female-headed households lack this source of water that triggers them to spend more time, energy and labor to collect water traveling a long distance (see annex: key-informant interview from water office/KIWO).

Group discussion participants reported that they used rope pump water mostly for drinking and there are some female household heads who are not using this water source because of the payments to be a member of a water association in a village. These household heads walk long distances to find spring water for drinking. One of divorced FHH said '*I used spring water for drinking and I spend 60 minutes per day to get 20-liter water. I have been doing this since I could not pay 80 birr to be a member of the water association in our village, Kudmi'*.

Results additionally show that low income and labour dependence are the main causes of female-headed households' less access to this water source (Figure 14). Another challenge they face is the loss of irrigation water use. These households who have land in the irrigation

command area could not use the water primarily because of their dependence on male labour that limits their opportunity to produce more and to improve their income. The result revealed that their sharecroppers are not interested in ploughing female household heads' land because of two main reasons. First, more expenses for cultivation and their less market access; and second, difficulties of farm management, i.e. irrigation needs more labour and time than the rain-fed farm. In the female household heads group discussion, one participant said, '*the irrigation water is useful for many farmers but we are not using it. Since we are female, we lack money, we lack oxen, and we lack labour to plough.* The other discussant replied, *'female household heads have land in the irrigation area, but it depends on the sharecropper's interest and capacity to cultivate during the irrigation season. If he is interested and capable to cultivate, our land also has equal access to water to use our turn like others. But if he is afraid of expenses like seed, fertilizer, and labour; our land will remain idle until the rain season.*

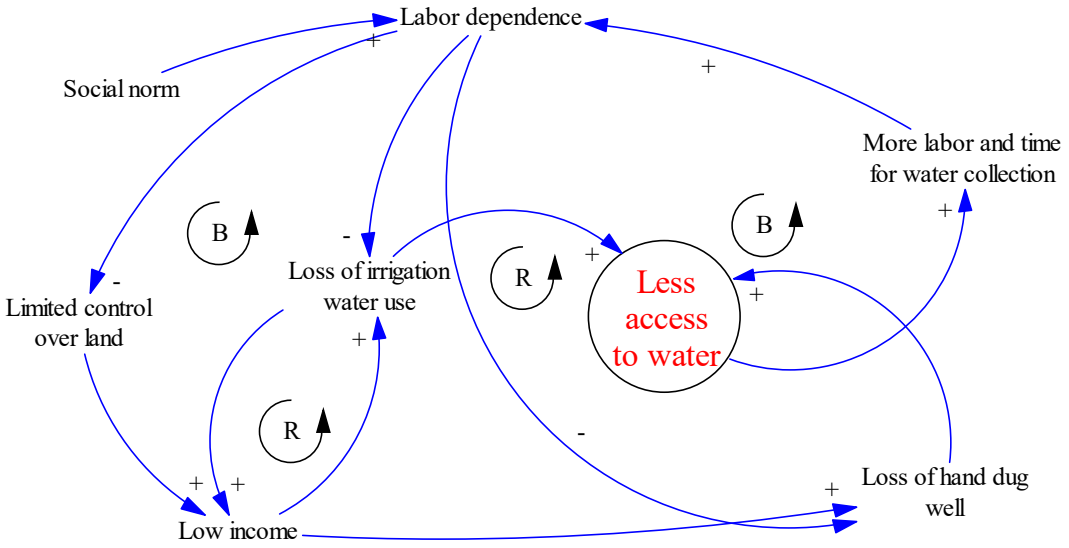


Figure 14: Causal Loop Diagram on access to water for female-headed households (B: Balancing (negative) feedback loop and R: Reinforcing (positive) feedback loop)

Access to energy

Results presented in Figure 15 pointed out female-headed households' dependence on male labour and limited control over their land interlocked with less access to domestic energy sources. Fuel wood, cow dung and crop residues are the main energy sources for cooking, but female household heads could not get these sources for three main reasons. First, they

rented out or sharecropped their land: they lose the crop residue since they only share the crop. Second, male household heads planted trees on their land and use for different purposes, but the opposite is true in female-headed households because of labour constraints. Third, they lack high-value animals like oxen and cows because of a lack of fodder and place to rear them. As a result, they cannot use cow dung as a domestic energy source. A female household head in her in-depth interview explained:

> *In our village, cow dung and crop residues are the main sources of domestic energy besides fuel wood. I used only fuel wood for cooking because I have no cow or ox to use their waste as an energy source. Male heads plant trees and used for fuel wood. I bought a minimum of one cart fuel wood, which costs 400-450 birr per two weeks. I used this fuel wood not only for cooking but for making a local brewery that is the other means of income for my family. And the other thing, I could not use crop residues as an energy source because my land is in the hand of my sharecropper and he is using the crop residue himself. Before the years, we could collect these energy sources from communal grazing lands since the animals were there. Now all the farmers kept their animals at home. Village's administrators prohibit the collection of these energy sources from communal lands.*

A key informant also added "previously, female household heads used cow dung from common grazing lands, but now village commons are not energy sources since animals kept at home for conservation and because of increasing dependence on individual resources" (Key-informant: village administrator). These households used fuel wood from a market that leads to other expenses perpetuating their low income. They cannot buy solar energy sources to use for lighting due to their low income, whereas most of the male-headed households use these alternative energy sources. The other female household heads interviewed replied:

> *I have no solar energy source for lighting because I have no money to buy. I couldn't afford it I swear. Now a day's many people are using it. Others have solar energy sources because they have a good income; they can sell eucalyptus trees, ox or crop. My crop is not enough even for my family to reach the crop season. My income from a*

local brewery is for my family's day-to-day survival. How could I buy solar? It costs over one thousand birr[5]

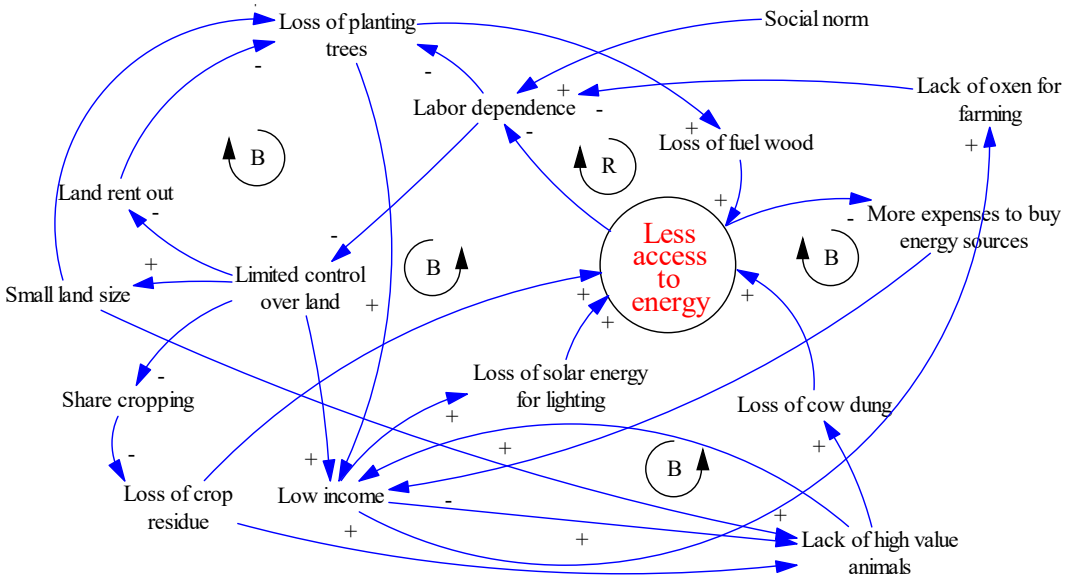


Figure 15: Causal Loop Diagram on access to energy for female-headed households (B: Balancing (negative) feedback loop and R: Reinforcing (positive) feedback loop)

Access to food

As Figure 16 depicted, besides female household heads' small land size, dependence on male labour and lack of control over their land contributes a lot to their less access to crops specifically grains, the major food in the study area. The culture that inhibits women farmers to plough their land forced them to rent out their land or to give to sharecropper except the few who have matured son capable of ploughing. The money from the land lease and their shared crop are not enough for annual consumption resulting in food shortage in their home usually from July-September or till harvest season every year. As we explain it in Table 13, they have less access to milk and milk products because of their lack of a cow while such kind of food is available to male-headed households. Male household heads used cow dung as an organic fertilizer, which boosts their land fertility and enhances the yield while female-headed households missed this opportunity.

