



**Evaluating the vulnerability context of livelihoods and responses in a  
changing climate condition: insights for sustainable livelihood in different  
agro-ecologies of Gurage Zone**

**Zelalem Dendir Nigani**



*A Dissertation Submitted to the Center for Environment and  
Development Studies, College of Development Studies*

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

**Addis Ababa University  
Addis Ababa, Ethiopia  
July 2020**

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Development Studies)**

**Supervisor  
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**Addis Ababa University  
Addis Ababa, Ethiopia  
May 2020**

## **Declaration**

I, the undersigned, declare that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation, have been fully acknowledged.

Name: Zelalem Dendir Nigani

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Date: July 30/2020

Place: Addis Ababa

Date of submission: July 30/2020

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

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**DISSERTATION APPROVAL**  
**ADDIS ABABA UNIVERSITY**  
**SCHOOL OF GRADUATE STUDIES**

This is to certify that the thesis prepared by Zelalem Dendir Nigani entitled: **“Evaluating the vulnerability context of livelihoods and responses in a changing climate condition: insights for sustainable livelihood in different agro-ecologies of Gurage Zone”** and submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy (Environment and Development) complies with the regulations of the University and meets the accepted standards concerning originality and quality.

Signed by the Examining Committee:

----- Chairman, Examining Committee	----- Signature	----- Date
----- External Examiner	----- Signature	----- Date
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Chair of Department or Graduate Program Coordinator

## Acknowledgments

First and foremost, I would like to extend my unshared thanks and give praise to the Almighty God and his mother St. Marry for providing me the opportunity and smoothening of all aspects regarding my Ph.D. work. My sincere appreciation goes to my supervisor Professor Belay Simane for his encouragement, guidance, and support throughout my Ph.D. period to make my Ph.D. experience productive. I have been extremely lucky to have had the opportunity to work with such an amazing and friendly person. The enthusiasm he has for research was motivational for me.

I would like to thank all who have contributed immensely to my Ph.D. work. Particularly, I am grateful to Gebrekidan Worku, Dr. Kumela Gudeta, Dr. Mussi Yebab, and Gemechis Mersha for their fruitful discussions and contribution. I also thank my fellow Ph.D. candidates for being a source of continuous motivation as well as collaboration. I also would like to thank my colleagues, Alemayehu Wudneh, Bereket Zeleke, Dr. Hadis Tadele, Kassahun Abie, and Belihu Zeberga and many other friends for their support and friendship during my Ph.D. journey. I am also thankful to the academic and administrative staff of the College of Development Studies of Addis Ababa University for providing a great environment to undertake my study.

I would like to thank individuals and organizations who helped me during my fieldwork in Gurage Zone, especially the Bureau of Agriculture and Rural Development of Sodo, Ezha and Cheha districts, the enumerators, supervisors, the sampled respondents and the participants in the focus group discussions. I am very indebted to their dedicated work, time, and hospitality.

Most importantly, I am very thankful to my father Dendir Nigani, my mother Tenaye Gizaw, my brothers Biniyam, Sisay, and Yosef who always pray for my success and remain in contact throughout my Ph.D. duration. I am so grateful to my beloved wife Eyerus Gossaye and my daughter Elana Zelalem for their unconditional love and support.

I gratefully acknowledge both Mada Walabu University and Addis Ababa University for sponsoring my Ph.D. study. I am also thankful to The Energy and Resource Institute, New Delhi, India for providing me training on an Integrated approach towards Sustainable Development, which helps me a lot in my Ph.D. work.

**Dedication**

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## General Abstract

Climate variability and change profoundly affect rural livelihood systems in Ethiopia, particularly those built around climate-sensitive sectors. Generally, the objective of this study was to evaluate the vulnerability context of livelihoods in a changing climate condition and to examine farmers' responses for sustainable livelihood to support effective ex-ante decision-making in different agro-ecologies of Gurage zone, Southern Ethiopia. The dissertation used a mixed research design to address the objectives. Representative 357 farm households were selected using a multistage sampling technique and data was collected using a semi-structured questionnaire. Complementarily, 2 focus group discussions and 12 key informant interviews for each agro-ecologies were carried-out. Agro-ecological variation of climate indices for extreme precipitation and temperature was analyzed for the time 1986–2016. The study used different data analysis methods, including the Livelihood Vulnerability Index (LVI) and Livelihood Vulnerability Index–Intergovernmental Panel on Climate Change (LVI–IPCC) to analyze livelihood vulnerability; the trend and magnitude of changes in precipitation and temperature extreme were examined by the Mann–Kendall (MK) test and Sen's slope estimator, respectively; adaptation difference between agro-ecologies was measured by one-way analysis of variance (ANOVA) and descriptive statistics; the Multinomial Logit Model (MNL) used to analyze determinants of the choice of adaptation strategies among farm households. The results indicate that there had been consistent warming trends in the study agro-ecologies. While inconsistent changes in precipitation extremes with insignificance trends were observed. The duration of extreme precipitation trends showed inconsistency among the studied agro-ecologies. The livelihood vulnerability analysis revealed that the lowland agro-ecological zone was more vulnerable to a changing climate condition, although there was a difference in components relative value in the three agro-ecological settings. Increasing temperature and declining precipitation are perceived by the majority of the respondents. Similarly, sampled farmers reported that the frequency of extreme events like drought, flood, frost, and storm had increased. In response to the adverse effects of climate variability and change, farmers employed adaptation strategies. But, a significant agro-ecological variation in farm management practices was found. The result from the multinomial logit model showed that different factors determine the adoption of adaptation measures. The result revealed that the adoption of crop management related strategy to a changing climate is significantly and positively affected by education level, farming experience, and extension advice. A positive and significant influence of sex, household size, credit service, access to market, and lowland agro-ecology was observed on the adoption of soil and water conservation measures. Context-specific interventions in response to a changing climate condition are recommended. Due to the availability of relatively large farm-land and less labor out-migration, crop management measures like drought-resistant and improved varieties and adoption of soil and water conservation measures are recommended in lowland agro-ecological zone to increase the productivity of agricultural activities and thereby to sustain the livelihood of farmers. While, diversification of livelihood and plantation of Enset is recommended in both midland and highland agro-ecological zones since there is a land shortage, migration of youths, and population density. Similarly, the results acknowledge the role of institutional support in terms of education, climate information, credit, extension services, and market access to increase farmers' readiness to implement adaptation strategies in response to the impacts of climate-related disasters, to improve livelihood, and support disaster risk reduction efforts.

Keywords: climate extremes; trend; livelihood vulnerability; determinant; agroecology; Gurage

## List of original papers

1. Dendir, Z., & Simane, B. (2020). Analysis of observed changes in daily temperature and precipitation extremes in Gurage Zone, Southern Ethiopia. **Theoretical and Applied Climatology, Springer (Submitted to Journal)**
2. Dendir, Z., & Simane, B. (2019). Livelihood vulnerability to climate variability and change in different agro-ecological zones of Gurage Administrative Zone, Ethiopia. *Progress in Disaster Science*. <https://doi.org/10.1016/j.pdisas.2019.100035> Elsevier
3. Dendir, Z., & Simane, B. (2020). Farmers' perceptions about changes in climate variables: perceived risks and household responses in different agroecologies, Southern Ethiopia. **Climate Services, Elsevier (Under review)**
4. Dendir, Z., & Simane, B. (2020). Determinants of farmers' choice of adaptation practices to climate change in Gurage Zone, Southern Ethiopia. **Environment, Development and Sustainability, Springer (Submitted to Journal)**

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## List of Abbreviations

ANOVA	Analysis of Variance
CC	Contingency Coefficients
Coef.	Coefficient
CO <sup>2</sup>	Carbon dioxide
CSA	Central Statistics Authority of Ethiopia
DFID	Department for International Development
E	Longitude
EPCC	Ethiopian Panel of Climate Change
ETCCDI	Expert Team on Climate Change Detection and Indices
FAO	Food and Agricultural Organization
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focus Group Discussions
FTC	Farmers Training Centers
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GZFED	Gurage zone finance and economic development
HH	Household
HSQ	Household Survey Questionnaire
IFAD	International Fund for Agricultural Development
IIA	Independence of Irrelevant Alternatives
IPCC	Intergovernmental Panel on Climate Change
KII	key informants' interviews
LVI	Livelihood Vulnerability Index
LVI-IPCC	Livelihood Vulnerability Index- Intergovernmental Panel on Climate Change
KM	Kilometer
m	Elevation
MK	Mann-Kendall
mm	millimeter
MNL	Multinomial Logit model

MNP	Multinomial Probit model
N	Latitude
NMA	National Metrology Agency of Ethiopia
PPS	Probability proportional to size
PSNP	Productive Safety Net Program
SD	Standard Deviation
SNNP	Southern Nation, Nationalities and People Regional State
SPSS	Statistical Package for Social Science
SSE	Sen's Slope Estimation
SUEST	seemingly unrelated post-estimation procedure
SWC	Soil and Water Conservation
TLU	Tropical Livestock Unit
Tmax	Maximum Temperature
Tmin	Minimum Temperature
UNDP	United Nation Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VIF	Variance Inflation Factor
WFP	World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization

## 1. General Introduction

### 1.1. Background of the study

Climate change poses significant risks and in many cases is already affecting a broad range of human and natural systems, particularly in the developing countries (IPCC, 2014; FAO, 2017). Climate change is experienced over longer time frames via changes in climatic norms and over shorter periods via changes in the frequency and severity of extreme weather events (IPCC, 2007). Since the 1980s, many climatologists have been predicting significant global warming due to the increasing atmospheric concentration of carbon dioxide and other trace gases (Bizikova L. *et al.*, 2007).

A report by the World Bank (2013) suggested that during the last decade, globally averaged temperature has risen by about 0.6–0.8 °C. The changing condition which is manifested through extremes weather conditions and related shocks including drought, floods, weeds, and pest infestation have significantly affected agricultural systems, water resources, rural livelihoods, and food security (FAO, 2011; IPCC, 2012; Abid *et al.*, 2016; Bocchiola *et al.*, 2019). Similarly, a 1.8°C - 4.0 °C temperature increase by 2100 is projected globally (IPCC, 2014). Studies have suggested that unless mitigation measures are taken to climate change, 20–30% of plant and animal species extinction is predicted, which in turn has a significant effect on human and natural systems (FAO 2007; IPCC, 2014; Thornton *et al.*, 2014).

Even though climate change is a global phenomenon the level of a vulnerability is spatially differentiated dictated by environmental and socio-economic factors (Adger *et al.*, 2003). Empirical findings and reports (e.g. Lobell *et al.*, 2011; Climate Analyticts, 2013; IPCC, 2014) suggested that Africa is particularly the most vulnerable hotspot to impacts of climate change and variability, mainly because of the underlying poverty, high exposure, low adaptive capacity, and dependence on climate-sensitive sectors.

Extreme climate events are a major cause of low productivity of the agriculture sector in sub-Saharan Africa (IPCC, 2014; Niang *et al.*, 2014; Tripathi and Mishra, 2016). Historically, the drier condition is observed across Africa (Williams *et al.*, 2012; Hartmann *et al.*, 2013). Likewise, by the end of the 21st century, a 2°C increase in annual temperature and reduction in precipitation is

predicted (IPCC, 2014) which will lead to increased stress on crop cultivation, livestock production, and water availability (Kassie *et al.*, 2013).

Ethiopia's vulnerability to climate variability and change is highly associated with the existing poverty, dependence on traditional and rain-fed agriculture systems (Bewket *et al.*, 2015). Similarly, climate change affects the efforts to improve the productivity of the agriculture sector in Ethiopia (Conway and Schipper, 2011) particularly, recurrent drought and flood adversely affected the sector. Droughts and floods are the major climate change extreme events that had a strong effect on poverty, food security, and livelihood in Ethiopia (Arragaw and Woldeamlak, 2016). Droughts are the greatest and most recurring climate hazard in Ethiopia, for instance, the 2011 drought left more than 4.5 million people in need of food assistance. Similarly, the risk and intensity of flooding are increased (World Bank, 2011).

Historical and projected studies have documented trends of increased variability in precipitation and an increase in temperature in Ethiopia. Average temperatures in Ethiopia have increased by 1.3°C between 1960 and 2006 (Eshetu *et al.*, 2014). Likewise, a projection suggests that an increase in mean annual temperature by 1.1 °C to 3.1 °C by the 2060s, and 1.5 °C to 5.1 °C by the 2090s (NMS, 2007). Even though it is difficult to project long-term trends in precipitation due to strong inter-annual and inter-decadal variability, some studies projected that precipitation is expected to decrease from a mean annual value of 2.04 mm/day (1961–1990) to 1.97 mm/day (2070–2099) with a collective decline in precipitation by 25.5 mm/year in Ethiopia (NMS, 2007; Kidanu *et al.*, 2009). Unless measures at different levels are taken these changes are likely to worsen the existing drivers of poverty.

The concept of vulnerability is dynamic and varies across temporal and spatial scales (O'Brien *et al.*, 2007). Vulnerability in the context of climate change is defined as the propensity or predisposition to be adversely affected (IPCC, 2012). This definition differs from the earlier IPCC definition, where vulnerability is dependent on exposure (IPCC, 2007) whereas the current definition of vulnerability is conceptualized independently of the physical event. Predisposition constitutes contextual characteristics that influence the capacity to anticipate, cope with, resist, and recover from the adverse effects of physical events (IPCC, 2012). Similar exposure of socio-

ecological systems to physical events may lead to differential levels of damage and loss due to the different levels of climate change vulnerability (Wisner et al., 2011).

In response to vulnerability to adverse effects of climate change coupled with the projected climate change, the significance of adaptation in climate-sensitive sectors particularly in developing countries gaining recognition (Thamo et al., 2017). Studies recognize the important role of practicing adaptation measures to offset the adverse impacts of climate change which in turn helps to assure improved livelihood and better readiness for projected changes in climate and associated damages (IPCC, 2012; Niang *et al.*, 2014). However, the effectiveness of adaptation to climate change varies based on the adaptive capacity of a system including socio-economic and institutional settings (Morton, 2007; IPCC, 2012).

Despite Ethiopia's agriculture sector supports 38.5% and 80.2% of Ethiopian Gross Domestic Product (GDP) and employment source, respectively, the sector is vulnerable to the adverse effects of climate change (CSA, 2013). Different adaptation measures were implemented so far to abet the negative effects of climate change by different stakeholders at a different level in Ethiopia (NMA, 2007). However, studies pinpoint that the loss and damage associated with the adverse effects of climate change is still a problem in Ethiopia (Bewket *et al.*, 2015).

Similarly, in Gurage Zone, smallholder farmers rely heavily on subsistence rain-fed agriculture for livelihood. However, the Zone is vulnerable to the adverse effects of changing climate conditions and experienced extreme weather events like drought, frost, and floods that have already resulted in problems (GZFD, 2019). There is reported erratic precipitation, delayed onset, early cessation, or insufficient quantity or distribution of Belg or Kiremt rains, which has profound implications for livelihood security in the zone (GZFD, 2019). Therefore, the sustenance of agricultural production depends on adapting and adjusting to the changing climate patterns. Thus, this research aims to understand farmers' livelihood vulnerability to climate variability and change and to examine adaptation measures for sustainable livelihood in the Gurage zone, Southern Ethiopia.

## 1.2. Statement of the problem

In Ethiopia, smallholder agricultural production which mainly dependent on rain and traditional technologies accounts for over 95 percent of the annual gross total agricultural output with an

average farm size ranging from 0.5 to 2 hectares (CSA, 2011). Moreover, despite Ethiopia's agriculture sector supports 38.5% and 80.2% of Ethiopian Gross Domestic Product (GDP) and employment source, respectively, the sector is highly vulnerable to the adverse effects of climate variability and change (CSA, 2013; Simane *et al.*, 2016). Extreme weather events like drought and flood pose a serious challenge to agricultural productivity and further development of the sector in particular and the development of the country in general (EPCC, 2015; Savage *et al.*, 2015; Yalew *et al.*, 2018).

Also, non-climate stressors like rapid population growth have contributed to over-farming and deforestation which in turn exacerbated vulnerability to climate change (IPCC, 2007). The total population size projected to increase to 133.5 million in 2032 and then to 171.8 million in 2050 (Bekele & Lakew, 2014). Moreover, inadequate infrastructure to handle the increasing population is also worsening the vulnerability to extreme climate events, the impact of which, together with land degradation, human population growth, and climate change (UNDP, 2011; Tessema *et al.*, 2013; EPCC, 2015). Thus, the recurrent climate change and vulnerability related extreme events coupled with non-climate drivers are greatly impaired the country's economic and social development.

Considering the substantial effects of climate variability and change on the agriculture sector and their repercussions on the socio-economic development, different policies and strategies have been developed in Ethiopia (NMA, 2007; World Bank, 2010; EPCC, 2015). The policies largely focus on reducing the vulnerability of livelihoods from droughts and floods by improving agricultural productivity, ensuring uninterrupted water availability, enhancing irrigation systems, expanding renewable energy, weather information systems, building climate-resilient infrastructure, creating effective insurance schemes, and diversifying economic opportunities (MoFED, 2010; FDRE, 2011; EPCC, 2015; NPC, 2016). Additionally, smallholder farmers used different adaptation measures to offset the adverse effects of climate change (Berhanu and Beyene, 2015). However, studies pinpoint that the loss and damage associated with the adverse effects of climate change is still a problem in Ethiopia (Bewket *et al.* 2015; EPCC, 2015).

The rural economy in the Gurage Zone is largely affected by a changing climate condition. For instance, a study by Gizachew & Shimelis (2014) between (1970-2002) reported 4 major drought

occurrences in Sodo Woreda of Gurage Zone. Similarly, some plant species like *Lobelia rhychopetalum* existing in the Gurage Mountains is becoming extinct (Sahle & Yeshitela, 2018). Additionally, non-climate (socio-economic) factors are also impacting the vulnerability to climate change. For example, land-use conversion to different purposes in the zone is becoming common. The forest cover had shown a decline with the annual rate of 0.074% during (1986–2017) and converted into cropland (Sahle & Yeshitela, 2018). Similarly, the Zone is among the most densely populated in Ethiopia. The Zone is well known in out-migration, it is estimated that around 60% of Gurages now reside outside the Gurage Zone (GZFEED, 2019). Poverty, inadequate infrastructure, unsustainable land use, overgrazing, land degradation, limited income opportunities, severe shortage of farmland affects rural livelihood (Sahle *et al.*, 2018b).

Enset (*Ensete ventricosum*) 'false banana tree' is among the main home garden food crops which is an indigenous agricultural system found in Gurage and much of southern Ethiopia. Gurage's identify themselves as "people of Enset" and the plant is extensively cultivated and contributes to the long-term sustainability of food production (Shank and Ertiro, 1996). This drought-resistant plant can be harvested at any time and stored for long periods (Brandt *et al.*, 1997). Enset farming systems play a multipurpose role like used for food, animal forage, and fiber (Ayele and Sahu 2014; Sahle *et al.*, 2018a); improves the nutrient balance in the soil (Elias *et al.*, 1998); promote compact and permanent villages (Shank and Ertiro, 1996), and providing shadow for coffee and khat plantation, thus moderating temperature (Tesfaye, 2008). However, due to severe drought, the area coverage of Enset-based plantation and its productivity decreased (Tenaye and Geta, 2009; Sahle & Yeshitela, 2018).

Various studies on household vulnerability to climate variability and change have been conducted in Ethiopia (Deressa *et al.*, 2008; Tagel & Anne van der, 2013; Simane *et al.*, 2016; Decahssa *et al.*, 2017; Amare & Simane, 2017). However, the existing empirical evidence fails to capture and address the complex nature of vulnerability at the local level (Fraser *et al.*, 2011; Simane *et al.*, 2016) and because many aspects of vulnerability to climate change is context-specific (Adger *et al.*, 2009; IPCC, 2012), the need to understand local-level/context-specific nature of vulnerability is growing. Likewise, with diverse socio-economic and bio-physical futures in Ethiopia place-based understanding of vulnerability is essential for local-level planning. A better scientific understanding of vulnerability and associated risks and adaptation practices in a changing climate

condition is essential for local-level planning. Despite previous scientific findings in Ethiopia, studies on framing climate change adaptation efforts within a local socio-economic and livelihood context are scarce in the Gurage zone.

Many empirical pieces of research in measuring vulnerability focus on climatic factors (Deressa *et al.*, 2008; Pearson and Langridge, 2008; Odjugo, 2010; Pandey *et al.*, 2015). This one-dimensional approach overlooking the non-climatic drivers of vulnerability and neglecting the complex dynamics of human-environment interactions (O'Brien *et al.*, 2007; Hinkel, 2011) masks the social-political causes of risk and vulnerability, as well as the socio-environmental processes that mediate responses to climate change and that have been central to how humans have always responded to environmental variability. Few studies (Deressa *et al.*, 2008; Abate, 2009; Abera *et al.*, 2011; Tesso *et al.*, 2012; Tagel & Anne van der, 2013; Simane *et al.*, 2016) go beyond a one-dimensional focus on climate in assessing vulnerability in Ethiopia, viewed vulnerability as a condition embedded in both climate and non-climatic factors. Yet, much research on climate change vulnerability continues to situate vulnerability within analyses of climate, rather than in societies and political economies. In doing so, this research integrates climatic and non-climatic stimuli in examining vulnerability that may be important for mitigating climate change impacts (Salter *et al.*, 2010; Malone and Engle, 2011).

Several studies have attempted to explore adaptation interventions as part of a broader study of decision-making around climate change responses in Ethiopia (Deressa *et al.*, 2009; Tazeze *et al.*, 2012; Tesso *et al.*, 2012; Debalke, 2014; Balew *et al.*, 2014; Habtemariam *et al.*, 2016). While these studies are useful to explain broad drivers of adaptation, they are not conducted at a scale appropriate for applying in different contexts and lacks consistency in results in terms of which factors shaping responses for sustainable rural livelihood development in a changing climate condition (Burnham and Ma, 2017). On the other hand, there is a need for meta-analyses that draw upon multiple case studies to identify broad drivers of adaptation across scales and sectors (Tucker *et al.*, 2015). Thus, this micro-level study helps to compliment designing and implementing effective adaptation interventions at the macro-level for vulnerability reduction in the context of ongoing social changes.

Thus, this study was conducted to evaluate the vulnerability context of livelihoods in a changing climate condition and to examine responses for sustainable livelihood to improve effective ex-ante adaptation decision-making in different agro-ecologies of Gurage zone, Southern Ethiopia.

### 1.3. Objectives of the study

#### 1.3.1. General objectives of the study

The main objectives of the study are to evaluate the vulnerability context of livelihoods in a changing climate condition and to examine responses for sustainable livelihood to support effective ex-ante decision-making in different agro-ecologies of Gurage zone, Southern Ethiopia.

#### 1.3.2. Specific objectives of the study

- To investigate observed trends in temperature and precipitation extremes in the different agro-ecological setting of Gurage
- To assess the vulnerability of farm household's livelihood to climate variability and change in different agro-ecological zones of Gurage
- To explore farmers' perception of climatic change, related risks and adaptation practices implemented to address the adverse pressures on livelihoods
- To investigate the factors that determine choices of farm-level adaptation strategies to climate variability and change in different agro-ecologies

### 1.4. Research questions

The research attempted to address the following interlinked research questions.

1. What are the observed trends in temperature and precipitation extremes in the different agro-ecological settings of Gurage?
2. How vulnerable are farmer's livelihoods to climate variability and change? Is there any difference in vulnerability profiles among agro-ecological zones of Gurage?
3. How do farmers perceive climate variability and change, what types of risks do farmers perceive and what are the existing practices for adaptation to climate change?
4. What are the factors that determine a farmer's choices of farm-level adaptation strategies to climate variability and change?

### 1.5. Significance of the study

For the Gurage zone, until now no detailed study has been carried on historical climate trend analysis, vulnerability, and adaptation mechanisms, and as a result, little empirical evidence exists so far in the Gurage Zone of Southern Ethiopia. Moreover, it has been argued that reliance on national or regional studies does not necessarily reflect the exposure of households or communities, nor do they capture in detail how households perceive or respond to shocks and stressors and are less useful for efficient and effective local level climate change adaptation decision-making. Thus, this study considers the local level analysis to understand the role of context-specific factors, which may help to promote targeted interventions in different agro-ecological zones of the study area to sustain rural livelihood in a changing climate condition. This study is also vital in identifying the dominant climate and non-climate stressors affecting smallholder farmers livelihood vulnerability and adaptation strategies in a changing climate condition in different agro-ecologies of the Gurage zone. As a result, the findings of this study will have important relevance to those stakeholders working to improve adaptive capacity, increase resilience and reduce vulnerability to climate variability and change to sustain the livelihood of the local community. Finally, this study will have a potential contribution to the existing literature and would help students and professionals to develop a sort of integration between farmers' livelihood and climate change particularly at the regional and local levels. Further, this study helps to address the challenges in the development of consistent factors or standard metrics that can be used in future similar studies in the area to evaluate the dynamics of vulnerability of smallholder households to climate vulnerability and change.

### 1.6. Scope and Limitations of the Study

The study was conducted in three different agro-ecologies of Gurage zone that are different in terms of climate, socioeconomic, agricultural practices, and ecological settings. The study used household as the major unit of analysis. Three woredas representing each agro-ecology were selected to represent the Gurage zone. Thus, based on traditional agro-ecological zones classification one lowland, one midland and one highland woredas were selected. The study focuses on smallholder farmers' livelihood vulnerability context and their adaptive responses in a changing climate in Gurage zone. Thus, the results of the study can be applied to other areas of the

country as well as for other developing countries with similar socio-economic and agro-ecological settings.

Some of the major limitations include:

There are limitations with the choice of indicator-based vulnerability assessment design which restricts the indicators used in the study context. In an indicator-based approach, the local socio-economic and environmental conditions play a significant role in framing and designing the indicators used in assessing the vulnerability of livelihood (Etwire et al., 2013). Moreover, there is some level of subjectivity in choosing indicators. To minimize the subjectivity nature of the approach, consultation of experts, personal observations, and detailed review of livelihood vulnerability and disaster risk reduction literature were carried out. Thus, as the indicators used in LVI and socio-economic and environmental conditions vary between studies, numerical values of LVI can be used in caution in making comparisons with other similar studies. This study included only the agro-ecological comparison of household livelihood vulnerability based on LVI results in the Gurage zone.

This study used cross-sectional data and analyzed some of the household data at one point in time. This might not be enough to generate adequate information to address the dynamics of livelihood vulnerability and the implications of adaptation practices on household livelihood because there could be temporal variation in many socioeconomic and climatic variables within a given locality and the effective nature of some adaptation measures are time-bounded (Turner et al., 2003). Due to time and budget limitations, this study is limited in analyzing the current state of livelihood vulnerability and fails to capture the dynamics and how the vulnerability of livelihood is produced at the household level. Moreover, the impact of different types of adaptation strategies on farm households' livelihood and food security recommended for further research using panel data since the efficiency of adaptation strategies on household livelihood inherently affected by time.

Retrieving meteorological data, particularly, covering specific locations in Ethiopia is much challenged. Similarly, the coverage of the meteorological stations is sparse in the Gurage zone, particularly for the lowland agro-ecology. Only two woredas have lowland agro-ecologies in Gurage Administrative Zone, the eastern lowlands and western lowland located in Sodo and

Abeshige woredas, respectively. These two areas have many similar livelihood features (USAID, 2005). Mixed farming is the main livelihood pattern. The landscape is generally flat and the elevation ranges from 1000 – 1500 meters above sea level. However, in Sodo woreda, lowland kebeles are far from the center of the metrological station whereas lowland kebeles in Abeshige are not conducive for conducting the household survey because of the limited household size and sparsely settled. Thus, metrological data was used from Wolkita station which is the center of the Abeshige woreda and the household survey data was collected from Sodo woreda. Hence, the comparison of farmers’ perceptions of climate variability and change with recorded long-term observed climate data is not conducted in this research.

### 1.7. Conceptual framework of the study

The adoption of a conceptual framework for the assessment of vulnerabilities and adaptation is important for understanding shocks and stresses that affect farm household’s livelihoods and the factors that render them vulnerable to those shocks and stresses. The assessment can ultimately help to identify entry points and prioritize interventions to strengthen capacities and to build human livelihood systems’ resilience (DfID, 1999; Adger et al., 2009; Turner, 2009; Frankenberger *et al.*, 2012). Several such frameworks have already been developed by different scholars and institutions (Fraser *et al.*, 2011). The conceptual framework of the study integrates the human-environment system. Thus, the conceptual framework presented here integrates a sustainable livelihoods framework, the vulnerability approach, and elements of Complex Adaptive Systems (CAS) to address how multiple forms of shocks and stress influence smallholder farm household’s livelihood system.

#### **Sustainable Livelihood Approach (SLF)**

Livelihood systems are an important part of the human organization (Chambers & Conway 1992; DFID, 1999). Long-term development of a society can be affected by livelihood shocks including economic, environmental, socio-cultural, or health-related, and push people into cycles of poverty and unhealthy living conditions (Wilkinson & Peters, 2015). Climate change increases the pressure on already vulnerable livelihoods, and particularly those that depend on natural resources. The livelihoods approach emphasizes the importance of vulnerability context, access to productive assets, institutional structures and processes, and the livelihood strategies pursued by households.

The vulnerability context in this study represents the shocks, trends, and seasonality of climatic and non-climatic drivers faced by smallholder farmers in the different agro-ecologies of the study area. Additionally, the framework focuses on productive assets on which farmers rely to adapt to minimize their vulnerability conditions or improve their wellbeing. The success of livelihood strategies is highly influenced by access to productive assets (Babulo *et al.*, 2008). The more assets (adaptive capacity) any household has access to, the less vulnerable they will be to shocks and sensitivity, and the more secure their livelihood will be. Particularly, the SLF used in the computation of the household's livelihood vulnerability index (LVI).

### **Complex Adaptive Systems (CAS)**

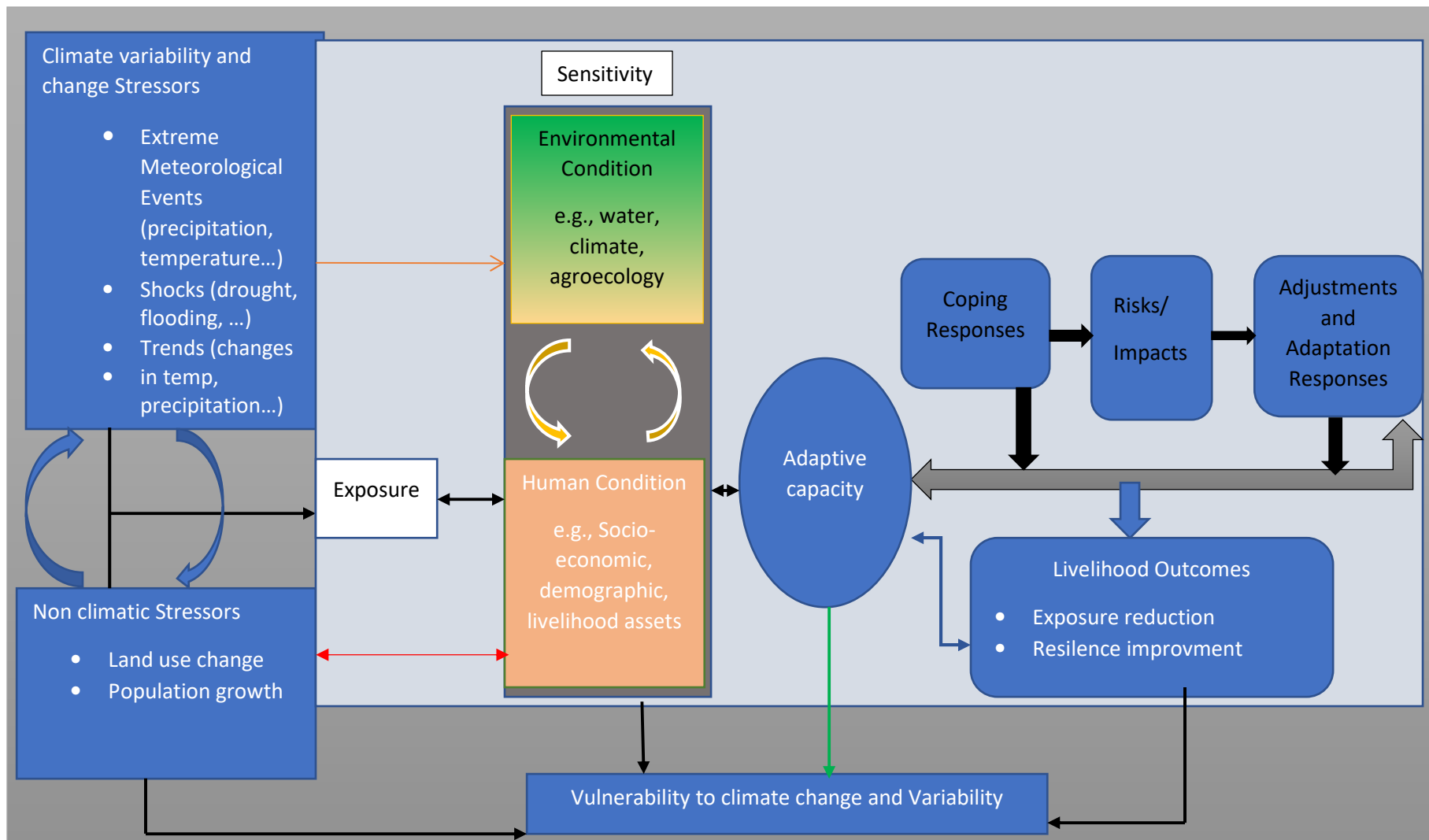
In research on climate change policies, according to Smit *et al.* (2009) system adaptation is a holistic response of the system that includes both environment and human action towards change (external stresses such as climate change). There is an increasing awareness in natural and social sciences that ecological, physical as well as socio-economic systems share the characteristics of CAS (Levin and Clark, 2010). CAS is based on “complex behavior that emerges as a result of interactions among system components (or agents) and the environment. Through interacting with and learning from its environment, a complex adaptive system modifies its behavior to adapt to changes in its environment “(Potgieter and Bishop, 2001). Coupled human-environment systems (CHES) are complex adaptive systems, in which individual agents' actions and interactions (Gunderson and Holling, 2002; Turner *et al.*, 2003; Ostrom, 2009; Cioffi-Revilla, 2016). In a human-environment system, many human agents, make decisions on actions to be taken in response to, and preparation for on-going changes in climate. Adaptability captures the capacity of a system, in this research a livelihood system, to learn, combine experience and knowledge, adjust its responses to changing external drivers and internal processes, and continue developing within the current stability domain or basin of attraction (Berkes & Ross, 2016). Thus, adaptive capacity maintains certain processes despite changing internal demands and external forces on the system (Carpenter and Brock, 2008).

### **Vulnerability framework**

The IPCC conceptual framework for vulnerability also used as part of the study framework (IPCC 2007; IPCC, 2014). Based on IPCC's vulnerability framework, vulnerability is a function of

exposure, sensitivity, and adaptive capacity. Addressing the drivers of vulnerability offers a reliable approach to reduce the current vulnerability and manage potential risk(s). Biophysical vulnerability and existing socio-economic circumstances that are detrimental to implementing action are included in the framework and needed to undertake the livelihood vulnerability index (LVI) and IPCC-LVI. The IPCC 2014 report defines sensitivity as ‘the degree to which a system or species is affected, either adversely or beneficially, by climate variability or changes’; Exposure as ‘nature and degree to which a system is exposed to significant climatic variations’ where the exposure unit is ‘an activity, group, region, or resource that is subjected to climatic stimuli’; Adaptive Capacity: is the ‘ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences’.

The overall objective of the study framework was to enable decision-makers and practitioners to have a comprehensive place-based understanding of the factors and processes influencing vulnerability and responses at the household and community levels. It helps to identify gaps in key livelihood assets, the functioning of structures and processes of key institutions, and the livelihood strategies of vulnerable households. The extent and nature of community and household responses to shocks and stresses will result either in increased vulnerability or increased adaptive capacity and resilience over time.



**Figure 1.1 Conceptual framework of the study**

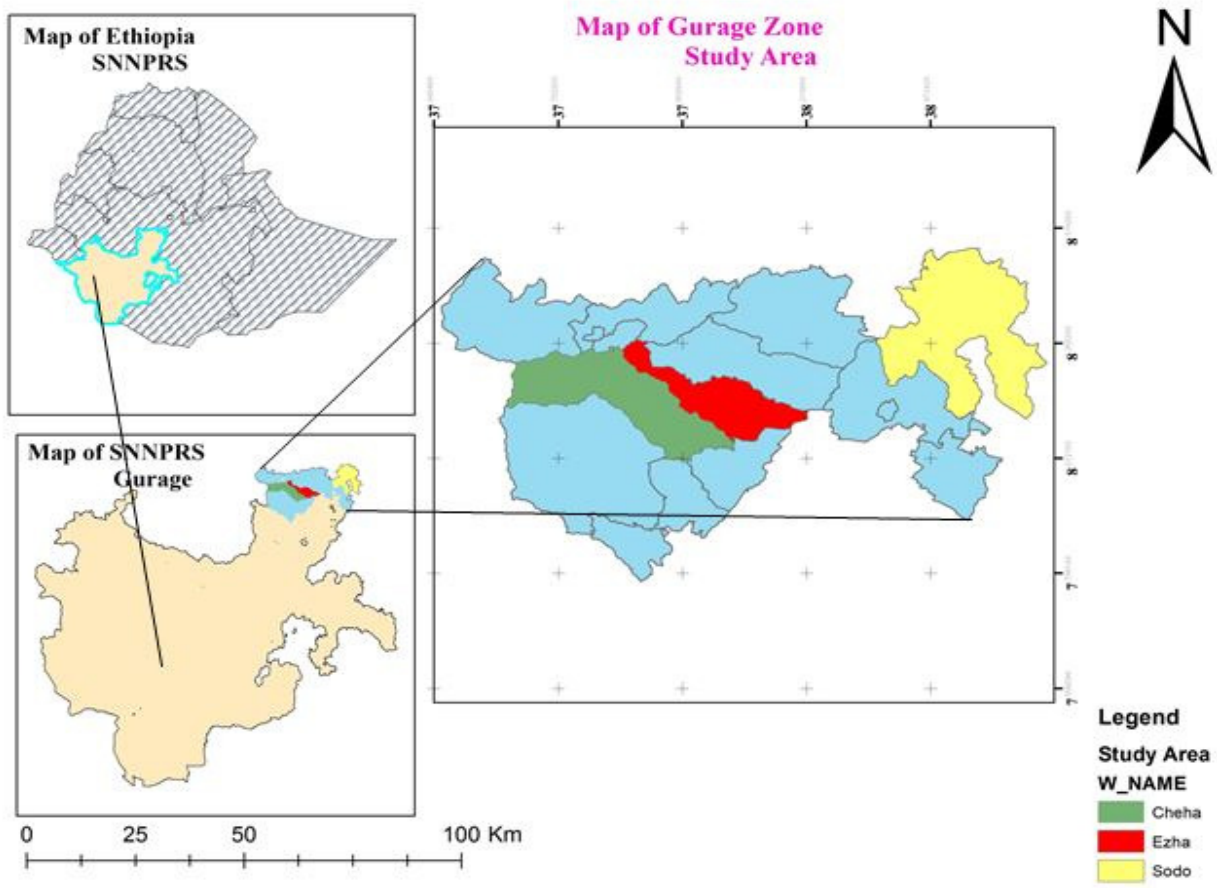
**Source:** Own construction based on Turner et al. (2003), Kaspersen et al. (2009); The National Academy of Science (2010); DFID (2011); IPCC (2007; 2014).

