Addis Ababa University

College of Development Studies

Center for Rural Development

Perceptions, Vulnerability and Livelihood Adaptation of Smallholder Farmers to Climate Change: Evidence from Kembata Tembaro Zone, Southern Ethiopia

By

Yohannes Petros Lamedjo

A Dissertation Submitted to the Center for Rural Development Presented in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Development Studies (Rural Development)

Research Advisors:

Abate Mekuriaw (PhD)

Ali Hassen (PhD)

Teshale W/Amanuel (PhD)

Addis Ababa, Ethiopia

December, 2019

Declaration

I, the undersigned, declare that this PhD dissertation entitled: **Perceptions, Vulnerability and Livelihood Adaptation of Smallholder Farmers to Climate Change: Evidence from Kembata Tembaro Zone, Southern Ethiopia** is my original work and has not been presented for a degree in any other academic institution. All sources of materials used for this dissertation have been dully cited and acknowledged and the examiners comments have been incorporated.

Declared by:

Name: Yohannes Petros Lamedjo

Signature: ________________

Date: ____________________

Place: Addis Ababa University, Ethiopia

Confirmed by Major Advisor:

Name: Abate Mekuriaw (PhD)

Signature: _________________

Date: ___________________

Place: Addis Ababa University, Ethiopia

Addis Ababa University

College of Development Studies

Center for Rural Development

Perceptions, Vulnerability and Livelihood Adaptation of Smallholder Farmers to Climate Change: Evidence from Kembata Tembaro Zone, Southern Ethiopia

Yohannes Petros Lamedjo

Approved by Supervisors:

Abate Mekuriaw (PhD)	Signature ____________	Date ____________
Ali Hassen (PhD)	Signature ____________	Date ___________
Teshale W/Amanuel (PhD)	Signature ____________	Date ___________

Addis Ababa University School of Graduate Studies

This is to certify that the dissertation prepared by Yohannes Petros Lamedjo, entitled: **Perceptions, Vulnerability and Livelihood Adaptation of Smallholder Farmers to Climate Change: Evidence from Kembata Tembaro Zone, Southern Ethiopia** and submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy (Development Studies) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee:

External Examiner: ______________________________ Signature _____________

Internal Examiner: ______________________________ Signature _____________

Advisor: ________________________________ Signature _____________

Acknowledgements

First and foremost, my thank goes to Almighty God for his grace, unconditional love and guidance throughout my life. I would like to thank the supervisors for their wise supervision, comments, feedbacks and encouragements from the start to the completion of the study. I have learned and benefited from their immense supervision and research experiences and knowledge at large. This thesis is especially made possible with the generous help of my family members. Truly speaking, your unconditional love and care strengthened and supported me in many ways in the research project.

My special thanks go to interviewed farmers for openly sharing both their local knowledge and climate change experiences, and for their respect in all my contacts and household visits. I extend my gratitude to key informants, who are included from regional, zonal and district level government workers at various levels, experts, NGO officials, Development Agents (DAs), and Peasant Association officials and data collectors for their time and all-rounded support.

I finally appreciate all the people who shared valuable time and thoughts but not mentioned by name due to reasons of anonymity and commitment to research ethics.

Yohannes Petros, December, 2019.

Abstract

Climate change is one of the most complex problems of our time presenting unique challenges for societies. This study explores perceptions, vulnerability and livelihood adaptation of smallholder farmers to climate change in Kembata Tembaro zone, southern Ethiopia. More specifically it seeks to analyze perceptions of climate change, examine vulnerability of farmers, and explore adaptive capacity and adaptation strategies of smallholder farmers. The study deployed comparative case study research design to analyze perceptions, vulnerability and adaptive capacity and adaptation to climate change in five livelihood zones. Primary data were collected from 508 randomly selected farming households from five livelihood zones using structured questionnaires, interviews, focus group discussions and observations. Both qualitative and quantitative research methods are used for data collection and analysis. A modified form of Sustainable Livelihoods Framework is deployed as analytical tool to investigate vulnerability context, livelihood assets, and desired outcomes. For analysis of perception to climate change, qualitative and quantitative methods were employed. For analysis of factors influencing perceptions to climate change, binary logistic regression model was used. The result revealed that farmers' perception to climate change is expressed in terms of increase in temperature, decrease in rainfall, change in timing of rain, change in the onset and cessation of rain, and erratic rainfall pattern. The perception results is in tandem with secondary data trend analysis of temperature and rainfall from 1984 to 2017 using Coefficient of Variation, Mann–Kendall test and Sen's slope estimator, indicating that there is an increasing trend of temperature, a decreasing trend of rainfall and high rainfall and temperature variability in annual and seasonal analysis. The binary logistic regression result indicated that perception of farmers to climate change is influenced by sex, farming experience, land slope and vegetation covers. For analysis of vulnerability to climate change, Livelihood Vulnerability Index approach was used, and the result indicated that coffee livelihood zone is the most vulnerable to climate change, whereas, ginger livelihood zone is the least vulnerable to climate change. The result further revealed that local level socio-economic and biophysical conditions affect the level of exposure, sensitivity and adaptive capacity of farmers in different livelihood zones. For analysis of farmers' adaptive capacity, adaptation to climate change and factors influencing farmers' adaptation to climate change, a combination of household survey, composite adaptive capacity index and binary logistic regression model are employed. The result revealed that farmers took a number of measures to adapt to climate change within their capacity. Farming experience, access to technology, farm income, access to electricity and land slope are factors significantly influencing adaptation strategies of farmers in the study area. Efforts are needed to build the adaptive capacity and adaptation of farmers through technology transfer, enhancing their farm income and awareness creation, among others. The result leads to conclude that livelihood adaptation measures to climate change should take into account the location specific livelihood zone settings and production systems.