[5] Birr= Ethiopian currency

Female household heads, in their FGD, reported *that m*ost female household heads have a small land size compared to male household heads. We faced a food shortage from July to September because we rented out our land or gave it to sharecroppers and received the crop by half. Concerning sharecropping: it depends on the agreement between the landowner and the sharecropper. Some sharecroppers give half of the crop yield and some give one-third of the yield. The participants added they have not been eating nutritious food even for the remaining nine food sufficient months. Most female-headed households use egg and meat during main holidays like Christ-mass or Easter (see annex FHFGD2).

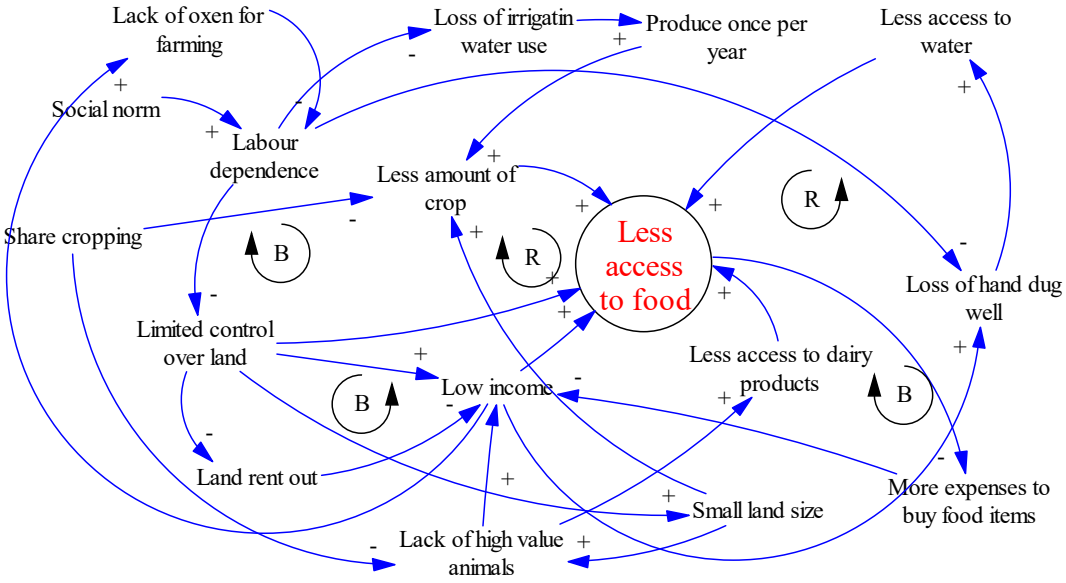


Figure 16: Causal Loop Diagram on access to food for female-headed households (B: Balancing (negative) feedback loop and R: Reinforcing (positive) feedback loop)

WEF resources and climate change/variability effects

Climate change/variability affected both female- and male-headed households, but we argue that climate-induced problems exacerbate the existing inequality between the households on their access to WEF resources. In the study area erratic rainfall, frost, hailstorm, and seasonal temperature variability are the main climate-related problems, observed for the last 10 years, reported by the participants. In the study area, Zewdu and Simane (2018) reported the existence of moderate rainfall anomalies; and increasing warming trends of minimum and maximum temperature by 0.35^{o}C and 0.24^{o}C per decade respectively from 1983-2014. Qualitative results revealed, for instance, the frost in 2016 harvesting season reduces crop

products for both households, but the effect is severe on female-headed households (see 19). Most of them often got half of the crop because of the crop sharing system during the normal time. This constraint, along with the frost made these households to face food shortage for almost half of the year since their crop reduced twofold. In most water points, both male and female-headed households may fetch/use only one plastic container (20-25 litters) of rope pump water because of seasonal temperature variability from April-May usually; and they travel longer distances to collect spring or river water. Here, some male-headed households use their donkey or cart to collect water, but female household heads fetch themselves by carrying the container that consumes their energy.

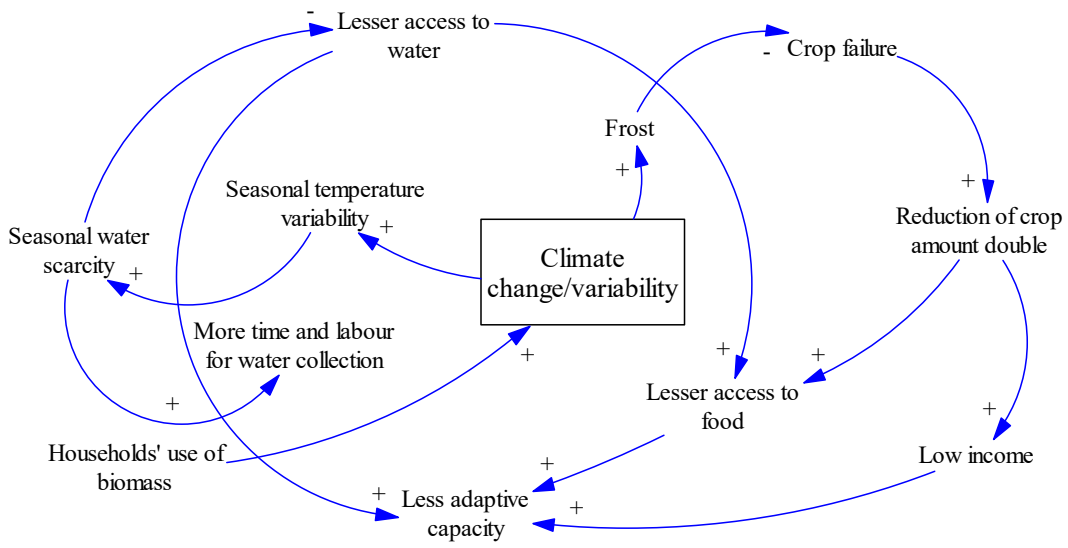


Figure 17: Causal Loop Diagram on access to WEF resources and climate change/variability effects for female-headed households (B: Balancing (negative) feedback loop and R: Reinforcing (positive) feedback loop)

Discussion

The study explored the gender dimension of water, energy food (WEF) nexus in terms of access to water, energy, and food at the household level because gender is one of the core areas that needs to include in the social system of WEF nexus. It also explored the effects of climate change in access to these resources. We used a qualitative system dynamic approach, Causal Loop Diagram, to show cause-effect interactions between access to WEF and other vital resources such as land, labour, income, etc. The findings illustrate female-headed households' limited access to the resources that lead them to less access to WEF and vice

versa. The results also show that the culture that inhibits female-headed households to plough their farm themselves triggers them to depend on male labour and to be engaged in a sharecropping system. Notably, the socio-cultural norms and power relations in the study area put the households in a big crisis. These results corroborate with the assertion of Feminist political ecology (FPE) which is a subfield that brings feminist theory and objectives to political ecology. Feminist political ecologists suggest gender as a crucial variable—concerning class, race, culture, age, ethnicity and other relevant aspect of power–shapes access to and control over natural resources. FPE also shows how social identities they make up in and through relations with nature and everyday material practices (Sundberg, 2016).

The results presented in Figure 14 show female-headed households' less access to water and contributing factors. Their limited access to land, labor, and less income creates differences regarding access to water compared to their counterparts, male-headed households. In agreement with our results, Parker et al. (2016); and Wahaj & Hartl (2007) reported labor restrictions and limited access to land is closely related access to water.