## 1.8. General research methodology

### 1.8.1. Description of the study area

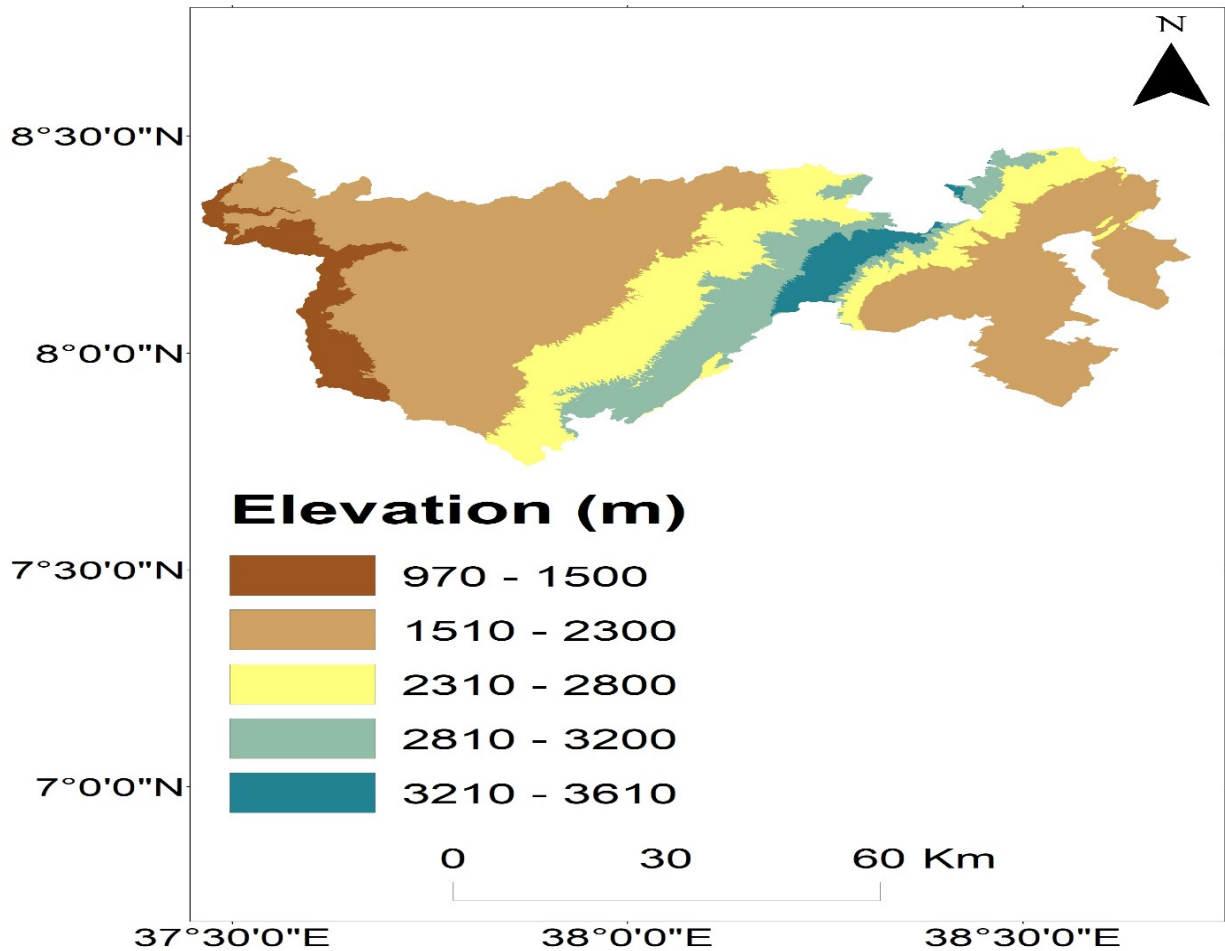
#### **Bio-physical settings**

**Location:** The study was conducted in three different agro-ecologies located in the Gurage Zone of Southern Nations, Nationalities, and People's Regional State of Ethiopia (Fig. 1.2). Welkita town is the administrative and trading center of the zone. The town is located at 155 km and 259 km South-West of Addis Ababa (capital city) and North of Hawassa (regional center), respectively. Gurage zone shares borders with Oromia National Regional State in the East, North and West, Yeme leyu woreda in the South-Western and Hadiya, and Siliti Zones in the south. Geographically, the study zone located between  $7^{\circ}76'$  and  $8^{\circ}45'$  N latitude and  $37^{\circ}46'$ - $38^{\circ}71'$  E longitudes. The Gurage zone has a land size of about 6,319 square kilometers and consists of 15 administrative woredas (CSA, 2013).



**Figure 1.2** Location Map of the Study Areas

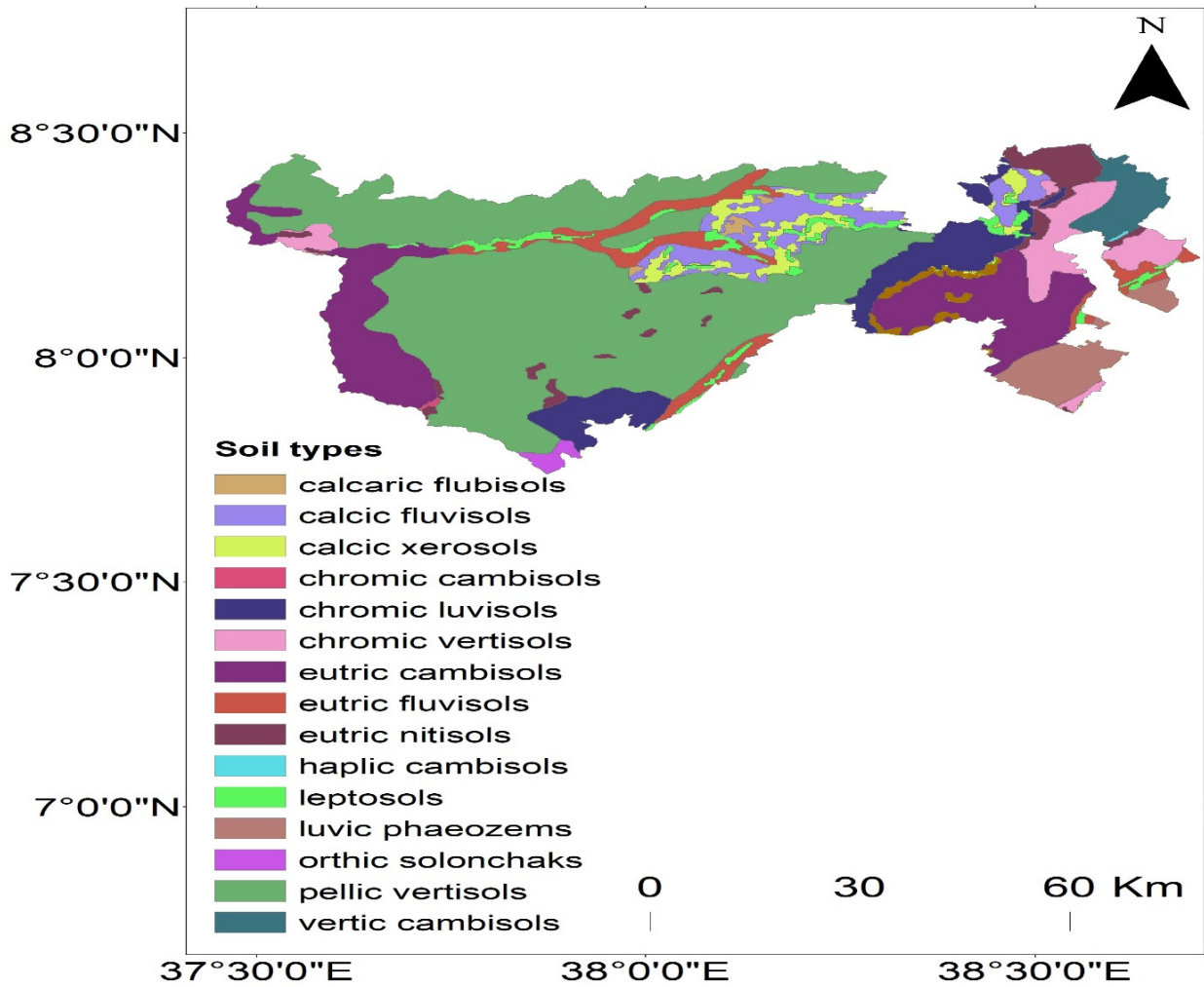
**Relief:** The elevation of the study zone ranges between 1000-3719 meters above sea level. Mount Zebidar is the highest point in Southern Nations, Nationalities, and Peoples' Region with an elevation of 3719 meters, which is part of Mount Gurage (GZFEED, 2019). Mount Gurage forms part of the divide separating the drainage basins of the Awash and Omo rivers.



**Figure 1.3** Relief map of the study Zone

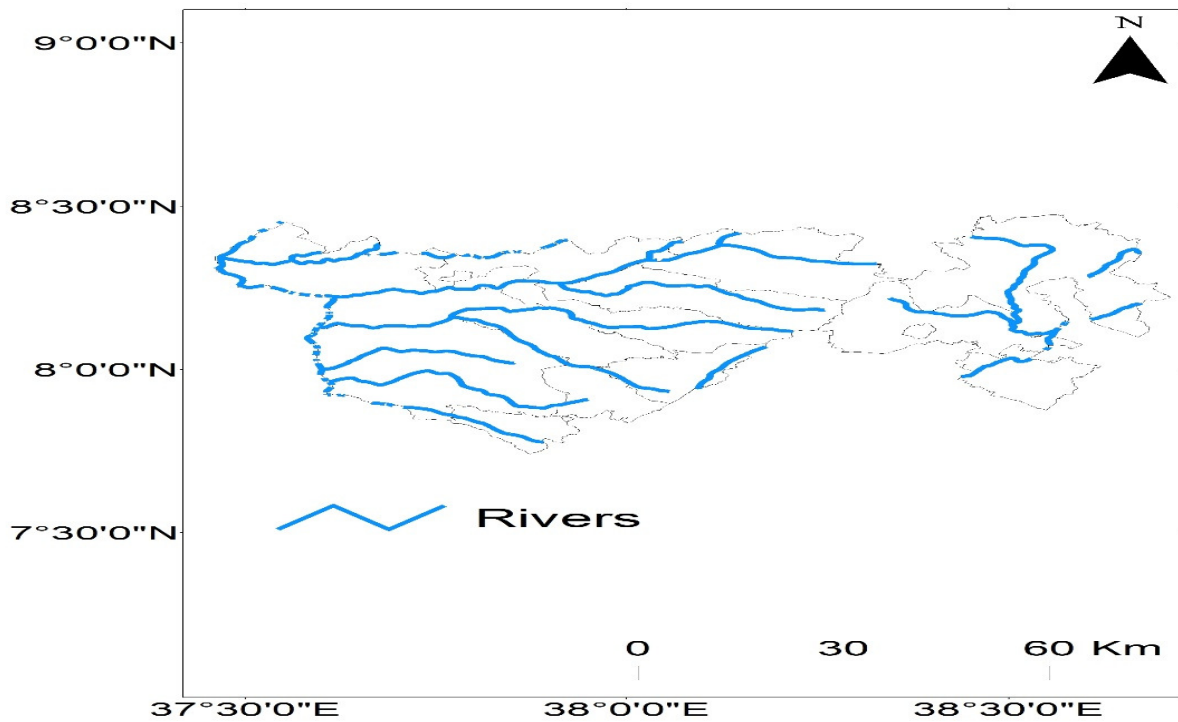
**Climate:** The annual average temperature of the zone ranges from 13°C to 30°C and the mean annual precipitation ranges from 600-1600 mm. The Gurage zone has two relatively discrete rainy seasons: the belg rains from February to April and the kirit rains from June to September. Crops are primarily dependent on the summer (June to September) locally called Kirit season, but spring season (February to April) locally called *Belg* season is also important for agricultural activity (GZFED, 2019).

**Soil Types:** Pellic vertisols, eutric cambisols, and chromic luvisols are the dominant soil types in the study zone. Concerning the distribution, vertisols, cambisols, and fluvisols are the dominant soils in the Gurage zone.



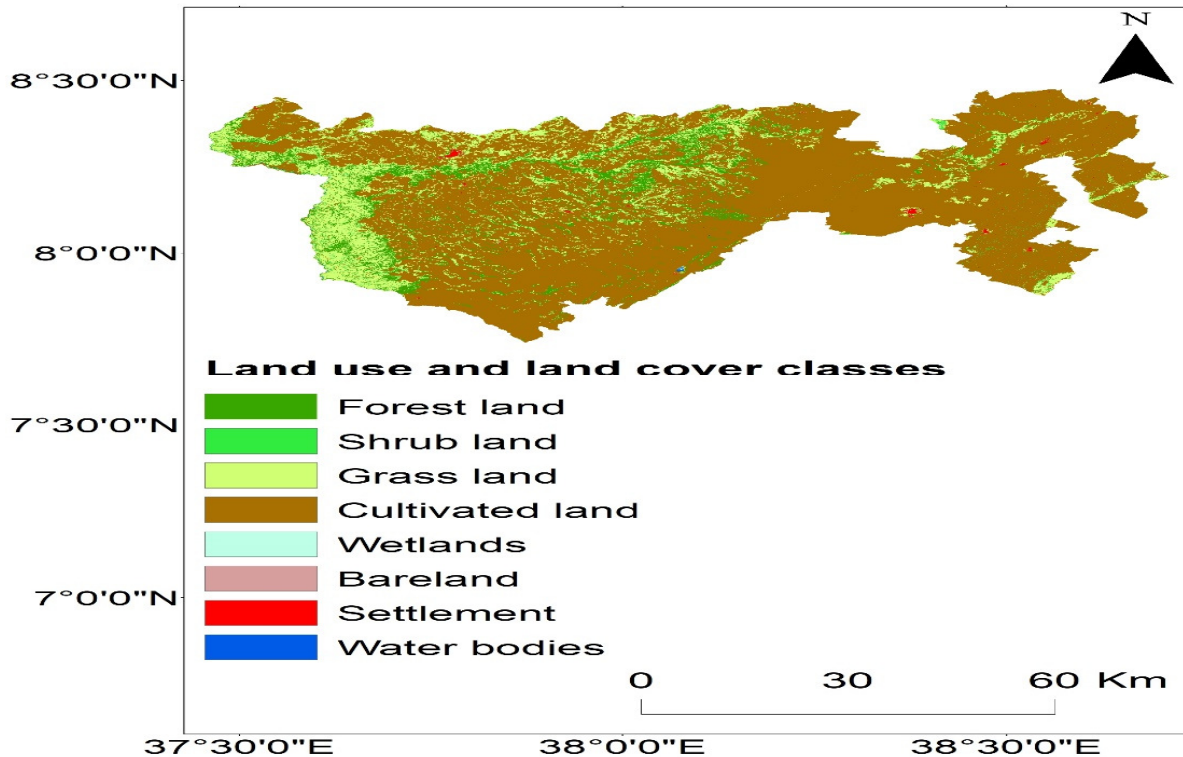
**Figure 1.4** Soil type map of the study Zone

**Drainage:** Due to the Mount Gurage, the eastern part of the zone falls in the Rift Valley drainage system, while the western part falls in the Omo Valley drainage system. The major rivers are the Meki River in the east and the Ghibe River and its tributaries (Wabe, Walga, Kulit, and Darge) in the west (USAID, 2005).



**Figure 1.5** Drainage map of the study Zone

**Land use types or classification:** Considering the land utilization, 52% of the total area is cultivated land, 13.4% is grazing land, 9.9% is a natural and man-made forest land, 7.3% unproductive land and other activities covered the remaining 17.6%.



**Figure 1.6** Land use and land cover map of the study Zone

### Agro-ecological Zones

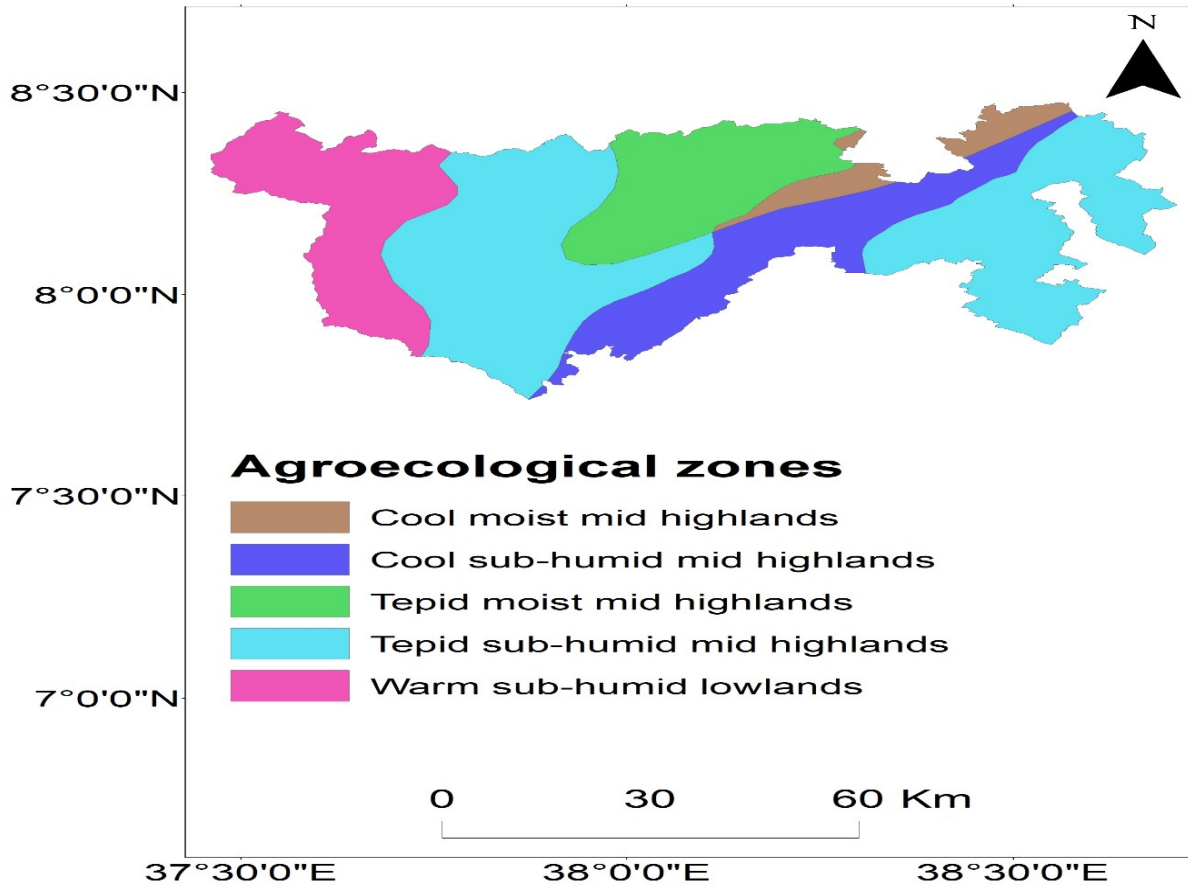
Using Hurni's (1998) classification of agro-ecological zones of Ethiopia, the zone has three agro-ecological zones including 35% Dega (highland), 62% Weyina-Dega (midland), and 3% Kolla (lowland). Detail agro-ecology classification of the study zone discussed below:

The **Gurage Lowland zone** is split into two separate geographical areas, located in the eastern and western lowlands of Gurage Administrative Zone, and includes parts of Abeshige and Sodo woredas. The landscape is generally flat and the elevation ranges from 1000 – 1500 meters above sea level, falling in the kola agro-ecological zone. Acacia trees and savannah grassland dominate the vegetation of the livelihood zone. The eastern part of the zone falls in the Rift Valley drainage system, while the western part falls in the Omo Valley drainage system. The major rivers are the Meki River in the east and the Ghibe River and its tributaries (Wabe, Walga, Kulit, and Darge) in the west. Mixed farming is the main livelihood pattern. The main food crops are maize, sorghum, haricot beans, and chickpeas. The main cash crops are teff, maize, and either wheat or pepper

depending on location. Cattle, goats, sheep, and donkeys are reared in this livelihood zone and oxen are crucial for plowing the large areas of land that households cultivate.

The **Gurage Weyina-Dega Zone** includes parts of Edja, Enemor and Ener, Cheha, Endegegn, Mehur Aklil, Kokir, and Meskan woredas. It is located on the eastern and western escarpments of the Gurage mountains. The livelihood zone has two relatively discrete rainy seasons: the belg rains from February to April and the kirit rains from June to September. The main cultivation season is dependent on the kirit rains and rainfed agriculture is the main economic activity. Belg precipitation is also important for the growth of perennial and long-cycle crops. Enset and chat are the major food and cash crops respectively.

The **Gurage Dega Zone** covers the highland parts of Edja, Enemor and Ener, Sodo, Gumer, and Mehur Aklil woredas. Rainfed agriculture is the main economic activity in the livelihood zone. Crops are primarily dependent on the kirit rains, but belg precipitation is also important for the cultivation of long cycle crops. The main food crops are enset, barley, pulses, Irish potatoes, and gomen (cabbage). Cattle, sheep, and horses are the main types of livestock kept in this highland livelihood zone. The main sources of income for households in this livelihood zone are the sale of crops, migratory urban employment, local employment (mainly casual agricultural work), and the sale of livestock (USAID, 2005).



**Figure 1.7** Agro-ecological map of the study Zone

**Socio-Economic Setting:** According to the national population projection values of 2017, it is estimated that about 1,635,311 people live in the Gurage zone. About 793,246 males and 842,065 females are live in the zone. Around 1,380,651 people live in rural areas and their livelihood is mainly based on agricultural activities and the rest 254,656 people are live in urban areas (CSA, 2013).

The crude population density of the zone is 281.3 people per square km, mostly settled in the midland and highland agro-ecologies of the study zone. Considering the dependency ratio of the zone, the working-age population (15-64 years) accounts for 52.5 % and children under age 15 and populations aged 65 and above cover the remaining 47.5 % (GZFED, 2019).

Rainfed agriculture is the main economic activity in the livelihood zone. The main food and cash crops are Maize, Teff, Sorghum Enset (*Enset ventricosum*), Chat, Barley, Pulses, Wheat, and Irish Potatoes. Cattle, goats, sheep, donkeys, and horses are the main types of livestock kept in the zone.

#### 1.8.2. Research design and justifications

There is a growing argument among scholars on the importance of discussing the research paradigms in empirical researches, though debating on the preferred paradigmatic approaches to study problems (Creswell & Plano Clark, 2017). The debate on paradigmatic approaches concerning research primarily based on our approaches to data and methods to researching the world, particularly on qualitative and quantitative approaches (Bryman, 2006; Biesta, 2010).

Each paradigm bases on distinctive foundations and specific approaches to guide research works. In quantitative approaches, positivism is used to guide the research work i.e. based on objective reality independent of human perception (Bryman, 2004). But, the ontological position of quantitative research i.e. bases only on objective facts and ignoring human (i.e., subjective) nature of reality, is highly criticized. Whereas, in qualitative research, the paradigm is based on interpretivism and constructivism i.e. subjective nature of reality. Epistemological and ontologically, the approach views reality as socially constructed and interpreted individually, respectively (Walliman, 2017). On the contrary, this approach ignores the objective nature of realities.

The mixed-method from both quantitative and qualitative helps to address the philosophical arguments of the above paradigms on social realities. In a mixed-method, research can understand a complex phenomenon (Morse & Niehaus, 2009). Pragmatism or compatibility theses is the underpinning philosophy for mixed-method. Therefore, pragmatism perspective is used to ground philosophically this research. Similarly, different scholars discussed the philosophical role of pragmatism perspective in mixed methods (Brannen, 2009; Hesse-Biber & Johnson, 2013).

According to Morgan (2007), pragmatism is characterized by an emphasis on communication and shared meaning-making (i.e. subjectivity in reflections and objectivity in data collection and analysis), uses abduction (i.e. between induction and deduction), transferability (i.e. the

implications of research), complementarity (i.e. combined qualitative and quantitative approaches) to create practical solutions to social problems.

The added value of mixed methods research from generating data to analysis and reporting – and reflections thereon have led to more robust and of greater quality (Stern *et al.*, 2012). The method can be viewed as an approach which draws upon the strengths and perspectives of the qualitative and quantitative method, recognizing the existence and importance of the physical, natural world as well as the importance of reality and influence of human experience at some stage of the research process (Johnson and Onuegbuzie, 2004; Kroll and Neri, 2009).

Given the nature of the study, a mixed-method approach was used as a methodological framework for the research. The method is particularly important to triangulate and complement data validation (Yauch & Steudel, 2003), creating a synergistic effect (Bernardi *et al.*, 2007). Moreover, it is grounded in complexity frameworks (Befani *et al.*, 2014).

In this research, a qualitative method was used to get detailed information about farmers' perceptions and their experiences, whereas biophysical contexts particularly, meteorological variables, vulnerability indices, and determinants were approached through the quantitative method.

### 1.8.3. Sampling techniques and procedures

In the first stage, the administrative zone (i.e. Gurage Zone) was clustered into three agro-ecologies namely Highland/ Dega, Midland/Woina-Dega, and Lowland/Kola to analyze the extent of households' vulnerability to climate change and their response. Then, one woreda from each agro-ecologies were selected purposively representing the dominant agro-ecology. In the third stage, since there are many Peasant Associations (PAs) within different agro-ecologies of the selected woredas, PAs were clustered by agro-ecology, and then random sampling was used to select representative PAs from each selected woreda based on their agro-ecology characteristics. In the last stage, representative households for the study were selected by employing a simple random sampling technique.

Then independent sample size was determined from each PAs using the probability proportional to size (PPS) method to ensure equal representation of households in expectation of different household sizes in each KAs. based on Israel (1992).

The sampling frame for the study was a non-overlapping, exhaustive, and clear list of sampled PAs with the corresponding household size which was collected from the study Woredas and was used during data collection. Using the formula indicated below, the sample household size was determined and proportionally distributed for each selected PAs of each Woreda.

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

Where:

n = designates the sample size the research uses,

N = designates total number of households in all kebeles,

e = designates maximum variability or margin of error 5 % (0.05), and

1 = designates the probability of the event occurring.

Based on the above formula a total sample size of 357 households was drawn and proportionally distributed to the six-kebele administrations using the following formula.

$$ni = \frac{n \times Ni}{\sum Ni}$$

Where:

n = determined sample size the research uses,

ni = households of the ith kebele, and Ni = total households of the ith kebele (Table 1)

**Table 1.1 Sample households in each Agro-ecological Zone in Gurage Zone**

Woredas	Kebeles	Agro-ecology	Total Population	Total household size	Sampled HHs	Percentage
Sodo	Dugeda-Gerio	Low land	2531	385	41	11.5
	Dugeda-Goro		2976	316	34	9.5

Cheha	Yefek Terekwedero	Mid land	6440	670	72	20.1
	Girardiber		3550	720	77	21.6
Ezha	Kokera	High land	3545	618	66	18.5
	Ketane		4697	624	67	18.8
Total					357	100

Accordingly, 75 (21 %) households from lowland agro-ecology, 149 (41.7%) households from midland agro-ecology, and 133 households (37.3 %) from highland agro-ecology were randomly selected. In supplementary, participants for key informant interviews and focus group discussions were selected purposively.

#### 1.8.4. Data sources and methods of data collection

Vital qualitative and quantitative data about the study were gathered from both primary and secondary data sources. To collect data, different tools and techniques were employed to promote the participation of everyone involved and to enhance understanding of important issues with respondents. In view of addressing the research objectives, a specific tool was used to respond to a series of guiding questions, and, on the opposite, a specific question was addressed by different tools to satisfy the data requirements of the research: this is particularly useful to triangulate information. Therefore, mixed methods of data collection were used for this study, which includes:

#### **Household Survey**

The primary data were collected from selected households from March to October 2018 in the Gurage zone. The survey was used to collect contextual and comprehensive information on the household's vulnerability situations to climate change, perception of climate change, response, and their determinants. Specifically, data on households' demographic characteristics, resource endowment, income sources, institutional arrangements, major climate-induced shocks, stressors on livelihood sources, farmers' perception of climate change, effects of climate change and coping and adaptive strategies pursued by farmers to adapt to climate variability and change were collected using semi-structured questionnaires. Moreover, data on climatic context – including climate extremes, variability, and change were collected.

The interview schedule was translated into the Amharic language to facilitate and ease communication among enumerators, sampled households, and the researcher. Also, the questioner was pre-tested on relevant respondents before conducting the formal survey to check the quality of the survey. The pre-tested result helped to modify some components of the interview schedule.

Data collection using the questionnaire was conducted by trained enumerators. The enumerators were recruited based on their competence to collect data. After the selection of eligible enumerators, theoretical and practical training was given to the enumerators on how to conduct the data collection. During data collection, there was a close follow up and detail discussion with the enumerators were held to solve problems encountered during the formal survey.

### **Key-informant Interview (KIIs)**

To obtain a greater depth of information on the objectives of the study, interviews with selected key informants were undertaken. Since the interview was conducted within specific time limits, checklists were prepared with some of the predetermined questions. Respondents were chosen based on their ability to provide specialized knowledge or insight into, experience, and knowledge of their community and consent to participate.

The key informants were elders, marginalized groups, Woreda level officials (from Agriculture and Rural Development Office and Early Warning and Disaster Risk Management Office), and development agents. Information on observed changes, vulnerability, effects, perceptions, and response to the changing climate conditions and factors for effective adaptation were obtained using key informant interviews. Thus, twelve Key Informant Interviews for each agro-ecologies were carried out to triangulate, supplement, and enrich the data for the study.

### **Focus Group Discussion (FGD)**

Focus Group Discussions foster replies of respondents from other data collection methods to stimulate richer responses and allow the emergence of new valuable thoughts. Moreover, it helps to complement and triangulating data from other methods. In the context of this study, FGDs was conducted in an interactive way to collect in-depth information on experiences, perceptions, and perspectives on climate changes, potential risks, and trends, and response to climate change from a group of six to eight persons for each agro-ecologies was carried out guided by a facilitator.

Two FGD for each agro-ecology was conducted. The first FGD was composed of male participants and the second FGD was arranged for women. This is based on the assumption that rural women and men have different tasks and responsibilities and they have different needs, priorities, and concerns for climate change impacts and adaptation options.

### **Field Observation**

This approach was used to directly observe the present shreds of evidence of the study areas. It was mostly used as a basis for late discussion with the key informants and focus group discussion and to analyze the different agro-ecologies in terms of variation and similarity. Through direct observation, information on topography, water sources, biophysical characteristics, distribution of settlements, infrastructure, environmental changes, land use, farmers' land management practices, etc. were obtained. Evidence was recorded in the form of photos and videos.

### **Secondary data**

Secondary data is particularly essential for information related to climate change, in terms of past and current scientific observations, trends, and changes. The method provides solid background information on the general context of the research area, including information related to shocks and stresses, climate extremes events, variability and change, the policy and institutional landscape, livelihoods and adaptation activities to a changing climate.

Sources of information include census data, assessments, and evaluation reports maintained at zonal and district offices. Related Ethiopian policies and strategies on the theme of the study were reviewed. Also, pertinent studies and literature in the study area that can provide valuable information were used.

Furthermore, meteorological data (observed daily precipitation, maximum and minimum temperature) from 1986 to 2016 were collected from the National Meteorological Agency of Ethiopia to analyze temperature and precipitation trends and seasonal variations of the study area.

### **Software Packages Used**

The collected household survey data was coded and cleaned by using EpiData software. Different techniques of data analysis were used to address the study objectives, including descriptive

statistics, One-way ANOVA test, Post-Hoc estimate, multinomial logit model, Mann-Kendal test (MK), and Sen's Slope Estimation (SSE). The paper used different software packages such as Statistical Package for Social Science (SPSS) (24.0.), STATA software (14.0), Addinsoft's XLSTAT (16.0), R software, RClimDex 1.1, and Microsoft Excel 2016. Besides, Arc-GIS (10.3.1) was used to map the different futures of the study areas.

#### 1.8.5. Organization of the dissertation

This dissertation consists of six chapters. The first chapter provides insights into the background of the study, problem statement, research objectives, significance, the conceptual framework of the study, and the study approach. Chapter two examines agro-ecological variation in trends in extreme climate events. Farmers' livelihood vulnerability to a changing climate condition in the three agro-ecological settings is assessed in chapter three. The fourth chapter investigates farmers' perceptions about climatic change, climate-related, and non-climate stress faced by farmers and ongoing adaptation measures. Further, adaptation responses to climate variability and change were also assessed in different agro-ecological settings. Chapter five examines the factors that determine the decision to adopt adaptation measures at the farm household level. The last chapter synthesizes the main findings of the research and provides potential policy implications. Further research areas also listed in this chapter.

## 2. Analysis of observed trends in daily temperature and precipitation extremes in different agro-ecologies of Gurage Zone, Southern Ethiopia

### Abstract

Ethiopia is particularly vulnerable to the effects of climate-related extreme events. Thus, examining extreme daily precipitation and temperature in the context of climate change is a critical factor in instigating climate change adaptation at the local spatial scales. Spatial changes of climate indices for extreme precipitation and temperatures were carried out for the period 1986–2016 in different agro-ecologies of the Gurage zone, Southern Ethiopia. The study used the Mann–Kendall (MK) test and Sen's slope estimator to estimate the trend and magnitude of changes in precipitation and temperature. The observation indicates that there had been a consistent warming trend in the study agro-ecologies. A statistically significant increase in the numbers of warm days and nights and a statistically significant reduction in the numbers of cold days and nights were observed in most of the agro-ecologies. Also, a positive trend of the intensity of temperature extremes indices (TX<sub>x</sub>, TX<sub>n</sub>, TN<sub>x</sub>, and TN<sub>n</sub>) with an inconsistent magnitude of change observed. In contrast, results showed inconsistent changes in precipitation extremes, while the trends are insignificant. The duration of extreme trend showed inconsistency, however, a drier condition is observed in lowland agro-ecology. Similarly, lowland agro-ecology had exhibited a decreasing RX1day (.35 mm/year) and RX5day (.59 mm/year) trends, while an increasing trend both in the RX1day (.25 mm/year) and RX5day (.1 mm/year) was found in midland agro-ecology. Thus, an increasing trend of temperature extremes observed in most of the climatic stations. Therefore, based on the findings of this study, appropriate climate adaptation efforts are needed at the local scale.

**Keywords:** climate extremes; climate change; precipitation; temperature; trend, Gurage

## 2.1. Introduction

Climatic extreme events may have significant impacts on human society and the environment (IPCC, 2012). Agricultural activities, particularly in developing countries, are highly affected by climatic extreme events such as drought, flood, and hail. This affects the food security and livelihood sources of small-scale farmers since the crop production system is greatly influenced by climate conditions. Precipitation and temperatures are useful indicators of climate variability and change (Braganza *et al.*, 2004). Detection of the past trend, change, and variability in the time series of climatic variables is very important for understanding the potential impact of future changes and to improve climate risk management capabilities (Sahoo and Smith, 2009; Some'e *et al.*, 2012; Huang *et al.*, 2013).

Consequences of climate extreme events, particularly, drought and flood are already being felt which affects livelihoods and ecosystems in Ethiopia (You and Ringler, 2010; FAO, 2016). The mean annual temperature has increased by 1.3°C between 1960 and 2006. Likewise, there is a projected increase in mean annual temperature by 1.1 °C to 3.1 °C by the 2060s, and 1.5 °C to 5.1 °C by the 2090s. Moreover, it is projected that precipitation in Ethiopia is expected to decline from a mean annual value of 2.04 mm/day (1961–1990) to 1.97 mm/day (2070–2099) (NMA, 2007). Several studies have been conducted to investigate climate trend analysis and trends of extreme climate events in different parts of the country. Regarding climate trend analysis, though the magnitude and trends of change reported varying with temporal and spatial scales, time series analysis of mean maximum and minimum temperatures have shown positive trends accompanied by an inconsistent trend in precipitation in many parts of the country. For example, a study by Esayas *et al.*, (2019) in different agro-ecologies of Wolaita Zone reported a positive trend in the annual maximum and minimum temperature and a decreasing trend on the annual precipitation in the lowland and highland agro-ecologies. Similarly, Seleshi and Zanke (2004) and Cheung *et al.* (2008) did not find a trend in annual precipitation in the central highlands of Ethiopia. Precipitation exhibited statistically decreasing trends and temperature showed statistically significant increasing trends in the Upper Omo-Ghibe River Basin, Ethiopia (Jaweso *et al.*, 2019). Similarly, Kahsay *et al.*, (2019) found a decreased annual precipitation and an increased mean annual temperature in the Semiarid Highlands of Eastern Tigray.