Key words: Climate Change, Ethiopia, Kembata Tembaro Zone, Mann-Kendall, Livelihood Zone, Perceptions, Vulnerability, Adaptation

Table of Contents

List of Tables

Title **Pages**

List of Figures

List of Abbreviations and Acronyms

Birr: Ethiopian currency.

CSA: Central Statistical Agency of Ethiopia

CELZ: Cereal and Enset Livelihood Zone

CLZ: Coffee Livelihood Zone

DA: Development Agent

DFID: Department for International Development

DRMFSS: Disaster Risk Management and Food Security Sector

DPPC/A: Disaster Prevention and Preparedness Commission/Agency

EPCC: Ethiopian Panel on Climate Change

FDRE: Federal Democratic Republic of Ethiopia

FEWSNET: Famine Early Warning Systems Network

FAO: Food and Agriculture Organization of the United Nations

FGD: Focus Group Discussion

GDP: Gross Domestic Product

GNI: Gross National Income

GTP: Growth and Transformation Plan

GLZ: Ginger Livelihood Zone

IDS: Institute of Development Studies at University of Sussex

IPCC: Intergovernmental Panel on Climate Change

KII: Key Informant Interview

LVI: Livelihood Vulnerability Index

LZs: Livelihood Zones

masl: meter above sea level

MLZ: Maize Livelihood Zone

MEFCC: Ministry of Environment, Forest and Climate Change

NGO: Non-Governmental Organization

ODI: Overseas Development Institute

PLZ: Pepper Livelihood Zone

PSNP: Productive Safety Net Programme

SLF: Sustainable Livelihood Framework

SNNPR: Southern Nations, Nationalities and Peoples Region

UN: United Nations

UNFCC: United Nations Framework Convention on Climate Change

Glossary of Terms

Belg: Short rains between February and May, in southern, north-eastern, eastern and north central parts of the country; also used to describe the secondary agricultural season.

Coffee: is a long maturity tree (3–4 years) and once planted and maintained, it can produce for decades. Depending on altitude, coffee beans are harvested between September and January. At lower elevations, harvesting takes place between October and December.

Enset: The 'false banana' tree *(Ensete ventricosum)* whose corm and stem provide a starch-based food.

Kebele: 'Locality': the smallest administrative unit, rural or urban.

Kremt (kiremt, kremti): The long rains between June and September throughout the cropping areas of the country.

Livelihood Zone/s (LZs): Geographical areas within which households (on average) share similar livelihood patterns, i.e. they have access to the same set of food and cash income sources and to the same markets.

Meher: The primary agricultural season, or main growing season, associated with the kremt rains but including long-cycle crops (sorghum, maize) which may be sown in the belg season.

Season: is defined as, meteorologically, a period when an air mass characterized by homogeneous weather elements such as temperature, relative humidity, wind, rainfall etc., dominate a region or part of a country (NMSA, 1996).

Smallholder farmers: are understood as 'farmers using predominantly family labour and for whom the farm provides their main source of income and livelihood' (Johansen, Haque, Bell, Thierfelder, & Esdaile, 2012, p. 19). They are variously described as family farmers, subsistence farmers, poor farmers and peasant farmers. Smallholder farming is characterized by small farm size, low technology and low capitalization (Hameso, 2015). In this study, the term is used interchangeably with rural households.

Teff: A very fine-sized grain (Eragrostis tef) with a grass-like stem, unique to Ethiopia as a staple.

Woreda/district: Administrative district. There are 677 woredas in Ethiopia.

Citation of Ethiopian Authors: in this study, Ethiopian authors are cited according to their established names in the literature. Some of them are commonly cited by using their last names and others using their first names. Thus, this trend is followed in this study.