Findings provide how access to and control over vital resources differentiate households' access to domestic energy sources (Figure 15). Findings suggest female-headed households' less access to domestic energy sources, mainly derived from labour restriction, small land size, and less income. This shows that they couldn't use crop residue because of crop sharing system and cow dung because of the loss of big animals like cows and oxen. Their small land size with limited labor inhibits planting eucalyptus trees and using it as fuel wood. Consistent with these results, the World Bank (2012) reported that limited land and livestock resources and agricultural production put more pressure on poor households to access biomass energy sources. Mulugeta (2013) also reported that the crop sharing system enhanced female-headed households' less access to traditional domestic energy sources in Bati Wereda, SouthWollo, Ethiopia.

Further findings show that how socio-cultural settings in the study area create differences between male- and female-headed households concerning access to food in their homes (Figure 16). Traditionally, female farmers cannot plough and manage their land themselves, which forced female-headed households to be engaged in the crop sharing system. This shows that the crop from their land is not enough for annual consumption resulting in less access to food. Coincides with our result, Desta et al. (2006) stated that female-headed

households in the Tigray region, Ethiopia, face food shortage by arrangements like crop sharing and renting out their lands because of labour dependence. Mulugata (2013) confirmed that dependence on male labor leads to a food shortage in female-headed households. Tibesigwa et al. (2015) additionally noted that shortage of food is likely to be more pronounced in rural female-headed households.

Climate change can jeopardize the food and water supplies of households that are already at risk of food shortages which include female-headed households (Verb and Entwicklungspolitik Niedersachsen, 2009). Findings in figure 17 indicate climate-induced problems put female-headed households in crises regarding access to water, energy, and food. Coincides with our result, Antwi-Agyei, Dougill, Fraser, & Stringer (2012) cited Sen, 1981; 1999 also stated that the entitlements of individuals to assets affect the individual's ability to cope with the impacts of climate change. Behrman et.al (2014) also stated climate change poses great challenges for poor rural people; most of them rely on natural resources for their livelihoods and have limited capacity to adapt. Similarly, Flatø et al. (2016) and the World Bank (2012) reported that female-headed households are more vulnerable to climate variability that applaud interlocking sources of women's problems (Tong, 2009), all the above results show that in the study area female-headed households face different challenges: one of their problems causes another problem.

In contrast, as Figure 17 shows, studies (e.g. Keller, 2009; Zhang, 2016; Souza et al., 2017; and Popp, Lakner, Harangi-Rakos & Fari, 201) showed that the use of biomass energy sources contributes to climate change/variability via carbon emission. For instance in Ethiopia, the energy sector (heating, cooking, and transport) contributes to the total GHG emissions to 15%. 95% of the energy consumption satisfied by biomass sources (mainly wood); Petroleum and electricity are of minor importance (Keller, 2009).

Findings suggest that research and development initiatives should introduce strategies to liberate female-household heads from depending on male labor so they could get out of renting out their land or engaging in a sharecropping system that causes food shortage, less access to domestic energy and water sources. Concerned organizations should give trainings with a specific target of female-headed households to build their capacity and to establish an alternative means of income.

6.5. Conclusion

Detail understanding of access to and control over resources in the WEF nexus from a gender perspective is important to develop gender-based strategies and speed up access to these resources for underprivileged groups. Using a qualitative system dynamic approach, causal loop diagram (CLD), we presented the WEF nexus approach from a gender perspective at the household level. Each CLD provides interlocked factors driving female-headed households' less access to water, energy, and food. We conclude that female-headed households' small land size along with their limited control over lands matters their access to WEF resources. The socio-cultural setting made these households dependent on male labour that forced them either to rent out their land or to be engaged in a sharecropping system: contributing a lot to their less access to the major food products and domestic energy sources. These households lack a source of water that triggers them to spend more time, energy and labour to collect water travelling a long distance. Climate-induced problems perpetuate the existing less access to WEF resources. The study provides baseline information to incorporate local contextual factors in the national nexus framework and micro-policies since the WEF nexus is a recently emerging approach worldwide and new for Ethiopia. In conclusion, our findings support that households' access to vital assets such as land and labour determines gender based access to water, energy and food and how coping with climate variability/change. Research and development initiatives should introduce strategies with a focus on female household heads for capacity building in different dimensions.

8. Conclusion and Recommendations

8.1 Conclusion

This thesis has aimed to react primarily on the spatiotemporal analysis of rainfall and temperature due to the fact that analysis of long-term changes in these climate variables is an essential component to determine the assessment of the next sections: vulnerability and adaptation studies. The study additionally reacts on the questions how gender inequality create differences among male and female farmers' vulnerability to climate change and associated risks; how these farmers perceive and respond the changes in temperature and rainfall; what factors confine their decision on adaptation options; and how and why their access to domestic water, energy and food resources vary. This section presents the four central research conclusions that shape the thesis and future insights for researchers, policy makers and program developers.

In the first specific theme of the thesis, temporal variation and spatial distribution of temperature and rainfall were analyzed at annual and seasonal time scales. Long-term annual mean values of the two variables were used for the analysis. The temporal analysis revealed that significantly increasing trends of both annual and seasonal minimum temperature; and winter and spring seasons of maximum temperature. The decadal spatial distribution of this variable indicates the area is being warm: the last decade is the warmest compared to the first and the second, and the second is warmer than the first decade. North and north-western parts of the area have experienced warmer temperatures in comparison with the south-eastern, the cooler area. Regular decadal spatial warming trends of maximum temperature were observed in the north and south-eastern parts of the area. Temporally, statistically non-significant increasing trends with moderate inter-annual rainfall variability were observed at annual and seasonal time scales. Spatially, the area has experienced the highest rainfall distributions in the annual and kiremt season in the southwest; and in Belg and Bega seasons in the south. This study contributes to the agricultural development workers and the farmers in the study area in future adaptation strategies. The spatial analysis is also helpful in understanding accurately: which place is the hottest and which one is the coldest and for the application of the appropriate cultivating system in crop variety and others.

This second theme of the thesis provides methodological steps concerning an assessment that can be used to describe adaptive capacity and hence, the vulnerability of gender-based farm households. This study additionally gave knowledge regarding how male- and female-headed

households could be affected by climate variability in a different way. The study focused on the local-level assessment of vulnerability to climate variability across male- and female-headed household groups. Assessment of vulnerability based on households' adaptive capacity, sensitivity, and exposure of households across gender is essential to develop adaptation programs targeted the deprived groups. Findings indicate that female-headed households have the lower adaptive capacity and higher sensitivity and exposure, which trigger to higher vulnerability in comparison with their counterpart male-headed households in both upper and lower stream. However, overall vulnerability comparison was made between the four household groups and revealed non-significant vulnerability differences among the groups which imply all are vulnerable to the existing change in climate and its unfavourable effect. Besides, results on the vulnerability level between similar household head sexes indicate the female-headed household in the irrigation area has higher vulnerability level comparing to these household groups in the non-irrigated area. In contrast, male-headed households in the irrigation area have lower vulnerability level than similar household groups in the non-irrigated area These results show that existence of irrigation scheme did not contribute to female-headed households' vulnerability level whereas, the opposite is true for male-headed households.

The third theme of this thesis study contributes to further researches on adaptation options based on gender at household level by enhancing knowledge on how farm households in the study area and more widely are deal with the challenges posed by variability in climate. The study aimed to examine gender-based household-level perception on climate variability, adaptation options and determinant factors that influence the decisions farmers make in the adoption of technology. Climate- associated risks continue to unfavorably affect households that are dependent on agriculture. Findings indicate that differences in the adaptation options households undertake were observed based on gender and location of household heads. In the study area, a range of climatic as well as non-climatic factors are found to be a bottleneck to implement suitable adaptation strategies and to deal with the risks posed by climate change and variability. Total land resource and access to extension services are among the main factors that distinguish male- and female-headed households' decision on adaptation options. More number of predictor variables influence female household heads' decision to the adoption of adaptation technologies significantly than male household heads.