Similarly, different studies have shown changes in climatic extremes. A study by Mekasha et al., (2014) concluded that trends of temperature and precipitation extremes vary considerably among stations located within a given eco-environment. Similarly, Worku et al., (2018) reported the presence of extreme precipitation and extreme temperature in the Jemma Sub-Basin. The study by Seleshi and Camberlin (2006) identified statistically significant declining trends for the wet day intensity and maximum consecutive five-day rain over eastern, southern, and southwestern parts of Ethiopia.

Although the abovementioned studies have documented the spatiotemporal trends and extremes of precipitation and temperature in different parts of Ethiopia, there is still limited work has been done on trends of extreme events for Southern Ethiopia, which may not fully explain the situation at the local level. For the Gurage zone, the analysis of extreme trend and variability in precipitation and temperature has not been reported in much detail in the literature. In line with this fact, using global or regional scale observations of historical climate is less useful for efficient and effective local level decision-making (Raucher, 2011, Sharma et al., 2014; Ahmad et al. 2018). Thus, trend analysis on low-scale time-series climate data is more preferential than global or regional scale observations for local-level climate change adaptation planning. Likewise, Bewket and Conway (2007) and McSweeney *et al.* (2010) reported that the existing information available so far on climate extremes in Ethiopia is limited in scope, fragmented in coverage, and does not give a full picture of the diverse topography, relief features, and eco-environments.

Thus, this study considers the local level analysis of extreme climate events along with trends, which may help to the planning of context-based adaptation strategies (e.g., Kampata et al., 2008; Some'e et al., 2012; Huang et al., 2013) to react timely to the associated shocks. Therefore, this paper aims to study trends in temperature and precipitation extremes using the Mann–Kendall (MK) test and Sen's slope estimator in Gurage zone, Southern Ethiopia.

## 2.2. Methodology of the study

### 2.2.1. Data and data quality control

Observed daily precipitation, maximum and minimum temperature data from 1986 to 2016 were collected from the National Meteorological Agency of Ethiopia for nine stations located in different parts of the study area. Data quality control tests were conducted to exclude and minimize unreliable and missed climate data for all stations. Considering spatial distribution, the proportion of missing data, and length of record period three climate stations representing each agro-ecology setting were selected for the study. The stations include Wolkita, Endibir, and Agena. RClimDex 1.1 (Zhang and Yang 2004) was used to check the quality of the data for each station. Errors like TMIN greater than TMAX, duplicated years, negative precipitation values, and outliers i.e values above or below the mean plus or minus four times the standard deviation (Albert *et al.*, 2009) were compared and replaced by using information from the day before and after the event and also by reference to nearby stations.

**Table 2.1 Characteristics of selected climate stations**

No.	Station Name	Longitude	Latitude	Elevation (m)	Agro-ecology	Period
1	Wolkita	37.75	8.27	1550	Lowland	1986-2016
2	Endibir	37.93	8.12	2082	Midland	1986-2016
3	Agena	38.02	8.12	2310	Highland	1986-2016

### 2.2.2. Statistical methods for testing and estimating trends and Extremes

Trend testing is helpful to determine if the values of a random variable generally increase (or decrease) over some time in statistical terms (Helsel & Hirsch, 1992). Mean annual trends of the precipitation, TMAX, and TMIN were estimated using the non-parametric Mann–Kendall (MK) test (Kendall 1975; Mann 1945). Mann Kendall test is a statistical test widely used for the analysis of the trend in climatologic and hydrologic time series (IPCC, 2012). Comparing to other parametric tests, the MK test does not require the data to be normally distributed. And it has an advantage over other parametric tests since the test has low sensitivity to outliers and skewed distributions.

The Mann-Kendall S Statistic is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sign}(X_j - X_i) \quad (1)$$

$$\text{sign}(X_j - X_i) = \begin{cases} 1 & \text{if } X_j - X_i > 0 \\ 0 & \text{if } X_j - X_i = 0 \\ -1 & \text{if } X_j - X_i < 0 \end{cases} \quad (2)$$

where  $X_j$  and  $X_i$  are the annual maximum daily values in years  $j$  and  $i$ ,  $j > i$ , respectively.

The magnitude of the detected trends was calculated using the Theil-Sen's slope estimator test. (Sen 1968; Theil 1950). The Theil Sen's slope estimator is a robust non-parametric estimator that uses the median slope to assess the trend over time (Sen 1968; Theil 1950).

The Theil Sen's slope estimator is computed as follows:

$$b_{Sen} = \text{median} \left( \frac{y_j - y_i}{x_j - x_i} \right)$$

Where  $i < j$  and  $j = 1, 2, \dots, n-1$  and  $j = 2, 3, \dots, n$ .

Addinsoft's XLSTAT 2018 and RCLimDex package were used for performing the trend analysis (R Development Core Team, 2012).

The temperature and precipitation extreme indices were computed for the period 1986–2016. Definitions of indices were taken from the Expert Team on Climate Change Detection and Indices (ETCCDI) (<http://cccma.seos.uvic.ca/ETCCDI>). Based on ETCCDI, 9 precipitations, and 12 temperature extreme indices were selected for this study. Table 2.2 presents the selected indices with their description and units. The RCLimDex tool (Zhang and Yang 2004) was used to measure the indices for each agro-ecology representing stations.

**Table 2.2** Selected ETCCDI precipitation and temperature extreme indices for the study Stations

Index	Index name	Definition of the Index	Units
	<b>Temperature</b>		
	<b>Intensity</b>		
TX <sub>x</sub>	Max Tmax	Monthly maximum value of daily maximum temp	°C
TN <sub>x</sub>	Max Tmin	Monthly maximum value of daily minimum temp	°C
TX <sub>n</sub>	Min Tmax	Monthly minimum value of daily maximum temp	°C
TN <sub>n</sub>	Min Tmin	Monthly minimum value of daily minimum temp	°C

DTR	Diurnal temperature range	Monthly mean difference between TX and TN	°C
	Duration		
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
	<b>Frequency</b>		
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
	<b>Precipitation</b>		
	<b>Intensity</b>		
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	Mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	Mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	Mm/day
R95p	Very wet days	Annual total PRCP when RR>95 <sup>th</sup> percentile	Mm
R99p	Extremely wet days	Annual total PRCP when RR>99 <sup>th</sup> percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm
	<b>Duration</b>		
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
	<b>Frequency</b>		
R10mm	Number of heavy precipitation days	Annual count of days when PRCP>=10mm	Days
R20mm	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days

## 2.3. Results and Discussion

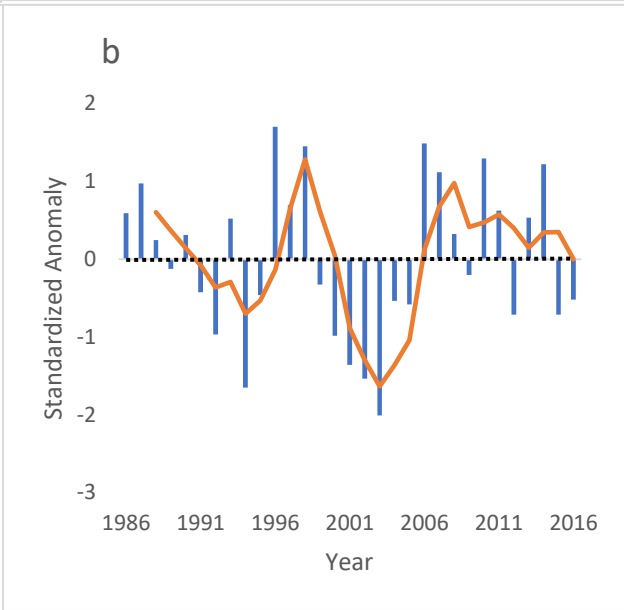
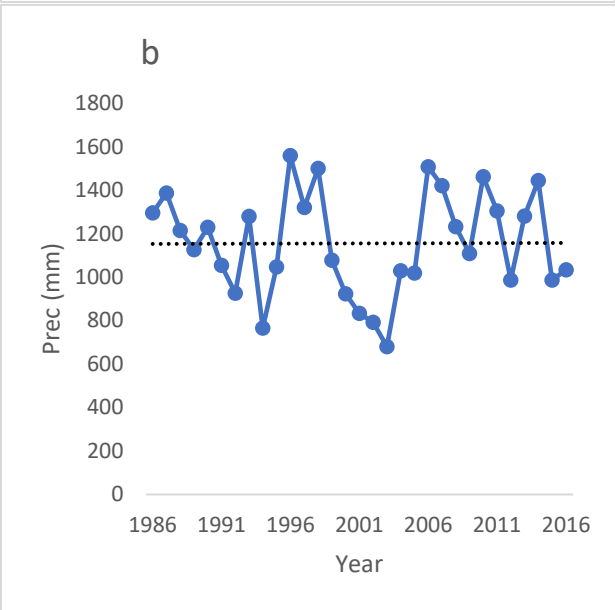
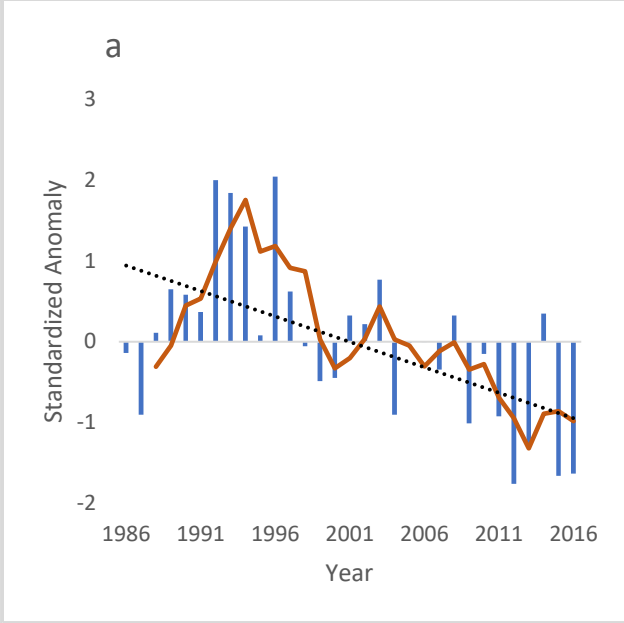
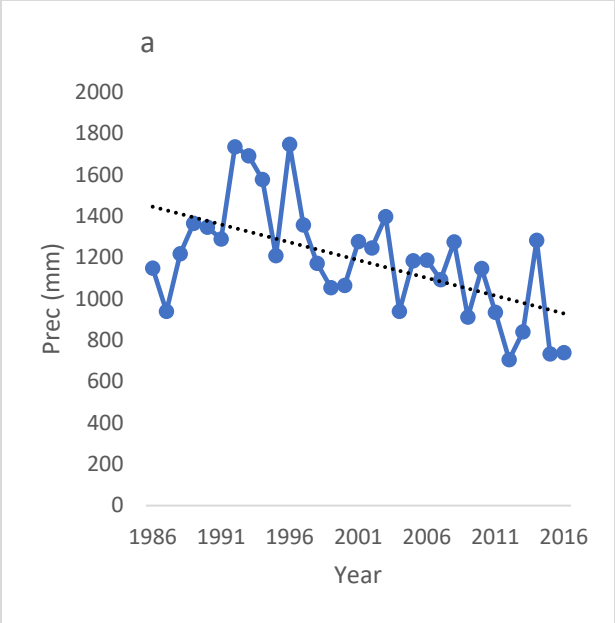
### 2.3.1. Trends in annual precipitation

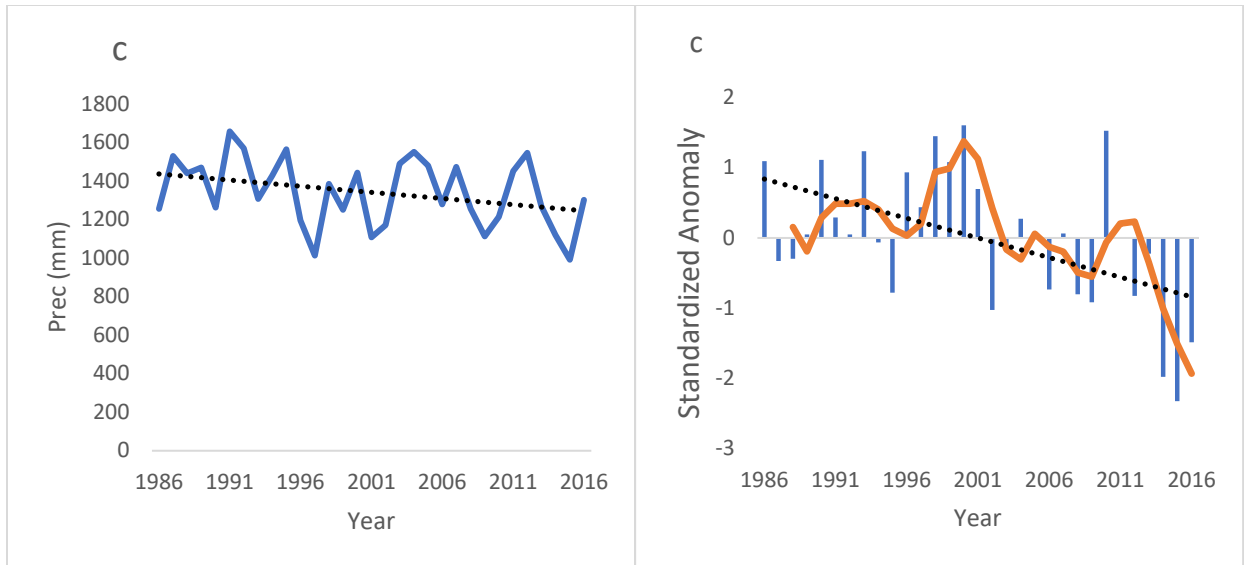
The analysis of annual precipitation in different agro-ecologies revealed that only the midland agro-ecology exhibited an upward trend, whereas both lowland and highland agro-ecologies experienced a decreasing trend for the period 1986–2016. Likewise, an increasing trend in annual precipitation was reported in midland agro-ecology (Mengistu et al. 2013; Bewket, 2014; Esayas et al., 2018).

**Table 2.3 Trend of annual precipitation, annual maximum and minimum temperature**

Index	Lowland		Midland		Highland	
	MK test	Sen slope	MK test	Sen slope	MK test	Sen slope
<b>Temperature</b>						
TMAX	0.261	0.115	0.289	0.16	0.051*	0.042*
TMIN	0.174*	0.04*	0.172*	0.038*	0.155	0.064
<b>Precipitation</b>						
PRCPTOT	-0.026*	-17.252*	0.023	0.134	-0.052*	-20.636*

\*Trends significant at the 5% level



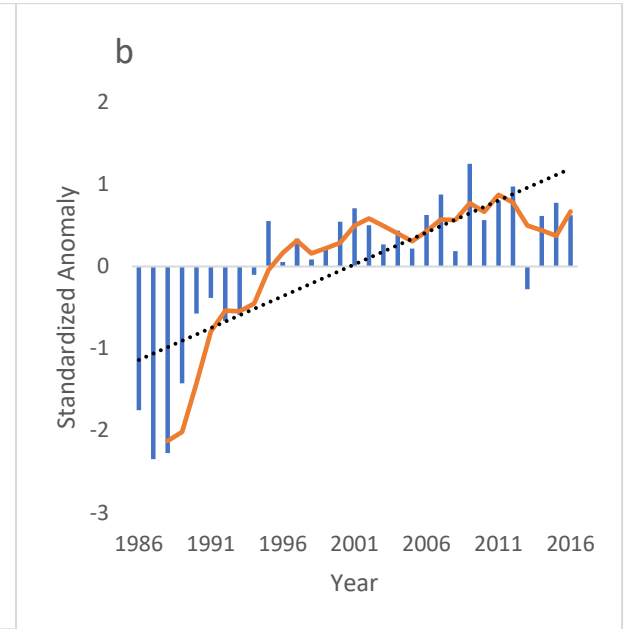
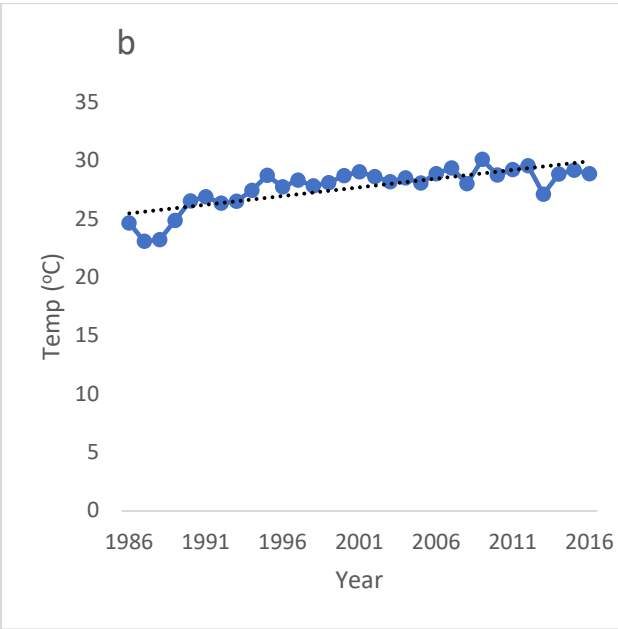
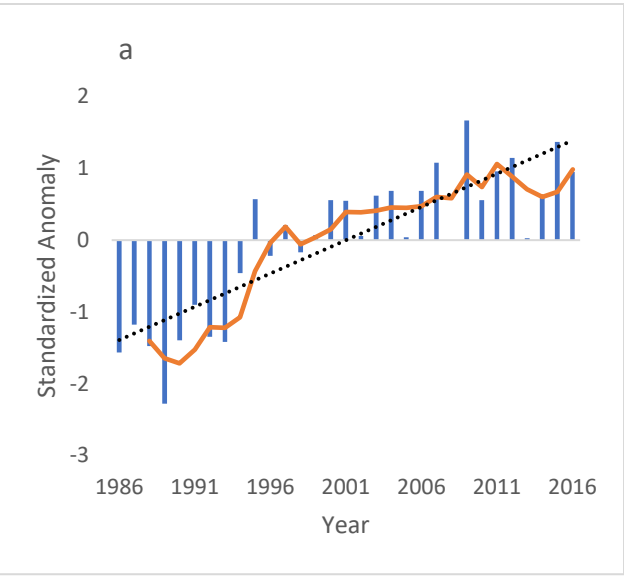
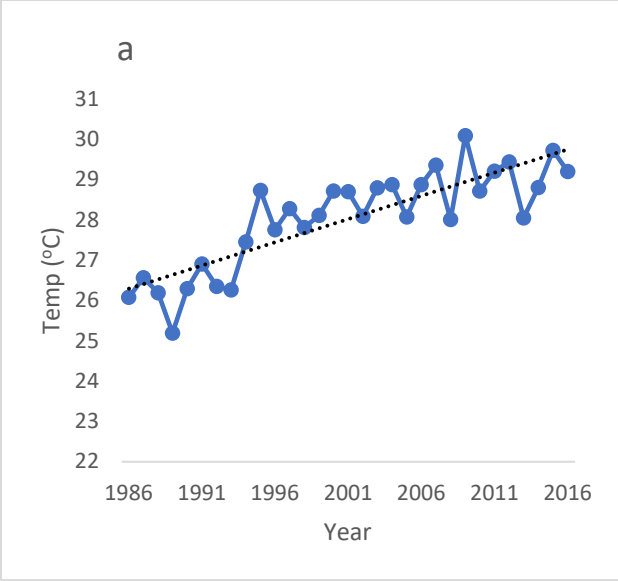


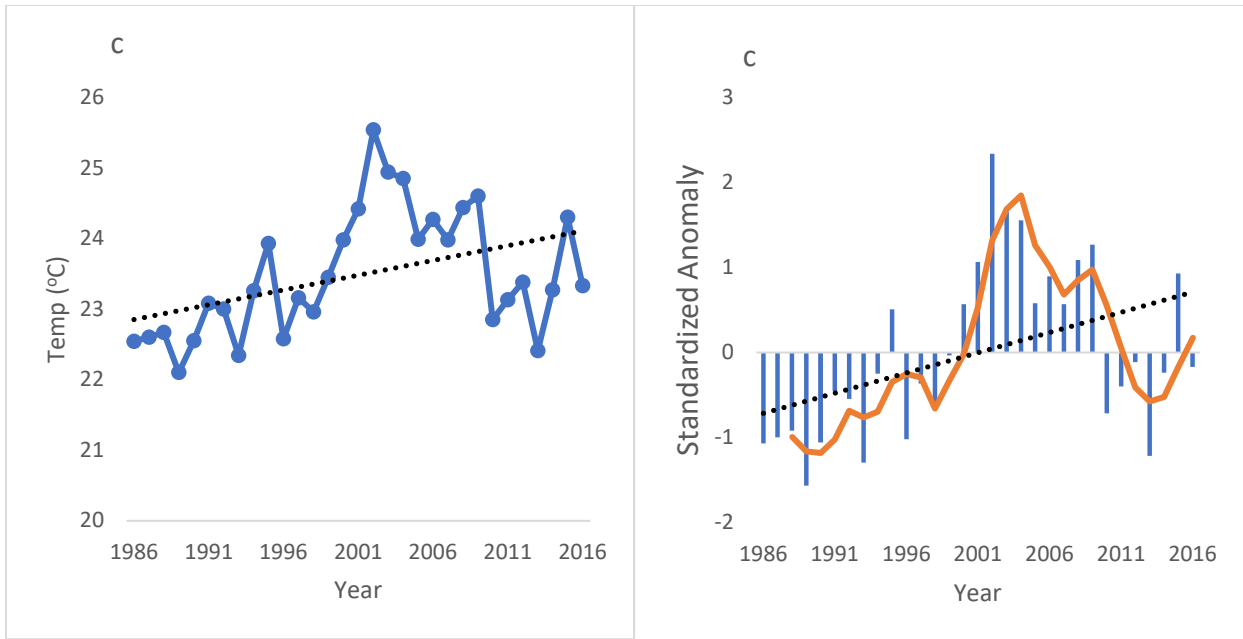
**Figure 2.1.** Spatial variations of precipitation trends at the annual scales in different agro-ecologies for the period 1986–2016.

a, b and c indicate lowland, midland, and highland, respectively. Trends (left) and Standardized Anomalies (right).

### 2.3.2. Trend in annual maximum and minimum temperature

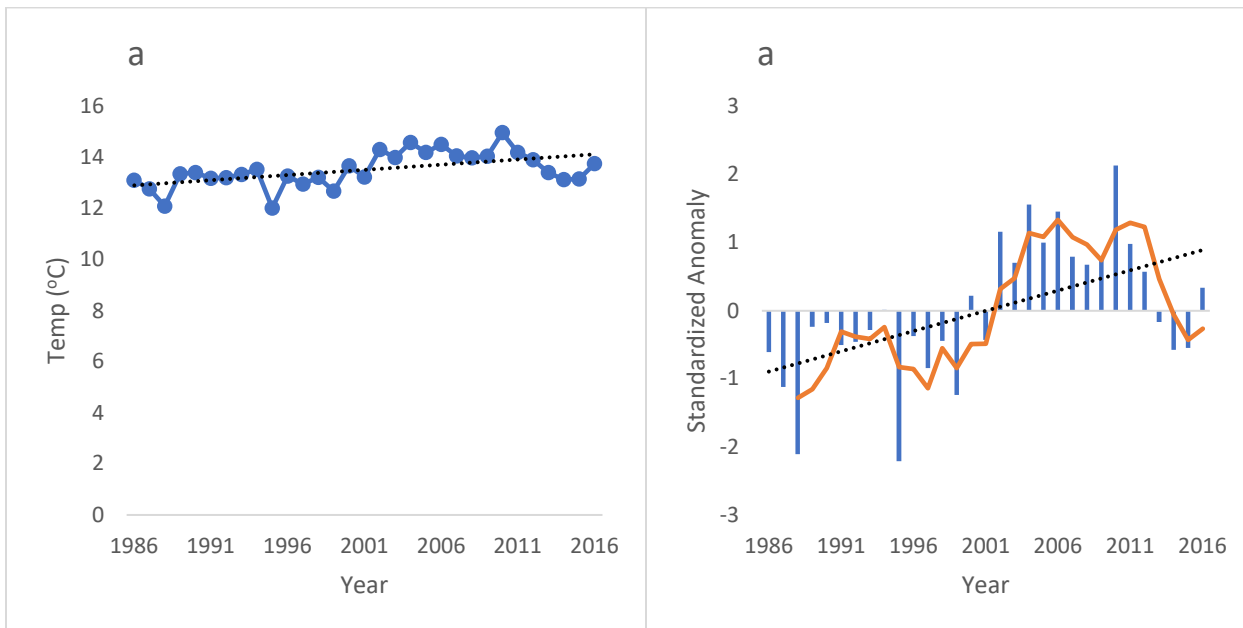
An increasing trend of both Tmax and Tmin was observed in all the agro-ecologies. Both lowland and midland agro-ecologies showed a significant increase in Tmin, whereas only the highland agro-ecology exhibited a statistically significant increasing trend in Tmax. Similar findings were reported an increasing trend in mean Tmax and Tmin in a different scale and agro-ecologies (NMA, 2007; Mengistu et al., 2013; Gedefaw et al., 2018; Worku et al., 2018). This increasing Tmax and Tmin finding in the different agro-ecologies may associate with the changing climate condition.

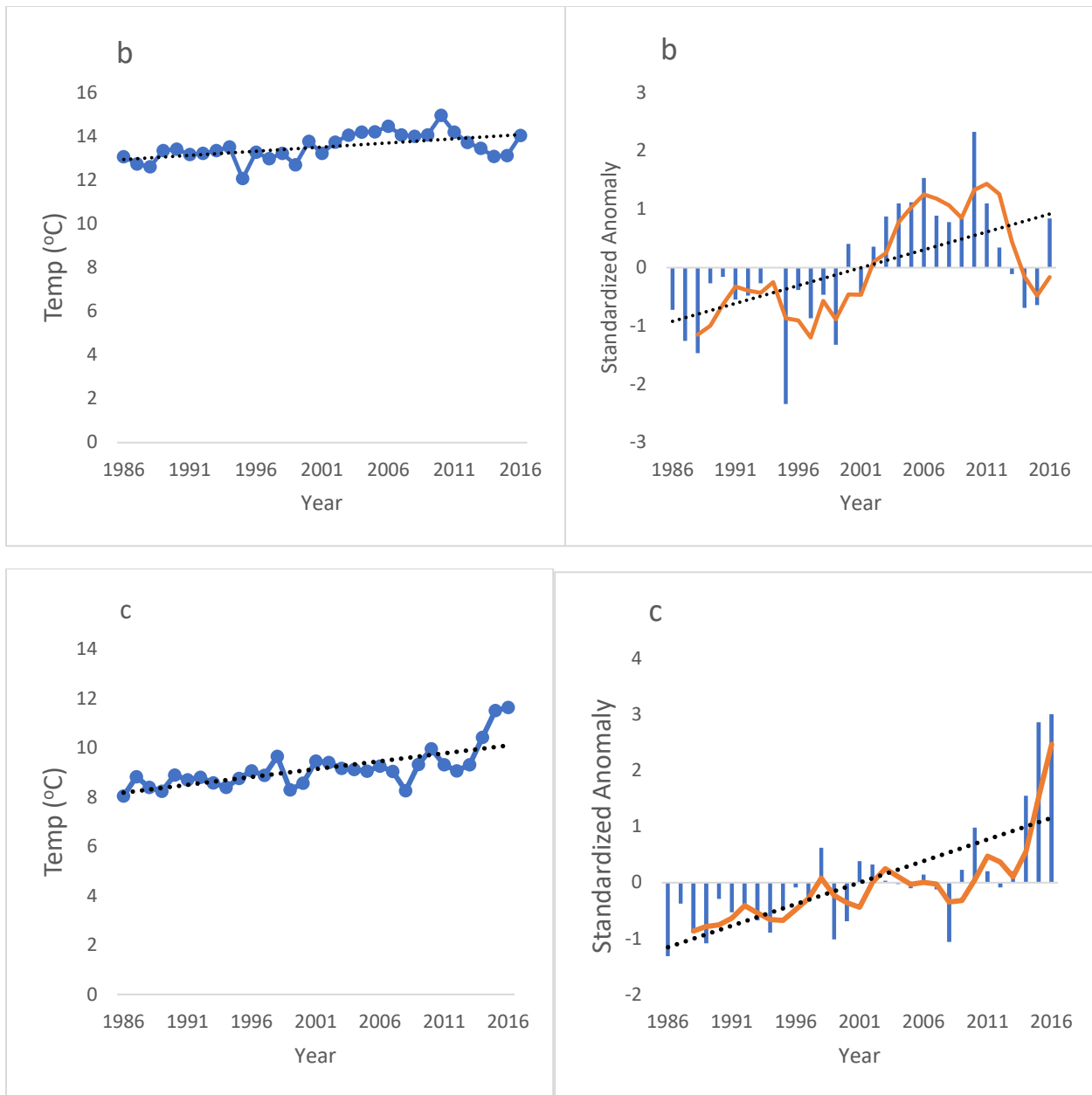




**Figure 2.2** Spatial variations of maximum temperature trends at the annual scales in different agro-ecologies for the period 1986–2016.

a, b and c indicate lowland, midland, and highland, respectively. Trends (left) and Standardized Anomalies (right).





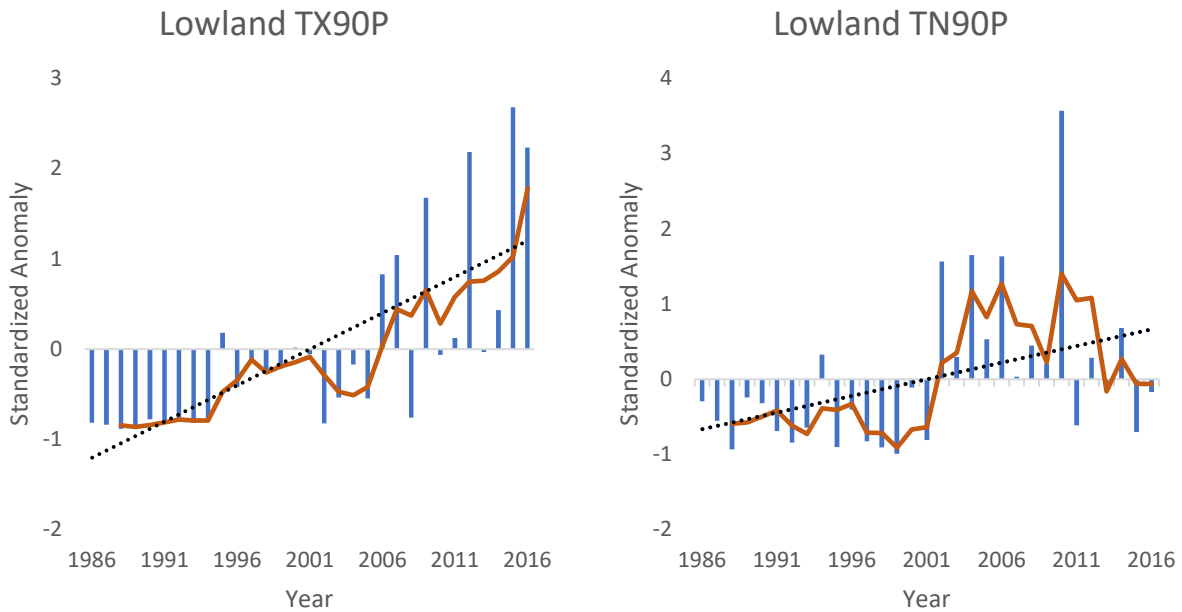
**Figure 2.3** Spatial variations of minimum temperature trends at the annual scales in different agro-ecologies for the period 1986–2016.

a, b and c indicate lowland, midland, and highland, respectively. Trends (left) and Standardized Anomalies (right).

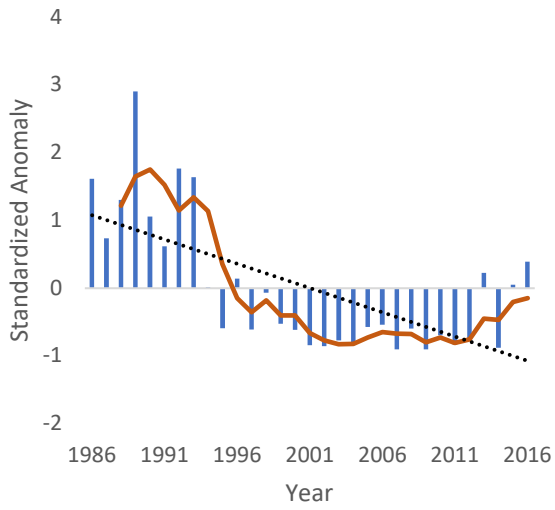
### 2.3.3. Trends in Temperature Extremes

#### **Warm Days (TX90p) and Warm Nights (TN90p); Cool Days (TX10p) and Cool Nights (TN10p)**

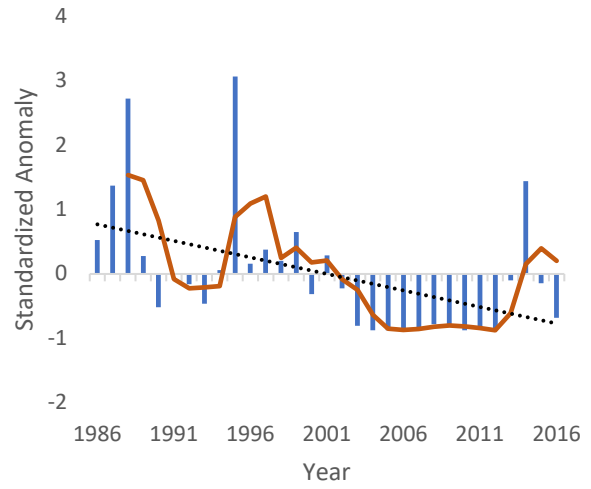
An increasing trend of warm extreme indices (TX90p and TN90p) was observed in all agro-ecology zones considered for this study. Only a significant TX90p observed in the highland agro-ecology zone, however, the trends in TN90p were significant in the three agro-ecologies at a different significance level. This finding implies that warming anomalies are increasing in all stations. A significant decreasing trend in the frequency of cool days (TX10p) and cool nights (TN10p) was observed in all stations. In general, the observation indicates that there is an increasing trend in the warm extremes (TX90p and TX90p) and decreasing trends in the cold extremes (TX10p and TN10p) in all agro-ecologies of the study area. Consistent with the present result, different studies in different agro-ecologies across Ethiopia reported an increasing trend in the occurrences of TX90p and TN90p while decreasing trends in TX10p and TN10p (McSweeney et al., 2010; Mekasha et al., 2013; Esayas et al., 2018; Worku et al. 2018).