Chapter One: Introduction

1.1. Background and Research Context

Climate change has become one of the core global pressing issues challenging human society whose imminent impacts on ecosystems, people and their livelihoods are often underestimated. An astonishing 17 of the 18 warmest years on record have occurred in the twenty-first century (UN, 2017). The adoption of the 17 Sustainable Development Goals by 193 countries in 2015 signalled global commitment to addressing the complex challenges facing human society in the 21st century. Delivery of the commitments made will, more than ever, require research that defines its focus through a lens of how important local drivers such as demographic changes, economic transformations and land use and land cover changes are putting increasing pressure on natural resources and challenging governments on how to meet the expectations of their populations. The World Economic Forum's (WEF) *Global Risk Report 2018* lists "failure of climate change mitigation and adaptation" as one of the three most significant global risks identified.

The inevitable nature of climate change, its unpredictable nature and the recent increasing frequency of occurrence has made it one of the core agendas of both the developed and developing world. Specifically, for the developing world, it is expected to further exacerbate the already existing burden of multidimensional poverty and well-being of billions of people. In this regard, Intergovernmental Panel on Climate Change (IPCC, 2018) stated that populations at disproportionately higher risk of adverse consequences with global warming of 1.5°C and beyond include disadvantaged and vulnerable populations, some indigenous people, and local communities who are dependent on agricultural livelihoods. According to FAO (2018), climate change is disproportionately affecting the world's poorest countries, which bear the brunt of its effects. Similarly, UNDP (2015) stated that it is the single biggest threat to development, and its widespread, unprecedented effects disproportionately burden the poorest and the most vulnerable.

It is known that many countries in Africa are poor. In relation with climate change, there is already evidence that Africa is warming faster than the global average, and this is likely to continue although the overall trend is geographically variable (Conway, 2009). According to

Bahal'okwibale (2017), half of the world's most risk-prone countries are in Africa. Similarly, Niang et.al., (2014) supports the above statement stating that Sub-Saharan Africa includes 46 developing countries that are highly vulnerable to climate change. East Africa's climate is already changing, as it is known for a drought prone, food and water insecure region with a highly variable climate. Specifically, because of geopolitical location, regional and socio-economic conditions, the Horn of Africa is one of those Sub-Saharan African countries severely hit by recurrent drought and other climate change related shocks and stressors. Oxfam Media Briefing (2017) indicated that seven of the last ten years have seen chronic droughts in East Africa due to poor or failed rains. According to IPCC (2014), climate changes are expected to increase average temperatures in the Horn of Africa at both spatial and temporal scales by up to 1.5°C in the next 20 years and up to 4.3°C by the 2080s. In this regard, Heady et.al., (2014) indicated that the increasing trends in exposure and vulnerability to disasters for the Sahel and the Horn of Africa remain constant over time and deeply worrying given the threat of further climate change.

Due to its geo-physical location and socio-economic context, Ethiopia is prone to several types of recurrent natural and human-induced disasters. According to the Index for Risk Management (INFORM) country risk profiles for 2018, Ethiopia is ranked as one of the countries with high risk. Out of 191 countries, the country ranks as the 16th most at risk country, the 39th in terms of hazard and exposure, the 11th in terms of vulnerability and 27th in terms of lack of coping capacity (Irish Aid, 2018).

Given the increasing trend of climatic risks and frequency of extreme events in Ethiopia, it is highly important to understand the human-livelihood-environment interactions in a local context by exploring the effects of climate change and variability on rural livelihood and associated adaptation efforts. It is known that Ethiopia's base of natural resources is the foundation of any economic development. Agriculture is the major source of livelihood and economy, contributing about 90 percent of the total export earnings of the country (MoFED, 2014). In this regard, a strong link has been observed between climate variations and the overall performance of the country's economy, mainly due to the direct impacts of unreliable weather on agriculture and the links to other sectors of the economy (EPCC, 2015). International Monetary Fund in its report stated that Ethiopia's macroeconomic outturn during the year 2015/16 has been adversely affected by a severe drought and the weak global environment (IMF, 2016). This leads to state that the frequency and degree of occurrence of climate variability and change and associated risks will have a negative effect on the country's economy and millions of smallholder farming communities' livelihood systems.

In 2011, the Government of Ethiopia launched its "Climate Resilient Green Economy" (CRGE) strategy, the first of its kind in Africa (FDRE, 2011). The overarching goal is to turn Ethiopia into a lower-middle-income status by 2025 through a climate-resilient green economy strategy. Building a climate resilient economy is about adapting effectively to climate change to minimize the potential damage while maximizing the potential benefits (ibid). Effective adaptation for climate change, however, must be location-specific and yet be contextualized to wider landscapes or ecosystems, taking into account diverse livelihood systems. While climate impacts can never be reduced to zero, the heavy and rising toll of weather-related disasters happening in recent years with varying in degrees and severity, exposing millions of rain-fed smallholder farmers for humanitarian assistance and emergency food aid indicate that we are not well adapted as we should be.