Unfavourable effects of climate change and variability are posing serious challenges to male- and female-headed households in their access to water, energy and food resources differently. Detail understanding of access to and control over these resources from a gender perspective is important to develop gender-based strategies and speed up access to these resources for underprivileged groups. The last theme of this thesis aimed to explore the gender dimension of water energy food nexus, especially households' access to these resources. We conclude that female-headed households' access to water energy food resources primarily depends on the small land size along with limited control over lands. Besides, the social norms, which include ploughing, are among the causes that enhance the households' limited access to these resources for domestic use. The study contributes to academia concerning how qualitative system dynamic approach, which is unusual, used to present cause-effect interactions qualitatively using software like Vensim. The study additionally provides baseline information to incorporate local contextual factors in the national nexus framework and micro-policies since the WEF nexus is a recently emerging approach worldwide and new for Ethiopia.

In sum, female-headed households' limited access to resources made them more vulnerable to climate change impacts and less capable to respond to climate change impacts. The gender inequality derived from the power structure of the society exposed these households to climate change impacts and extreme events due to their unequal access to productive resources that are important to respond and not to be vulnerable to climate change.

8.2. Recommendations

Drawing upon the main findings of the thesis, this section tries to provide recommendations to public policy because public policy contributes a lot in integrating an issue like gender to development issues like climate change policies, adaptation planning as well as the implementation of any climate-related strategies.

Findings in this thesis guide to the gender-specific discussion of packages that enhance the adaptive capacity of female-headed households to future climate changes. Besides, findings imply that policymakers need to formulate gender-specific climate adaptation policies and programs that promote households' asset building to increase their adaptive potential of vulnerable households. Susceptible households should additionally be targeted in terms of interventions aimed at reducing their vulnerability to climate- associated risks.

Findings from chapter 3 suggest the existence of significant spatiotemporal increasing trends of temperature, though trends in rainfall are not significant. In line with the metrology data, both male- and female-headed households perceived an increase in temperature and rainfall amount in the study area. If the same trend persists in the future, more chances of flooding and drought are expected. Therefore, the development of gender-specific adaptation strategies at household and community levels should be implemented to reduce the impact which might arise from it. Early warning system on climate is additionally important to make the farmers and concerned bodies ready ahead of any risks.

Irrigation scheme is expected to have an economic and climatic advantage; however, in the study area, households are partially benefited based on gender. Results presented in chapter 4 shows female-headed households' vulnerability level are higher in the irrigation area whereas the vulnerability level of male-headed households in the same area is the lowest. Qualitative results in chapter 6 additionally indicate female farmers are not using the water during the irrigation season because they have been faced socio-cultural and labour constraints to cultivate their land themselves. Hence, it is highly recommended that any development package which includes irrigation scheme should be gender-touchy starting from the design of any package to share the benefit. In addition, vulnerability reduction should be interlocked with the poverty reduction strategy of households, particularly female-headed households.

Results in chapter 5 show both male- and female-headed households perceived changes in temperature and rainfall, however, the number of these households that undertake adaptation options were unequal: number of male-headed households took adaptation measures in comparison with their counterparts. Accordingly, raising female-headed households' consciousness on climate-associated risks and their unfavourable impacts, on adaptation options and on how to prepare in advance for climate associated problems are proposed as policy actions. Besides, findings in this chapter indicate that the lack of extension services and credit services were among the determinants for female-headed households' implementation of adaptation options. Hence, there should be strong gender-sensitive institutional services through door-to-door extension services to make the service inclusive. Female-headed households have limited access to credit services due to the fact they cannot offer the essential collateral that the institution demands the provision of credit. To make credit facilities accessible for these household groups, it is recommended that these

households should have another alternative through making them stand in front of law if they cannot pay back their loan and decreasing interest.

In general, access to vital resources is an essential option for all subjects in the thesis: for higher adaptive capacity of households on adverse impacts of climate change that triggers to lower vulnerability to climate change risks; and for good access to water, energy and food at the household level. For instance, qualitative results presented in chapter 6 indicate that female-headed households have limited access to resources such as water, energy and food comparing to their counterparts. Access to these resources is interlocked with other resources: access to water, energy and food resources interlocked with main access to labour, land, income, livestock and others mentioned in Table 13. Hence, it is highly recommended that this group of households' access to vital resources should be improved through gender-specific capacity building by using credit provision and giving training on alternative livelihoods; and deconstruction of socio-cultural factors that inhibit their farming practices, their participation in public and their involvement in development planning.

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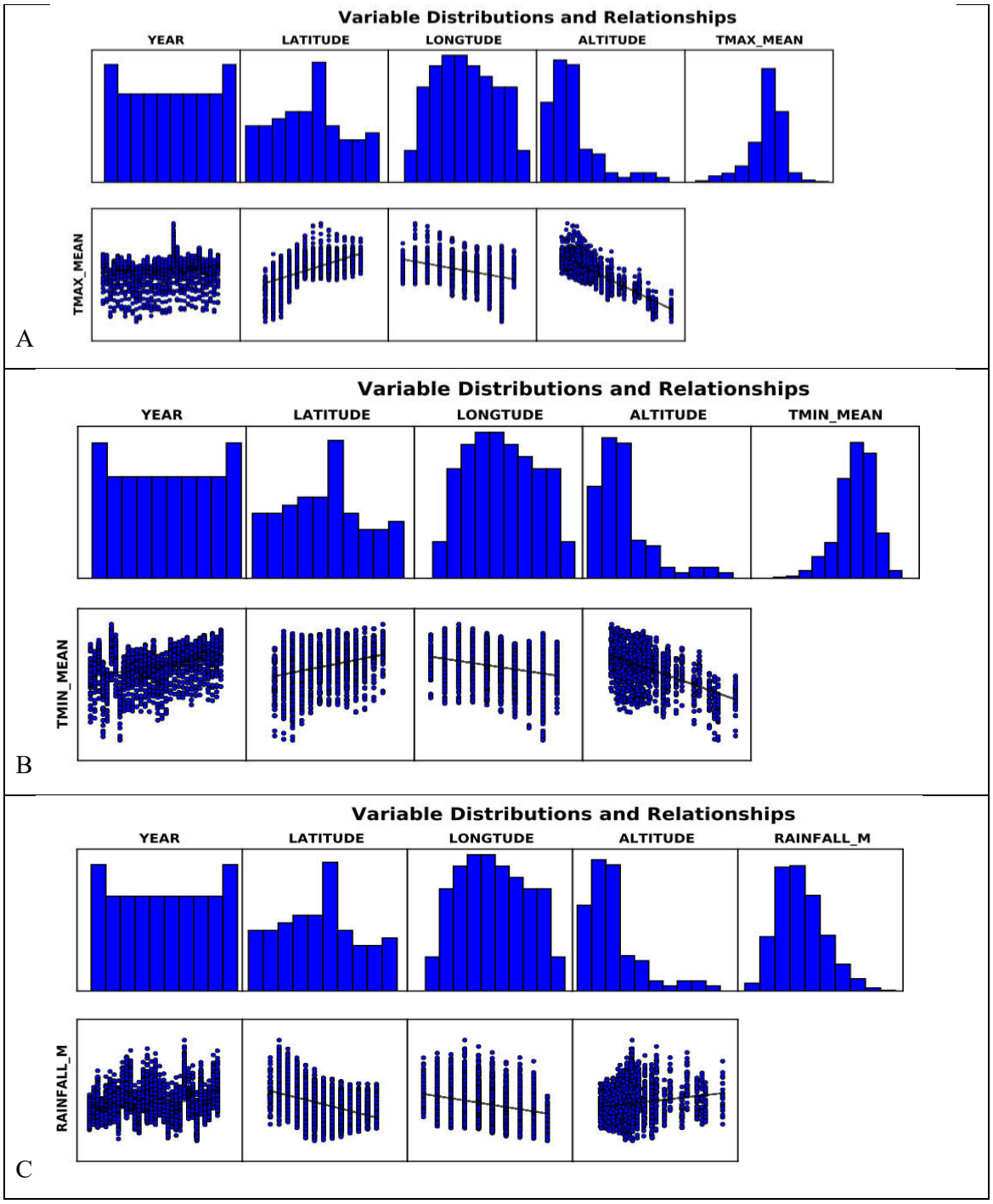
APPENDICES

Appendix I: Scatter plot matrix between dependent variable: (A) Annual Maximum Temperature, (B) Annual Minimum Temperature and (C) Annual Rainfall and independent variables (latitude, longitude and altitude) from 1983 to 2014: Ordinary Least Square Results (GIS output)



The above graphs are Histograms and Scatterplots for each explanatory variable and the dependent variable. The histograms show how each variable is distributed. OLS does not require variables to be normally distributed. However, if you are having trouble finding a properly-specified model, you can try transforming strongly skewed variables to see if you get a better result.