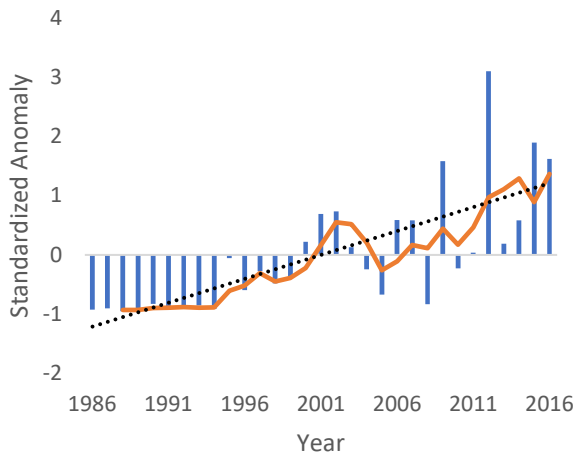
Lowland TX10P



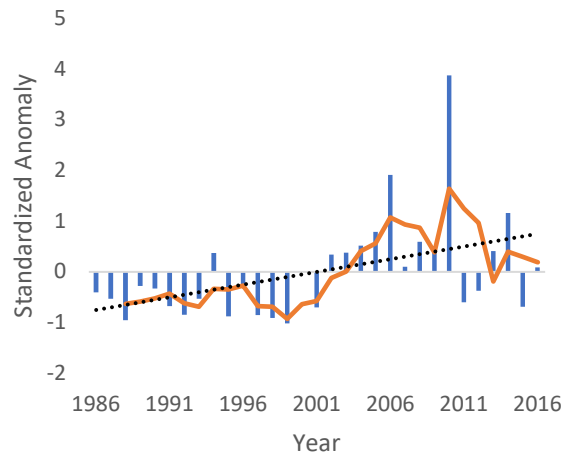
Lowland TN10P



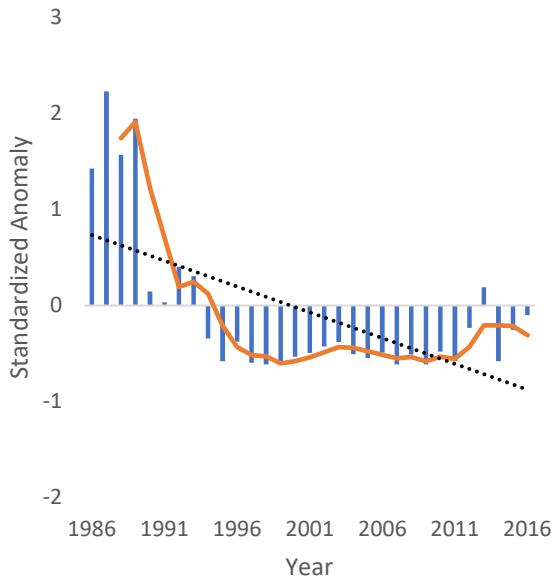
Midland TX90P



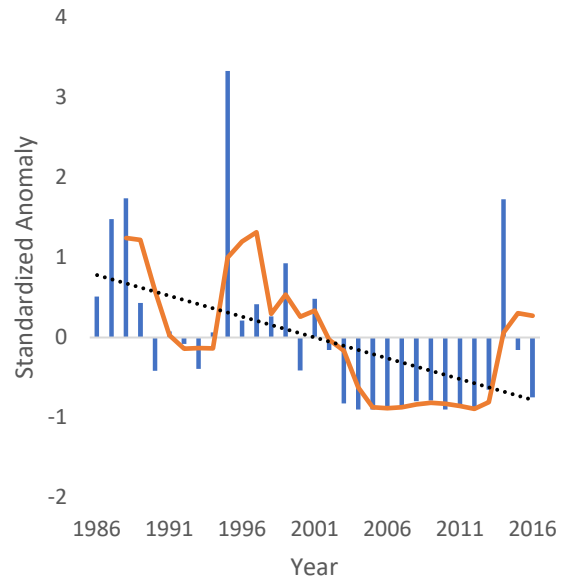
Midland TN90P



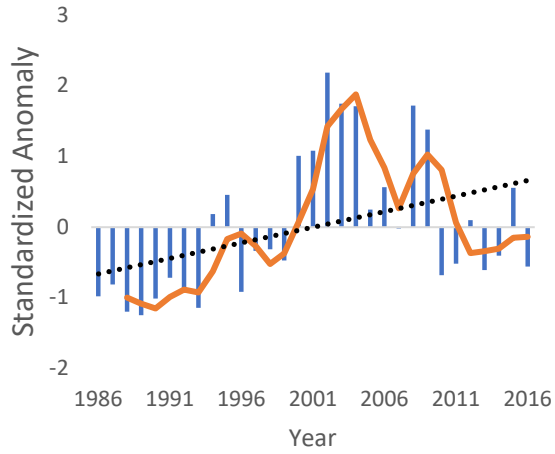
Midland TX10P



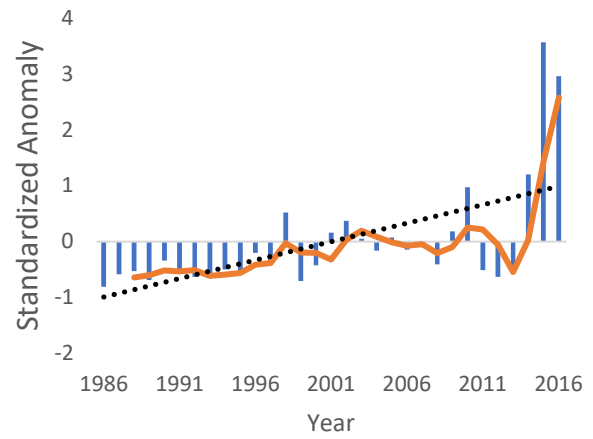
Midland TN10P

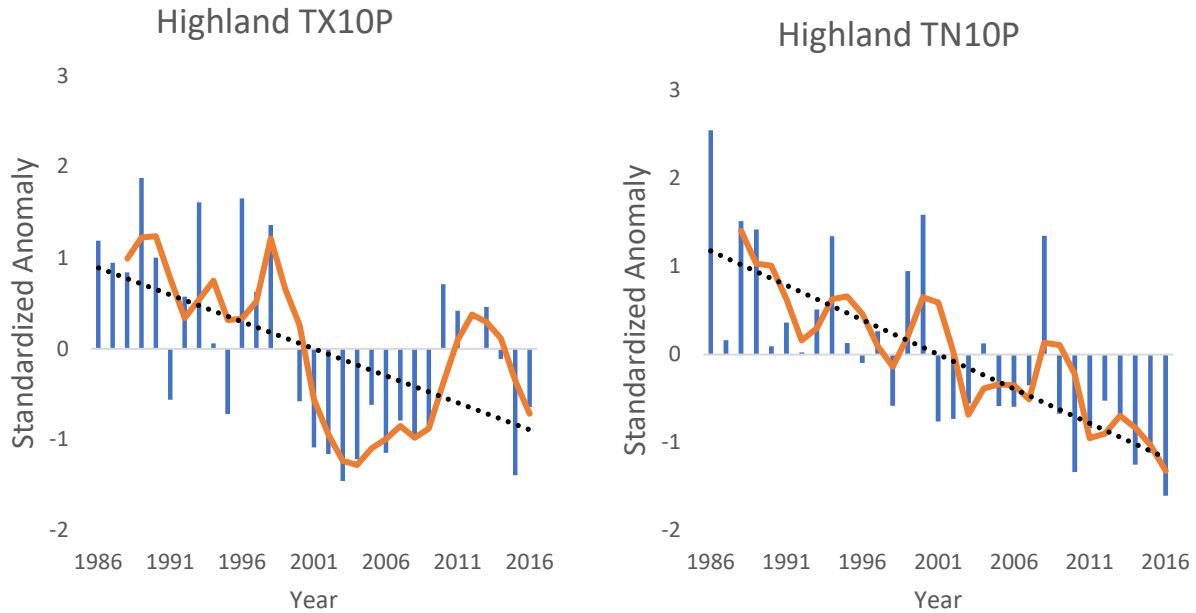


Highland TX90P



Highland TN90P





**Figure 2.4** Annual trends in TX90P, TN90P, TX10P, and TN10P for the period 1986–2016.

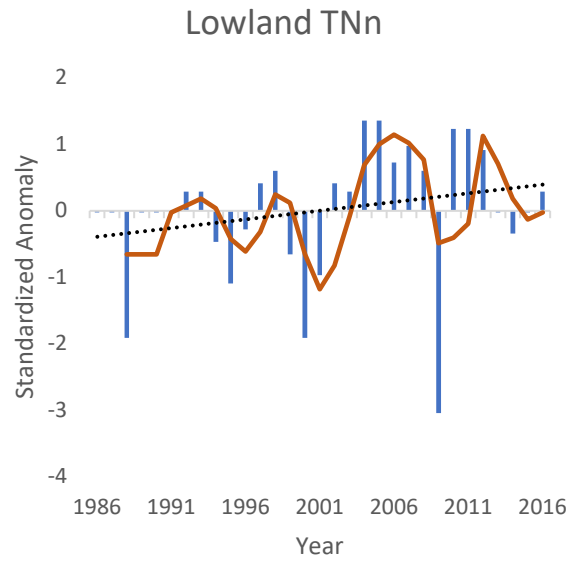
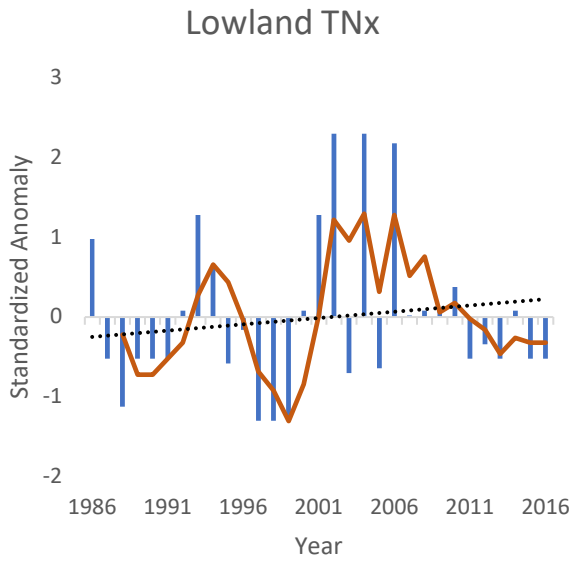
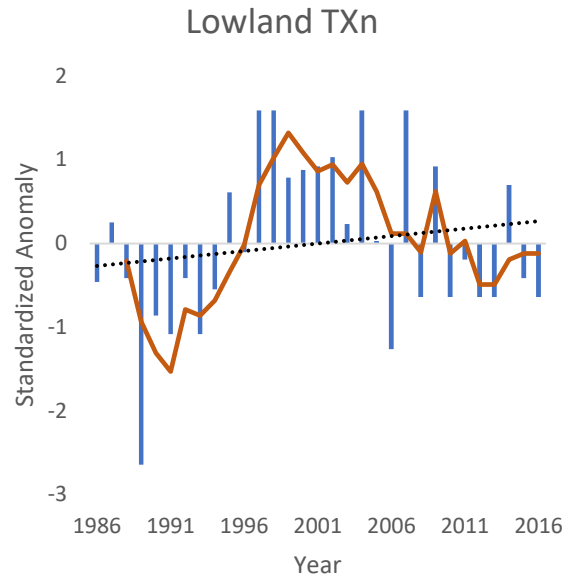
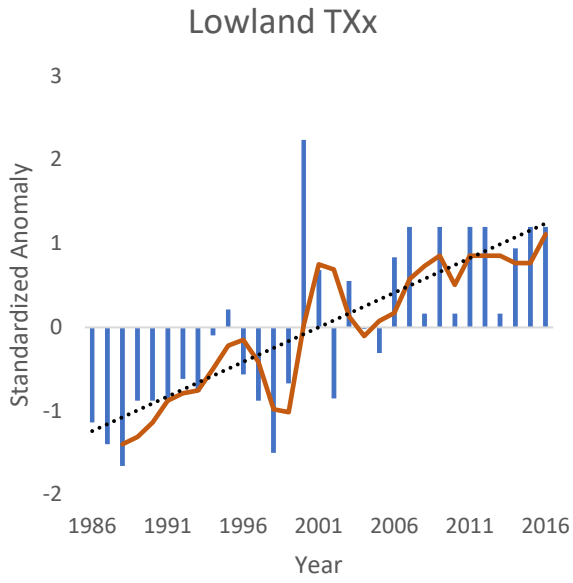
The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

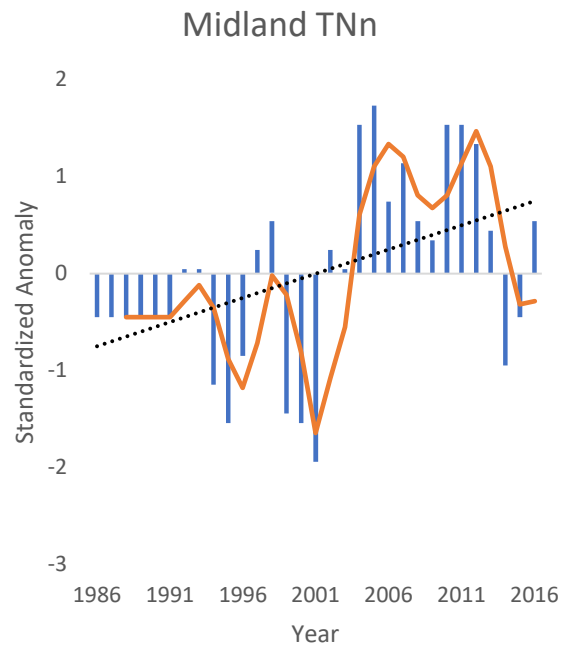
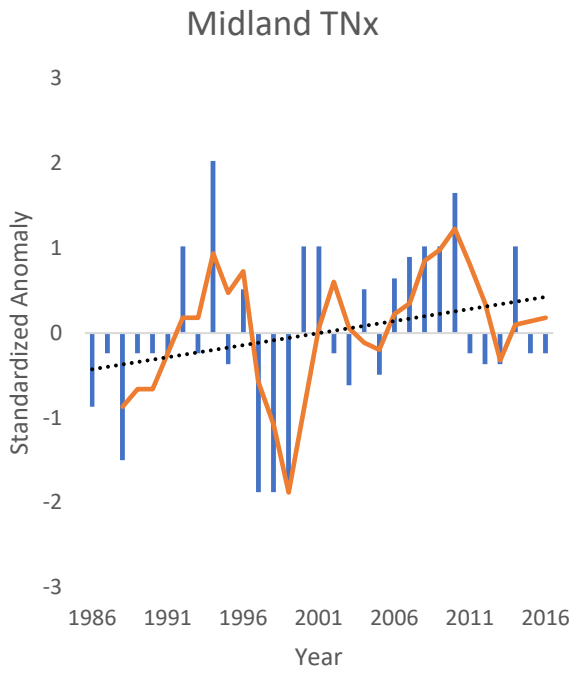
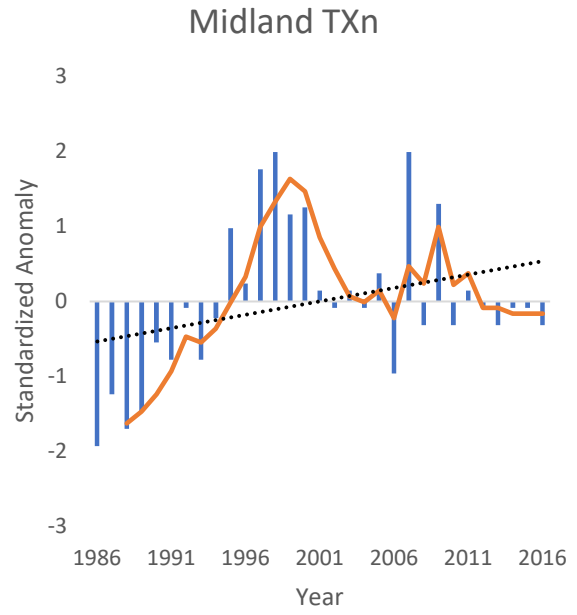
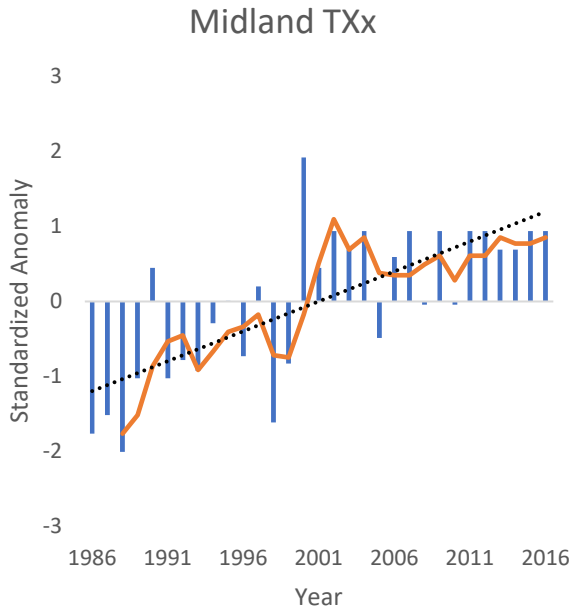
***Max Tmax (TXx) and Min Tmax (TXn)***

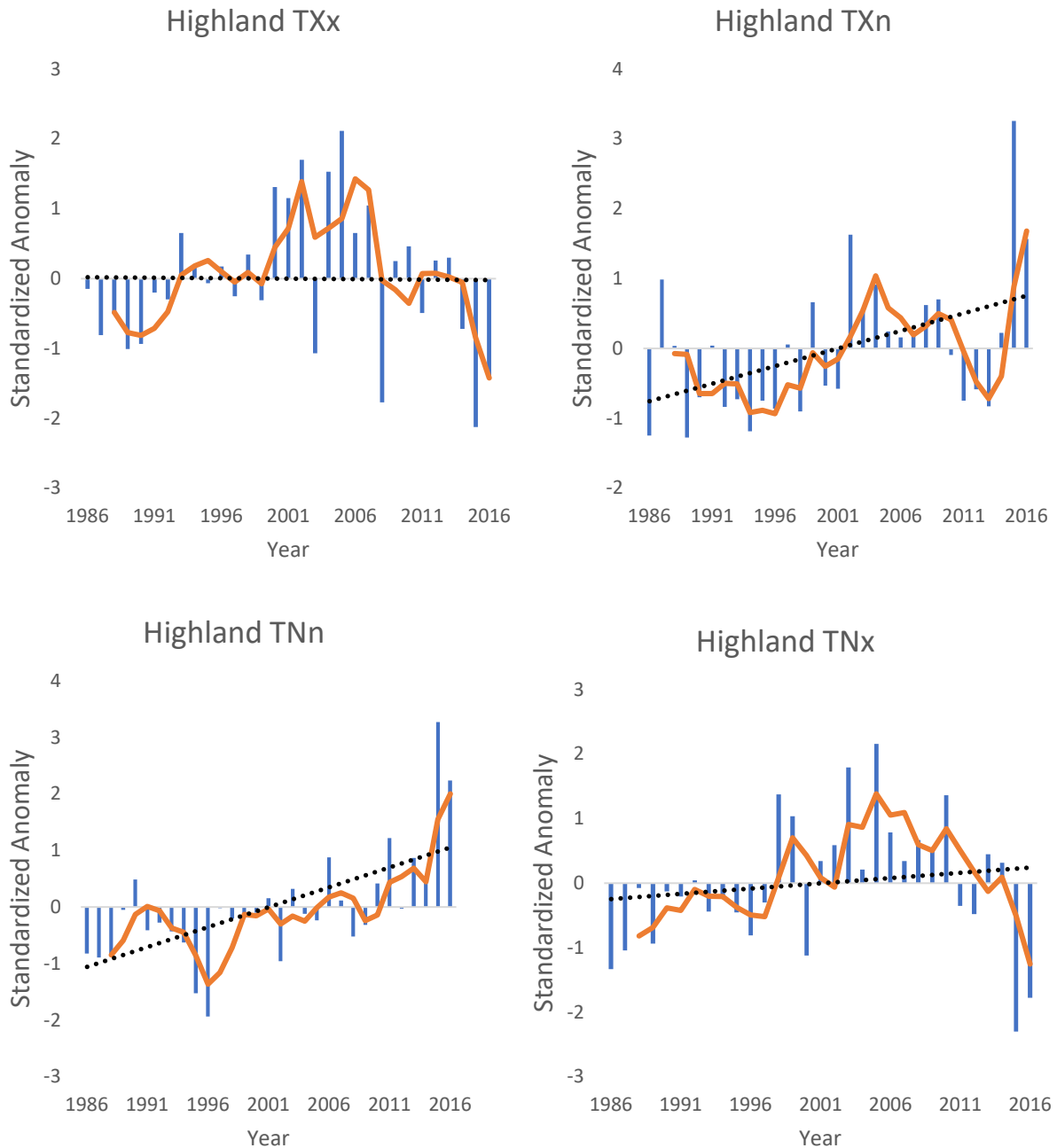
The temperature trend of TXx and TXn showed an increasing trend in the study stations. However, inconsistency in magnitude was observed among the stations. Statistically significant trend in TXx was observed in lowland and midland agro-ecology stations, while a significant increase in TXn was observed only in highland agro-ecology. Similarly, Worku et al. (2018) reported an upward trend in TXx and TXn in Jemma Sub-Basin, Upper Blue Nile Basin.

***Max Tmin (TNx) and Min Tmin (TNn)***

Similarly, an increasing trend but inconsistent in magnitude was observed overtime at almost all agro-ecologies in TNx and TNn. Except in midland agro-ecology, the trend in TNx and TNn is statistically insignificant in all the stations. In line with this, increasing intensity of temperature extremes indices also reported in Ethiopia (Worku et al. 2018; Mekasha et al., 2013). On the contrary, Esayas et.al (2018) reported a statistically significant decreasing trend in TXx in the midland agro-ecology in southern Ethiopia.







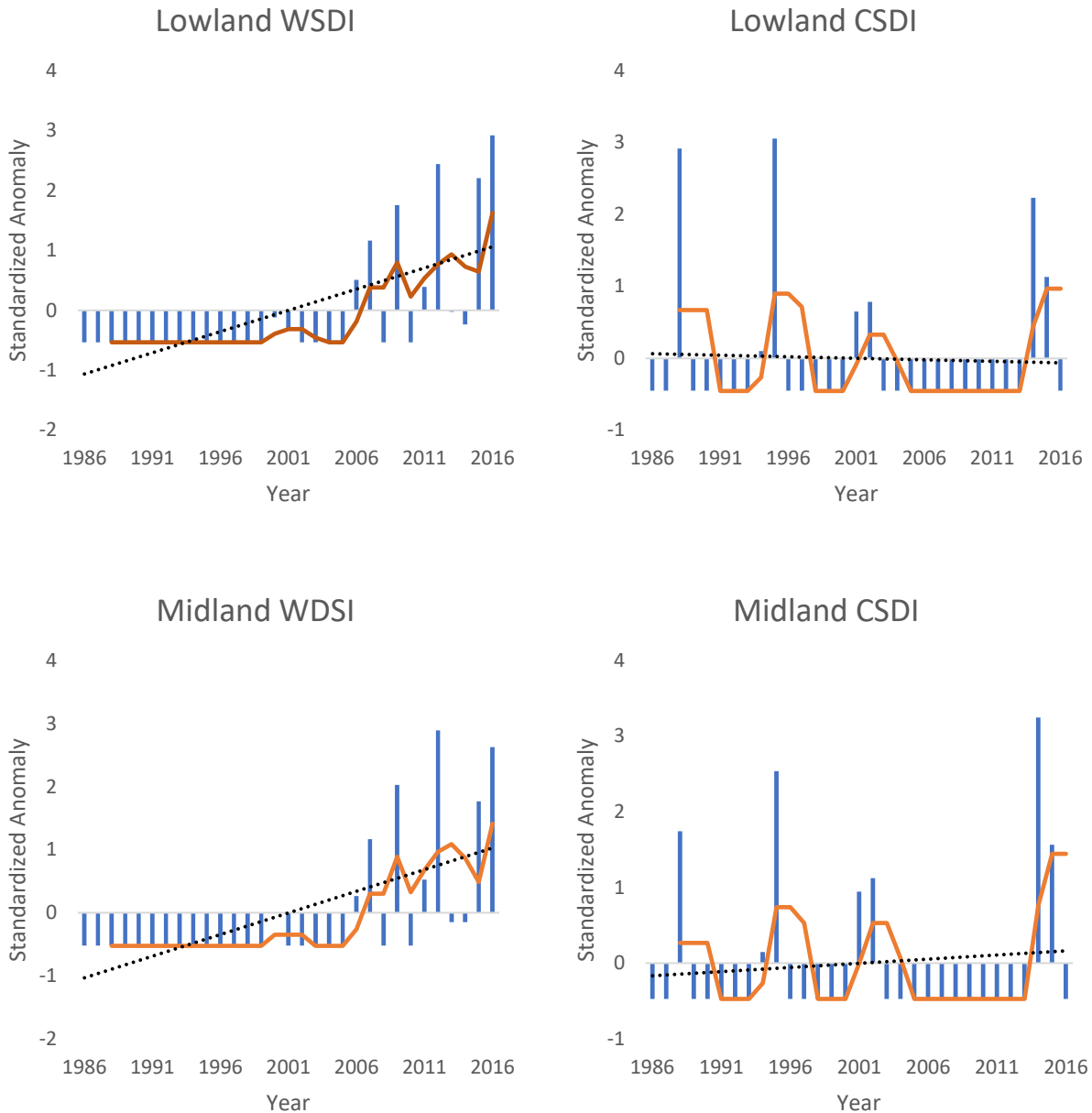
**Figure 2.5** Annual trends in TXx, TXn, TNx, and TNn for the period 1986–2016.

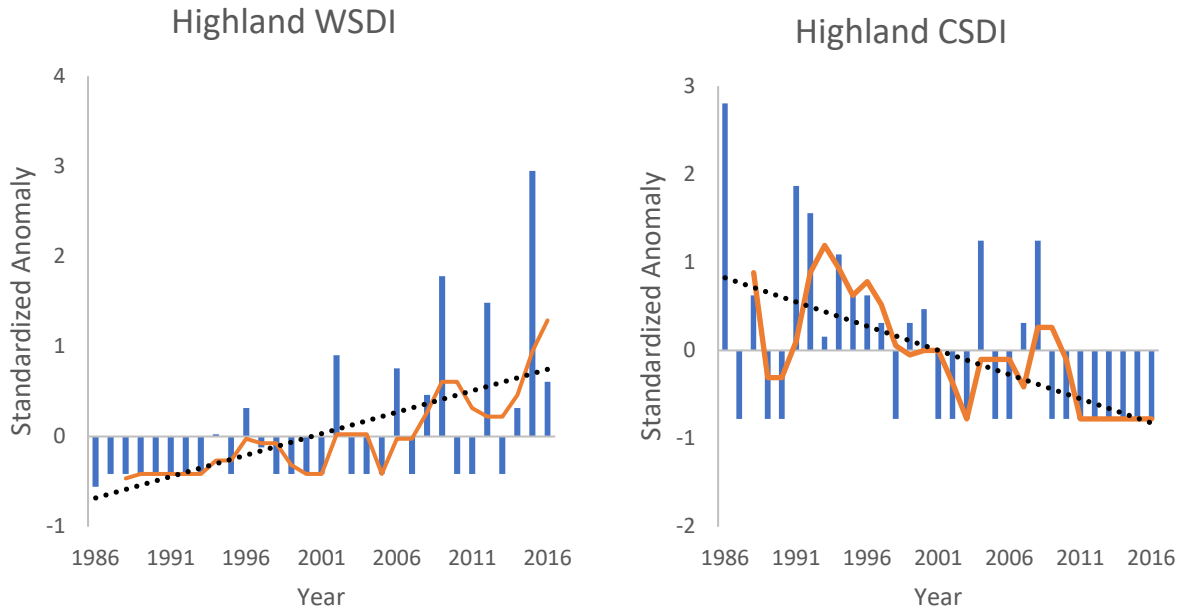
The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

***Warm Spell Duration Indicator (WSDI) and Cold Spell Duration Indicator (CSDI)***

The warm spell duration indicator (WSDI) index was increasing in all agro-ecologies, while it was significant only in lowland and highland agro-ecologies. In regards to Cold Spell Duration

Indicator (CSDI), a decreasing trend was observed in lowland and highland agro-ecologies whereas an increasing trend was observed in midland agro-ecology but the trend was insignificant. Similar mixed WSDI and CSDI trends were reported in the Upper Blue Nile Basin (Worku et al. 2018). However, decreasing trends in CSDI were reported by Donat et al. (2014) in the Arab region and Esayas et al. (2018) over three agro-ecological zones of Southern Ethiopia.



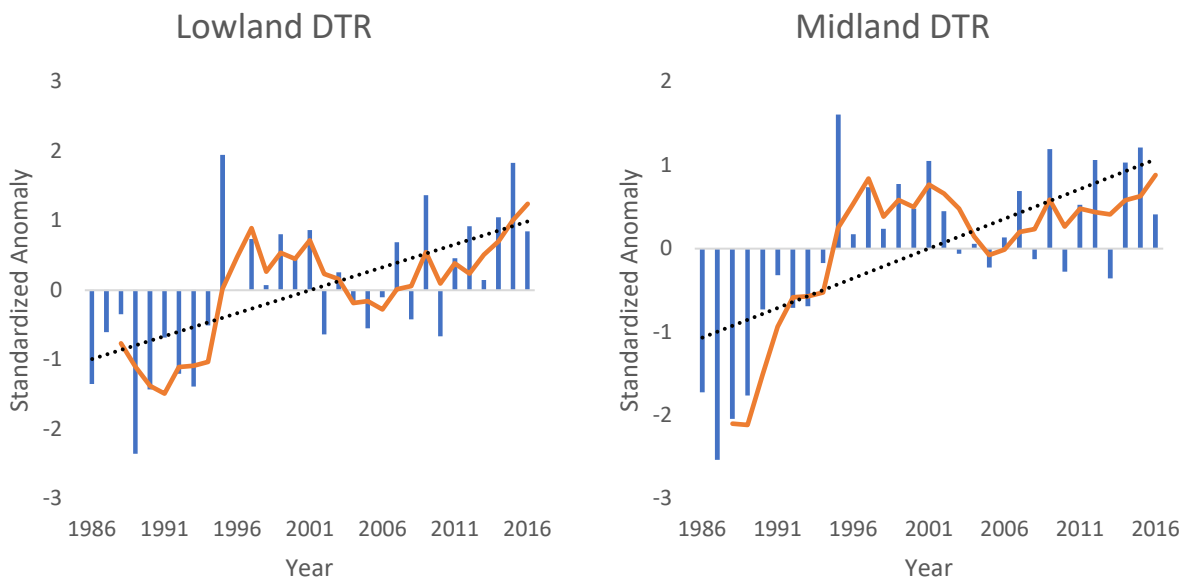


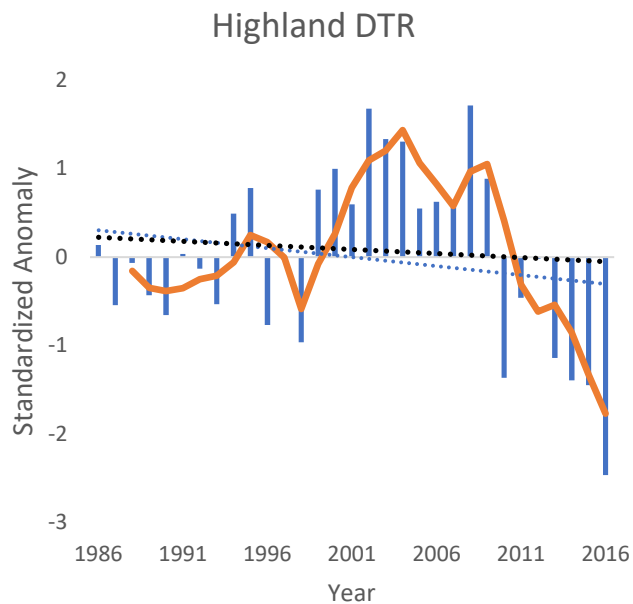
**Figure 2.6** Annual trends in WSDI and CSDI for the period 1986–2016.

The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

***Diurnal Temperature Range (DTR)***

Trends of DTR exhibited an insignificant trend in lowland and highland agro-ecologies, indicating the differences between TXmean and TNmean are not changing in the opposite direction.





**Figure 2.7** Annual trends in DTR for the period 1986–2016.

The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

**Table 2.4** Trends in climate extreme indices for the period 1986–2016 in different agro-ecologies.

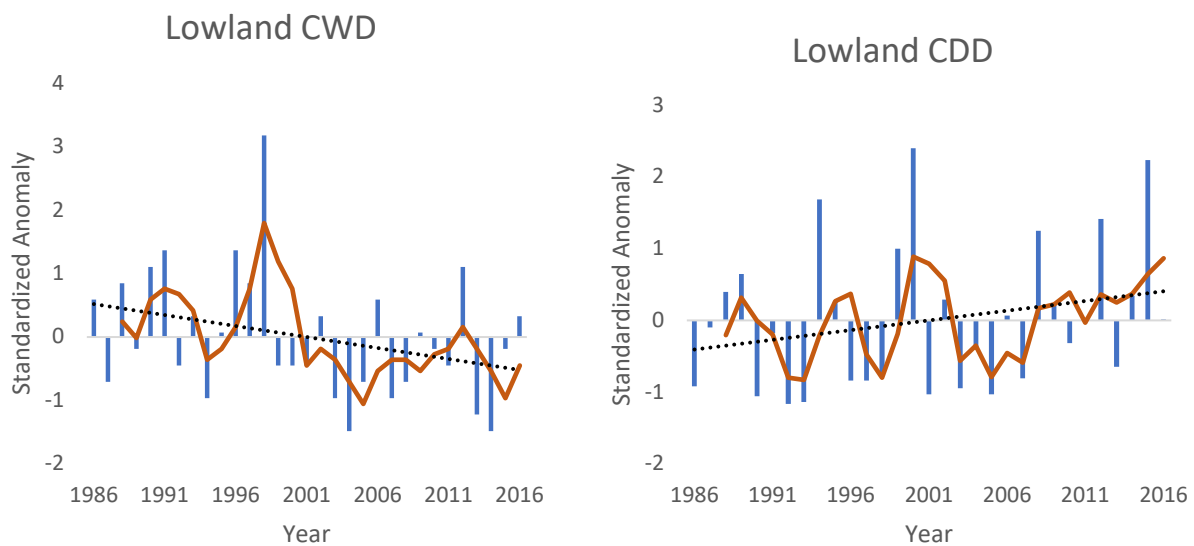
Index	Units	Lowland	Midland	Highland
		Sen's slope	Sen's Slope	Slope
<b>Temperature</b>				
TXx	°C	0.159**	0.184**	0.017
TNx	°C	0.04	0.077*	0.06
TXn	°C	0.011	0.022	0.075**
TNn	°C	0.042	0.05**	0.068
DTR	°C	0.075	0.122	-0.022
WSDI	Days	2.375**	1.835*	0.226
CSDI	Days	-0.061	0.124	-0.353***
TN10p	Days	-0.573**	-0.565***	-0.511*
TX10p	Days	-0.851**	-1.252***	-0.291**
TN90p	Days	0.398**	0.445**	0.831*
TX90p	Days	0.965	0.863	0.292*
<b>Precipitation</b>				

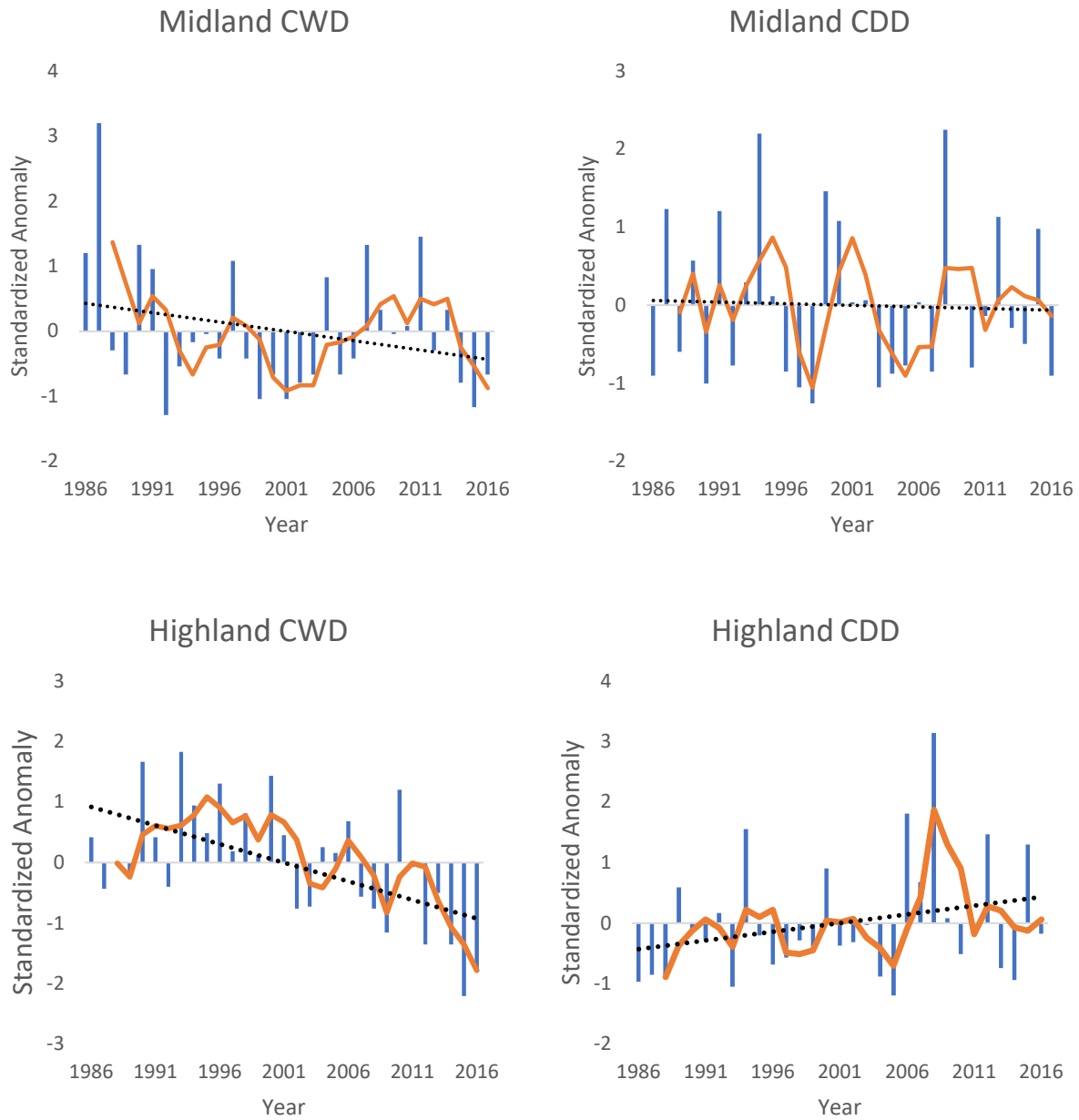
RX1day	Mm	-0.35*	0.252	-0.186
Rx5day	Mm	-0.588	0.158	-0.657*
SDII	Mm/day	-0.095***	-0.022	-0.049
R95p	Mm	-7.087**	3.268	-0.768
R99p	mm	-2.342	-0.078	-1.388
CWD	Days	-0.134*	-0.23	-1.876***
CDD	Days	0.987	-0.159	1.015
R10mm	Days	-0.6***	-0.219	-1.172***
R20mm	Days	-0.438***	0.221*	-0.089

#### 2.3.4. Trends in precipitation extremes

##### **Consecutive Dry Days (CDD), and Consecutive Wet Days (CWD)**

The trend analysis of both consecutive dry days (CDD) and consecutive wet days (CWD) showed mixed results in the selected agro-ecologies. Only a decreasing trend in CDD showed in midland agro-ecology. A drier condition was observed in both lowland and highland agro-ecologies i.e. the agro-ecologies showed an increasing trend in CDD and a decreasing trend in CWD. The results are in line with similar findings reported in different parts of Ethiopia where CDD and CWD showed a mixed trend (Esayas et al., 2018; Seleshi and Camberlin, 2006). However, Mekasha et al., (2013) and Worku et al. (2018) observed a significantly decreasing trend for CDD in Lemi and Asela station, respectively.