Currently the Government of Ethiopia is implementing the second phase of its Growth and Transformation Plan (GTP II) which is running from 2015/16 to 2019/20, aiming to continue improvements in development (FDRE, 2016). The GTP II acknowledges that in the long term, if climate change is not tackled, growth itself will be at risk. The main challenge, however, will be sustaining positive green economic growth and accelerating poverty reduction. In the process of sustaining positive green economic growth, the CRGE is a master plan, drawing from previous policies and strategies through linking with the national Growth and Transformational Plans of both the first and the second periods.

Hence to ensure CRGE, the agricultural production system, which is the economy's most climate sensitive sector has to be resilient to climate change. The sector is dominated by about 11.7 million smallholders responsible for about 95 percent of the national agricultural production (FDRE, 2011). This shows that smallholder farmers' role in the overall economy of the country is significant. In this connection, good knowledge of perception, vulnerability and adaptive capacity of smallholder farmers to climate variability and change and the potentials and constraints of the sector will play a major role in coping and adapting with the negative impacts of climate change through effective policy formulation. Ethiopia’s urgent adaptation needs stem from the country’s foremost sensitivity and vulnerability to climate change, together with its low levels of adaptive capacity.

Ethiopia’s heterogeneity in elevation has led to have different livelihood zones and production systems across the country. According to the livelihood zone classification, there are 175 different livelihood zones in Ethiopia and 40 in SNNPR (DRMFSS, 2010). The study area, Kembatta Tembaro zone, covers five main livelihood zones, namely: Kambata Cereal and Enset LZ, Badewacho-Alaba maize LZ, Hadero-Ginger LZ, Kedida-Badewacho Coffee LZ and Alaba-Mareko Lowland Pepper livelihood zones. The degrees, therefore, of vulnerabilities to climate change of different livelihood zones and farming systems vary accordingly. In this regard, little has been done in densely populated enset-farming system regarding assessment of perceptions, vulnerability status and adaptation to climate variability and changes at lower scale level. Hence, with diverse livelihood zones and farming system, vulnerability assessment, building adaptive capacity and adaptation to climate change should be flexible and inclusive, focused to locally appropriate situations facilitating for communities and institutions to prepare for inevitable climate changes and adapt to vulnerability contexts. This leads to integrate researches on perceptions, vulnerability, adaptive capacity and adaptation to climate change based on the context of a given livelihood zone and farming system.

1.2. Statement of the Problem

It is known that the changing climate is threatening the sustainability of the livelihoods of billions of people across the world. It is from this reality that in recent years, there is an increasing interest in using livelihood analysis as a ‘lens’ through which to view a number of issues pertaining on how to ensure sustainable livelihood. It is to be noted that livelihood framework offers a comprehensive approach to conceptualize about how people make their living. In livelihood approach, developing an understanding of what comprises a livelihood, what strategies are pursued in good and bad times in relation with climate change and how to make the livelihood sustainable are key elements. In this regard, Seamana et.al., (2014) indicated that livelihood-based approach provides logic to know livelihoods, how they are affected by changes and shocks, and how households cope and adapt with the challenges to reduce vulnerability. Similarly, UN (2016) noted that better understanding of the impact of climate change on lives and livelihoods will lead to better-informed policymaking. And policies designed to close the development gaps that leave people vulnerable to climate hazards are sound development policies and are essential to reducing the risk posed by climate change (ibid).

According to UN (2016), climate scenarios predict unambiguously that tropical areas will be at higher risk of climate hazards, including countries in Africa. In Ethiopian context, scientific reports indicate that the country has become warmer over the past century and expected further to get warming over the next century at unprecedented rates. The country's climate is influenced by diverse topographical and agro-ecological settings as well as multi-decadal global oscillations, complicating long-term forecasting and climate models for rainfall (Cochrane and Singh, 2018). Despite the fact that Ethiopia has a long history of drought, it remains the country's leading major hazard, especially the recent experience shows an apparent marked increase in area coverage and frequency, almost becoming every year's development agenda. Similarly, Mahoo et.al., (2015) stated that the frequency and severity of climate change related shocks in Ethiopia have increased in recent years.

Studies suggest that losses from climate change will be concentrated in Ethiopia's humid highlands. This area is densely populated and highly cultivated (World Bank, 2010; OECD, 2013). In this regard, Diao (2010a) argues that in some regions of Ethiopia, notably the highlands, pressures on land resources have led to an expansion of the agricultural frontier into forest areas and steep slopes. This has accelerated environmental degradation and made agricultural production very vulnerable to weather shocks. In connection with future projections, Niang et.al., (2014) and IPCC, (2013) indicated that there will be increases in annual rainfall, but these increases are largely due to increasing rainfall in the October-December period in southern Ethiopia (McSweeney, et.al., 2010). However, seasonal rainfall projections, according to FDRE, Ministry of Environment and Forest (2015), indicate a significant decline in the Belg season (short rainy season in February/March-April/May) across the south-central and eastern parts of the country. This may have far reaching adverse implications for smallholder farmers who rely on the Belg season rains for their livelihoods.