Each scatterplot depicts the relationship between an explanatory variable and the dependent variable. Strong relationships appear as diagonals and the direction of the slant indicates if the relationship is positive or negative. Try transforming your variables if you detect any non-linear relationships. For more information see the Regression Analysis Basics documentation.

Appendix II: Ordinary Least Square Results: (A) Annual Maximum Temperature, (B) Annual Minimum Temperature and (C) Annual Rainfall from 1983 to 2014 (GIS output)

A

Summary of OLS Results - Model Variables

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	-22.266273	6.408075	-3.474721	0.000535*	5.923096	-3.759229	0.000186*	--------
YEAR	0.018654	0.001300	14.347895	0.000000*	0.001252	14.903986	0.000000*	1.000000
LATITUDE	-0.173580	0.166013	-1.045584	0.295832	0.160699	-1.080158	0.280156	2.631624
LONGTUDE	0.635446	0.172002	3.694421	0.000237*	0.163101	3.896039	0.000110*	1.691556
ALTITUDE	-0.004862	0.000114	-42.717019	0.000000*	0.000113	-43.203138	0.000000*	3.659115

OLS Diagnostics

Input Features:	AnnualTmaxmecha	Dependent Variable:	TMAX_MEAN
Number of Observations:	2848	Akaike's Information Criterion (AICc) [d]:	5552.716477
Multiple R-Squared [d]:	0.687865	Adjusted R-Squared [d]:	0.687426
Joint F-Statistic [e]:	1566.309542	Prob(>F), (4,2843) degrees of freedom:	0.000000*
Joint Wald Statistic [e]:	5923.949421	Prob(>chi-squared), (4) degrees of freedom:	0.000000*
Koenker (BP) Statistic [f]:	9.935960	Prob(>chi-squared), (4) degrees of freedom:	0.041520*
Jarque-Bera Statistic [g]:	658.496663	Prob(>chi-squared), (2) degrees of freedom:	0.000000*

B

Summary of OLS Results - Model Variables

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	-46.973021	5.712296	-8.223143	0.000000*	5.641567	-8.326236	0.000000*	-------
YEAR	0.033489	0.001159	28.896068	0.000000*	0.001233	27.163398	0.000000*	1.000000
LATITUDE	-0.801381	0.147987	-5.415206	0.000000*	0.149442	-5.362491	0.000000*	2.631624
LONGTUDE	0.117822	0.153326	0.768444	0.442276	0.151180	0.779353	0.435825	1.691556
ALTITUDE	-0.002346	0.000101	-23.116351	0.000000*	0.000104	-22.519620	0.000000*	3.659115

OLS Diagnostics

Input Features:	AnnualTminmecha	Dependent Variable:	TMIN_MEAN
Number of Observations:	2848	Akaike's Information Criterion (AICc) [d]:	4898.029721
Multiple R-Squared [d]:	0.440897	Adjusted R-Squared [d]:	0.440110
Joint F-Statistic [e]:	560.482301	Prob(>F), (4,2843) degrees of freedom:	0.000000*
Joint Wald Statistic [e]:	1990.114967	Prob(>chi-squared), (4) degrees of freedom:	0.000000*
Koenker (BP) Statistic [f]:	286.219039	Prob(>chi-squared), (4) degrees of freedom:	0.000000*
Jarque-Bera Statistic [g]:	95.175680	Prob(>chi-squared), (2) degrees of freedom:	0.000000*

C

Summary of OLS Results - Model Variables

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	4339.722583	152.143330	28.523909	0.000000*	147.640961	29.393757	0.000000*	--------
YEAR	0.324871	0.030868	10.524617	0.000000*	0.027870	11.656497	0.000000*	1.000000
LATITUDE	-83.956400	3.941545	-21.300378	0.000000*	4.278045	-19.624944	0.000000*	2.631624
LONGTUDE	-105.450009	4.083737	-25.821939	0.000000*	3.994904	-26.396129	0.000000*	1.691556
ALTITUDE	0.006758	0.002703	2.500730	0.012438*	0.002883	2.344414	0.019110*	3.659115

OLS Diagnostics

Input Features:	annualrfaltmecha	Dependent Variable:	RAINFALL_M
Number of Observations:	2848	Akaike's Information Criterion (AICc) [d]:	23593.452764
Multiple R-Squared [d]:	0.416156	Adjusted R-Squared [d]:	0.415334
Joint F-Statistic [e]:	506.612349	Prob(>F), (4,2843) degrees of freedom:	0.000000*
Joint Wald Statistic [e]:	1833.534132	Prob(>chi-squared), (4) degrees of freedom:	0.000000*
Koenker (BP) Statistic [f]:	150.027685	Prob(>chi-squared), (4) degrees of freedom:	0.000000*
Jarque-Bera Statistic [g]:	24.632461	Prob(>chi-squared), (2) degrees of freedom:	0.000004*

Notes on Interpretation

* An asterisk next to a number indicates a statistically significant p-value ($p < 0.01$).

[a] Coefficient: Represents the strength and type of relationship between each explanatory variable and the dependent variable.

[b] Probability and Robust Probability (Robust_Pr): Asterisk (*) indicates a coefficient is statistically significant ($p < 0.01$); if the Koenker (BP) Statistic [f] is statistically significant, use the Robust Probability column (Robust_Pr) to determine coefficient significance.

[c] Variance Inflation Factor (VIF): Large Variance Inflation Factor (VIF) values (> 7.5) indicate redundancy among explanatory variables.

[d] R-Squared and Akaike's Information Criterion (AICc): Measures of model fit/performance.

[e] Joint F and Wald Statistics: Asterisk (*) indicates overall model significance ($p < 0.01$); if the Koenker (BP) Statistic [f] is statistically significant, use the Wald Statistic to determine overall model significance.

Appendix III: Eigenvalues and percent of variance from principal component analysis of Vulnerability indicators for aggregated data

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.461	13.003	13.003	5.461	13.003	13.003
2	4.263	10.149	23.152	4.263	10.149	23.152
3	3.652	8.695	31.847	3.652	8.695	31.847
4	2.776	6.609	38.456	2.776	6.609	38.456
5	2.545	6.060	44.516	2.545	6.060	44.516
6	2.464	5.868	50.384	2.464	5.868	50.384
7	2.044	4.866	55.250	2.044	4.866	55.250
8	1.783	4.246	59.496	1.783	4.246	59.496
9	1.581	3.764	63.261	1.581	3.764	63.261
10	1.548	3.686	66.947	1.548	3.686	66.947
11	1.420	3.382	70.329	1.420	3.382	70.329
12	1.277	3.041	73.369	1.277	3.041	73.369
13	1.160	2.762	76.131	1.160	2.762	76.131
14	1.120	2.666	78.797	1.120	2.666	78.797
15	1.080	2.571	81.368	1.080	2.571	81.368
16	.872	2.077	83.444			
17	.815	1.940	85.384			
18	.723	1.721	87.105			
19	.699	1.665	88.770			
20	.632	1.506	90.276			
21	.557	1.327	91.603			
22	.477	1.136	92.739			
23	.442	1.052	93.790			
24	.368	.876	94.666			
25	.339	.808	95.475			
26	.325	.773	96.247			
27	.277	.659	96.906			
28	.250	.596	97.502			
29	.222	.529	98.031			
30	.194	.461	98.492			
31	.158	.376	98.868			
32	.122	.290	99.158			
33	.105	.250	99.408			
34	.072	.171	99.579			
35	.067	.160	99.739			
36	.046	.110	99.849			
37	.037	.087	99.937			
38	.014	.034	99.971			
39	.010	.024	99.995			
40	.002	.005	100.000			
41	4.148E-017	9.875E-017	100.000			
42	-1.237E-017	-2.944E-017	100.000			
Extraction Method: Principal Component Analysis.						