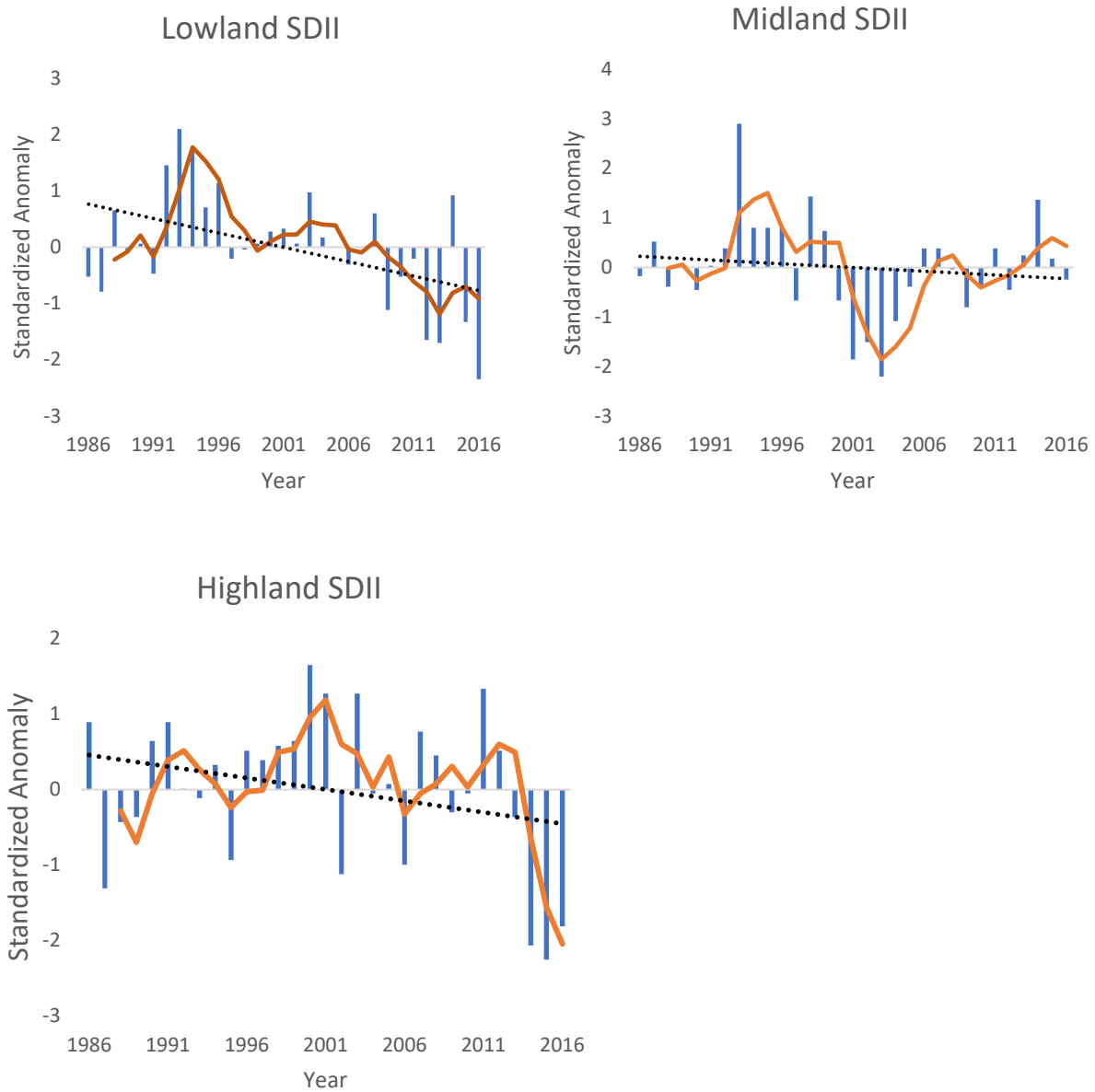
**Figure 2.8** Annual trends in CWD and CDD for the period 1986–2016.

The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

***Simple Daily Intensity Index (SDII)***

A decreasing trend in Simple Daily Intensity Index (SDII) was observed in all the agro-ecologies, where a significant SDII was observed only in lowland agro-ecology. Mekasha et al., (2013)

reported a similar finding where except for a significant increasing trend at Koka and a significant decreasing trend at Negele-Borana, trends in SDII were not significant in different agro-ecologies studied.

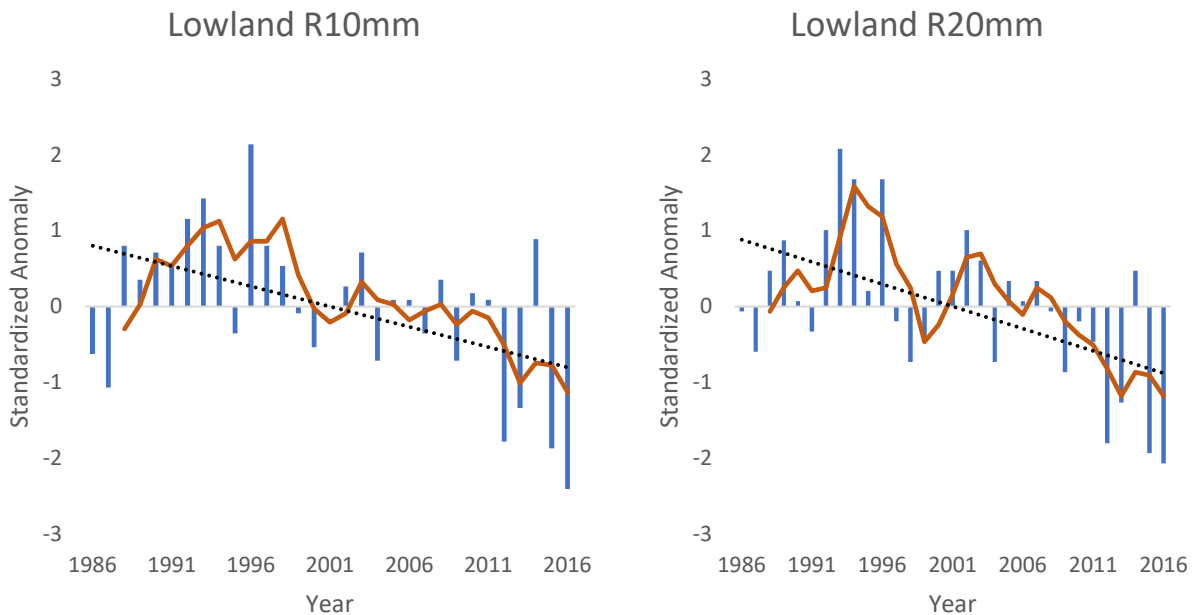


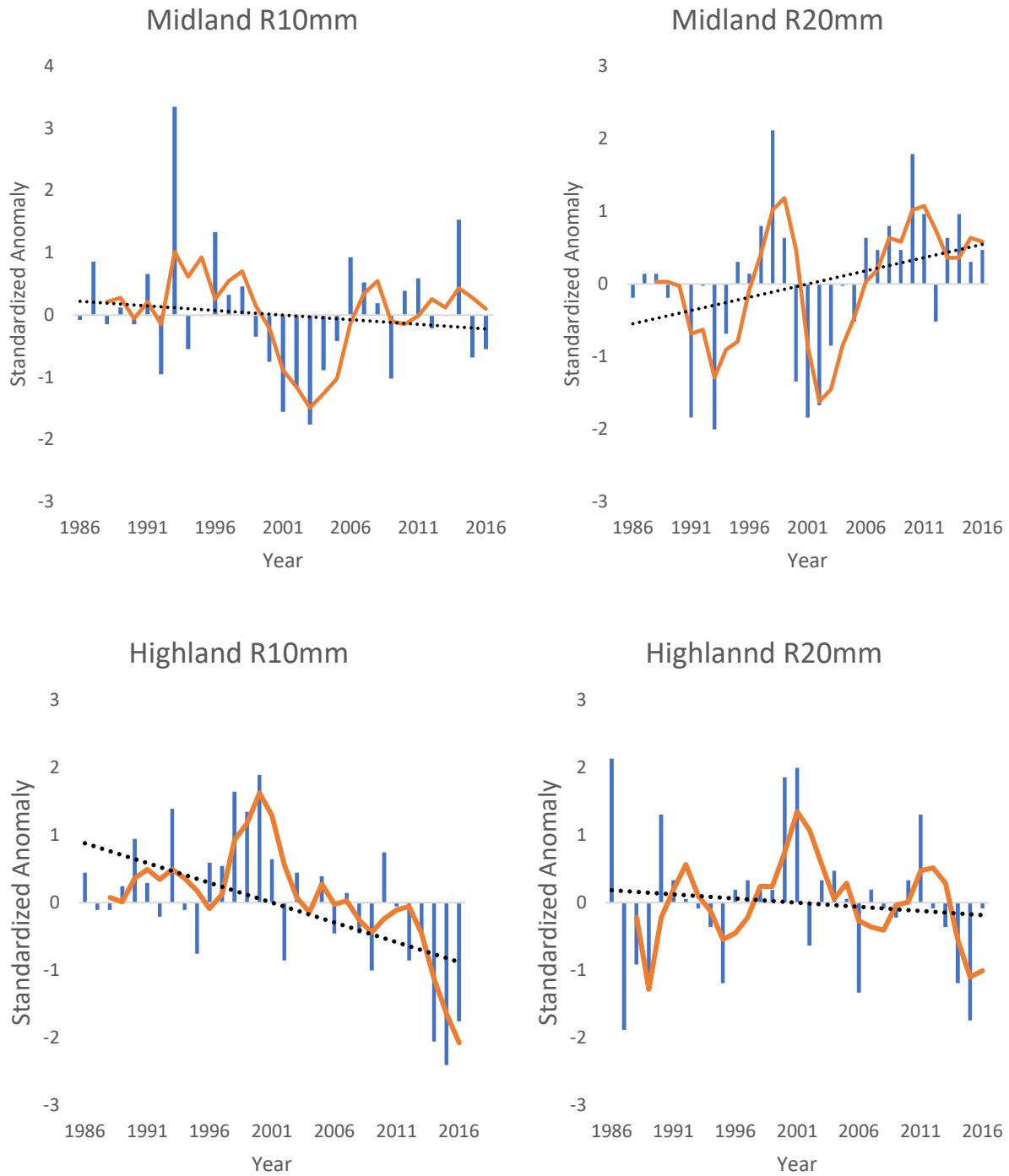
**Figure 2.9** Annual trends in SDII for the period 1986–2016.

The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

### **Number of Heavy (R10mm) and Very Heavy (R20mm) Precipitation Days**

Except for a significantly increasing trend in R20mm in midland agro-ecology, the number of heavy (R10mm) and very heavy (R20mm) precipitation days showed a decreasing trend in both lowland and highland agro-ecologies. Both R10mm and R20mm precipitation days were significantly decreasing in lowland agro-ecologies. The study found that the midland agro-ecology was at risk particularly related to flooding unless measures are taken. The study is in line with recent findings from Esayas et al., (2018) that reported a mix of an insignificant decreasing trend in the lowland and the highland agro-ecology in R10mm while it was an insignificant increasing trend in the midland agro-ecology. Similarly, Mekasha et al., (2013), observed insignificant trends in R10mm and R25mm at most of the stations over 42 years. However, a similar study showed a significant decreasing trend in R10mm in Negele-Borena and Asela station and significant increasing trends in R25mm in Koka station.



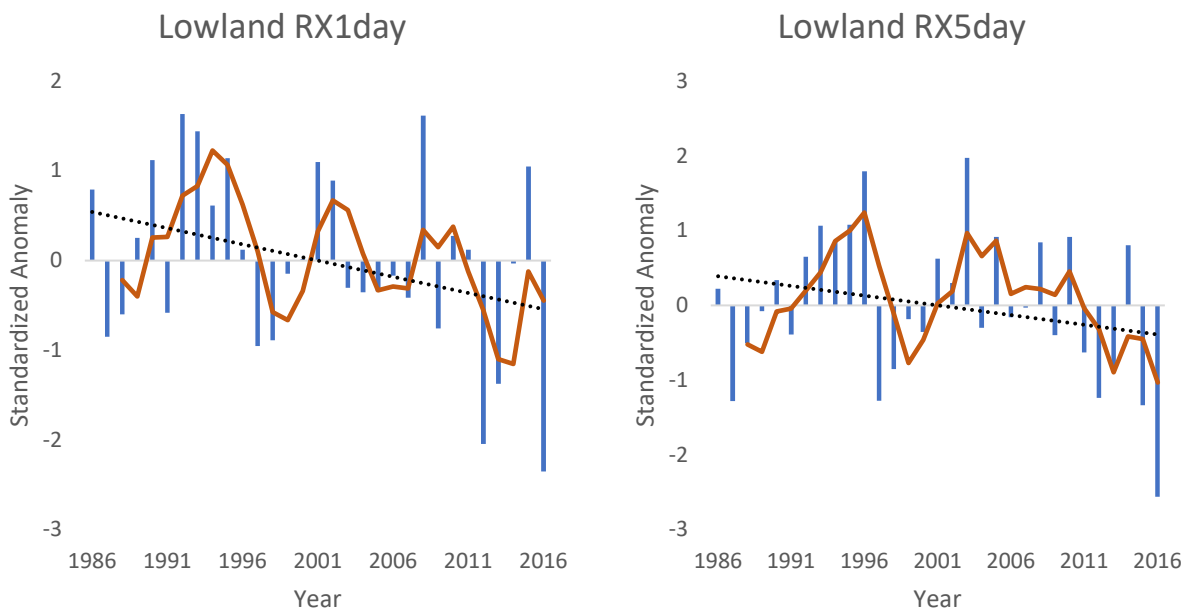


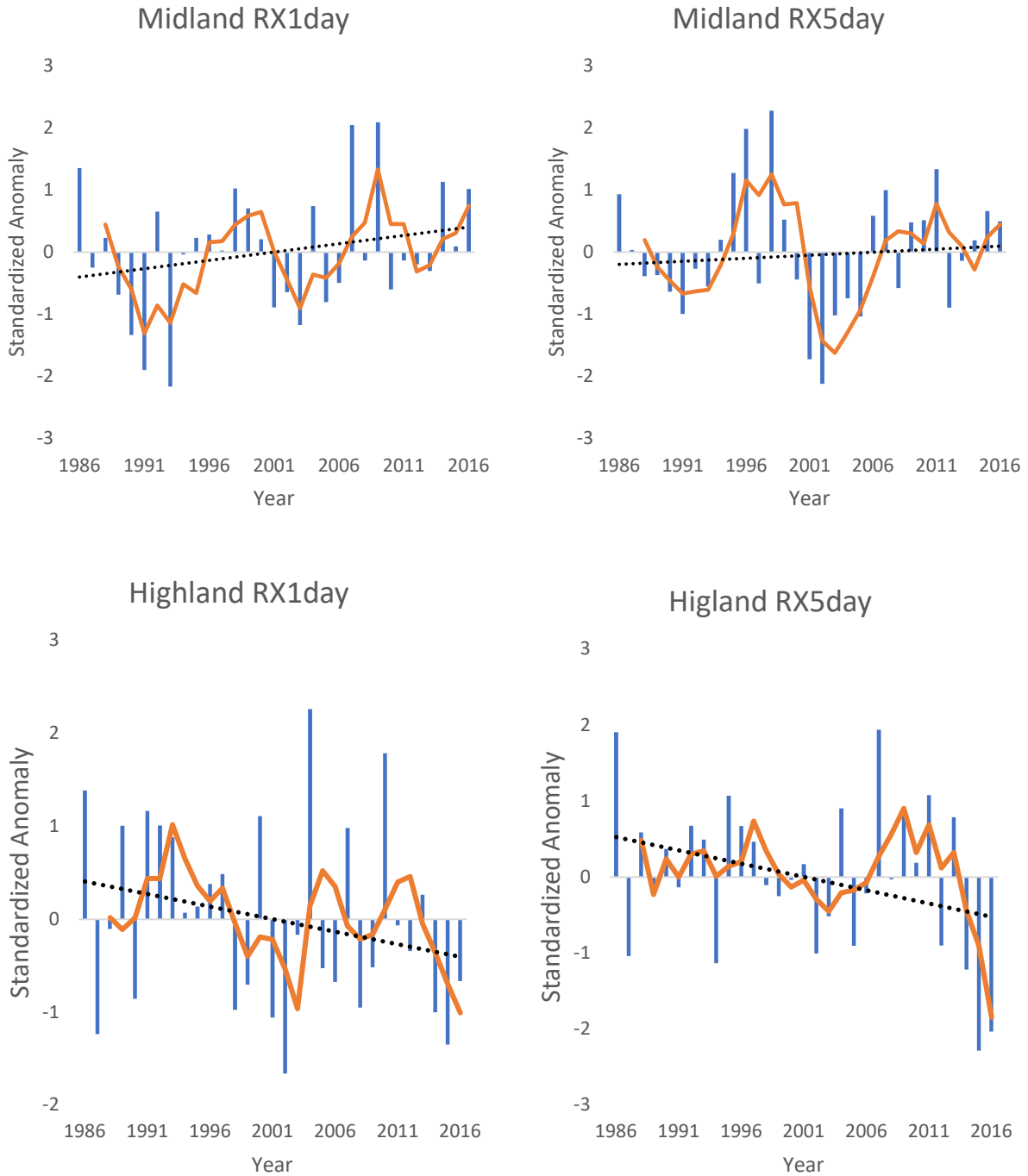
**Figure 2.10** Annual trends in R10mm and R20mm for the period 1986–2016.

The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

### **Maximum 1-Day (RX1day) and 5-Day (RX5day) Precipitations**

Insignificant trends of the Maximum 1-Day (RX1day) and 5-Day (RX5day) precipitations were observed in most of the studied agro-ecologies. The evaluation indicates that there was spatial inconsistency among the selected agro-ecologies on the trend of Rx1d and Rx5d indices. Both lowland and highland agro-ecologies had a decreasing RX1day and RX5 day trends, while an increasing trend both in the RX1day and RX5 day was found in midland agro-ecology. Similarly, Esayas et al. (2018) reported an insignificant trend both in the RX1day and RX5 day in lowland and midland agro-ecology in southern Ethiopia. The finding is contrary to Worku et al. (2018) where significant increasing trends of Rx1d and Rx5d were reported in Alem ketema station and Fichie and Mendida stations, respectively. These contrasting results may be explained by the geographical difference.



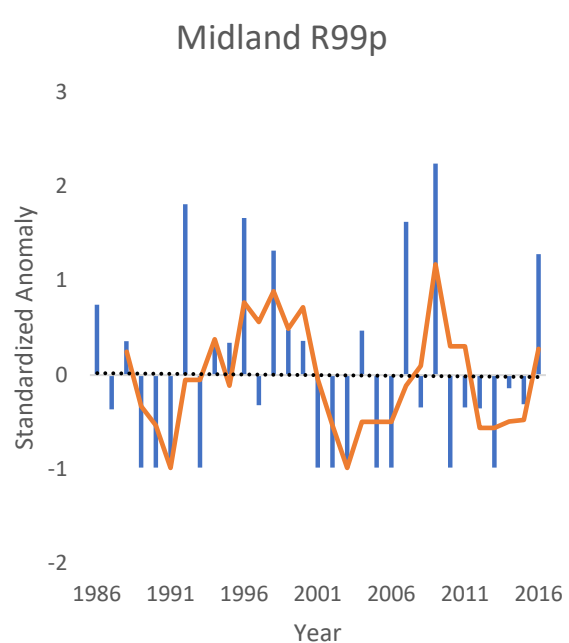
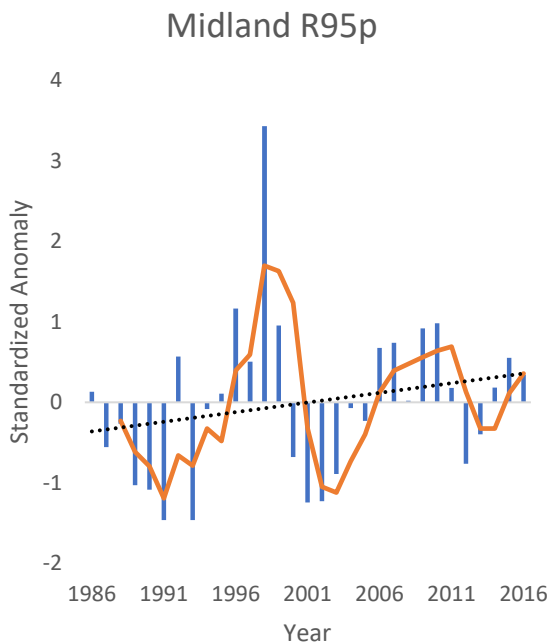
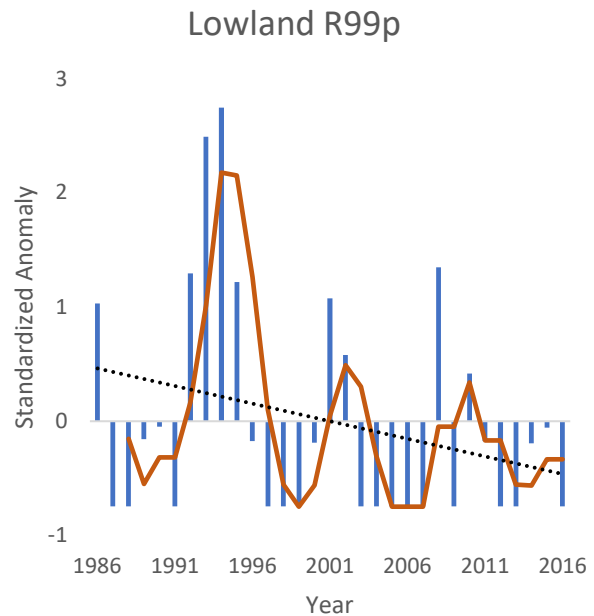
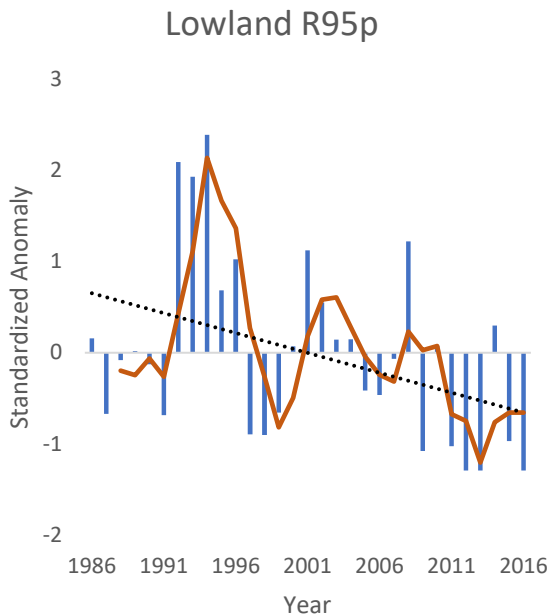


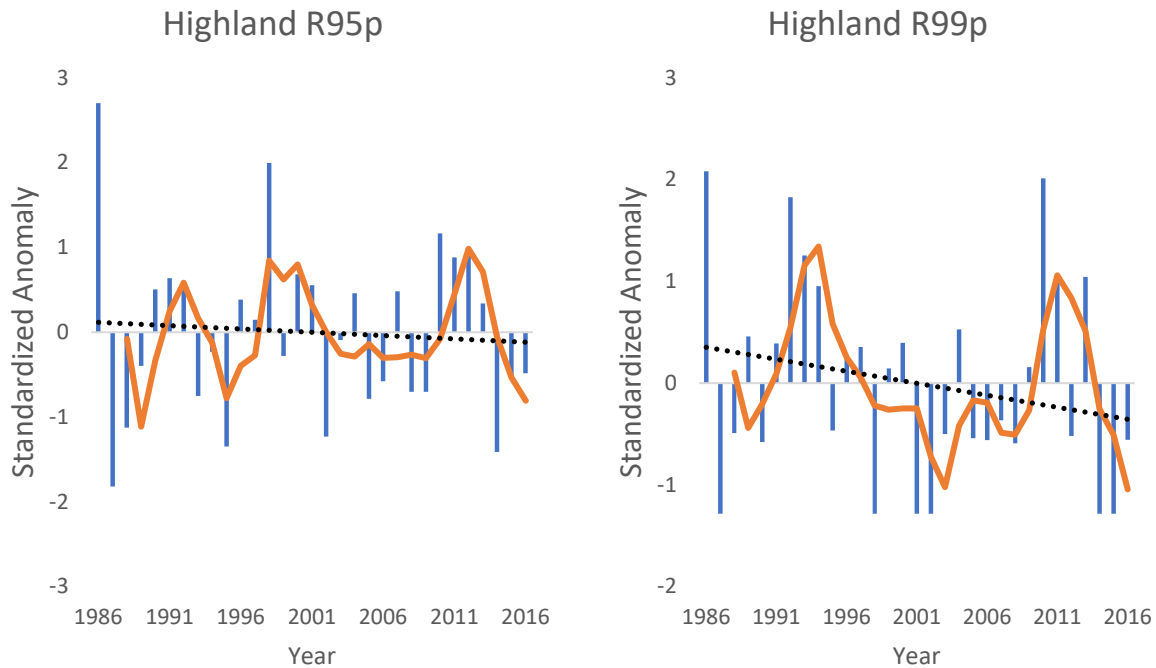
**Figure 2.11** Annual trends in RX1day and RX5day for the period 1986–2016.

The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

### Very Wet Days (R95p) Extremely Wet Days (R99p)

The trend in very wet days (R95p) and extremely wet days (R99p) showed consistency among the observed agro-ecologies. Except for lowland where a significant decreasing trend was observed in R95p (7.087 mm/year), the remaining stations had an insignificant trend in both R95p and R99p. An increasing trend was only observed in midland agro-ecology for R95p.





**Figure 2.12** Annual trends in R95p and R99p for the period 1986–2016.

The dashed line and straight line on the bar chart represent the linear trend and 5-year moving average, respectively.

In general, the observed spatial and temporal characteristics of extreme precipitation in the studied climate stations had shown inconsistency in used climate indices and the trends are mostly insignificant.

### 2.3. Conclusion

This paper has evaluated trends in temperature and precipitation extremes using the Mann–Kendall (MK) test and Sen's slope estimator in different agro-ecologies of Gurage Zone, Southern Ethiopia. The evidence indicates that the trends in temperature extremes are on the rise in different agro-ecologies of the study zone over the study period. The observation indicates that there is an increasing trend in the warm extremes and decreasing trends in the cold extremes. A statistically significant increase in the numbers of warm days and nights and a statistically significant reduction in the numbers of cold days and nights were observed in most of the agro-ecologies studied. Similarly, the IPCC AR4 assessed that it was very likely that there had been trends toward warmer and more frequent warm days and warm nights, and warmer and less frequent cold days and cold

nights in most land areas. Also, positive trends of the intensity of temperature extremes indices (TX<sub>x</sub>, TX<sub>n</sub>, TN<sub>x</sub>, and TN<sub>n</sub>) with the inconsistent magnitude of change observed. A higher length or number of warm spells and inconsistent trends in cold spell duration were observed in the studied agro-ecologies. In summary, analyses of temperature extremes revealed that there is a warming trend. Analysis of trends of precipitation extremes revealed spatial inconsistency in the study agro-ecologies. The duration of extreme precipitation trend showed inconsistency, however, a drier condition is observed in both lowland and highland agro-ecologies. There was spatial inconsistency among the selected agro-ecologies on the intensity of extreme precipitation. Finally, results from extreme event analysis revealed an increasing trend of climate extremes in most of the climatic stations. This could result in severe losses of livelihood sources and associated impacts on household food security unless appropriate adaptation measures are taken. Therefore, the findings of this study will help in initiating agro-ecological based preparedness to offset and reduce the impact of climate variability and change by improving climate risk management capabilities.

### 3. Livelihood vulnerability to climate variability and change in different agro-ecological zones of Gurage, Southern Ethiopia

#### **Abstract**

Climate change and related extreme events are negatively affecting agricultural production where millions of smallholder farmers depend upon it. Ethiopian rain-fed agriculture system is becoming more vulnerable to the impacts of climate change. Identification of difference in the level of vulnerability of a system is important in selecting appropriate and effective adaptation options to climate change. Thus, this study examined the vulnerability of farm household's livelihood to climate variability and change in different agro-ecological zones of Gurage Zone using the Livelihood Vulnerability Index (LVI) and Livelihood Vulnerability Index–Intergovernmental Panel on Climate Change (LVI–IPCC) methods. Data were collected from a representative of 357 sample households in the three agro-ecological zones using a mixture of participatory methods. Results suggested that although there was a difference in components relative value, the overall LVI indicates that the lowland agro-ecological zone was more vulnerable to climate variability and change. This study found that vulnerability differences were attributable to variations in agro-ecological setting, household characteristics, lack of access to infrastructure, low level of livelihood diversification, and lack of available technologies. Therefore, this study calls for stakeholders to prepare context-specific intervention to reduce smallholder farmer's vulnerability to climate variability and change and strengthen the adaptive capacity of farm households.

**Keywords:** Vulnerability Index; Agro-ecological Zones; Gurage Zone.

### 3.1. Introduction

Climate change and related extreme events are negatively affecting agricultural production where millions of smallholder farmers depend upon it. The risk of food insecurity is greater nowadays in developing countries because livelihoods are more exposed and vulnerable to climate change (FAO, IFAD & UNICEF, WFP & WHO, 2018). Climate change is a global phenomenon that indiscriminately affects all sectors of the economy and all social groups. However, the level of vulnerability of a system, household, and location is differentiated dictated by environmental and socioeconomic factors (Adger, 2006; Adger *et al.*, 2003). Understanding the vulnerability of livelihood systems of poor people in the context of wider transformational shifts — social and political as well as biophysical — must now be seen as a normative priority (UNDP, 2014).

Empirical findings (e.g. Boko *et al.*, 2007; Lobell *et al.*, 2011; IPCC, 2014) indicate that Africa's climate is already changing and the impacts are already being felt by communities across the continent. In sub-Saharan Africa, extreme events like drought already impede people's ability to grow a crop and rear livestock (Kebede *et al.*, 2011; Songok *et al.*, 2011). This is mainly because of Africa's poor socio-economic development status and which in turn affects the continent's aspiration towards sustainable development goals (Boko *et al.*, 2007; UNFCCC, 2007; Yesuf *et al.*, 2008; McBean and Rodgers, 2010).

Projected climate change in Ethiopia is expected to result in increased variability in precipitation and an increase in temperature (1.1 to 3.1 °C by 2060 and 1.5 to 5.1 °C by 2090) with associated increases in the frequency and intensity of extreme events like drought and flood (NMA, 2007). These trends of increasing temperature, decreasing precipitation, and the increasing frequency of extreme events are predicted to continue in the future in the tropics of Africa where Ethiopia is located (Mitchell and Tanner, 2006; EPCC, 2015).

Ethiopia is an agro-based economy where agriculture contributes 45 percent to the Gross domestic product (GDP). The agriculture sector is a source of livelihood for more than 80 percent of the population. Despite its significant share of the overall economy, agriculture is predominantly rain-fed and as such vulnerable to climate change and extremes events (Evans, 2012). For example, the major drought in 2002-3 resulted in a drop in food production by 26 percent (Barnett *et al.*, 2009).

Moreover, due to population growth and traditional agricultural practice, there is pressure for the natural resources which is likely to lead to deforestation and land degradation (FAO, 2013).

Different vulnerability assessments have been used to analyze climate vulnerability and its interplay with livelihood security which is required to identify and implement climate resilience interventions (Hahn *et al.*, 2009). However, despite some research work on vulnerability to climate change, little empirical evidence exists on the level of vulnerability to climate change at the household and community level so far in Ethiopia in general and the Gurage zone in particular. Previous studies on vulnerability to climate change in Ethiopia have mostly been macro-level studies. For example, a study by Deressa, Hassan, & Ringler (2008) measured Ethiopian farmers' vulnerability to climate change across regional states using national aggregates data. Only a few studies have focused on measuring smallholder farmer's vulnerability to climate change at the household and community level. Teshome (2016) assessed agricultural land vulnerability to climate change at the household level in Northwest Ethiopia. Similarly, Simane, Zaitchik, & Foltz (2016) conduct a study on agroecosystem specific climate vulnerability in Choke Mountain.

Macro-level studies elsewhere in the country do not necessarily reflect the exposure of households or communities, nor do they capture in detail how households perceive or respond to shocks and stress. Vulnerability assessments relying on aggregate data could mask significant local-level variability and which might have directed to intervention failure (Eakin and Bojorquez-Tapia, 2008; Morse and Fraser, 2005). Thus, local-based studies help to understand the role of context-specific factors (Eriksen *et al.*, 2005) which must be accounted for if associated interventions are to benefit vulnerable groups. Moreover, place-based studies help to address the challenges in the development of consistent factors or standard metrics that can be used to evaluate the resilience of communities to climate vulnerability and change. It is imperative to understand the vulnerability of natural resource-dependent households to climate variability and change at the local level and fills the gap in the literature.

Thus, this study examined the vulnerability of farm households to climate variability and change in different agro-ecological zones of the Gurage Zone.

## 3.2. Methodology of the Study

### 3.2.1. Sources and Methods of Data Collection

Vital information about the study was gathered from both primary and secondary data sources. Data presented in this paper were collected using a mixture of different data collection methods. A specific tool was used to respond to a series of guiding questions, and, on the opposite, a specific question was addressed by different methods: this helped particularly to triangulate information. The data were collected from March to October 2018. Data were collected from representatives of 357 sample households in the three agro-ecological zones. The questionnaire survey was used to collect a range of information on households' capital assets, farmers' perception of climate change, and vulnerability situations. Also, climatic context—including observations regarding patterns of temperature and precipitation; climate extremes; impacts of climate change, and prevailing uncertainties were asked. Moreover, twelve Key Informant Interviews (KIIs) and two Focus Group Discussions (FGDs) for each agro-ecologies were carried out to triangulate, supplement, and enrich the data.

Records of extreme events at the local level were collected from woreda Disaster and prevention office. Furthermore, meteorological data for the nearest station in each agro-ecology were collected from the Ethiopian Meteorological Agency to analyze temperature and precipitation trends and seasonal variations. The reference period for the meteorological data was between 1986 and 2016.

### 3.2.2. Methods of Data Analysis

Both qualitative and quantitative data analysis methods were employed to analyze the collected data. The quantitative data analysis was carried out using the Statistical Package for Social Science (SPSS) 24.0. The baseline household survey data were used to conduct a descriptive analysis of indicators describing the household's shock exposure, vulnerability, food security, and livelihood situation. The qualitative data analysis was used to interpret information from the FGDs and KIIs to capture contextual information about the vulnerability and it was integrated with quantitative findings to provide a more comprehensive and contextually-specific picture of livelihood vulnerability at the local level.

### Calculating the Livelihood Vulnerability Index

This study adopts the method used in Hahn *et al.* (2009) and Mohan and Sinha (2010) to calculate household livelihood vulnerability. The method is a balanced weighted average approach where each subcomponent contributes equally to the overall index even though each major component of different livelihood assets includes a different number of sub-components (Sullivan, 2002).

First, the indicators were standardized to an index by an equation:

$$IndexS_d = \frac{S_d - S_{min}}{S_{max} - S_{min}} \quad \text{--- (1)}$$

After standardizing each indicator, the sub-components were averaged using Equation (2) to calculate the value of each major component.

$$M_d = \frac{\sum_{i=1}^n IndexS_{di}}{n} \quad \text{--- (2)}$$

where  $M_d$  = one of the seven major components for the woredas ,  
 Socio-demographic (S), Health (H), Food (F), Livelihood Strategies (L) Water (W), Social Network (SN), and Natural disasters and climate variability (C); index represents the sub-components, indexed by  $i$ , and  $n$  is the number of sub-components in each major component.

Once values for each of the seven major components for each agro-ecology is calculated, they were averaged using Eq. (3) to obtain the woreda-level

$$LVI_d = \frac{\sum_{i=1}^7 W_{mi} M_{di}}{\sum_{i=1}^7 W_{mi}} \quad \text{--- (3)}$$

Expanded form

$$LVI_d = \frac{W_S S_d + W_H H_d + W_F F_d + W_L L_d + W_W W_d + W_{SN} SN_d + W_C C_d}{W_S + W_h + W_f + W_l + W_w + W_{sn} + W_v} \quad \text{--- (4)}$$

Where LVI, the LVI for the woredas, equals the weighted average of the seven major components. The weights of each major component,  $W_{mi}$ , were determined by the number of sub-components. In this study, the LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable). This analysis was done by using SPSS-24 and MS-excel worksheet.

IPCC

$$CF_d = \frac{\sum_{i=1}^n W_{mi} M_{di}}{\sum_{i=1}^n W_{mi}} \text{ --- (5)}$$

$$LVI - IPCC_d = e_d - a_d * s_d \text{ --- (6)}$$

On the bases of the analytical framework, vulnerability indicators, and measurements were identified and operationalized. Measurable indicators are identified from observations and climate change adaptation and disaster risk reduction literature as presented as follows.

**Table 3.13.1.1** Vulnerability Indicators and Unit of Measurements

Main Component	Sub-components	Unit of measurements
<b>Socio-demographic profile</b>	Dependency Ratio in the sample	Ratio
	%of female-headed household	%
	% of HH heads who has not attended school	%
	Average years of farming experience	1/years
<b>Health</b>	Average time to the nearest health center	Min
	% of HHs reported at least one chronically ill member 12 m	%
	Percentage of households without sanitary latrine/toilet	%
<b>Food</b>	Average food insufficient months	1/month
	% of HHs faced with food shortage	%
	Average crop diversity index	1/# crops
	Percent of households that do not save Crops in the last 12 months	%
<b>Livelihood Strategies</b>	Average farmland size of the household	Hectare
	Percentage of households solely reliant on agriculture as the main source of livelihood income and food	%
	Percentage of households with no solar plates for power supply	%

	Percentage of households with family members migrated outside communities	%
<b>Water</b>	% of HHs who haven't consistent water supply	%
	% of HHs utilizing natural water sys	%
	Average time to a water source	Min
<b>Social Network</b>	% of household heads who have not been head of the community in the last 12 months	%
	% of HHs who do not receive any kind of support/help from neighbors/relatives	%
	Average distance to the nearest market	Km
<b>Natural disasters and climate variability</b>	Average No. of drought, flood, and frost in the last 5 years	Count
	Mean standard deviation of monthly average precipitation 2009–2016	Mm
	Mean standard deviation of the monthly average of average maximum daily temperature 2009–2016	°C
	Mean standard deviation of the monthly average of average minimum daily temperature 2009–2016	°C

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### 3.3. Results and Discussion

#### 3.3.1. Households' Livelihood Vulnerability Index

The results revealed that the livelihood vulnerability indices of the agro-ecologies ranged from 0.35 to 0.38. Smallholder farmers in lowland agro-ecology were found to be slightly more vulnerable to climate change than the midland and highland agro-ecologies as measured by LVI, although the value of different components in the three agro-ecologies was different.