Projection for the Kiremt rains (the long rainy season in June/July-August/September) indicates large rainfall declines across the western and southern parts of the country. This has serious socio-economic implications as the southern and western regions include the densely populated long cycle crop growing areas of the country (ibid). This situation calls for the need of smallholder farmers to prepare for unavoidable climate change and adapt their livelihood systems with the changing trends of it. Hence, reducing vulnerability to climate change risks and shocks as well as increasing adaptive capacity and adaptation is key for Ethiopia as climate related disasters are expected to increase in the future. In this regard, the recent preparation of the National Adaptation Plan (NAP) of the country (FDRE, 2019), stresses the need for advancing adaptation research and development in the area of climate change.

It is known that livelihood researches seek to understand changing combinations of modes of livelihood in a dynamic and historical context, which provides a sampling frame for livelihood baseline development. Even though there is an increasing surge of researches in the area of vulnerability and adaptation to climate change in Ethiopia in recent years, however, lack of understanding of perceptions, vulnerability, adaptive capacity and adaptation to climate variability and change in local livelihood zone-based context is creating gaps for identifying the root causes for building resilient livelihood. The studies conducted mainly are based on agro-ecology approach (Deressa et.al., 2011; Tazeze et.al., 2012; Tesso et.al., 2012; Tesso et.al., 2012b; Balew et.al., 2014; Debalke, 2014; Teshome, 2016; Simane et.al., 2016; Hameso, 2018; Asrat and Simane, 2018; Belay et.al., 2017). As Ethiopia is highly heterogeneous nation (e.g., in elevation, climatic conditions, agricultural production, cultural practices and other socio-economic factors), this has led to have different livelihood zones and farming systems across the country. Capturing this variation in assessing perceptions, vulnerability and the differential adaptive capacity and adaptation strategies to climate change are essential for laying the basis for developing and prioritizing different adaptation responses for different vulnerable groups.

The study area, Kembata Tembaro zone, is one of the areas with enset-based farming system, characterized with high population pressure, serious land shortage, continuous cultivation, deforestation and land degradation. A small-scale agriculture with traditional technology and subsistence production is typical of the area. It belongs to one of the most densely settled areas in Ethiopia, with a population density of 665 per square kilometer (CSA, 2013). Due to a very high population growth, there is shrinkage of cultivable land per household. In most peasant associations, the land holding size for households is less than a quarter of hectare. Furthermore, the arable land potential of the zone is seriously threatened by erosion, thereby aggravating the population pressure on land. With this trend of population pressure and land fragmentation, ensuring resilient livelihood system becomes a critical question. For ensuring resilient livelihood system, identifying the livelihood profiles and production system of the local communities becomes a prerequisite, as the concept of vulnerability is dynamic, context specific and multidimensional in nature.

The zone formerly was capable to absorb and support a high and growing population pressure and known for relatively being resilient for droughts, climate variability and change. According to Dessalegn, (1996: 92, 2007: 13), even during the 1974 famine that affected most parts of the country, 'the enset growing highlands of Kambata, Sidama and Guraghe did not face the famine'. However, since the late 1990s onwards, the conditions have been changing in a radical way, undermining the resilience of the livelihood system making vulnerable to various shocks resulting from intertwined environmental, economic and social factors (Handino, 2014). Hence, with the increasing trend of population pressure, land fragmentation, and subsequently placing stress on fragile ecosystems coupled with climate variability and change has exposed smallholder farmers to lead insecure livelihoods, to the extent of even disruption of production systems that has been established for many decades.

Unless proper livelihood zone-based assessments on vulnerability and adaptation strategies are implemented, it will have far reaching environmental, social, economic and political consequences. This calls for the need to raise livelihood zone based systematic inquiry of analyzing vulnerability of smallholder farmer's to climate change and the adaptation strategies practiced by them. This study fills the knowledge gap by analyzing the perceptions, vulnerability and adaptation strategies of smallholder farmers' to climate change on livelihood zone-based approach in Kembatta Tembaro zone, southern Ethiopia.

1.3. Research Objectives and Questions

1.3.1. Objectives of the Study

General Objective

The overall objective of the study is to explore smallholder farmers' perceptions, vulnerability and their adaptation strategies to climate change based on livelihood zone approach in Kembatta Tembaro Zone, Southern Ethiopia.

Specific Objectives

Specifically, the study intends to:

- assess smallholder farmers' perceptions to climate change and their perceived effect on their livelihoods;
- investigate the extent of vulnerability of smallholder farmers to climate change in different livelihood zones; and
- investigate smallholder farmers' adaptive capacity and the factors that hinder their adaptation strategies pursued in response to climate change in different livelihood zones.