Appendix IV: Factor loadings of the first principal component analysis for adaptive capacity profile

	Major indicators	Sub-indicators	Upper stream households		Lower stream households		Aggregated households	
			Male-head	Female-head	Male-head	Female-head	Male-head	Female-head
Adaptive capacity profile	Wealth	Farm size	.013	-.007	-.001	.002	.009	-.001
		Total livestock number	-.018	.020	.042	.027	.039	.052
		Off-farm income	.015	-.006	-.023	.001	.035	-.001
		Saving	.009	-.002	-.013	-.004	.014	.004
		Radio	-.007	.003	.014	-.030	-.008	-.033
		Mobile phone	.015	.010	.049	.014	.026	.006
		Hand dug well water	-.023	.027	.006	-.058	-.024	-.017
		Energy saving stove	-.027	-.017	.010	.021	.022	-.020
		Solar energy source	-.012	.011	-.032	-.017	.010	-.051
	Agricultural technology	Use of fertilizer	.238	.213	-.022	.168	.245	.012
		Use of improved seeds	.238	.217	-.011	.168	.242	.026
		Use of pesticides	.238	.213	-.005	.168	.245	.022
	Institution	Access to credit services	.010	-.015	.046	.003	.021	.032
		Access to telephone services	.076	.212	.021	.158	.244	-.001
		Access to extension services	.214	.016	-.016	.022	.005	-.033
	Skill and information	Access to weather information	-.015	.039	.051	-.002	.045	.028
		Households with formal education	.035	-.112	-.022	.007	-.047	-.008
	Infrastructure	Distance to health centers	-.021	.038	.219	.012	.017	.233
		Distance to market	-.002	.077	.086	.023	.040	-.010
		Distance to school	.025	.007	.280	.012	.015	.314
		Distance to veterinary centers	.027	.034	.275	.007	.012	.299
		Distance to main road	-.002	-.009	.274	.011	-.017	.301
	Social networks	Membership in peasant association	.019	-.014	.016	-.018	-.030	.019
		Membership in informal associations	-.011	-.005	.005	.018	.005	-.013
		Number of close persons to borrow	-.018	-.056	-.010	.006	-.064	-.026
	Socio demography	Total family member	-.010	-.037	-.018	-.002	-.002	-.021
		Dependent family members	-.002	-.052	-.021	.025	-.003	-.025
			1.007	**.803**	**1.198**	**.739**	**1.095**	**1.089**

Appendix V: Factor loadings of the first principal component analysis for sensitivity and exposure variables

	Major indicators	Sub-indicators	Upper stream households		Lower stream households		Aggregated households	
			Male-headed	Female-headed	Male-headed	Female-headed	Male-headed	Female-headed
Sensitivity Profile	Water	Irrigated land	.040	-.024	-.020	-.036	-.023	-.029
		Sufficient water for domestic use	.009	.005	-.006	.000	.003	.015
		Time to collect water	.026	.004	-.029	-.038	.021	-.010
		Water insufficient months	.015	.013	.026	-.018	.012	.014
	Food	Total annual production	-.043	.014	.018	-.005	-.023	.003
		Diversity of crop species	-.004	.015	.003	-.045	.012	.000
		Food insufficient months	.058	.050	-.002	.024	-.009	-.001
		Natural resource conservation practices	-.074	.075	.038	.021	.015	.057
	Health	Family member illness	.028	.081	-.038	-.024	-.017	-.017
		Days of family member illness	-.030	-.039	-.002	-.002	.017	-.054
		Health centre use	-.011	-.018	-.001	.004	.013	-.006
		Membership to health insurance enterprise	.016	-.054	-.018	-.004	.001	-.012
			0.03	**.123**	**-.030**	**-.124**	**.022**	**-.038**
Exposure profile	Climate extremes	Noticed change in drought frequency	.033	.013	-.012	.052	-.006	.019
		Noticed change in flood frequency	-.072	.002	-.031	-.009	-.005	.000
		Land damaged by flood	.057	.009	-.020	.010	-.005	.051
	Climate variability	Change in rainfall	.006	-.271	.009	-.129	.151	-.090
		Change in temperature	-.083	.059	.055	.417	-.385	-.124
			-.059	**-.188**	**.001**	**.341**	**-.251**	**-.143**

Appendix VI: In-depth and key informant interview and focus group discussions of male and female household heads

Interviews	Interview Code	Code description
Wa![6] female household heads have access to smaller land size, for instance, in our village, the minimum land size for male household heads is 2 kada[7] and maximum land size 12 kada without the land they used by rent and sharecropping. For female household heads, the minimum land size is 1 kada even there are female household heads without land whose major income source is making local brewery; and the maximum is 6 kada. Most of the female heads give their land to a sharecropper and few rents out because they couldn't plow. Few female household heads, whose husbands are dead, have 8 or 9 kada land.	KIVL-1	Key informant interview with village leaders
One discussant replied, 'Most of the female household heads have small land sizes compared to MHHs. We faced a food shortage from July to November end because we gave our land to sharecroppers or rent out it and receive the crop by half. Not all female household heads have such a kind of problem few are rich. Let me talk about myself as an example. I have only one kada land and I rent out for male farmers since I couldn't plough it myself. He gave me 1800 birr for two years. If I had a son like other female household heads, I would use it more than the money' the other discussant said '*I have 2 kada lands, I gave it to the sharecropper. My land is in the irrigation area, but the sharecropper is plough only once in a year. Male farmers who have land in the irrigation area are getting products twice per year. If I were male, I could*	FHFGD1	Female household heads focus group discussion- 1

[6] Wa**!** a local term to express someone's amazement.

[7] Kada is local measurement units for land 4 kada land is like 1 hectare.

plow my land myself and produce twice in a year like them' the third discussant reacted, '*In case of sharecropping; it is depending on the agreement between the landowner and the sharecropper. Some sharecroppers give half of the crop yield and some give one-third of the yield. Few sharecroppers share crop residues and most of them do not share the residues* "		
In our village, cow dung and crop residues are the main sources of domestic energy besides fuel wood. I used only fuel wood for cooking because I have no cow or ox to use their waste as an energy source. Male heads plant trees and used for fuel wood. I bought a minimum of one cart fuel wood, which costs 400-450 birr per two weeks. I used this fuel wood not only for cooking but for making a local brewery that is the other means of income for my family. And the other thing, I couldn't use crop residues as an energy source because my land is on the hand of my sharecropper and he is using the crop residue himself. Before years, we could collect these energy sources from communal grazing lands since the animals were there. Now all farmers kept their animals at home. village administrators prohibit the communal lands '	*FHII-2*	Female household head in-depth interview 2
'*I have no solar energy source because I have no money to buy. I couldn't afford it I swear. Now a day's many people are using it. Others have solar energy sources because they have a good income; they can sell eucalyptus tree, ox or crop. My crop is not enough even for my family to reach the crop season. My income from the local brewery is for my family's day-to-day survival. How could I buy solar? It costs over one thousand birr*[8]*'*	FHII-1	Female household head in-depth interview
"We have no big animals like ox and cow because of lack of fodder and place. These animal costs big, for	*FHFGD2*	Female household

[8] Birr= Ethiopian currency

instance, one ox costs 8- 15 thousand depending on its size. We have only small animals like sheep because we have no enough places to keep and fodder to feed big animals like a cow and an ox. But these small animals could fatten with little expense, they eat less. One discussant replied, 'I used Brint[9] *and some amount of crop residue for two sheep this fodder cannot feed big animals'.*		heads focus group discussion
Our domestic energy source for cooking is fuelwood, cow dung, and crop residues. Regarding solar energy sources for lighting, we all have it. There are even two solar energy sources in some male-headed households. We are planting trees for many purposes besides fuelwood: for selling, for construction, and for making charcoal to use at home and to sell. We used some of our lands for planting eucalyptus trees and some lands for a crop. For instance, I have six kada land; I used four kada for crop and two kada for the eucalyptus tree planted before 8 years, and I sold two times. I used the money for different purposes for home expenses, for farming expenses and my child's college fee. I sold trunks and used the branches for charcoal and fuelwood. I bought solar energy sources for lighting before 3 years "	MHFGD1	Male household heads focus group discussion
The district water office is trying its best to improve access to water sources for different purposes. For drinking, we are providing rope pump water for a group of people in each village and they have their own rules to use. For sanitation and livestock, most of the farmers have hand-dug well water they are using it. Comparing male and female household heads in access to hand-dug well water, in our district, most of the male household heads have this water source to use for livestock and sanitation. However, female household heads lack this water source because of lack of labor and limited income. Few female household heads	KIWO	Key informant with head of water office