The different indices being relative values were compared for the three agro-ecologies.

**Table 3.13.1.2** Indexed sub-components, major components, and overall LVI

Main Component	Sub-components	Units	Lowland		Midland		Highland	
			Actual Value	Standardized	Actual value	Standardized	Actual value	Standardized
<b>Socio-demographic profile</b>	Dependency Ratio in the sample	Ratio	53.67	0.268	43.7	0.218	55.23	0.276
	%of female headed household	%	14.7	0.15	10.1	0.1	12	0.12
	% of HH heads who has not attended school	%	37	0.37	52	0.52	61.3	.61
	Average years of farming experience	1/years	24.6	0.4	28.5	0.36	28.2	.38
	<b>Weighted Average Score (st. dev.)</b>			<b>0.3</b>		<b>0.3</b>		<b>0.35</b>
<b>Health</b>	Average time to the nearest health center	Min	30	0.45	30	0.4	35	0.46
	% of HHs reported at least one chronically ill member 12 m	%	9.3	.09	8.7	0.08	10.5	0.1
	Percentage of households without sanitary latrine/toilet	%	33	.33	21	.21	43	.43
	<b>Weighted Average Score (st. dev.)</b>			<b>0.29</b>		<b>0.23</b>		<b>0.33</b>
	<b>Food</b>	Average food insufficient months	1/month	4	0.43	3	0.25	3.57
	% of HHs faced with food shortage	%	40	.40	36	.36	30.1	.3
	Average crop diversity index	1/# crops	2.3	0.43	1.78	0.26	1.75	.25
	Percent of households that do not save Crops in the last 12 months	%	63	.63	56	.56	48	.48
	<b>Weighted Average Score (st. dev.)</b>			<b>0.47</b>		<b>0.35</b>		<b>0.33</b>

<b>Livelihood Strategies</b>	Average farmland size of the household	Hectare	2.5	0.1	1	.23	.88	0.19
	Percentage of households solely reliant on agriculture as the main source of livelihood income and food	%	65.3	.65	77.9	.78	72.97	.73
	Percentage of households with no solar plates for power supply		73.1	.73	58.1	.58	54.4	.54
	Percentage of households with family members migrated outside communities		17.3	.17	12.1	.12	10.5	.1
	<b>Weighted Average Score (st. dev.)</b>			<b>0.41</b>		<b>0.43</b>		<b>0.39</b>
<b>Water</b>	% of HHs who haven't consistent water supply	%	61.3	.61	36.2	0.36	44.3	0.44
	% of HHs utilizing natural water sys	%	31.3	.31	32.2	0.32	29.7	0.29
	Average time to a water source	Min	60	0.47	30	.31	25	0.37
	<b>Weighted Average Score (st. dev.)</b>			<b>0.46</b>		<b>0.33</b>		<b>0.37</b>
<b>Social Network</b>	% of household heads who have not been head of the community in the last 12 months	%	81.3	0.81	83.2	.83	88	.88
	% of HHs who do not receive any kind of support/help from neighbors/relatives	%	32	.32	25.1	.25	33.2	.33
	Average distance to the nearest market	Km	6	0.21	4.5	0.18	5	.25
	<b>Weighted Average Score (st. dev.)</b>			<b>0.45</b>		<b>0.42</b>		<b>0.49</b>

<b>Natural disasters and climate variability</b>	Average No. of drought, flood and frost in the last 5 years	Count	5	0.45	3	0.27	7	0.63
	Mean standard deviation of monthly average precipitation 2009–2016	mm	48	0.367	50.05	0.38	47.13	0.37
	Mean standard deviation of monthly average of average maximum daily temperature 2009–2016	°C	1.32	0.41	0.85	0.49	0.83	0.34
	Mean standard deviation of monthly average of average minimum daily temperature 2009–2016	°C	1.6	0.24	1.12	0.5	0.96	0.29
	<b>Weighted Average Score (st. dev.)</b>			<b>0.37</b>		<b>0.41</b>		<b>0.41</b>
LIVELIHOOD VULNERABILITY INDEX			0.390		0.353		0.381	

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NB: The LVI is on a scale from 0 (least vulnerable) to 0.5 (most vulnerable)

The highland agro-ecology showed greater vulnerability in terms of the socio-demographic profile, with a weighted average score of 0.35, followed by midland (0.3) and lowland (0.3) agro-ecologies. The dependency ratio index was higher for highland than lowland and midland agro-ecologies. Highland agro-ecology showed greater vulnerability (0.61) based on the percentage of household heads with no basic education than midland (0.52) and lowland (0.37). Illiteracy hinders farmers' access to information, especially from written sources, thereby increasing their vulnerability to climatic stresses (Adu *et al.*, 2018). The study also showed midland agro-ecology was less vulnerable (0.36) on years of farming experience than lowland and midland. Furthermore, approximately 14.7%, 12%, and 10.1% of household heads in lowland, highland, and midland agro-ecologies were female-headed households, respectively.

Based on the overall health vulnerability score, highland agro-ecology was more vulnerable with a weighted average score of 0.33, whereas midland (0.23) showed less vulnerability. Highland had greater vulnerability (0.46) for the average time a household took to reach a health facility than midland (0.4) and lowland (0.45). Vulnerabilities to climate variability and change are in some cases also exacerbated by a lack of education and healthcare facilities, leading to economic impediments with long-term effects (J. Hoddinott, 2006). Access to toilet was 79% in midland, 67% in lowland, and 57% in highland agro-ecologies. Midland agro-ecology showed less vulnerability (0.08) for a household with family members with chronic illness than lowland (0.09) and highland (0.1).

The study revealed that lowland agro-ecology was found to be more vulnerable to the food component (0.47), whereas midland (.35) and highland (.33). Households in lowland agro-ecology reported that, on average, 4 months per year they had struggled to provide adequate food for their families, which was higher than highland (3.57 months) and midland (3 months) per year. Farmers reported that the difficult periods for obtaining food occurred during the off-seasons and the inter-cultivation periods. About 40% of the households in lowland reported food insecurity while 36% for midland and 30% for highland. The extent to which climate change affects people's food security situation depends on their degree of exposure to climate shocks and vulnerability to these shocks (FAO, IFAD, UNICEF, WFP & WHO, 2018). The average crop diversity index showed that almost midland and highland agro-ecologies were similar and lowland agro-ecology scores

average 0.43. 73% of households in lowland reported they didn't save crops which is higher than midland (56%) and highland (48%).

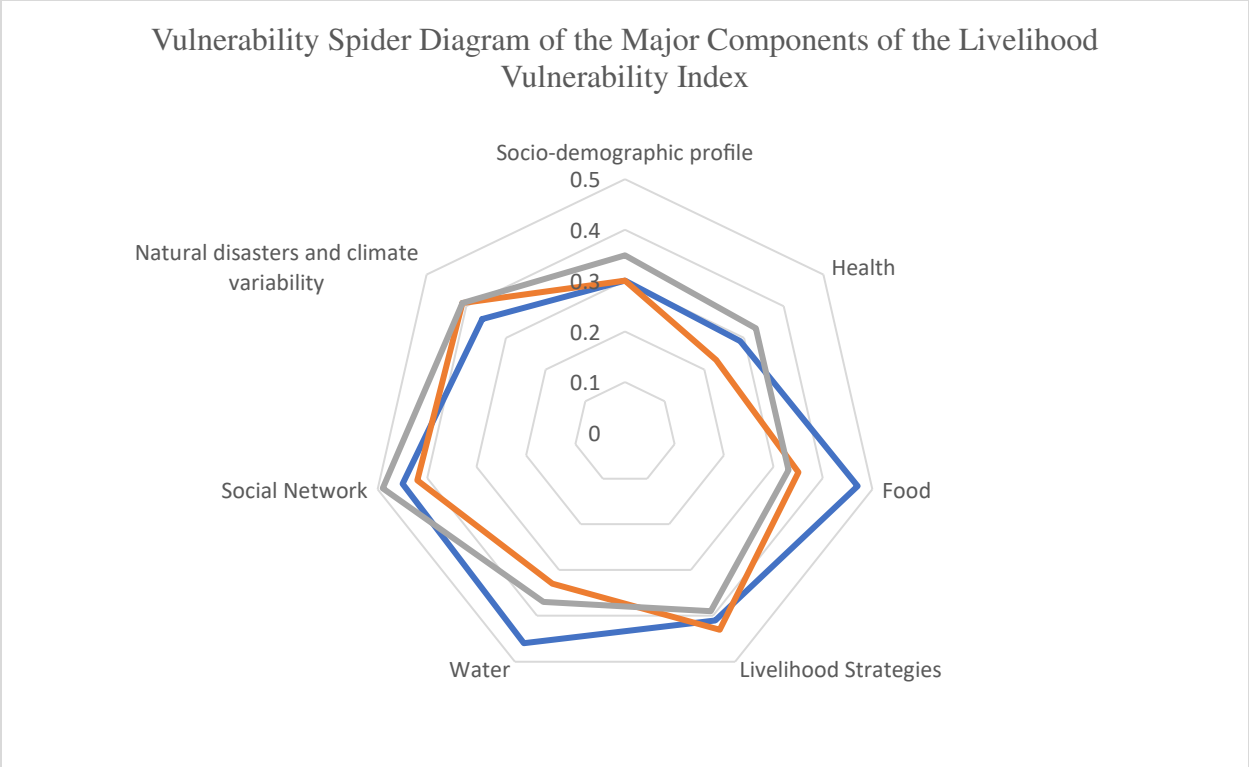
Based on the weighted average score for the livelihood strategies component of LVI, both midland (0.43) and lowland (0.41) agro-ecologies showed greater vulnerability than highland agro-ecology (0.39). The lowland agro-ecology showed a greater vulnerability based on the percentage of households with family members migrated outside communities than highland and midland agro-ecologies. Moreover, about 78 % of the households in midland dependent only on agriculture as a source of livelihood while 73 % for highland and 65% for lowland agro-ecologies. This implies that households in lowland practiced slightly diversified livelihood activities compared with highland and midland agro-ecologies. Even though other research findings suggest that the fewer agricultural activities a household engage in, the more vulnerable it is to climatic stress (Adu *et al.*, 2018), however, this research work pinpoints out that livelihood diversification was not a guarantee to reduce livelihood vulnerability. This was because of cross-cutting factors like access to credit, market, and availability of technology influence the whole livelihoods system. Additionally, livelihoods are affected differently by various climate shocks and stressors, depending on the types of livelihoods and their ability to withstand the impacts of extreme events (FAO, 2016a).

Water vulnerability in a rural area is mainly caused when the agriculture sector is highly dependent on water sources and the existing infrastructure is poor (Pandey *et al.*, 2014). However, due to a lack of irrigation facilities in the selected study areas, this study considered only water availability for domestic purposes in the water component of vulnerability. The water component of the LVI showed that lowland agro-ecology was more vulnerable (0.46) than highland (0.37) and midland (0.33). Almost there was a similar finding between households who depend more on the natural water source for household purposes. The average time taken to get a water source was higher in lowland (around 1 hour) than in midland (30 minutes) and highland (25 minutes). Also, the percentage of households who did not have a consistent water supply higher in lowland (61.3%) compared to highland (44.3%) and midland (36.2%) agro-ecologies. The majority of the households in the three agro-ecologies reported that there was a shortage in the availability of pipe and boreholes. Many respondents from lowland agro-ecology mentioned that natural springs, and

other natural water sources have dried up during the dry season. Moreover, they mentioned the availability of water in the source is also inconsistent.

In terms of the social network component of LVI, highland agro-ecology (0.49) was more vulnerable than lowland (0.45) and midland (0.42). 81.3% of the households in lowland and 83.2% in midland and 88% in highland agro-ecologies reported that they have not taken any administrative position within their community. In terms of help received from their neighbors/relatives, the finding showed higher in midland agro-ecology than lowland and highland. Well-developed and organized social networks are important for reducing household and community vulnerability to climate change (Thomas *et al.*, 2005). Farmers in lowland reported an average traveling distance of 6 km to the nearest market, whereas for highland (5 km) and midland (4.5 km).

Highland and midland agro-ecologies had the highest vulnerability in terms of the natural hazard component of LVI. The highland agro-ecology recorded greater vulnerability to the average number of natural hazard events. The mean standard deviation of monthly average minimum and maximum daily temperatures in the 8 years, with 0.24 and 0.41 for lowland, with 0.5 and 0.49 for midland and with 0.29 and 0.34 for highland, respectively. Indices recorded for the mean standard deviation of monthly average precipitation were 50.05 for midland, 48 for lowland, and 47.13 for highland.



**Figure 3.13.1.1** Vulnerability spider diagram of the major components of the LVI for the three agro-ecologies of the Gurage Zone. lowland (blue color), midland (orange color), and highland (gray color).

Overall LVI for lowland was (0.39), midland (0.353), and highland (0.381), indicating relative vulnerability of farm household’s livelihood to climate variability and change.

3.3.2. LVI-IPCC

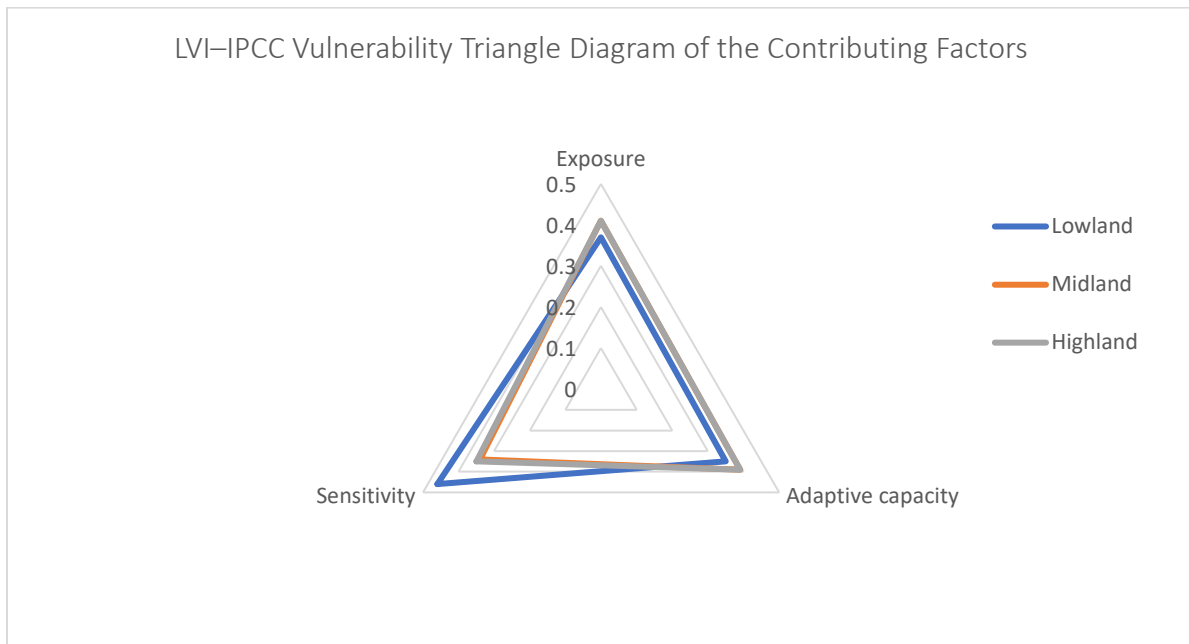
The LVI-IPCC analysis result showed (LVI-IPCC: lowland 0.0092, midland 0.0068, and highland 0.007).

**Table 3.13.1.3** LVI-IPCC contributing factors calculation for Gurage Zone.

IPCC contributing factors to vulnerability	Lowland	Midland	Highland
Exposure	0.37	0.41	0.41
Adaptive capacity	0.35	0.39	0.39
Sensitivity	0.46	0.34	0.35
LVI-IPCC	0.0092	0.0068	0.007

NB: The LVI-IPCC is on a scale from -1 (least vulnerable) to 1 (most vulnerable)

Figure 3.2 shows a vulnerability triangle, which plots the contributing factor scores for exposure, adaptive capacity, and sensitivity. The triangle illustrates that the lowland agro-ecology may be more sensitive to climate change impacts than midland and highland agro-ecologies, respectively. Similarly, based on demographics, livelihoods, and social networks, the lowland agro-ecology showed a relatively lower adaptive capacity.



**Figure 3.13.1.2** Vulnerability triangle diagram of the contributing factors of the LVI-IPCC for the three agro-ecologies of Gurage zone.

### 3.4. Conclusion and Recommendation

The study examined the vulnerability of farm households in three agro-ecological zones of Gurage Zone using the LVI and LVI-IPCC methods for assessing relative vulnerability to climate change. Although there was a difference in components relative value in different agro-ecologies of the study area, the overall LVI indicates that lowland agro-ecology was more vulnerable.

Livelihood diversification plays a key role in enhancing the resilience of household's livelihood to climate change. This finding also suggests that poorly managed livelihood activities also weaken the adaptive capacities of households and increases their vulnerability. There was food insecurity in the study agro-ecologies. The level of vulnerability, however, varies across households and agro-ecological zones. Households who are heavily dependent on natural resources to meet their food and livelihood are more affected by climate-related events. There was evidence that climate change-related disasters in the study areas weaken social capital, thereby reducing the local

community's adaptive capacities. Other factors like poor infrastructure, land shortage, population growth, lack of support by government and other concerned bodies were cited by farmers as a source of weak social capital in the area. Moreover, this study found that climate-related disasters contribute to ecosystem degradation, including increased soil erosion, declining rangeland quality, deforestation, and water shortage. Farmers reported that land management activities are necessary and crucial for improving natural resource use and management in the study areas. However, challenges prevail in terms of selecting suitable technologies and resource allocation which have likely decreased the efficiency and effectiveness of current natural resource management practices.

Households in the lowland agro-ecological zone own relatively large areas of land for agricultural activities and there is less labor migration out of the zone, therefore priority should be given to increase the productivity of agricultural production by introducing drought-resistant and improved varieties. But, in both midland and highland agro-ecological zones there is a relatively densely populated and agriculture land per household is shrinking. Besides, migration of youths to urban areas considers as a viable option to sustain their livelihood. However, this partly creates a dependency on remittances in rural areas and it is becoming increasingly difficult for migrant laborers to find employment opportunities. Thus, diversification of income in both on and off-farm agriculture and plantation of Enset (drought-resistant reserve food crop) in both midland and highland agro-ecologies were recommended as a strategy to sustain household livelihood in a changing climate condition.

This study concludes that differences in vulnerability to climate variability and change were attributable to variations in household characteristics, agro-ecological setting, lack of farm households' access to basic infrastructure, low level of diversification, and lack of available technologies. Therefore, this study calls for stakeholders to prepare context-specific intervention to reduce smallholder farmer's vulnerability to climate change and strengthen the adaptive capacity of smallholder farmers.

#### 4. Farmers' perceptions about changes in climate variables: perceived risks and household responses in different agro-ecologies, Southern Ethiopia

##### **Abstract**

Rain-fed dependent farmers in Ethiopia are highly affected by changing climate situations. Thus, this study examines farmers' perception of climatic change, related risks and adaptation practices that farmers have adopted to address the adverse pressures on livelihoods and resources in different agro-ecologies of the Gurage zone, Southern Ethiopia. A research approach involving both quantitative and qualitative methods was used. 357 household surveys were conducted with representative households. Statistical differences between the agro-ecologies in selecting adaptation strategies were measured by employing a one-way analysis of variance (ANOVA). A Post-Hoc analysis was also performed to identify the location of the variance. The study revealed, the majority of the respondents interviewed in different agro-ecologies had perceived declining precipitation and increased temperature. Similarly, respondents reported that the frequency of extreme events like drought, flood, frost, and storm had increased. A significant difference was found between agro-ecologies in farm management practices ( $F(2,354)=4.9$ ,  $P=0.008$ ). A Tukey post hoc test revealed that farm management practices were mostly practiced by the lowland and highland ( $p < 0.005$ ) agro-ecologies. Besides, there was no significant difference was found between agro-ecologies in off-farm activity ( $F(2,354)=2.0$ ,  $P=0.136$ ), and soil and water management ( $F(2,354)=4.3$ ,  $P=.115$ ) adaptation strategies. Thus, agro-ecological variation should be accounted for planning efficient local farm management adaptation interventions to contrast climate change impacts.

**Keywords:** Perceived Changes; Adaptation; Agro-ecologies; Gurage

#### 4.1. Introduction

A changing climate condition is recognized to have major implications for agriculture activities particularly in developing countries where smallholder farmers are greatly affected and are becoming increasingly vulnerable to extreme weather events (Thompson and Scoones 2009; Wheeler and Von Braun 2013; Kahsay and Hansen 2016; Altieri and Nicholls 2017). Moreover, climate change is a stressor that undermines past development gains and threatens future development efforts. Climate change manifests itself through increasing variation in the weather and expected to aggravate in the coming years (Stern 2006; IPCC 2007). Spatial difference to the adverse impacts of climate change is documented, particularly, Sub-Saharan Africa is highly vulnerable and this hampers progress towards development goals (FAO 2008; Kebede et al. 2011; Songok et al. 2011; Niang et al. 2014). Moreover, climatic projections suggest that Sub-Saharan Africa becomes drier (Boko et al. 2007; Christensen et al. 2007).

Adaptation to climate change is gaining wide recognition since climate change has substantial negative pressures on the most vulnerable (Thornton and Comberti 2013; Field et al. 2014). More than ever, agrarian peoples will need to anticipate and prepare for climate change (Nelson et al. 2007). The Inter-Governmental Panel on Climate Change (IPCC) Fourth Assessment Report stated that “for many in Africa adaptation is not an option but a necessity” (IPCC, 2014). However, smallholder farmers in Africa have a weak adaptive capacity and do not have the essential technology for adaptation to climate variability and change (Verchot et al. 2007; Lotze-Campen & Schellnhuber 2009; Nyamadzawo et al. 2013). Hence, improving farmers’ adaptive capacity and adapting the agricultural sector to the adverse effects of climate change is essential to ensure improved livelihood and food security (Adger et al. 2003; Nelson et al. 2009; Niles et al. 2015).

Scientific evidence recognizes that enhancing farmers' adaptive capacity and adaptation to climate change can potentially reduce its adverse effects, protect the livelihoods of poor farmers and reinforce any potential advantages it may bring (Seo 2011; Gandure et al. 2013; Wheeler et al. 2013). According to Maddison (2007), the adaptation process is fundamentally a function of perception and adaptation strategies. Perception strongly affects the precise nature of farmers' behavioral responses to climate-induced risks and opportunities (Adger et al. 2009; Bryan et al. 2013; Pauw 2013). Farmers first need to perceive climate change to take appropriate adaptation

strategies, misleading perceptions on the impact of climate change can cause inappropriate adjustment which in turn results to worsen vulnerability (Grothmann and Patt 2005). Understanding the perception of farmers about climate change is essential since any response to climate change events are in many cases conditional on perceptions (Gordon et al. 2013; Niles et al. 2013; Capstick et al. 2015).

Empirical findings on farmers' perception of climate change and adaptation used are useful for effective adaptation planning at the local level. Several studies have assessed farmers' perceptions and adaptation strategies employed to reduce the adverse impacts of climate change in different parts of Ethiopia (Admassie & Adenew 2008; Deressa & Hassan 2010; Di Falco & Veronesi 2014). A Study by Belay et al. (2017) revealed that from 90% of farmers who perceived climate variability, 85% of farmers used adaptation practices. Lasage et al, 2013, for example, analyze the role of small-scale sand dams as an adaptation strategy in securing water supply under climate change in Ethiopia. Amare and Simane (2017) identified soil and water conservation practices are the most widely used adaptation option in response to climate change in the Muger River sub-basin of the Blue-Nile Basin. Deressa et al. (2009) shown that farmers use several agricultural adaptation techniques such as changing the timing of operations, diversification in crop practices to climate change.

Even though previous studies on perceptions and farmers' actual adaptation at a different level and elsewhere in the country have been crucial to planning adaptation strategies at a macro level but it fails to design appropriate adaptation responses at a specific local level (Adger and Vincent 2005; Smit and Wandel 2006). Context-specific studies help to understand the role of context-specific factors in designing appropriate adaptation strategies (Eriksen et al. 2005). Moreover, aforementioned studies entirely focused on adaptation in the agriculture sector to climatic stressors, however considering only climatic stressors restrict understanding of farmers' perception of both climate and non-climate stressors which in turn affects the development of holistic climate change adaptation planning.

In general, there is little empirical evidence on farmers' perceptions and adaptation responses to a changing climate exists in Gurage Zone, and this has made it difficult in examining differential perceptions and to promote targeted interventions in different agro-ecological zones of the study

area. Thus, this paper intends to examine farmers' perceptions and the actual adaptation and coping practices adopted to abate the negative impact of climate variability and change in different agro-ecologies of the Gurage zone.

## 4.2. Materials and methods

The Gurage zone is located in the Southern Nations Nationalities and Peoples Region of Ethiopia. The livelihood source of the zone is fundamentally based on small-scale farming. Gurage has three agro-ecological zones, namely the lowland, midland, and highland agro-ecology (USAID 2005; Dendir & Simane 2019). The study used a multistage sampling method to gather data regarding the study objective.

To collect the required data, various participatory data collection methods were used. The household questionnaire was held with 357 representative households to gather data on stressors on livelihood sources, farmers' perception of climate change, effects of climate change and coping and adaptive strategies pursued by farmers to adapt to climate change and variability. Farmer's knowledge about climate change and their risk perception was assessed using survey statements which were developed in consultation with subject experts, local agricultural experts, reviewed literature, and field visits. Similarly, content validation was carried out to check the adequacy of each perception element covered. Supplementary, Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and transect walks were used.

Descriptive statistics using the latest version of SPSS were used to describe households' perceptions of climate change, related risk, and preferred adaptation strategies. Also, information from the FGDs and KIIs were integrated with quantitative data to picture-out agro-ecological based responses to climate change and variability. One-way ANOVA test was also performed to identify whether there were differences between the agro-ecologies in selecting adaptation strategies. A Post-Hoc analysis also conducted to see the location of the difference.

## 4.3. Result and discussion

### 4.3.1. Farmers' perceptions about changes in climatic attributes and extreme events

Having a clear picture of smallholder farmers' perceptions about undefined environments is essential for any adjustment to their farming activity (Rasul et al. 2012; Huong et al. 2018). A four-point Likert scale of the agreement about farmers' perceptions about climate change and related

extreme events is presented in Table 4.1. The study revealed that the majority of the respondents interviewed in different agro-ecologies had observed declining precipitation. However, the result was varied between the agro-ecological zones. Farmers in the lowland perceived more decline (81.3%) in precipitation than those in highland (69.9%) and midland (56.4%) agro-ecologies. Respondents from each of the agro-ecologies reported an increasing trend in temperature. A higher proportion (90.7 %) from the lowland perceived that temperature had increased compared to 81.9 % and 78.6% in highland and midland, respectively. Similarly, earlier studies (e.g. Gbetibouo 2009; Deressa et al. 2011; Muluneh and Demeke 2011; Mengistu 2011; Woldeamlak and Dawit 2011; Belaineh et al. 2013; Sahu and Mishra 2013; Nega et al. 2015; Limantol et al. 2016) reported that farmers perceived an increasing trend of temperature and decreased precipitation in Ethiopia. On the contrary, Sofoluwe et al. (2011) and Okonya et al. (2013) reported increased precipitation, which is inconsistent with the findings of this research.

In addition, respondents indicated that they observed an increased occurrence of extreme climate events during the most recent years. Regarding the occurrence of droughts, 86.9% of respondents from the lowland agro-ecology believed that the frequency of drought had increased, which was higher than both midland and highland agro-ecologies. Similarly, respondents in the different agro-ecologies suggested that the frequency of flood, frost, and the storm had increased (Table 4.1).

**Table 4.1** Perceptions of farmers about climate variability and extreme events based on a four-point Likert scale of agreement (Increasing (1), Decreasing (2), Stable (3), I don't know (4)).

Parameters	Perception Indicators	Trend	Respondents (%) in respective agro-ecologies		
			Lowland	Midland	Highland
Precipitation	Overall precipitation	Increasing	14.7	34.9	20.3
		Decreasing	81.3	56.4	69.9
		Stable	4	8.7	8.3
		I don't know			1.5
Temperature	Local atmospheric temperature	Increasing	90.7	78.6	81.9
		Decreasing	1.3	20.1	12.8
		Stable	8	1.3	3.8
		I don't know			1.5
Extreme Events	Frequency of drought	Increasing	86.9	4.7	41.9
		Decreasing	3.3		6.5
		Stable	9.8	95.3	51.6

	I don't know			
Frequency of storms	Increasing	52.6	72.5	60
	Decreasing	31.6	12.5	30
	Stable	12	15	10
	I don't know	3.8		
Frequency of flood	Increasing	63.6	66.7	76.9
	Decreasing	27.3	20	15.4
	Stable	9.1	13.3	7.7
	I don't know			
Frequency of frost	Increasing	85.7	58.4	75.2
	Decreasing		11.4	20.1
	Stable	14.3	30.2	4.8
	I don't know			.9

Respondents from each of the agro-ecologies reported that precipitation has become more irregular in frequency, timing, and intensity. During focus group discussions, particularly in lowland agro-ecology, participants mentioned that precipitation would typically come in June up to September, but nowadays it has been coming irregularly and water reservoirs have been drying up early in the season due to insufficient rains and high evaporation (Fig 4.1.). Drier soil conditions are resulted due to high rates of evapotranspiration, which in turn results in increased temperatures (Girvetz and Zganjar 2014).



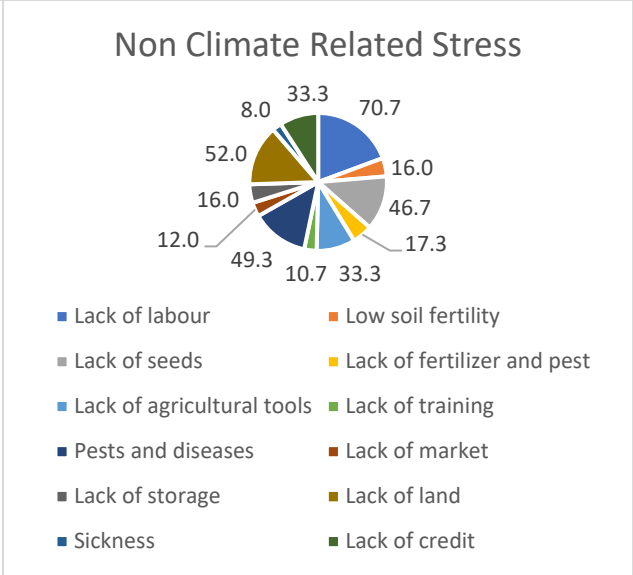
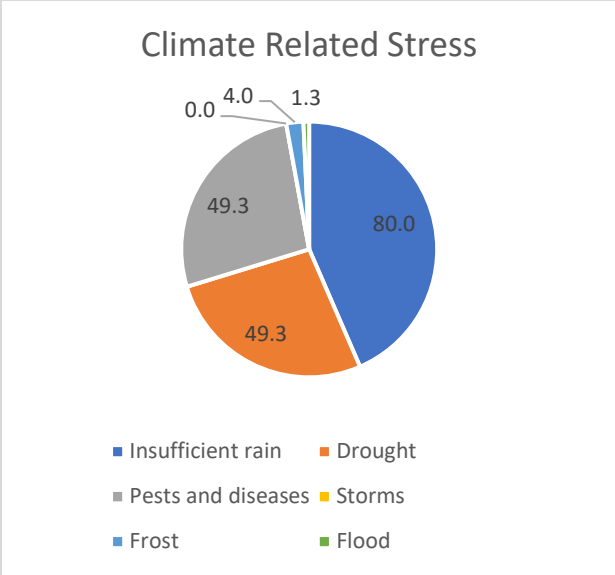
**Figure 4.1** Dry water reservoir in lowland agro-ecology

#### 4.3.2. Farmers' perception of climate change and non-climate stressors on agricultural production

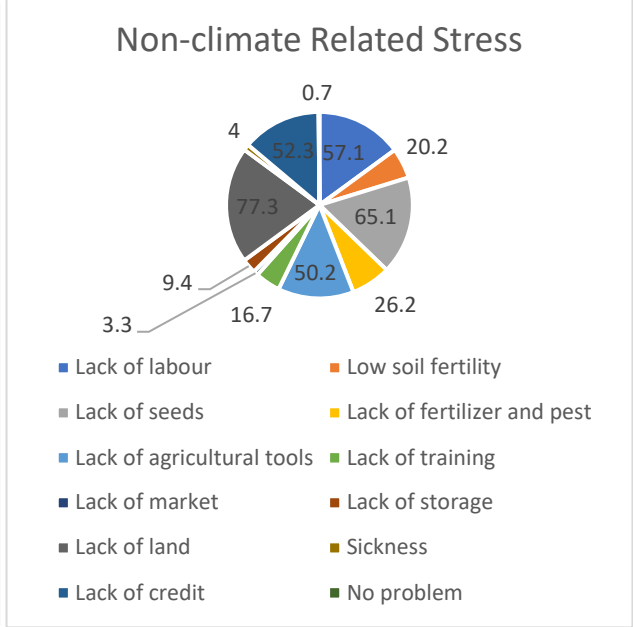
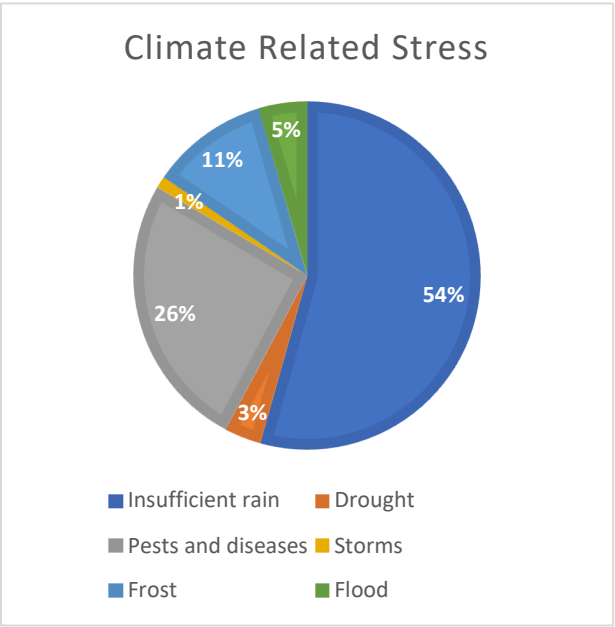
Farmers perceived that the frequency and intensity of extreme weather events have increased in different agro-ecological. During the discussion with farmers in different agro-ecologies, both climatic and socio-economic stressors were recognized as the main factors influencing agricultural activities.

Farmers in each agro-ecologies mentioned both climate and non-climate stressors which adversely affect their agricultural production, particularly on crop production (Fig 2.). Droughts, floods, frost, erratic precipitation, storms and pests, and diseases were mentioned by the respondents as main climate-related stressors that affect their crop production.

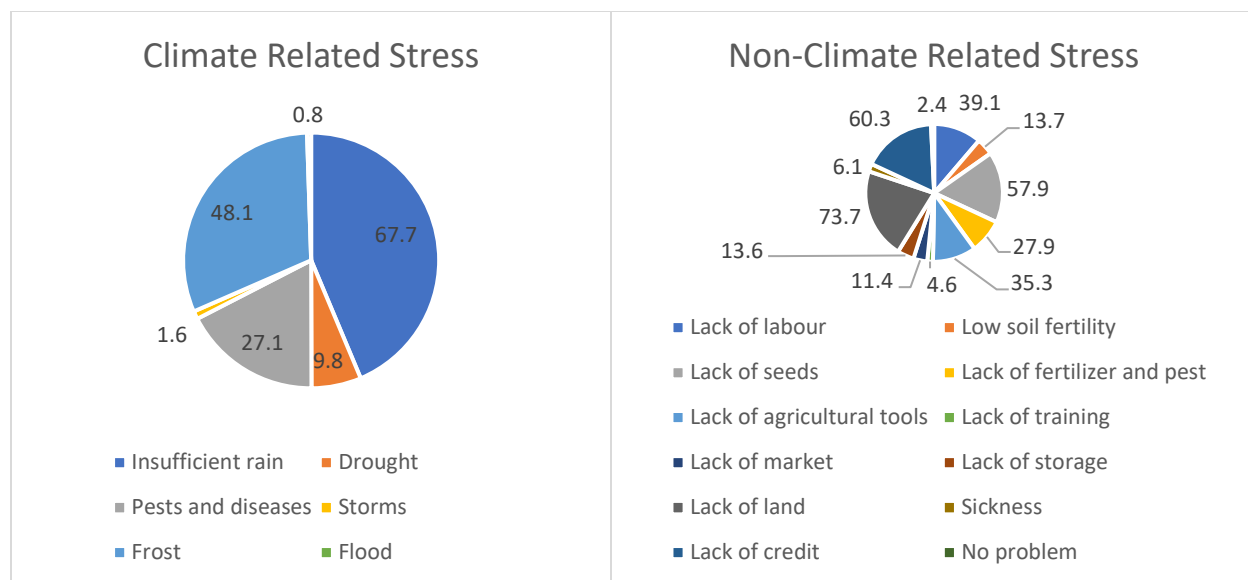
Lowland Agro-ecology



Midland Agro-ecology



Highland Agro-ecology



**Fig 2** Climate-related and Non-climate related stressors as perceived by farmers

Farmers in the lowland agro-ecology reported that erratic precipitation patterns (80%) and drought (49.3%) were the main climate-related stressors related to low crop productivity. Participants in FGD also mentioned that after the occurrence of drought they were not able to prepare their land for the next season. Moreover, lack of irrigation sighted as an aggravating factor for their vulnerability to the effect of precipitation irregularity. Erratic precipitation patterns (80%) and pest and disease (30.2%) were reported as the main climate-related stressors in the midland agro-ecology. During the FGD discussion, participants mentioned due to climate change it is difficult to predict weather conditions to perform agricultural activities using indigenous knowledge. About 67.7% and 48.1% of respondents in the household survey cited erratic precipitation patterns and frost were the main climate-related stressors in the highland agro-ecologies.