1.3.2. Research Questions

The study intends to answer the following questions:

1. How is climate change perceived by smallholder farmers in the study areas? How do farmers perceive long-term precipitation and temperature changes?
2. Why do smallholder farmers are vulnerable to climate change in different livelihood zones? To what extents are smallholder farmers vulnerable to climate change and what factors influenced their vulnerability in the study area? and
3. How do smallholder farmers adapt to climate change? What strategies are being practiced by smallholder farmers to cope and adapt to climate change and the barriers that hinder farmers' adaptation strategies to climate change?

1.4. Scope and Limitations of the Study

1.4.1. Scope of the Study

It is known that terms like climate change, vulnerability and adaptive capacity/resilience are becoming the recently catchy words in the developing world lexicon. Describing vulnerability and adaptive capacity, socio-economic and biophysical conditions of smallholder farmers in their local contexts is difficult as the concepts are dynamic and multidimensional in nature, which deserves systematic exploration of contributing as well as hindering factors. The scope of this study is delimited by geography, farming system, livelihood zones and also thematically. With regards to geography, the study is undertaken in Kembatta Tembaro Zone, located in the north-eastern part of SNNPR (DPPC, 2005b). It comprises seven *woreda*s, namely: Kedida Gamela, Damboya, Angecha, Doyogena, Kacha Bira, Hadero-Tunto and Tembaro with a total area of 1,356 sq. km. Regarding farming system, smallholder farmers in the study area practice mixed farming system, with Enset dominantly grown around the homesteads by most smallholder farmers in Cereal and Enset, Kedida Badewacho Coffee and Hadero-Tunto Ginger livelihood zones (in highland and mid-land agro-ecological zones). The study focused on five Livelihood Zones, namely; *(i) Kambata Cereal and Enset LZ, (ii) Kedida-Badewacho Coffee LZ, (iii) Hadero-Ginger LZ, (iv) Badewacho-Alaba Maize LZ,* and *(v) Alaba-Mareko Lowland Pepper LZ.* Even though the study is limited to a specific area with different livelihood zones, its findings offer useful understanding of similar contexts in other areas in bordering administrative zonal and regional level, as livelihood zones do not normally follow political administrative boundaries.

In terms of response measures to climate change, the scope of the study is confined to coping and adaptation rather than mitigation to climate change and households were taken as unit of analysis. The reason to prioritize coping and adaptation as an important and urgent policy imperative and research agenda rests with the fact that mitigation efforts to reduce greenhouse gases take time and are often fraught with complicated and protracted international negotiations. This study, therefore, confined itself to the assessment of vulnerability of smallholder farmers' to climate change across different livelihood zones and their coping and adaptation strategies for building resilient livelihoods.

1.4.2. Limitations of the Study

Undertaking an adequate assessment of perception, vulnerability, adaptive capacity and adaptation to climate change demands multidimensional and context specific analysis. The complexity of climate change, its causes and effects and the uncertainties associated with future projections remains a challenge, particularly at local livelihood zone level. The reality of climate change, however, is alarming requiring thoughtful and sensitive facilitation to ensure that better understandings among various stakeholders are ensured. Sample size determination from the distribution of population across the five LZs is another limitation of the study as the study adopted a formula that considered household population size than variability of the population. This combined with resource constraints were relevant to mention limiting the scope and depth of analysis of the study.

The concept of vulnerability itself has a future oriented perspective, dynamic and seasonal/timing value of analysis, making it difficult to set a single and best formula for analysis. In addition to this, finding reliable and recent data on multidimensional aspects of households, including household asset, remittance, means of income earning, consumption/expenditure patterns, institutional roles (may be politicized) social protection schemes and recovery mechanisms are some of the possible issues that were taken into account in this study.

1.5. Significance of the Study

The significance of this study lies in its topic and relevance. In a country like Ethiopia, where geographically located in extremely vulnerable region of the Horn of Africa, understanding the perceptions, vulnerability and livelihood adaptation of smallholder farmers becomes a pressing issue. In this regard, research related with vulnerability for climate change has remained fragmented. Specifically, there is a gap of knowledge on the perceptions, vulnerability and adaptive capacity and adaptation strategies of smallholder farmers to climate change based on livelihood zone approach in Ethiopia, in general, and Kembatta Tembaro Zone in particular. Yet there is a strong signal among smallholder farmers in different livelihood zones feeling the impacts of climate change in their overall livelihood systems.

In addition, knowledge emerging from empirical research and specifically from livelihood zone-based findings inform policy makers by pointing to relevant appropriate coping and adaptation technologies. Livelihood perspectives offer a unique starting point for an integrated analysis of complex, highly dynamic rural contexts. Hence, methodologically analyzing grass root level findings inform the government at different levels more critical and accurate information to prioritize the support needs of the local communities in order to fill the gaps.