[9] Brint = a local term to explain the waste product of a local brewery used to feed animals.

living with young boys have hand-dug well'		
"*The irrigation water is useful for many farmers but we are not using. Since we are female, we lack money, we lack oxen, and we lack labor to plow. For instance, last year* (2008 E.C.), *my land was idle during the irrigation season. This year, I rent out for the irrigation season and I will use it for the rain season.* The other discussant replied*, "Female household heads have land in the irrigation area but it depends on the sharecropper's interest and capacity to cultivate during the irrigation season. If he is interested and capable of cultivating our land also has equal access to water to use our turn like others. But if he is afraid of expenses like seed, fertilizer, and labor; our land will remain idle until the rain season.* "	FHFGD2	Female household heads focus group discussion 2
the crop from our land is not enough for annual consumption: usually their crop in July completed and they spend at least three months, July-September. The participants added they have not been eating nutritious food even for the rest nine food sufficient months. For instance one of them replied 'most of female headed households use egg and meat during main holidays like Christ mass or Easter'.	FHFGD 2	Female household heads focus group discussion 2
The land size held by female household heads and their counterpart male household heads is not equal, as we observed from the document, the average[10] land size for females and the male household head is 1.3 and 3.1 hectare respectively.	DR	Document review
There is no constant change in rainfall; one year increases the amount the other year decreases; one year begins early the other year late; one year ends early the other year late. Regarding temperature, there is a seasonal variation. One season in one year is hot and the other season is cold, e.g. in 2016 in January it was	MHFGD1	Male household heads focus group discussion 1

[10] Average land size = a result from a document by dividing total landholding by household heads number.

hot this year, it is freezing. In one year in May, it is hot and in another year in May; it is cold even it would be rain.		
Last year (2016), we had no water access from April to June. We travel a long distance to find a river and spring water, which took from 30 to 40 minutes on foot. Some male household heads collect water using a cart or donkey.	FHFGD1	Female household heads focus group discussion 1
There is no remarkable drought, but when frost hit our farm, the yield minimized and our crop is not enough for annual consumption. We eat twice instead of three times, and we make local brewery as a means of income and buy the cheapest grain called Gibto.	FN	Field notes

Appendix VII: Questionnaire for Respondents

Addis Ababa University

College of Development Studies

Center for Environment and Development Studies

The purpose of this instrument is to gather information related to the title "Gender Dimension of Climate Change Adaptation as Linked to Water Energy Food Nexus in Mecha area Northwest Ethiopia". The eligible subjects in this study are male and female farmers who are household heads. The quality of the study depends on the information that you are supposed to give. Therefore, you are kindly requested to answer all questions frankly and honestly. Please also note that all information you are supposed to provide will be kept secret and used only for research purpose.

Questionnaire number_____

Date: _____

Village name: _____

Enumerator's name: _____

Meseret Zewdu

January, 2017

Addis Ababa

1 General Household Information

Sex of HH	Age in Years	Education	Occupation	Religion	Ethnic background	Total Family Member	Total Adult Female	Total Adult Male	Total Children (<18 years)	Farming Experience (in years)

Education code: Illiterate=**1**, Read and write=**2**, Primary School (1-4)=**3**, Upper primary (5-8)=**4**, High School (9-10)=**5**, Preparatory school (11-12)= **6**, Certificate (TTI/TVT)= **7,** Diploma= **6**, Degree=**7**, other = **8** (Specify) _____

Religion code: Orthodox= **1,** Muslim=**2**, Protestant = **3**, Other = **4** (Specify)_____

Ethnic group: Amhara = **1**, Oromo= **2**, Tigre = **3** Gurage = **4**, Other = **5** (specify) _____

2. **Farmers recall of weather (rain) during 2015/2016 crop season**

1. In your view, when the rainy season begins?	2015: Early=1, On time=2, Late=3 2016: Early=1, On time=2, Late=3		
2. In which month did the rainy season begin?	2015: 2016:		
3. How would you characterize the amount of rain in the rainy season on the given year, relative to the average rainy season?	Significantly below average…….1 Slightly below average……..2 Average…… ……...3 Slightly above average…… …..…4 Significantly above average...…….5 Do not know ……..…6	2015	2016
4. In which month in the rainy season did you get the most rain?	2015: 2016:		
5. In which month did the dry spell occur?	2015: 2016:		

4. Exposure and sensitivity to climate change

Drought frequency for the past 5 years in number	
Flood frequency for the past 5 years in Number	
Family member's death due to climate hazards for last 5 years in No	
Land damaged by flood for the last 5 years in hectare	
Livestock death due to flood/drought for last 5 years in number	
Land topography by Slope (Hilly, flat)	
Soil Fertility (increasing, decreasing, constant)	
Vegetation cover of grazing land / (increasing, decreasing, constant)	

5. Household and farm assets

Asset	Asset type	Total number of asset	How old?
Communication	Radio		
	Television		
	Phone (land or cell)		
Transportation	Motor bike		
	Bicycle		
	Horse		
	Mule		
	Donkey		
	Other----------		
Farm tools	Tractor		
	Plough (wooden)		
	Plough (iron)		
	Pesticide sprayer		
	Threshing machine		
	Diesel /Electric pump		
	Fodder cutting		
	Other (specify)		

House equipment	Refrigerator		
	Water tank (borehole)		
	Stove (Kerosene)		
	Energy saving stove		
	Biogas plant		
	Solar energy source		
	In house water connection		
	Flour mill		
	Others (specify)		
Accommodation	House ownership*		
	House type*		

House ownership: private ownership= **1**, Joint ownership= **2** Rented= **3** Other (specify)___

House type: Iron roofed house=**1** Grass roofed house=**2** Other (specify)_____

6. Livestock Information:

Type	Bull	Ox	Local cow	Heifer	Improved Cow	Calf	Sheep	Goat	Horse	Mule	Donkey	Hen	Beehive
Number													
Present value in birr													
Reason for keeping**													

Reason ** Cultivation=1**, Milk consumption= 2, Milk selling =**3**, Breeding=**5**, Meat=**6**, Egg=**7**, Sale of young stock=**8**, Wealth status=**9**, Others=**10** (specify)_____

7. Access to institutional resources

Resources	**1= yes 0= otherwise**
Access to weather information	
Access to improved seeds	
Access to fertilizer	
Access to extension services	
Access to market (distance in kilo meter)	

8. Energy Resources

1. Which sources of energy mainly used at home?
   a. Fuel wood b. crop residue c. cow dung d. char coal e. Biogas f. solar energy source g. other _____
2. Reason for choosing the mainly used energy source
   a. It is comfortable b. it is cheap c. easily accessible d. culturally preferred
3. Do you have access to electricity?
   a. Yes B. No
4. Do you have access to alternative energy sources?
   a. Yes B. No
5. If yes, which of alternative energy sources you used?
   a. Solar b. biogas c. hand battery
6. Energy sources and purposes

Energy sources & purposes	Fuel wood	crop residue	cow dung	char coal	Biogas	solar	Electric	Hand battery
For cooking								
For lighting								
For baking								

Distance to get energy sources (in meter /minutes)								
Frequency per week								
Family members to collect**								
Family member to collect** Mother=1, daughter=2, father= 3, son=4, mother & daughter =5, father & son=6								

7. Did you plant trees for fuel wood for the last 5 years?
   a. Yes b. No

9. Current Plot information

1. Total land/ hectare _____Total rain fed land: _____Total irrigated land: _____

Farm Type	**Land size**	**Ownership***	**Crop type**	Crop value/ quintal/birr	Land certificate (1= yes, 0= no)
Rainfed					
Irrigated					
Fallow**					
Plantation					
Grazing land					
	*** Farm ownership**: Own=**1**, Lease in=**2**, Share cropping=**3** **Fallow**** Temporary fallow=**1**, Permanent fallow=**2**				

2. What are the reasons for not cultivating the land? *(Ask only if farmers not cultivating land in any season)* _____

_____

*3. **Applicable only for farmers with irrigated land***

a. Do you have access to irrigation sources 1. Yes 2. No

b. If yes, what are your irrigation sources?