The small size of agricultural land, labor shortage, lack of agricultural inputs, and lack of credit service were reported as the major non-climatic stressors influencing agricultural activity in different agro-ecologies of the study area. Farmers in the lowland agro-ecology perceived labor shortage (70.7%), land shortage (52%), and lack of seeds (46.7%) were the major non-climate stressors. Land shortage (77.3%), lack of seeds (65.1.), and labor shortage (57.1%) were listed as major non-climate stressors in midland agro-ecology as showed in Fig. 3. Respondents in highland agro-ecology perceived that land shortage (73.7%), lack of credit (60.3%), and lack of seeds (57.9%) were among the main non-climate stressors to their farming activities. Focus group participants in different agro-ecologies attributed labor shortages to youth's migration to urban

areas. Similarly, labor shortages and lack of farm inputs were reported as socioeconomic stressors as drivers of changing agricultural practices in the study communities (Antwi-agyeyi et al. 2018).

#### 4.3.3. Adaptation measures in study agro-ecologies

The study revealed that farm households used various coping and adaptive practices to sustain and improve their livelihood against climate change effects. The adaptation strategies are grouped into farm management practices, land and water management practices, and off-farm practices which were practiced by the respondents (Table 4.2).

**Table 4.2** Adaptation strategies to climate variability and change in different Agro-ecologies

Type of adaptation measures	Respondents (%) in Respective Agro-ecologies				
	Lowland	Midland	Highland	F	Sig.
<b>Farm Management</b>				4.9	0.008
Crop selection (Grow drought tolerant/short duration varieties)	21.3	16.8	19.5		
Improved Variety	69.3	42.3	57.1		
Adjusting planting dates	10.7	7.4	7.5		
Adopt cropping densities	22.7	22.1	39.8		
Row planting	10.7	7.4	4.5		
Adopt fertilizer/pesticide	93.3	83.9	87.2		
Adopt tillage practice	1.3	0	0		
Home garden agriculture	10.7	2.7	0		
Change the herd composition	5.3	18.1	8.3		
Forage trees	14.7	3.4	2.3		
Cut & Carry system	37.3	21.5	22.6		
<b>Soil and Water Management</b>				4.3	.115
Use water harvesting technique	5.3	1.3	0		
Improve, construct or rehabilitate terraces	46.7	20.8	30.1		
Use irrigation	4	6.7	0		
Agroforestry	5.3	5.4	6		
Composting	6.7	0	0		
Reafforestation	6.7	3.4	5.3		

Area closure	8	2	0		
<b>Off-Farm Activities</b>				2.0	0.136
Handicrafts	5.3	9.4	7.5		
Pity Trade	5.3	7.4	5.3		

Farmers were using different farm management strategies as part of their response to climate change and variability. There were clear differences between the agro-ecological zones in terms of preferred farm management adaptation practices. Practicing home garden agriculture (10.7%), planting forage trees (14.7%), practicing cut & carry system (37.3%) and using improved seed variety (69.3%) was a predominantly lowland preferred strategies whilst change the herd composition (18.1%) was mostly reported by farmers from the midland agro-ecology. Adopt cropping densities (39.8%) was mostly practiced in the highland agro-ecologies. Almost there was a similarity in other farm management measures used by the respondents in different agro-ecologies in response to climate change. Table 4.2 showed that 19% of the respondents reported that they used drought-tolerant and short-duration varieties to adapt climate change in different agro-ecologies of the study zone. During different FGDs, crop diversification in the same plot or in different plots to reduce the risk of crop failure was practiced as a farm management strategy in the area. Similarly, as mentioned by officers in the Gurage zone, “growing of single crop such as maize increases the vulnerability of farmers to climate variability, though, our Development Agents has been advising farmers to grow a variety of improved crops and planting drought resistance crops like Ensete (*Ensete ventricosum*) to reduce risks of total crop failure due to climate change”. Ensete planting has been identified by both farmers and local government development experts as one of the key indigenous strategies for coping and adapting the adverse effects of climate change. Unlike many other crops, Ensete has high drought tolerance capacity and harvested at any time. Moreover, few stalks can feed a household for months whereas the residual part is used as a feed and manure. A similar finding is reported by (Belay et al. 2017).

Due to natural and economic problems, only 5% of the respondent from different agro-ecologies practiced water management strategies (Table 4.2). As mentioned by farmers in the lowland, sometimes the local reservoirs were not fill in rainy season due to irregularity in precipitation. Moreover, constructing water reservoirs at the household level and using a generator to pump water from rivers is quite expensive.

It costs more than 21,000ETB for diesel generator and related supplements to pump water from different sources. As eye-witnessed during the fieldwork, some water reservoirs were dried up in lowland areas. Construction or rehabilitation of terraces, which benefits farmers by exercising control over the environmental threat such as floods, accounts for 46.7% of the respondents in lowland agro-ecologies than 30.1% in highland and 20.8% in midland agro-ecologies. The percentage of people who practiced agroforestry, area closure, and reforestation in different agro-ecologies was very low. Exotic tree species, mainly Eucalyptus, were found in some places and planted mostly on the edges of farm boundaries and used as an income source and buffer for soil degradation. However, FGD participants mentioned that the Eucalyptus tree affects agricultural productivity since it competes for water and nutrients with growing crops. To minimize the adverse effects on crop productivity, local agricultural experts advise farmers to grow crops at a distance of 20m from the Eucalyptus.

Households, particularly the small and the landless farmers, were practicing some off-farm activities (Table 4.2). However, limited access to financial institutions was noted as a constraint. Nearby forest and bushlands were considered as a continuous source of energy for the household, agricultural land and can be an important source of income in almost all agro-ecologies of the study area. Even though the degree of adaptation practices differ, similar practices were reported by Nhemachena & Hassan (2007), Melka et al. (2015), Fahad & Wang (2018), Harvey et al. (2018), Quang et al. (2018), and Shewa et al. (2018) on how farmers adapted to climate variability and change in different areas.

One-way analysis of variance (ANOVA) was used to evaluate adaptation strategies between agro-ecologies. A significant difference was found between agro-ecologies in farm management practices ( $F(2,354)=4.9$ ,  $P=0.008$ ). The location of the difference was tested by using Tukey post hoc test. The result revealed that farm management practices were mostly practiced by the lowland and high land households ( $p < 0.005$ ) compared to midland agro-ecology. However, there was no significant difference between the lowland and highland agro-ecologies ( $p = .74$ ). However, there was no statistically significant difference was found between agro-ecologies in off-farm activity ( $F(2,354)=2.0$ ,  $P=0.136$ ), and soil and water management ( $F(2,354)=4.3$ ,  $P=.115$ ) adaptation practices.

#### 4.3.4. Coping measures in study agro-ecologies

Table 3 shows the coping strategies used by farmers to cope with climate variability and change related to adverse effects. The major coping strategies include selling livestock and reduce expenses by changing consumption (type and number of meals) accounts for 68.6% and 68% of respondents, respectively in different agro-ecologies. Further, the households reported that they used selling charcoal or firewood (49.9%) and consumed seed stock held for next season (46.1%) as coping strategies. Antwi-agyei et al., (2018) and Ahsan, 2017) also reported similar coping practices.

There were also differences between farmers in different agro-ecologies in favored coping strategies. Rented out/sold land was predominantly a lowland agro-ecology coping strategy. This was mainly because of the average farmland size of the household was higher in lowland agro-ecology (2.5ha) compared to midland (1ha) and highland (0.88ha) agro-ecology (Dendir & Simane 2019). The result also revealed that charcoal/timber sales and selling livestock were mainly practiced in both midland and highland agro-ecology. This can be due to the relative differences in forest coverage between the agro-ecologies. Additional coping measures which were practiced by the household in different agro-ecologies listed in the table below.

**Table 4.3** Coping Strategies to climate variability and change

Strategies	Respondents (%) in Respective Agro-ecologies			F	Sig.
	Lowland	Midland	Highland		
<b>Coping Strategies</b>				3.1	.046
Borrowed food/Purchased food on credit	32	34.9	36.8		
Reduce expenses by changing consumption (type and number of meals)	57.3	71.1	75.2		
Consumed seed stock held for next season	41.3	36.9	60.2		
Sold durable household goods	4	1.3	3		
Sent children to live with relatives	17.3	14.8	14.3		
Reduced expenditures on health & education	9.3	8.1	20.3		
Spent savings	42.7	17.4	15.8		

Sold livestock	50.7	72.5	82.7
Sold agricultural tools, seeds or other inputs	2.7	0	0
Sold crop before harvest	2.7	.7	0
Rented out/Sold land	14.7	4.7	7.5
Temporal migration to urban/rural areas	5.3	4	4.5
Charcoal or timber sales	38.7	59.1	51.9
Child labour	8	10.7	7.5

According to (Eriksen & Lind 2009), strategies based on short-term considerations, survival needs, and lack of information can worsen environmental degradation and thereby weaken future adaptive capacity and livelihood options. Some of the local coping measures which were taken by farmers were not efficient or appropriate for addressing long term climate-related risks. Farmers mentioned in FGD that traditional coping strategies such as selling firewood and charcoal involve indiscriminate cutting of trees which further lead to deforestation and leading to an intensification of drought. Also, food rationing and traditional asset redistribution mechanisms like Edir might be effective when there are rare climate-related extreme events like drought, as there used to be. However, if there is a frequent extreme event, continuous food rationing and traditional asset redistribution mechanisms like Edir become obsolete strategies if there are too many losses and too many people in need. The ineffectiveness of coping strategies in the face of current climate change is already visible and has been mentioned by community members and government officials in different focus group discussions.

#### 4.4. Conclusion and recommendation

This paper has explored households' perception of climate change, climatic stressors, and response strategies to adverse effects. The study result revealed that the local climate is changing and already having substantial adverse impacts on farmers' livelihood sources. Respondents in all the agro-ecological zones had perceived changes in the climate attributes and extreme events, particularly change in frequency and intensity of precipitation and an increase in mean temperature. Also, farm households perceived the impacts of climatic stressors on agricultural activities.

Subsequently, smallholder farmers endeavored to adjust their agricultural activities by adopting a number of adaptation and coping strategies. Adapted alternatives were grouped into farm management, soil and water management, and off-farm activities. Different adaptation strategies

were evaluated and significant differences were observed among agro-ecologies when choosing farm management practices. Farm management practices were mostly practiced by the lowland and highland households compared to midland agro-ecology. However, there was no statistically significant difference between agro-ecologies in off-farm and land and water management adaptation practices.

Both climatic and non-climatic stressors have serious implications for farmer's livelihood sources in different agro-ecologies of the study area. Therefore, it is important to develop a holistic climate change adaptation strategy considering both climatic and non-climate stressors to minimize vulnerability and to increase the adaptive capacity of smallholder farmers in the context of the Gurage zone.

Further, these findings suggest that because of ongoing processes of climate change, technological progress, and heterogeneity of the study area both on-farm and off-farm adaptations strategies need to consider local contexts to develop appropriate and sustainable interventions. Institutional access in terms of credit, advice, skill development training is also crucial for dealing with risks and uncertainty of climate change.

## 5. Determinants of farmers' choice of adaptation practices to climate change in Gurage Zone, Southern Ethiopia

### **Abstract**

Ethiopia has faced the adverse effects of climate change on agricultural production and rural livelihoods. To offset the adverse effects of climate change smallholder farmers, opt to adopt various adaptation measures, where decisions to adopt the options available are influenced by different factors. This study, therefore, investigates determinants of farmers choices of farm-level adaptation strategies to climate change and variability in different agro-ecologies of the Gurage zone, Southern Ethiopia. Data collected from 357 smallholder farm households were analyzed using descriptive statistics and the Multinomial Logit model (MNL). The descriptive analysis showed that most of the respondents (87.11 %) used different adaptation strategies in response to a changing climate condition. Furthermore, the result obtained from marginal estimation using the multinomial logit model showed that smallholder farmers choice of climate change adaptation measures was statistically and positively influenced by age, gender, education level, farming experience, livestock ownership, extension service, access to credit service, distance to market, and agro-ecological settings. The results indicating that decision of adaptation measures to climate change at farm household level can be context specific and for effective future intervention at farm level institutional support in terms of education, climate information, credit and extension services are essential. Furthermore, there is a need to consider agro-ecological settings to better help farmers response to climate change in the study area.

**Keywords:** Determinant, Multinomial Logit model; Climate change adaptation; Gurage

## 5.1. Introduction

Agricultural production and rural livelihoods are greatly affected by climate variability and change particularly in developing countries, though their contribution is around 10% to the annual global carbon dioxide emissions (Esham and Garforth, 2013; Comoé and Siegrist, 2015; Zhang et al., 2017). Specifically, Sub-Saharan Africa where Ethiopia is located, long-term changes in precipitation patterns, and shifting temperature is expected to affect the existing low agricultural productivity of smallholder farmers (Ringler et al., 2010). This situation mainly attributed and exacerbated by their economic dependence on climate-sensitive sectors and low adaptive capacity (Tripathi and Mishra, 2016).

Ethiopia has experienced the effects of climate change events like increasing temperature and variable precipitation along with recurrent droughts and frequent floods, which adversely affected the agricultural sector (Conway and Schipper, 2011; Karthikeyan and Tadesse, 2014). The agriculture sector supports 38.5% of Ethiopian Gross Domestic Product (GDP) and 80.2% of the population depend primarily on rain-fed agriculture for employment and, thus for food and livelihoods (CSA, 2013).

Adaptation practices are vital to reduce the long-term negative impacts of climate variability and change on agriculture. Studies recognize that the adverse effects of climate change can be reduced and offset by adaptation measures and in-turn secure food and livelihood sources for smallholder farmers (Wheeler et al., 2013). Different adaptation measures such as an adjustment in planting dates, use of drought-tolerant crop varieties, shifting to new crops, irrigation, tree planting, soil and water conservation, and others used to reduce the vulnerability of smallholder farmers to climate variability and change (Challinor et al., 2014; Ubisi et al., 2017).

However, in the process of taking adaptation actions at smallholder farmer level, there exist different factors which determine positively or negatively the selection of adaptation practices and thereby the effectiveness to overcome the adverse effects to climate variability and change (Conway and Schipper, 2011; Yibekal et al., 2013). Piya et al. (2013) emphasis that understanding determinants which affecting farmer's decision in selecting a particular adaptation measure may provide a very basis for formulating future intervention that would be more effective to address climate changes impacts at the local level.

Previous studies on adaptation to climate change have identified major farm-level adaptations determinants in the developing countries, which includes factors such as the importance of information (Kichamu et al., 2017), farm experience (Arunrat et al., 2017), education level (Maddison (2007) access to credit and access to extension (Falco et al., 2011).

Climate change adaptation measures are mostly location-specific i.e. cannot be directly adopted and implemented in different settings, and its effectiveness depends on local institutions and socioeconomic settings (De Jalon et al., 2014; IPCC, 2014). However, so far, very limited studies have identified the determinants of farm-level adaptation choices to climate variability and change in the context of the Gurage zone, Southern Ethiopia.

The effectiveness of adaptation to climate variability and change by the majority of smallholder farmers in developing countries has been low (Nyamadzawo et al., 2013; Kibue et al., 2015). Thus, understanding determinants of farmers' choice of adaptation options to climate variability and change at the household level are essential in identifying target factors to enhance the effectiveness of adaptation interventions to ensure food security and improved livelihood (Nelson et al., 2009). This study, therefore, addresses this limitation by investigating the factors that determine choice of farm-level adaptation strategies to climate variability and change in the context of the Gurage zone, Southern Ethiopia.

## 5.2. Methods

### 5.2.1. Sampling and data collection

The multi-staged sampling method was used in determining the representative respondents for each target agro-ecology of the study. Since the effects of climate change vary in different agro-ecologies, farmers' responses are also shaped by the context of the agro-ecologies. Both primary and secondary data were collected using qualitative and quantitative data collection tools. Questionnaires survey with a total of 357 representative households for each agro-ecology were undertaken. Supplementary qualitative data were collected using focus group discussions and key informant interviews.

In addition to the econometric model for the estimation of parameters, the study used descriptive statistical tools to analyze variables related to the objective. For analyzing the data, the paper used STATA software version 14 and Microsoft Excel.

### 5.2.2. Empirical model

In response to the adverse impacts of climatic change, smallholder farmers adopt different strategies as a way of adaptation. Multinomial logit (MNL) and Multinomial Probit (MNP) models are the two most frequently used analytical approaches in studying adoption decisions involving multiple choices for climate change. Both models estimate the effect of explanatory variables on a dependent variable involving multiple choices with unordered response categories (Wooldridge, 2002).

The analyses presented in this study examines important factors that determine farm households' choice of adaptation strategies in the Gurage zone to provide information on supporting policies for farm-level intervention strategies. Previous studies on determinants of adaptation at the farm household level used the discrete choice models (Hassan and Nhemachena, 2008).

MNL was the preferred econometric model for this study because the model provides a more precise (Kropko, 2007); simple estimation (Pryanishnikov and Katarina, 2003) and parameter estimates are easier to interpret (Cameron and Trivedi, 2005) than the MNP. Moreover, the MNL model permits the analysis of maximum likelihood for more than five alternatives, whereas the MNP model is infeasible for such cases (Wooldridge, 2002).

To describe the MNL model, let  $Y$  denote a random variable with values  $\{1,2,\dots,J\}$  for a positive integer  $J$  which represents the adaptation options and  $X$  set of variables which represents the factors that influence the choice of the adaptation measures. We assume that each farm household faces a set of discrete, mutually exclusive choices of adaptation measures. The MNL model for adaptation choice specifies the following relationship between the probability of choosing option  $y_i$  and the set of explanatory variables  $X$  as (Greene, 2003):

$$prob_{(y_i=j)} = \frac{e^{\beta_j x_i}}{\sum_{k=0}^J e^{\beta_k x_i}} = 0, 1, 2, \dots, J \quad (1)$$

Where  $\beta_j$  is a vector of coefficients on each of the independent variables  $X$ . Equation (1) can be normalized to remove indeterminacy in the model by assuming that  $\beta_0=0$  and the probabilities can be estimated as:

$$prob_{(y_i=j/x_i)} = \frac{e^{\beta_j x_i}}{1 + \sum_{k=1}^J e^{\beta_k x_i}} \quad j = 0, 1, 2, \dots, J, \quad \beta_0 = 0 \quad (2)$$

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

$$\ln\left(\frac{p_{ij}}{p_{ik}}\right) = x'_i(\beta_j - \beta_k) = x'_i\beta_j \quad \text{if } k = 0 \quad (3)$$

The dependent variable is therefore the log of one alternative relative to the base alternative.

The parameter estimates of the MNL model only provide the direction of the effect of the independent variables on the dependent variable; estimates represent neither the actual magnitude of change nor the probabilities. Therefore, to interpret the effects of explanatory variables on the probabilities, marginal effects are used (Greene, 2003). The marginal effect is the function of probabilities and measures the expected change in probabilities where particular adaptation choice is being made by a unit change of the independent variable from the mean (Long, 1997).

Thus, marginal effects of the explanatory variables given as:

$$\frac{\partial p_j}{\partial x_i} = p_j(\beta_j - \sum_{k=0}^J p_k \beta_k) = p_j(\beta_j - \beta) \quad (4)$$

The signs of the marginal effects and respective coefficients may be different, as the former depends on the sign and magnitude of all other coefficients.

The MNL model requires that households are associated with only their most preferred option from a given set of adaptation strategies. Unbiased and consistent parameter estimates using this model need to assume independence of irrelevant alternatives (IIA) that requires that the probability of using a certain adaptation method by a given household is independent of the probability of choosing another adaptation method.

For this study, based on the current preferred adaptation measures at the farm household level, the response measures were grouped into six. Similarly, the “No adaptation strategy” was designated

as the reference category in the MNL model. The probability of choosing a specific adaptation measure was then compared to the probability of choosing with the reference measure. Consequently, for a dependent variable with  $j$  categories, this requires the calculation of  $j - 1$  equation, one for each category relative to the reference category, to describe the relationship between the dependent variable and the independent variables.

Before running the MNL model, different statistical tests were conducted to check outliers and multicollinearity among independent variables, which affects the result of parameter estimates. Both Variance Inflation Factor (VIF) for continuous variables and Contingency Coefficients (CC) for dummy variables were used to test potential multicollinearity problems among explanatory variables. The result indicates that the mean VIFs were 2.90 which is below the threshold level of 10 or higher and this implies that there was no multicollinearity problem and the explanatory variables were fitted in the model. Similarly, descriptive statistics (tables and box plots) were used to address outliers.

The MNL model requires that households are associated with only their most preferred option from a given set of adaptation strategies. Unbiased and consistent parameter estimates using this model need to assume independence of irrelevant alternatives (IIA) that requires that the probability of using a certain adaptation method by a given household is independent of the probability of choosing another adaptation method. Therefore, Hausman's specification test (Hausman and McFadden, 1984) and the seemingly unrelated post-estimation procedure (SUEST) were used and the result indicates that the validity of the independence of the irrelevant alternatives (IIA) assumptions for the MNL model.

### **Description of the explanatory variables**

To estimate the expected influence of independent variables on the choice of adaptation options, explanatory variables were selected based on the availability of data and empirical findings. The dependent variable i.e. choice of adaptation practices from the set of adaptation measures for this study was grouped into planting trees, crop management, livestock management, soil and water conservation, and diversification to non-farm activities. The base category was 'No Adaptation'. The description of explanatory variables with their hypothesized effects against the adaptation strategies are presented below.

**Table 5.1** Description of explanatory variables.

Explanatory variable	Description	Expected signs
Age of household head	Continuous	(±)
Gender of the household head	Dummy, takes a value of 1 if male and 0 otherwise	(±)
Education	Continuous	(+)
Social capital	Dummy, 1 = yes, 0 = no	(+)
Household size	Continuous	(+)
Farming Experience	Continuous	(+)
Farm size	Continuous	(+)
Livestock ownership	Continuous	(+)
Access to extension	Dummy, 1 = yes, 0 = no	(±)
Access to credit	Dummy, 1 = yes, 0 = no	(+)
Distance from the local market (kilometres)	Continuous	(-)
Climate information	Dummy, 1 = yes, 0 = no	(+)
Local agro-ecology kola/lowland	Dummy, takes a value of 1 if Kola and 0 otherwise	(-)
Local agro-ecology Weynadega/midland	Dummy, takes a value of 1 if Weynadega and 0 otherwise	(±)
Local agro-ecology Dega/highland	Dummy, takes a value of 1 if Dega and 0 otherwise	(±)

**Age of the Household Head:** Empirical studies pointed out that age has a mixed effect on the choice of adaption strategies. Scholars like Bayard et al. (2007) and Oo et al. (2017) found that age has a positive relationship with the adoption of climate change measures. On the other hand, Falco et al. (2011) reported that farmers' decisions to adopt particular adaptation measures are significantly and negatively related to the age of the household head. Accordingly, this study hypothesizes that age influences the probability of adapting to climate change positively or negatively.

**Gender of Household Head:** Empirical studies show that sex of the household head is an important variable affecting the choice of adoption decision. A study by Ragasa et al. (2013) found that male-headed households were more likely to adopt measures to climate change since they have better access to technology and information. Other empirical studies found female-headed households more likely to adapt to climate change (Bayard et al., 2007). Thus, it is hypothesized that adaption measures at the household level are expected to differ based on the sex of the

household head since both men and women have different access to different resources which are essential for adaptation.

**Education:** Households with better education levels are believed to have a chance to better manage their farm and agricultural activities. Education increases the ability of farmers to adapt agronomic practices in response to the changing climate condition (Maddison, 2006). Also, improving education increases farmers' participation in various development and natural resource management initiatives, which thereby increases farm-level adaptation options (Deressa, et al., 2009). Thus, it is hypothesized that the likelihood of farmers to take up adaptation decisions influenced positively by the level of education.

**Social Capital:** Different forms of social capital help farmers response to climate change, particularly, it helps equip farmers with the latest information and technology. Moreover, it serves as a source of finance (Munasib and Jordan, 2011). Hence, social capital is expected to influence adaptation choices positively.

**Family Size:** Larger family size is expected to have a mixed impact on farmers' decisions to adapt to climate change. On one hand, larger family size is expected to enable farmers to take up labor-intensive adaptation measures and off-farm activities (Asfaw et al., 2012). However, the opportunity cost of labor might be low in most smallholder farming systems as off-farm opportunities are rare. On the other hand, Deressa et al. (2009) found that increasing household size did not significantly increase the probability of adaptation. In this study, we presumed that farm households with a large family size are better able to adapt to changes in climate. Therefore, farmers with large family sizes are more likely to adapt better to climate change.

**Farming Experience:** Farming experience has a positive association with the choice of climate change adaptation because it is the main source of information on climate change (Tessema et al., 2013). Likewise, a positive association between farming experience and choice of adaptation hypothesized in this study.

**Farmland Size:** the land is a major asset for agriculturally dependent livelihood and it plays a significant role in food and livelihood security. Empirical studies have found a mixed result on the correlation between farmland size and households' choice of adaptation measures to climate

change in subsistence agriculture. For instance, a positive relation reported by Fosu-Mensah et al. (2012) and a negative association between the size of farmland and farmers' choices of measures to climate change reported by Abid et al. (2016). In this study, it is hypothesized that farmers with large farm size would be more likely to adapt.

**Livestock Ownership:** Studies on determinants of climate change adaptation have shown that ownership of livestock positively affects adoption decisions (Amsalu and de Graaff, 2007). Likewise, Yirga (2007) emphasizes the traction, source of an asset, and manure role of livestock. Therefore, the paper hypothesized that livestock ownership influences the choice of adaptation positively.

**Extension services:** Enhancing information and technology flow through extension service has a paramount role in improving the productivity of agricultural activities in a changing climate, particularly in developing countries (Rahut and Ali, 2017). Similarly, a study by Amsalu and de Graaff (2007) reported a positive influence of extension service on the likelihood of adapting to climate change at the farm household level. Thus, a positive influence of extension service is expected on adaptation to climate change.

**Access to Credit Service:** Studies have shown a positive relationship between credit service and response measures to climate change (Armah et al., 2013). They reason-out that access to credit improves farmers' response to the effects of climate change. Similarly, this study hypothesizes that access to credit service increases the probability of adapting to climate change.

**Distance to market:** Proximity to market is essential for input-output exchange, information flow and it also provides non-farm employment opportunities. Several studies indicated that long distance to market places affected the choices of adaptation practices to climate change negatively (Adugna et al., 2013). Hence, the relation between distance to market and adaptation practices hypothesized negatively.

**Access to climate information** is another important determinant of the adoption of different measures to climate change. Deressa, et al. (2009) found that farmers' access to climate and weather information has a positive influence on adaptation decision making. Therefore, it is hypothesized that farmers who have access to climate and weather information have a higher

likelihood of adapting different adaptation measures to climate change to reduce the impact or take advantage of the opportunities.

**Agro-ecology:** Farmer's choice of adaptation measures to climate change influenced by the agro-ecological setting, because there is bio-physical variation between agro-ecologies (Tesfaye and Seifu, 2016). A study by Deressa et al. (2009) revealed that kola/lowland agro-ecology areas significantly reduce the probability of using different adaptation measures to climate change than other agro-ecology settings. Thus, for this study, lowland agro-ecological settings are hypothesized to influence adaptation to climate change negatively.

### 5.3. Results and discussion

Parameter estimates and marginal effects from the multinomial logit of climate change adaptation model along with their levels of significance presented in Table 5.2 and 5.3, respectively.

#### **Age of the household head**

The analysis revealed that the age of the household head had a mixed effect on the choice of adaptation practices to climate change in the study area (Table 5.3). A unit increase in the age of the household head increased the probability of using planting trees by 0.3 %, livestock management by 0.7 %, and off-farm activity by 0.1 %. However, an increase in the age of the farmers decreased the use of crop management by 0.3 % and soil and water conservation measures by 0.8 %. This result indicates that planting trees, livestock management, and off-farm activity are the preferred options among older farmers. Similar findings reported that the age of the household head had a negative influence on soil and water conservation (Atinkut and Mebrat, 2016), and a positive influence on planting trees (Deressa et al., 2009). However, Belay et al. (2017) reported a contrary finding that the probability of practicing soil and water conservation as an adaptation strategy to climate change increased as the age of the household head increase.

#### **Gender of the head of household**

The results from the marginal effects of the MNL model indicate that male-headed households were 0.4 % more likely to plant trees, 18.1 % more likely to practice soil and water conservation, and 3.2 % more likely to diverse to off-farm activities (Table 5.3). This study implies that relative

to crop management and livestock management measures, male-headed households had a higher probability to practice soil and water conservation, planting trees and diversifying to off-farm activities as an adaptation strategy to climate change. This findings are consistent with the findings of Amare and Simane (2017) in which being a female head of household had positive effects on the adoption of crop management measures; and male-headed households more likely to use soil and water conservation practices and planting trees to climate change adaptation (Gebrehiwot and Veen, 2013). Contrary claims also reported by Moroda et al. (2018) where male-headed households are less likely to adopt diversification into non-farm activities as an adaptation strategy to climate change. Therefore, preferring measures to climate change adaptation was more or less based on the context of the area under study.

### **Education**

The analyses showed that a unit increase in the number of years of schooling of the head of household resulted in a 1.3 % increase in the probability of planting trees, a 2.6 % increase in the probability of crop management, and a 1.1 % increase in the probability of livestock management as an adaptation strategy to climate change. Therefore, this implies that a positive relationship was observed and education would increase farmers' likelihood of planting trees, crops, and livestock management relative to the likelihood of using other adaptation measures. Similarly, various studies indicate that education increases the probability of using different adaptation measures to climate change at the household level (Bryan et al., 2013).

### **Social Capital**

This study found that having social capital in the respective areas encouraged farm households positively to practice planting trees (2.6 %), livestock management (3.2 %), soil and water conservation measures (0.2 %), and diversification into off-farm activity (1.3 %), while the coefficients are not statistically significant. This result implies that social capital increases the adoption of most of the options against climate change. This might be because the Gurage communities have a strong supporting system, through Equb and Edir, which can help their response to climate change. Previous studies have found that social capital, in its different forms, affected farmers' response to climate change positively (Mekonnen et al., 2017).

## **Household Size**

This study showed that more labor demanding adaptation strategies had a positive relationship with an increase in household size, this increase was not significant. An increase in the household size resulted in a 2.1 % increase in the probability of crop management and a 3.3 % increase in the probability of soil and water conservation practices to adapt to the changing climate. For other methods of adaptation, increasing household size had decreased the probability of adaptation of planting trees (1.3 %), livestock management (1.3 %), and diversification to non-farm activities (1.5 %) (Table 5.3). Thus, large family sizes could increase the use of crop management and soil and water conservation measures and reduction in planting trees, livestock management, and farmers' diversification to non-farm activities. This finding is consistent with the findings of (Abid et al., 2015) that household size had a positive influence on labor demanding adaptation measures to climate change. In contrary to the research result, other studies argued that having large family size had a positive influence on non-farm activities (Rahut and Micevska Scharf, 2012; Gautam and Andersen, 2016), where the surplus labor from the agricultural activities engaged.

**Table 5.2** Parameter estimates of the multinomial logit climate change adaptation model

Adaptation options	Planting Trees		Crop management related strategy		Livestock management related strategy		SWC related strategy		Diversification into Off-farm activity	
	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Age of the household head	.088	0.122	.012	0.786	.091*	0.064	-.0008	0.985	.039	0.399
Gender	.327	0.783	-.275	0.658	.230	0.779	1.005	0.104	.528	0.440
Education	.061***	0.000	.331***	0.000	.345***	0.000	.156**	0.039	.195**	0.023
Social Capital	.569	0.640	-.015	0.989	.455	0.705	.208	0.860	.296	0.813
Household size	-.032	0.885	.064	0.146	.080	0.690	.030*	0.091	.079	0.679
Farming experience	.105**	0.050	.118***	0.004	.051	0.243	.053	0.153	.018	0.647
Farm size	.405	0.477	.393	0.420	.512	0.325	.141	0.773	.140	0.791
Livestock ownership	.101	0.112	.342	0.194	.602**	0.034	.376	0.151	-.011	0.969
Access to extension	.111*	0.070	.685***	0.004	.174**	0.019	.400***	0.009	.127	0.460
Access to credit	2.15**	0.041	1.192**	0.023	1.377	0.182	.734***	0.006	1.556**	0.028
Access to market	.065	0.019	.219*	0.061	-.339**	0.014	-.127	0.246	.487***	0.000
Climate information	.078*	0.089	.235***	0.003	.690*	0.084	.320**	0.032	.033	0.137
Lowland agro-ecology	-2.71***	0.007	-.0565	0.937	-3.174***	0.007	.620*	0.064	.588	0.465
Midland agro-ecology	.695	0.252	-.699	0.155	.089	0.866	-.308	0.510	-.273	0.593

Base category            No adaptation

Number of obs    =    357

LR chi2(70)    =    237.70

Prob > chi2    =    0.0000

Log likelihood = -493.78545

Pseudo R2      =    0.1940

\*\*\*, \*\*, \*Significant at 1%, 5%, and 10% probability level, respectively

## **Farming experience**

The farming experience of the farmers significantly increases the likelihood of using crop management as adaptation strategies for climate change. Also, an increase in farmer's years of experience increases the probability of planting trees by 0.2 %, although the result is not statistically significant. On the contrary, the years of farming experience had discouraged significantly farmers diversification into off-farm activity as an adaptation option. These indicate that when farmers have experience in farming, crop management related strategy was preferred as an adaptation method to a changing climate condition. This positive relationship is mainly because more experienced farmers are assumed to have better knowledge about weather information and weather forecasts than to those with less experience. This result is consistent with similar studies on the effect of years of experience in agriculture on the adoption of different strategies to climate change (Obayelu et al. 2014; Quang et al., 2018).

## **Farm size**

The finding in table 5.3 shows mixed results on the role of farm size on the household's preferred measures to climate change. A unit increase in farm size increases the likelihood of using planting trees, crop management, and livestock management by 0.8 %, 3.9 %, and 2.7 %, respectively, to adapt to climate change. However, a one-unit increase in farm size resulted in a 4 % decline in soil and water conservation practices and a 1.6 % decline in diversification into off-farm activity. This result may imply that the size of farmland influences the choice of adaptation measures that farmers prefer to engage in. Earlier studies reported similar findings on the role of farm size on the probability of adopting soil and water management strategies (Adugna et al., 2013). Some contradictory arguments also reported by (Misganaw et al., 2014; Amare and Simane, 2017) where farm size has a positive influence on the adoption of soil and water conservation measures to climate change.

## **Livestock Ownership**

Livestock ownership is an important part of the farming system and livelihood security in the study area. The result of the study indicates that ownership of livestock, measured in TLU using

conversion factors (Annex 1), increased the probability of adapting to climate change. Except for diversification into off-farm activity, livestock ownership was positively related to adaptation options including planting trees, crop management, livestock management, and soil and water conservation strategies as an adaptation option. This is consistent with the findings of Gebrehiwot and Veen (2013) that ownership of livestock encouraged the probability of using different adaptation measures to climate change.

### **Extension Services**

Access to extension service had a positive and significant impact on crop management strategies. Having access to extension service increases the probability of crop management by 15.3 %, livestock management by 0.5 %, and soil and water conservation strategies by 3.6 %. However, farmers' access to extension service discouraged the adoption of diversification into off-farm activity as an adaptation strategy for climate change significantly. The result conforms with other similar studies on the positive role of extension service on climate change adaptation (Belay et al, 2017).

### **Access to credit service**

The research analyses indicated that the probability of farmers to adapt to climate change increases with higher access to credit services. Farmers with access to credit services have increased the likelihood of choosing crop management measures by 0.5 %, livestock management by 2.4%, soil and water conservation by 8.5 %, and diversification into off-farm activity by 5.5 % for adapting to climate change (Table 5.3). Thus, access to credit positively influenced most of the adaptation measures to climate change. Similarly, a study by Adugna et al. (2013), and Mulwa et al. (2017) finds a positive association between credit service and crop management adaptation practices. On the contrary, Armah et al. (2013) reported access to credit service had a negative association with crop management strategies and a positive influence on diversification into non-farm activities, respectively.

### **Distance to market**

Distance to markets influences farm household's preference to adapt to climate change. An increase in distance to market decreases the probability of using diversification into off-farm activity by 3.2 % ( $p < 0.01$ ) and livestock management by 1.1 %. These results indicate that proximity to the market is an important factor for market-based interventions for climate change adaptation. However, this study found that distance increases to market places associated with the likelihood of using planting trees, crop management, and soil and water conservation strategies to adapt to climate change. Like our findings, other researchers indicated a positive relation of further distance to the market place with crop management and land management practices and a negative association with diversification into off-farm activity, respectively (Yibekal et al., 2013; Moroda et al., 2018). Contrary results were reported by different researchers like further distance to market place discouraged rural farmers adoption of crop management and soil and water conservation measures (Aemro et al., 2012; Feleke et al., 2016).

### **Access to climate information**

Households with better access to weather forecasting may apply the adaptation strategies which suit them according to the information they obtain. This study indicates that better access to climate information increases the probability of using crop management strategies by 4.7 % and livestock management by 3.7 %, even though the results are not statistically significant. Conversely, the result shows that low access to climate information decreased the likelihood of using planting trees, soil and water conservation measures, and diversification into off-farm activity by 1.6 %, 0.8 %, and 3.5 %, respectively. In conformity, a positive correlation between access to climate information and the adoption of crop management practices to climate change is reported by Asayehegn (2012) and Phillippo et al. (2015). Contrary to this research finding on the effect of access to climate information on adopting soil and water conservation measures are reported by other researchers (Melka et al., 2015; Arragaw and Woldeamlak, 2016).