Consequently, this study engaged with the critical phases in climate change study, including the perceptions, vulnerability, adaptive capacity and adaptation of smallholder farmers to climate change. The findings of this study are likely to be relevant for other livelihood zones with similar production systems, geographical profiles and socio-economic settings in southern Ethiopia. The findings of this study is also useful for academicians, stakeholders, policy makers, governmental and non-governmental organizations both at local, regional and federal levels to design location-specific, efficient and effective, flexible and responsive approaches for appropriately targeted vulnerable smallholder farmers for building their resilience capacity to climate change.

1.6. Research Methodology

1.6.1. Description of the Study Area

The study was conducted in five livelihood zones of Kembata Tembaro Zone, Southern Nations, Nationalities, and Peoples' Region (SNNPR) of Ethiopia. The SNNPR is one of the nine regional states of the Federal Democratic Republic of Ethiopia. According to CSA (2013), the study area is projected to have a population size of 902,073 by the end of 2017, of which 442,883 are male and 459,190 are female. Kembata Tembaro Zone is located within the $7^0$10'-$7^0$61'latitude and37^0 34'-38^0 07'longitude, has a total area of 1523.6 sq.km, and elevation of 1400 to 3028 meter above sea level. The average annual precipitation ranges between 900 and 1400 mm while the average daily temperature ranges from 7 to 25^{o}C and the mean annual temperature and rainfall of the zone are 22^{o}C and 1100mm, respectively (Kembata Tembaro Zonal Report, 2016). The study area has a population density of 665 per square kilometer, much higher than the estimated regional average of 164 (CSA, 2013).

This study used livelihood zone approach to analyze perceptions, vulnerability and adaptation strategies of smallholder farmers. According to the livelihoods zone classification, there are 175 different livelihood zones in Ethiopia, out of this 40 are found in SNNPR (DPPC, 2005a; and DRMFSS, 2010). The study area covers five main livelihood zones, namely; Kambata Cereal and Enset Livelihood Zone, Badewacho-Alaba Maize Livelihood Zone, Hadero-Ginger Livelihood Zone, Alaba-Mareko Lowland Pepper Livelihood Zone and Kedida-Badewacho Coffee Livelihood Zone (DPPC, 2005b). Description of each LZs is given below.