1. Tank Irrigation 2. River 3. Borehole water 4. Other (specify)_____

c. Does the water supply meet your needs for irrigation? 1. Yes 2. No

d. If yes, what type of lifting technologies you used?

1. Human labor 2. Animal labor 3. Farrow 4. Water pumps motor 5. Other _____

E. who is responsible for management of irrigation water sources?

1. Communities 2. Individuals 3. Village leaders

10. Water resource

1. Water sources for different purpose

Water purpose and sources	**Borehole**	**Rope pump**	**River**	**Spring**	**Pond**	**Rain water**	**Family member to collect****
For drinking							
For cooking							
For sanitation							
For animals							
Family member to collect** Mother=1, daughter=2, father= 3, son=4, mother & daughter =5, father & son=6							

2. How far you walk to get clean drinking water (in minutes)_____ Frequency per day (in number) _____
3. Average amount of water used at home per day (in liter) _____
4. Access to sufficient water per year for 2015/16
   a. For 3 months b. for 6 months c. for 9 months d. throughout the year
5. Management of water sources for different purpose
   a. Communities b. individuals c. village leaders
6. Do you have equal access to water resources?
   a. Yes b. no
7. If no, why? _____

11. Income from livelihood activities (2015/2016)

Types of Income	Yes=1	No=0	Amount in Birr	Saving amount
Income from main crops				
Income from dairy/livestock				
Income from agriculture labor (within the village or neighbor village)				
Income from beekeeping				
Income from poultry				
Income from handicrafts				
Income from plantation				
Income from selling wood				
Income from petty trade				
Income from migration				
Other (specify) ----------				

1. At what time of a year (months) is cash income most needed? _____ Why?

_____

2. At what time of year (months) do you have more cash available for agricultural expenses?

_____

3. Source of cash income _____

4. Do you have access to credit services? 1. Yes 2. No If yes,

No	Year	Sources of loan	Amount of loan taken	Repaid	Remark
1					
2					
3					
4					

12. **Formal and Informal Institutional Membership Index:**

No	Institution's name	Yes	No	If yes, Function as a member	If no, reason
1	Member in peasant association				
2	Member in women group				
3	Member in one to five arrangements				
4	Member in "*Senbete"*				
5	Member in "*Edir"*				
6	Member in "Ekub"				
	Any other membership (specify)_____				

1. Do you participate in knowledge exchange with other farmers of this village or other villages? 1. Yes 2. No
2. What type of knowledge?

_____

3. Frequency of contact with friends, family relatives -outside of the household and cooperativeness

1. Frequency of neighbors visiting in a month _____
2. How many close friends or relatives do you have?_____
3.The relationship with whom you can feel at ease with, can talk to about private matters?_____
4. How many friends and relatives would you offer help during need without hesitation? _____
5. Have you been asked to help other households in the village? 1. Yes 2. No
6. In the last 5 years, how many times have you helped your relatives and friends when the household was in need? _____

13. Human capital

1. Concerning education, do you feel that you are particularly lacking in certain types of information? 1. Yes 2. No

2. If yes, which one(s)? *[Tick all that apply]*

a) Weather

b) Cropping (seeds, fertilizers, pesticides)

c) Market, prices

d) Health

e) Government programs on subsides F) other (specify) _____

3. How many member of your family provide labor service? _____

4. Health status of the household members (2015/2016)

Type of illness	No. of days	Missed work days	No. HH member
a) Diarrhoea			
b) Respiratory illness			
c) Pregnancy			
d) Accident			
e) Surgery			
f) Other (specify)_____			

6. Do you have access to health services? 1 = Yes 0 = No

7. How far is the health service center from your house? (In meter/ minutes) _____

8. Does your household have access to a latrine? 1 = Yes 0 = No

9. If yes, How far is the latrine from your house? (In meter) _____

10. Are you a member of health insurance enterprise in your village? 1 = Yes 0 = No

11. Do you have access to dry waste disposal? 1 = Yes 0 = No

12. Do you have access to liquid waste disposal? 1 = Yes 0 = No

13. Nourishment and Food Security

a. Is your crop product cover your household annual food consumption?

1=yes 0=No

b. If no, what do you do when there is food shortage?

(a) Eat less preferred food (b) sale family labor (c) Buy from off-farm income (d) buys after sell of livestock (e) Migrate to other places

c. Which months are most difficult to provide adequate food for HH_____. Why? _____

_____

d. How many kilos in a year does your family usually purchase food grains? _____

e. How many kilos in a year does your family usually borrow food grains? _____

_____

f. Type of meals usually consumed per day: *1. Normal time* _____

2. Difficult time _____

g. What percentage of your household food grains need is met by your own farm land in a year?

%	For a year with enough rainfall	For a year with not enough rainfall
0-25%		
26-50%		
51-75%		
76-100%		

14. Perception and adaptation

1. Climate variability/change perceptions (local indicators of climate change) and adaptation strategy

Changes	Over the last 10 years have you noticed changes? Yes=1, No=0
Less rain	
More rain	
Constant rain	
Increase in Temperature	
Decrease in Temperature	
Constant Temperature	

2. What kind of strategies that you are using to adapt to climate change / variability mainly?

a. Soil and water conservation

b. Using Short season crops( )
c. Using crops resistant to drought ( )
d. Changing to irrigation ( )
e. The use of chemical fertilizer ( )
f. Use of organic fertilizer ( )
g. Changing planting dates ( )
h. Planting trees ( )
i. Migration ( )
j. No adaptation method used ( )
k. Other (specify)_____

15. Problems and adaptations related to agricultural practices

Climate-specific related problems*	**Adaptations**
Delay in onset of monsoon	
Rainy season end sooner	
Erratic rainfall	
More rain	
Less rain	
Frequent floods	
Other (specify)_____	

*[***Examples:** Soil not suitable, slope land, crop needs less water, crop needs more water, power problem, water yield is low, sharing water with other joint owners, pump capacity is low/high, pump fail frequently, rainfall is less, inefficiency in water use, poor infrastructure, crop water requirement not known, pump is old, pump ran dry...]*

1. What do women do during dry season?
   A. Patty trade, (b) selling fire wood, (c) charcoal production, (d) Making local brew
   (e) other (specify) _____
2. What do men do during dry season?

(a) Construction (b) Brick making (c) seasonal Migration (d) Charcoal production

3. What other activities do you do to cope with climate change?

(a) Irrigation (b) Gardening (c) Grazing (d) Making local brew (e) Selling fire wood (f) hand craft (h) Milling (i) cutting fire wood

4. Natural resource conservation activities

Activities	Individual (1=yes, 0=no)	In group (1=yes, 0=no)
1. Soil bund		
2. Stone bund		
3. Terracing		
4. Small Dam		
5. Organic fertilizer use		
6. Planting trees		
7. Water conservation		
8. Area closure		
9. Other (specify) _____		

16. Sources of access to climate information

Sources	Onset of monsoon /delay in monsoon/scanty monsoon	How frequently is forecast information available?	Did you use advice and information about when to plant/sow crops from these sources?
	Yes=**1**, No=**0**	Daily=**1**, Weekly=**2**, Monthly=**3**, Seasonal=**4**	Yes=**1**, No=**0**
Television			
Radio			
News Paper			
Neighbors/Relatives/			
Extension workers			
Extension worker			

Others (specify)			

3.2. Does the information help you in planning your land use activities? Yes ( ) No ( )

3.3. What type of extension service do you receive? (a) Home visit (b) Farm field

(c) Others----------