**Table 5.3** Marginal effects from the multinomial logit of climate change adaptation model

Adaptation options	Planting Trees		Crop management related strategy		Livestock management related strategy		SWC related strategy		Diversification into Off-farm activity	
	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Age of the household head	.003**	0.043	-.003	0.596	.007**	0.032	-.008	0.215	.001	0.623
Gender	.004	0.935	-.199*	0.084	-.001	0.982	.181**	0.015	.032	0.549
Education	.013***	0.009	.026***	0.008	.011**	0.041	.028**	0.011	.006	0.372
Social Capital	.026	0.557	-.062	0.509	.032	0.626	.002	0.981	.013	0.877
Household size	-.013	0.172	.021	0.365	-.013	0.362	.033	0.169	-.015	0.349
Farming experience	.002	0.372	.015**	0.012	-.001	0.539	-.004	0.399	-.006*	0.061
Farm size	.008	0.675	.039	0.310	.027	0.277	-.040	0.335	-.016	0.619
Livestock ownership	.010	0.374	.005	0.825	.031***	0.004	.016	0.549	-.043**	0.029
Access to extension	-.000	0.981	.153**	0.017	.005	0.898	.036	0.400	-.186**	0.013
Access to credit	-.118*	0.096	.005	0.940	.024	0.644	.085***	0.005	.055**	0.020
Access to market	-.008	0.260	.004	0.791	-.011	0.246	.033**	0.046	-.032***	0.004
Climate information	-.016	0.512	.047	0.219	.037	0.285	-.008	0.882	-.035	0.552
Lowland agro-ecology	-.087***	0.001	.0269	0.747	-.184***	0.000	.282***	0.002	-.045	0.343
Midland agro-ecology	.066 **	0.036	-.124**	0.041	.043	0.255	-.006	0.923	.001	0.965

\*\*\*, \*\*, \*Significant at 1%, 5%, and 10% probability level, respectively

### **Agro-ecological setting**

The preferred adaptation measures by farm households are expected to vary in different agro-ecologies since the sensitivity of livelihood systems to climate change differs among different agro-ecological settings. The analysis of the study reveals that agro-ecological settings had a negative and significant ( $p < 0.01$ ) influence on using planting trees and livestock management measures as an adaptation strategy in lowland agro-ecology comparing to the midland agro-ecological zone. Crop management measures also positively associated with lowland agro-ecology. However, a significant ( $p < 0.01$ ) increase in the probability of using soil and water conservation measures had observed in the lowland zone, compared with the midland agro-ecological setting. This is mainly because of the recurrent drought of the area. Moreover, tree planting is a preferred measure of climate change adaptation in midland agro-ecology, which is significant ( $p < 0.1$ ). However, midland agro-ecology reduces the probability of using crop management measures ( $p < 0.1$ ) and soil and water conservation by 12.4 %, and 0.6 %, respectively, compared with lowland agro-ecology. Similarly, smallholder farmers living in different agro-ecological settings are likely to practice different adaptation options against the effects of climate change (Feleke et al., 2016; Atinkut and Mebrat, 2016).

### 5.4. [Conclusion and recommendation](#)

Farmers in the Gurage zone try to use different adaptation methods in response to the adverse effects of a changing climate condition. The study result showed that around 87 % of the respondents used adaptation measures. The adaptation measures were grouped into five main adaptation methods including planting trees, crop management related strategy, livestock management related strategy, SWC related strategy, and diversification into off-farm activity. Various factors are influencing the choice of adaptation strategies. Thus, using a multinomial logit (MNL) model, the study investigates the determinant factors influencing the choice of climate-change adaptation practices at farm household level in the area.

The study showed that age, education level, and midland agro-ecology significantly and positively associated with the adoption of planting trees, whereas lowland agro-ecology, credit service significantly and negatively affected the selection. The result also revealed that adoption of crop management related strategy to a changing climate is significantly and positively affected by education level, farming experience, and extension advice and on the contrary, sex and midland agro-ecology have a negative influence. Moreover, the analysis point-out that selection of livestock management related strategy significantly and positively

influenced by age, education level, ownership of livestock, whereas negatively and significantly by lowland agro-ecology setting. A positive and significant influence of sex, household size, credit service, access to market, and lowland agro-ecology was observed on the adoption of SWC related strategy. An increasing distance to market significantly discourages the selection of diversification into off-farm activity by farm households. Similarly, farming experience, ownership of livestock, and extension advice negatively affected the adoption of diversification into off-farm activity.

In general, the study result suggests that different factors influenced the choice of climate change measures at the household level differently. Due to limited irrigation access, almost all study areas efficient water use measures like small-scale irrigation and other water harvesting methods for agriculture purpose are lacking. Therefore, future interventions have to encourage farmers to use the available water resource by providing technologies that promote the effectiveness of adoption of SWC measures and crop management measures to climate change at the farm level. In addition, since the agro-ecological setting has influenced the choice of measures taken by households, it should be considered for interventions stimulating the effectiveness of farm household choice of adaptation measures. Further, the study acknowledges the role of climate information, education, extension services, credit access, and access to markets to increase farmers' readiness to implement adaptation strategies in response to climate change and variability. Similarly, promoting off-farm income sources especially for women has to promote in reducing their vulnerability.

## 6. Chapter Synthesis

### 6.1. Major findings of the Study

Ethiopian farmers are highly vulnerable to the effects of climate variability and change and have experienced the adverse impacts on agricultural production and rural livelihoods. Similarly, several empirical studies projected climate variability in Ethiopia. Thus, to reduce and offset the adverse effects of climate change on smallholder farmer's livelihood and to improve adaptive capacity, an effective adaptation of the current farming and livelihood systems is crucial. Similarly, local-level information on scientific understanding of vulnerability, associated risks, farmers' perceptions of climate variability and change, and current adaptation capacities requires for effective adaptation planning and implementation. Despite previous scientific findings in Ethiopia which are essential for macro-level intervention, research on framing trends of extreme climate events, the current level of farmers' livelihood vulnerabilities and climate change adaptation efforts within a local context are still limited in the Gurage zone.

Thus, this study explores the vulnerability context of livelihoods in a changing climate condition and to examine responses for sustainable livelihood in different agro-ecologies of Gurage zone, Southern Ethiopia. The study covers trends in extreme climate events; livelihood vulnerability; farmers' perception of climate change and associated risks, current responses, and determinants of choices of adaptation practices in different agro-ecologies of the study area.

A mixed research design was used to address the objectives of the study. To address the objectives, different data types including cross-sectional data collected from sample households and other selected participants. In addition, gridded time series data for the period 1986–2016 was used to estimate the trend and magnitude of changes in precipitation and temperature extremes. The study used different data analysis methods, including the Livelihood Vulnerability Index (LVI) and Livelihood Vulnerability Index–Intergovernmental Panel on Climate Change (LVI–IPCC) to analyze livelihood vulnerability; the Mann–Kendall (MK) test and Sen's slope estimator to estimate the trend and magnitude of changes in precipitation and temperature extremes; descriptive statistics including one-way analysis of variance (ANOVA) and a Post-Hoc analysis to measure and identify statistical differences in adaptation strategies among agro-ecologies; and descriptive statistics and the Multinomial Logit Model (MNL) to analyze determinants of the choice of adaptation strategies among farm households.

Access to local information on trends of climate extremes is essential for developing effective adaptation strategies at the local level. Thus, the first chapter of the dissertation focused on examining trends on precipitation and temperature extremes for the period 1986–2016 in different agro-ecologies of the Gurage zone, Southern Ethiopia. The analysis revealed that there is a warming trend in different agro-ecological settings of the Gurage zone. A consistent increasing trend in the warm extremes with inconsistent magnitude and significantly decreasing trend in the cold extremes have exhibited. Regarding the intensity of temperature extremes trends (TXx, TXn, TNx, and TNn), a positive trend with an inconsistent magnitude of change was observed. The increase in the intensity of temperature extremes is accompanied by a significant increasing trend in the number of warm nights and warm days and a significant decreasing trend in cold days and cold nights was observed. The warming trend in the Gurage area is in agreement with other similar empirical findings in different parts of Ethiopia. This spatially consistent warming trend in the different agro-ecological setting indicates a changing climate condition in the Gurage zone. Due to the change in extreme events, it was observed that the frequency of extreme events like drought, frost, and storm had increased in the Gurage Zone (Chapter 4).

Spatial difference was observed in precipitation extreme indices in the Gurage zone for the period 1986–2016. A significant decreasing trend in most of the precipitation extreme indices was observed in the lowland agro-ecology of the study zone. Only the midland agro-ecology exhibited a relatively upward trend in annual precipitation trends. It was evident that a drier condition in lowland agro-ecology resulted in a recurrent drought condition which in turn affects the livelihood sources of smallholder farmers (Dendir & Simane, 2019). Similarly, the overall farm household's livelihood vulnerability indicates that the lowland and highland agro-ecologies are relatively vulnerable to climate variability and change compared to the midland agro-ecology (Dendir & Simane, 2019). In general, an increasing change in climate extremes has resulted in losses of livelihood sources. Thus, the findings of this study help in developing adaptation interventions for managing the impacts associated with extreme climate events in different agro-ecology context.

The second chapter clearly showed that there is a changing climate condition in the different agro-ecologies of the Gurage zone (Chapter 2). In line with the second chapter, the third chapter of the dissertation examined how vulnerable the livelihood source of smallholder farmers to climate variability and change in different agro-ecological setting. The livelihood vulnerability

index result revealed that there was a relative difference between the agro-ecologies of the Gurage zone in the level of livelihood vulnerability to climate variability and change. The lowland and midland agro-ecologies are relatively more vulnerable and less vulnerable to the adverse effects of a changing climate condition, respectively (Dendir & Simane, 2019). The variation in terms of vulnerability explained by the difference in household characteristics, access to infrastructure, level of livelihood diversification, and access to available technologies. Moreover, climate change-related stress and disasters, poor infrastructure, land shortage, population growth, lack of support by the government weaken adaptive capacities (Chapter 4). This finding also suggests that poorly managed livelihood activities also weaken the adaptive capacities of households and increases their vulnerability. Therefore, the vulnerability variation between agro-ecologies calls for context-specific intervention to enhance smallholders' adaptive capacity and to reduce livelihood vulnerability to climate variability and change.

In chapter four, the study examines smallholder farmers' perception of changes in climate, climatic and non-climate stressors, and responses adopted to address the adverse effects of climate variability and change in different agro-ecologies. Understanding farmers' behavioral responses to climate change are essential to support effective ex-ante decision-making to reduce the potential impacts of climate variability and change. Although there was variation in results between the different agro-ecological settings, smallholder farmers perceived a changing climate condition and an increasing frequency of extreme events in their locality. The result is in conformity with most of the trend analysis of the metrological data (Chapter 2). Farmers also mentioned different climatic and non-climatic stressors that adversely affect their sources of livelihood, particularly their farming activities. Similarly, this led to a weakened adaptive capacity and more sensitive livelihood sources to climate variability and change (Dendir & Simane, 2019). Several short- and long-term measures were adopted by farmers to cope and protect their livelihood from the negative effects of climate variability and change. Agro-ecological variation was observed in farm management practices, mostly practiced by the lowland and highland agro-ecologies. Therefore, since climate stress coupled with socio-economic and institutional stress has serious implications for farmer's livelihood sources, a holistic climate change adaptation strategy considering agro-ecological variation is required to sustain farm household livelihood.

To reduce and offset the adverse effects of climate change smallholder farmers opt to adopt various adaptation measures, where decisions to adopt the options available are influenced by

different factors. Farmers in the Gurage zone tries to use different adaption methods in response to the adverse effects of a changing climate condition (chapter 4). The adaptation measures were grouped into five main adaptation methods including planting trees, crop management related strategy, livestock management related strategy, SWC related strategy, and diversification into off-farm activity. Analyzing the determinants of farmer's choice of adaptation strategies is useful in addressing barriers to the adoption of adaptation measures. The analysis revealed that several social, economic, institutional, and environmental factors influenced the farmer's choice of adaptation decision. In general, sex of the household head, age of the household head, household size, education level, credit service, extension advice, distance to market, and agro-ecological setting affected farmers' choice of adaptation measures in response to climate variability and change. Therefore, the study output can help to support informed decisions in response to a changing climate condition at the local level.

## 6.2. Conclusions and Policy implication

Climate change and variability tend to play a dominant part in farm households' livelihood on a local scale. Therefore, contextual knowledge on climate change, risk perceptions, livelihood vulnerability, and responses and their determinants are highly demanded to improve adaptive capacity and to reduce uncertainties related to a changing climate condition at the local level. Thus, this research demonstrates the analysis of trends of climate change, vulnerability and adaptation analyses of rural livelihood systems in different agro-ecologies to support decisions on strategies for adapting climate change. Both recorded climate data and farmer's perception analysis revealed that there is a changing climate condition in different agro-ecologies of the Gurage zone. From the findings of the research work, it is concluded that smallholders' farmers are exposed to the risks associated with a changing climate condition irrespective of their agro-ecological setting. However, sensitivity is highly dependent on the existing socio-economic, physical, and agro-ecological factors. The evidence indicated that extreme climatic events adversely affect the livelihood sources of vulnerable farmers in the three agro-ecological zones of Gurage, particularly recurrent drought and frost in lowland and highland agro-ecologies, respectively. Despite adaptation measures were taken to reduce the adverse effects of climate variability and change, the substantial capability to sustain livelihood in a changing climate condition at smallholder farmers level is still a problem.

Therefore, the following recommendations were made based on the findings of the study

The findings of the research indicate that there is agro-ecological variation in the choice of farm management measures in the agricultural sector. This indicates the need for targeted interventions to each agro-ecological setting by considering other socio-economic and environmental differences into account. Therefore, based on the empirical findings, introducing drought-resistant and improved varieties to improve agricultural productivity are recommended for lowland agro-ecology since farmers own relatively large farm size and there is less youth out-migration from the agro-ecology. Whereas, due to a shortage of farmland, high out-migration of youths, and densely populated, livelihood diversification and plantation of Enset are most appropriate for the midland and highland agro-ecological zones for stimulating the effectiveness of adaptation measures to sustain and protect livelihood from the adverse effects of climate change and variability.

The research findings also revealed that the capacity and initiatives to adopt a set of adaptation measures to reduce the adverse effects of climate variability and change were undermined by the existing weak institutions. Therefore, to enhance adaptive capacity and to improve the effectiveness of interventions, institutional support like improved extension service, credit services, and market access are suggested thereby enhance resilience to climate change at the household level in the Gurage zone.

The other recommendation from the findings of the study is there is a need to improve awareness among farm households about climate change and associated issues and thereby to create climate-informed rural communities. Further, it is important to consider farmers' indigenous skills and knowledge in dealing with adverse effects of climate change when planning and implementing adaptation strategies to minimize the likely impacts of climate change in the future. This could be achieved by organizing climate campaigns, climate information centers (the existing Farmers Training Centers (FTC) can be used as climate information centers) and by improving their active participation in the decision-making process.

Access to reliable local scale climate forecast information is essential to minimize uncertainties and improve anticipation for developing sustainable adaptation measures for climate-sensitive sectors. Consequently, the emphasis should be on improving local weather recording systems, forecasting system, analysis, and implications which is important to monitor and manage the impacts associated with climate extreme events; to enhance the preparedness of farm households to extreme events, and to develop timely disaster risk response measures.

Final, it is imperative to suggest specific cross-cutting measures based on the empirical findings that help to improve adaptive capacity and thereby achieve food security and sustain livelihood against the effects of climate variability and change. Therefore, future intervention planning, and implementation should consider the promotion of water harvesting, small scale irrigation, crop diversification, use of drought-tolerant varieties, natural resource management efforts in the context of a changing climate. Further household characteristics and social capital needs to be considered when interventions are planned and implemented at the household level in response to climate change and variability. Industrialization like the establishment of an industrial zone to absorb surplus labor/unemployed youths from the agriculture sector also recommended. Final message, holistic approach to have integrated results and appropriate to each agro-ecological zone for addressing climate variability and change is recommended.

### 6.3. Future research

Based on the findings of this dissertation, the following key spatial, temporal, empirical, and practical issues are suggested for further investigation.

This study is limited to only the selected agro-ecologies covering three woredas from the Gurage administrative zone and can provide an indicative insight about the study objectives. Since there is spatial heterogeneity in terms of topography, environment, and socio-economic factors, future research can thus be needed covering most parts of the Gurage zone to assess the vulnerability context and the adaptation choices of farmers to support evidence-based planning and implementation interventions against climate change impacts.

This study only analyzed historical climate trends and extreme events of the three agro-ecological areas of the Gurage zone. However, in developing context-specific climate change adaptation measures on farming households' livelihood, consideration of future climate conditions is equally important. Further research and analysis are therefore clearly needed to project future climate conditions of the areas to design innovative interventions.

The research result is based on cross-sectional and household-level data. However, there is a temporal variation on the impact of the choice of adaptation measures on household livelihood. More robust evidence on the impact of adaptation on household livelihood sustainability is needed. To address this issue, further research on the performance of adaptation practices on livelihood resilience using panel data is recommended.

Climate adaptation efforts to reduce and cope with the adverse effect of climate change are likely to affect agricultural production thereby the food security situation of farmers. Therefore, exploring the implications of farmers' climate change adaptation strategies on food security is the other key future research area.

The Gurage people are known in their reach social capital in Ethiopia. Particularly Equib (traditional asset distribution mechanism) and remittance flow from urban areas to the rural family has several benefits to the farming households. Therefore, further studies are needed to assess the adaptation benefits of social capital to improve adaptive capacity and thereby to reduce household vulnerability to the adverse effects of changing climate conditions in the Gurage zone.

Farmers in this study reported challenges in terms of selecting suitable technologies which have likely decrease the efficiency and effectiveness of current adaptation efforts to climate change. Therefore, further research is recommended to prioritize cost-efficient adaptation options for each agro-ecology context.

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**Annex 1. The conversion factor of various classes of livestock to TLU**

<b>No.</b>	<b>Animal Category</b>	<b>Tropical Livestock Unit (TLU)</b>
<b>1</b>	Bulls/Oxen	1.42
<b>2</b>	Cows	1
<b>3</b>	Calves	1
<b>4</b>	Horses	0.8
<b>5</b>	Donkeys	0.8
<b>6</b>	Heifer	0.78
<b>7</b>	Mules	0.7
<b>8</b>	Goats	0.2
<b>9</b>	Sheep	0.2
<b>10</b>	Poultry	0.04

Source: Strock et al. (1991)

**ADDIS ABEBA UNIVERSITY**  
**SCHOOL OF GRAGUATE STUDIES**  
**CENTER OF DEVELOPMENT STUDIES**  
**DEPARTMENT OF ENVIRONMENT AND DEVELOPMENT**

Date (Eth Calendar) \_\_\_\_\_ Name of Woreda \_\_\_\_\_  
Respondent code: \_\_\_\_\_ Name of Peasant Association \_\_\_\_\_  
Enumerator Name \_\_\_\_\_ Signature \_\_\_\_\_  
Supervisor Name \_\_\_\_\_ Signature \_\_\_\_\_

## **INTERVIEW SCHEDULE**

### **I. General Instructions to Enumerators**

- ☞ Make a brief introduction to each farmer before starting any question, get introduced to the farmers (greet them the local way), the institutions you are working for, and make clear the purpose and objective of the study.
- ☞ Please ask each question so clearly and patiently until the farmer understands (gets your point)
- ☞ Please fill up the questionnaire according to the farmer's reply (do not put your own opinion).
- ☞ Please try not to use technical terms while discussing with the farmer and do not forget the local unit.

### **Objectives of the Study**

The general objective of this study is to examine the vulnerability context of livelihood and farmer's response in a changing climate condition in the Gurage Zone.

- Examine trends in daily temperature and precipitation extremes.
- Analyze the vulnerability of farm household's livelihood to climate variability and change in different agro-ecological zones.
- Examines farmers' perception of climatic change, related risks and adaptation practices to abate the negative impact of climate change and variability.
- Investigates the factors that determine choices of farm-level adaptation strategies to climate change and variability.

## 1. General Background

- 1.1. Sex of respondent:        A. Male                      B. Female
- 1.2. Age of the respondent: \_\_\_\_\_
- 1.3. Number of years the family of the household members is has lived in the village: \_\_\_\_\_
- 1.4. Marital status of the household head
- A. Married    C. Divorced
- B. Single     D. Widowed
- 1.5. Education level of the household head
- A. Illiterate    B. Read and write
- C. Primary education (1-8)                      D. Secondary education (9-12)
- E. Above secondary education
- 1.6. If the household head are literate, what is the highest level of education attended (years)? \_\_
- 1.7. Has the head of the household had some social position in the community so far?
- A. Yes    B. No
- 1.8. If yes, what is his/her position in the community?
- A. Administrative Leader                              B. Spiritual leader
- C. Elder    D. Member    E. Other specify \_\_\_\_\_
- 1.9. What is the number of household members (male and female) in different age classes (members currently living in the household and those who migrated for periods less than 12 months)?

Age class	<14 year	15-34	35-65 years	> 65 year	Total
Male					
Female					
Total					

## 2. Land Use system

- 2.1. How long it is since you started farming? \_\_\_\_\_ (in years).
- 2.2. Do you own a farmland?        A. Yes                      B. No
- 2.3. If yes, your total land size in hectare \_\_\_\_\_
- 2.4. Do you lease-in land?        A. Yes                      B. No
- 2.5. If yes, what is the area of land leased in? \_\_\_\_\_ hectare
- 2.6. Do you lease-out land?        A. Yes                      B. No
- 2.7. If yes, what is the area of land leased out (rent)? \_\_\_\_\_ hectare
- 2.8. Do you sharecrop-in land?        A. Yes                      B. No
- 2.9. If yes, how much land do you sharecrop in? \_\_\_\_\_ hectare
- 2.10. Out of your total land holding, how many hectares are allocated for:

Land-use type	Allocated in hectare
Cultivation	
Forest and woodland	
Grazing land	
Inset production	
Others (specify)	

### 3. Agriculture

#### Section A Crop production

3.1. Crops cultivated last year,

A. Did you cultivate any of the crops listed below during the last 12 months (tick if the crop is grown)?

B. How much land have you cultivated with each of these crops?

C. From which crops harvested during the last 12 months did you sell a part? (Tick 'yes' or 'no'). If crops are sold, how much money earned? And what is the main use of crop produced?

<i>Crops cultivated during the last 12 months</i>	<i>Land cultivated (in Hectare)</i>	<i>Amount produced in Quintal</i>	<b>Main use of crop</b> 1 = Consumption 2 = Sale 3 = Both
Maize			
Sorghum			
Barley			
Teff			
Wheat			
Pulses			
Irish Potatoes			
other (specify) _____			

3.2. Do you save crops in the last 12 months? A. Yes B. No

3.3. Did you have income from the listed items during the last 12 months? If yes, how much money earned?

Type	Annual Income (Birr)
Chat	
Coffee	
Eucalyptus	

3.4. What were the 5 main reasons which prevented you from obtaining a higher production during the last agricultural season? List a maximum of 5 in order of importance.

#### Codes for Reasons:

01 = Lack of seeds \_\_\_\_\_

02 = Lack of tools \_\_\_\_\_

03 = Lack of fertilizer/pesticide \_\_\_\_\_

04 = Lack of household labour \_\_\_\_\_

05 = Lack of training/technical advice \_\_\_\_\_

06 = Low soil fertility \_\_\_\_\_

07 = Pests and diseases \_\_\_\_\_

08 = Heavy rains \_\_\_\_\_

09 = No marketing opportunities \_\_\_\_\_

10 = Lack of storage facilities \_\_\_\_\_

11 = Lack of land \_\_\_\_\_

12 = Late/insufficient rain \_\_\_\_\_

13 = Ill health/ sickness \_\_\_\_\_

14 = Lack of access to credit \_\_\_\_\_

15 = lack of labour \_\_\_\_\_

15 = other (specify) \_\_\_\_\_

#### Section B Livestock production

3.5. Does the household own livestock? A. Yes B. No

3.6. If yes, how much livestock does the household currently own?

<i>Livestock</i>	<i>Size in number</i>
Oxen	
Cow	

Sheep	
Goats	
Horse	
Mule	
Donkey	
Poultry	
Bee colony	

3.7. What is the dominant grazing system in your community?

- A. Free and uncontrolled  
 B. Regulated by number of animals grazed  
 C. Regulated by number of days grazed  
 D. Regulated by season  
 E. others specify

3.8. What were the 5 main reasons which prevented you from obtaining a higher livestock production during the last agricultural season? List a maximum of 5 in order of importance.

**Codes for Reasons:**

- 01 = Shortage of feed \_\_\_\_\_  
 02 = Drought \_\_\_\_\_  
 03 = Livestock disease \_\_\_\_\_  
 04 = Lack of household labour \_\_\_\_\_  
 05 = Lack of training/technical advice \_\_\_\_\_  
 06 = No marketing opportunities \_\_\_\_\_  
 07 = Shortage of land \_\_\_\_\_  
 08 = Lack of access to credit \_\_\_\_\_  
 09 = other (specify) \_\_\_\_\_

**Section C Inset production (local food item i.e. usually produced in the southern part of Ethiopia)**

3.9. Does the household own inset? A. Yes B. No

3.10. If the household own inset, how much do you have (in number)? \_\_\_\_\_

**4. Household Facilities/Assets**

4.1. What is the main source of lighting for this house?

- A. Pan lamp  
 B. Kerosene lantern  
 C. Solar  
 D. Electricity  
 E. Generator  
 F. Firewood  
 G. Other. Specify

4.2. What is your main source of energy for cooking?

- A. Wood  
 B. Charcoal  
 C. Solar  
 D. Electricity  
 E. Kerosene  
 F. Other. Specify

4.3. What is the main source of drinking water for your household?

- A. Piped water  
 B. Public tap  
 C. Borehole with pump  
 D. Protected dug well  
 E. Protected spring  
 F. River, stream or pond  
 G. Other, specify \_\_\_\_\_

4.4 How long time it takes to the water source? \_\_\_\_\_ (in minute)

4.5. Do you have a consistent water supply? A. Yes B. No

4.6. Does your household own any of the following assets? *Only the ones which are in working conditions (which could be used today)*

<b>Productive/transport assets</b>	<b>Household assets</b>
------------------------------------	-------------------------

	Yes	No		Yes	No
Shovel/spade			Chair		
Sickle			Table		
Hoe			Sleeping mats		
Axe			Bed		
Plough			Mosquito net		
Cutlass/ Machete			Stove (gas/fuel)		
Hand tractor/power tiller			Mobile phone		
Bicycle			Radio/radio-cassette		
Motorcycle			TV		

## 5. Household Income and Expenditure

5.1. What is your main source of income, during various seasons? (Please choose all that apply and rate according to their importance 1-5)

Main Source of Income			Annual average income	Use number 5 for the most important & 1 for the least
	Yes	No		
Crop production				
Livestock				
Mixed farming				
Inset production				
Beekeeping				
Charcoal making and other forest products				
Shop/small business				
Employment in an urban area				
Remittance				
Other _____				

5.2. Did you sell any of your household assets in the last 2 years? A. Yes B. No

5.3. If yes, would you please mention the reasons why you sold the household assets?

- |                            |                           |
|----------------------------|---------------------------|
| A. To pay for school fee   | E. To buy oxen            |
| B. To pay for labor        | F. To buy grains for food |
| C. To pay for medical care | G. To buy inputs          |
| D. To pay tax              | H. others (specify)       |

## 6. Access and utilization of services

### A. Extension Services

6.1. Have you ever got the extension agents' advice (consult) on the impact of climate change and variability? A. Yes B. No

6.2. If yes, what type of advice did you get?

- |                                       |  |
|---------------------------------------|--|
| A. protection of the natural resource | E. Application of herbicides and insecticide |
| B. Seed and sowing                    | F. Early warning information                 |
| C. Application of seed and fertilizer | G. Any other (specify)                       |
| D. Weather information                |  |

### B. Access to climate-related Information

6.3. Do you have access to climate-related information? A. Yes B. No

6.4. Do you have access to early warning information? A. Yes B. No

**C. Credit service**

- 6.5. Is the credit service available in the area? A. Yes B. No
- 6.6. From where you usually borrow money?
- A. Bank D. Local organizations  
B. NGO E. Government/cooperatives  
C. Friends/relatives F. Others, Specify\_\_\_\_\_
- 6.7. By order of importance, what are the 3 main problems people face to access cash credit (write number in front of the identified cause by order of importance)
- A. Lack of banks and formal credit institution D. Need to be in group / cooperative type  
B. Formalities too complicated E. Others, Specify\_\_\_\_\_  
C. Need collateral

**D. Market Access**

- 6.8. Is there a market in this village/community? A. Yes B. No
- 6.9. If there is no market in the community, how far are the nearest market by foot and one way? (Kilo Meter) \_\_\_\_\_
- 6.10. How often is the nearest market taking place?  
A. Daily B. Weekly/Periodic C. Twice in a week
- 6.11. Do people in this village have problems to sell their agricultural products?  
A. Yes B. No
- 6.12. If yes, why?
- A. Lack of improved infrastructure B. Lack of transport  
C. Located at far distance D. others (specify)

**E. Transport**

- 6.13. Is this community accessible by vehicles? A. Yes B. No
- 6.14. If no, how far from this community is there a motorable road? In KM \_\_\_\_\_
- 6.15. Is the road that comes to (or passes by) the community impassable during certain times of the year? A. Yes B. No
- 6.16. If yes, for how many months is the road impassable during the year? \_\_\_\_\_

**F. Assistance and Food Aid**

- 6.17. Has your village/community benefited from external assistance (food or non-food) in the last 12 months? A. Yes B. No
- 6.18. What type of assistance was it?
- A. Food C. Both food and non-food items  
B. Non-food items

**G. Social Network**

- 6.19. What social linkages or networks exist? List as much as possible  
\_\_\_\_\_
- 6.20. To what extent do these links provide tangible resources and services that support livelihoods? A. None B. Very Low C. Medium D. High E. Very High
- 6.21. Does your household receive any kind of support/help from neighbors/relatives? A. Yes B. No

**7. Migration and Relocation**

7.1. Did any household member leave the community for at least 2 consecutive months in the past 12 months? A. Yes B. No

7.2. What was the reason to leave?

- |                                |                            |
|--------------------------------|----------------------------|
| A. To do agricultural work     | E. Conflict                |
| B. To do non-agricultural work | F. Health treatment        |
| C. Divorce/Separation          | G. Family reunion/marriage |
| D. Education / studies         | H. others (specify)        |

## 8. Health Service

8.1. How long time it takes to the nearest health center? \_\_\_\_\_ (in minute)

8.2. Is there a chronically ill member in your family in the last 12 months? A. Yes B. No

8.3. Do you own sanitary latrine/toilet in your compound? A. Yes B. No

**9. Climate change, and related Shocks and Stresses**

9.1. Have you ever noticed any changes in temperature? A. Increasing B. Decreasing C. No change D. I don't know E. Other, please specify\_\_\_\_\_

9.2. Have you ever noticed any changes in precipitation? A. Increasing B. Decreasing C. No change D. I don't know E. Other, please specify\_\_\_\_\_

9.3. Have you ever noticed the following conditions in precipitation? (Multiple responses is possible)

- A. Belg rain has decreased
- B. Early cessation of precipitation
- C. Precipitation during the main rainy season has decreased
- D. Precipitation starts lately

9.4. How do you perceive the main climate events (shocks or negative trends) that have affected livelihood in the community?

Climate Trends	Trend				
	Increasing	Decreasing	No change	I don't	Almost certain
Frequent storms					
Frequent droughts					
Heat Waves					
Frost					
More prolonged rains					
More intermittent/unseasonal rains					
Changed average and extreme temperatures					
Other (please add here):					

9.5.If you compare the situation in the last five years with the period before, have the hazards become more threatening in the last 5 years?

9.6. For those climate-related hazards that you have experienced, to what extent did you experience effects in your livelihood sources? (1 = Insignificant, 2 = Minor, 3 = Moderate, 4 = Major, 5 = Catastrophic)

9.7. Which household members are affected more by the hazard; men, women, or no difference between them (tick both)?

9.8.Rank the hazards given below from the least important (10) to most important (1)

Hazards	More or less threatening than in the past?		Effect of hazard on Key livelihoods				Gender effect		Hazard ranking
	Yes	No	Crop production	Livestock owned	Inset production	Other off-farm income	Man	Women	
1. Drought due to less precipitation during the rainy season									
2. Floods due to excessive precipitation									
3. Crop Damage due to excessively heavy showers									
4. Forest fire									
5. Landslide									
6. Human diseases									
7. Animal or crop pests and diseases									
8. Decreasing soil fertility									
9. Problems with input purchase or output sales									
10. High food prices									
Other: .....									

9.9. To what extent do you believe that climate change is already affecting livelihood in your community?

- A. Not at all
- B. A bit
- C. Somewhat affected
- D. Quite a lot
- E. Highly affected
- F. Don't know

**10. Food Security**

10.1. In the last 12 months, what are the periods of hardships throughout the year in which the household experienced difficulties to sufficiently feed all household members? If there were such periods, which months were difficult?

- A. Experience any difficult periods last year?                      A. Yes                      B. No
- B. Which months were difficult?

Jan	Feb	march	April	May	June	July	Aug	Sept	Oct	Nov	Dec

**11. Major strategies of the household to adapt and cope with climate change**

11.1. Do you apply the adaptation and coping measures given below to adapt or cope with climate change? If the adaptation strategy is adopted, what was the likely effect on your livelihood? Please indicate (1. None 2. Very Low 3. Medium 4. High 5. Very High)

Sectors	Adaptation Strategy	Strategy Adopted		Likely effect on Livelihood				
		Yes	No	1	2	3	4	5
	Crop selection							
	Improved Variety							
	Adjusting planting dates							
	Adopt cropping densities							

<b>Agricultural techniques (for crop and livestock)</b>	Row planting							
	Adopt fertilizer/pesticide application							
	Adopt tillage practice							
	Home garden agriculture							
	Change the herd composition							
	Forage trees							
	Cut & Carry system							
	Other.....							
<b>Soil and Water management techniques</b>	Use water harvesting technique: water collection							
	Improve, construct or rehabilitate terraces SWC							
	Use irrigation							
	Agroforestry							
	Composting							
	Other .....							
<b>Off-Farm Activities</b>	Permanent migration to other rural areas or urban areas							
	Handicrafts							
	Other.....							

<b>Forest</b>	Reforestation							
	Area closure							
	Other.....							
<b>Energy</b>	Electricity							
	Efficient stoves							
	Biogas							
	Other.....							
	Other.....							
<b>Communal pooling</b>	<b>Adaptation Strategy</b>	<b>Have you participated?</b>		<b>Likely effect on Livelihood</b>				
		<b>Yes</b>	<b>No</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
	Restore and preserve homestead or mountain forests							
	reduce erosion							
	Rangeland preservation and grazing restrictions							
	Soil erosion prevention programs (e.g. community terracing)							
	Communal water harvesting							
	Communal irrigation							
	Other .....							

	Other .....							
Coping Strategies	Adaptation Strategy	Strategy Adopted		Likely effect on Livelihood				
		Yes	No	1	2	3	4	5
	Borrowed food/Purchased food on credit							
	Reduce expenses by changing consumption (type and number of meals)							
	Consumed seed stock held for next season							
	Sold durable household goods							
	Sent children to live with relatives							
	Reduced expenditures on health & education							
	Spent savings							
	Sold or consumed livestock							
	Sold agricultural tools, seeds or other inputs							
	Sold crop before harvest							
	Rented out/Sold land							

	Temporal migration to urban/rural areas							
	Charcoal or timber sales							
	Other.....							

11.2. Please rank the most preferred adaptation strategies you used.

- \_\_\_\_\_ 1. Crop management related strategy
- \_\_\_\_\_ 2. Livestock management related strategy
- \_\_\_\_\_ 3. Soil and water conservation strategy
- \_\_\_\_\_ 4. Diversification into Off-farm activity
- \_\_\_\_\_ 5. Planting Trees
- \_\_\_\_\_ 6. I don't use any adaptation strategy

## 12. Opportunities/Enabling Conditions for Adaptation

12.1. What opportunities/ **Enabling Conditions** do you have for the implementation of different adaptation and coping measures? Some most commonly influencing factors are listed below, please indicate and rank factors from those that enable you dominantly to the least.

**Note: Use number 1 for the most influential and 5 for the least.**

- \_\_\_\_\_ 1. Awareness
- \_\_\_\_\_ 2. Available human capacity
- \_\_\_\_\_ 3. Access to early warning tools
- \_\_\_\_\_ 4. Supportive policy
- \_\_\_\_\_ 5. Mutual experiential sharing
- \_\_\_\_\_ 6. Development and dissemination of new information
- \_\_\_\_\_ 7. Institutional capacity
- \_\_\_\_\_ 8. Other (if any):
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
  - d. \_\_\_\_\_

## 13. Barriers and Limits for Adaptation

13.1. What are the major barriers which reduce the range of adaptation options, increases in the costs of implementation, or reduced efficacy of selected options concerning achieving adaptation objectives? Please rank the top 5 **Barriers** from those that affect you dominantly to the least.

- A. Existing livelihoods
- B. Farming system
- C. Inaccurate weather forecast
- D. Intensity and frequency of extreme events including storms, drought, and wind
- E. Lack of access to information or technology
- F. Lack of access to markets
- G. Lack of awareness
- H. Lack of education
- I. Unfavorable credit schemes
- J. Presence of physical barriers
- K. Rules and regulations/Lack of supportive institutions
- L. Salinity and acidity of the soil
- M. Social norms and cultural factors
- N. Transaction costs
- O. others (if any):

<b>Sectors</b>	<b>Barriers</b>
Agricultural (for crop and livestock)	1. _____ 2. _____ 3. _____ 4. _____ 5. _____
Off-Farm Activities	1. _____ 2. _____ 3. _____ 4. _____ 5. _____
Soil and Water management	1. _____ 2. _____ 3. _____
Forest	1. _____ 2. _____

	3. _____
Energy	1. _____ 2. _____ 3. _____