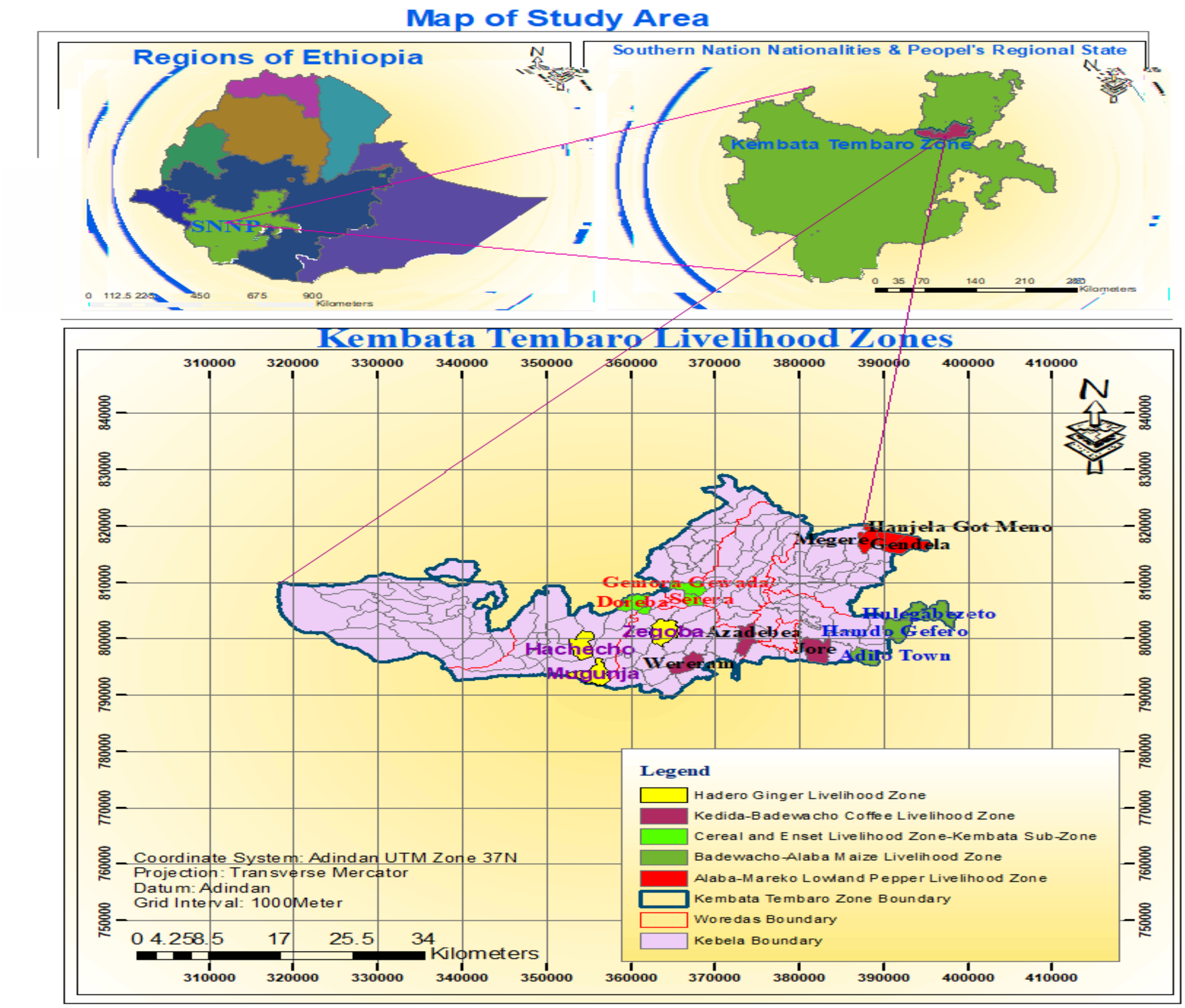


Figure 1. 1: Map of the Study Area

Source: Based on the data from Ethiopian Geospatial Information Agency (2018)

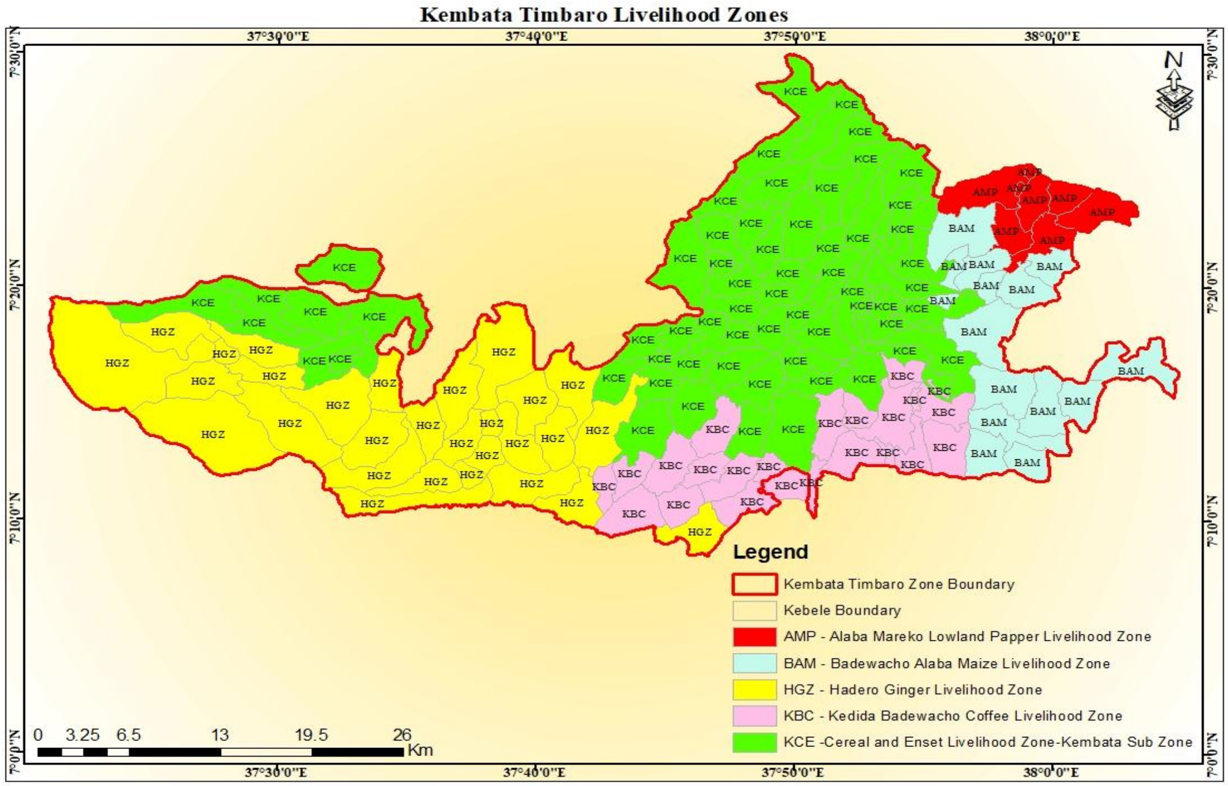


Figure 1. 2: Map of the Study Area Based on Livelihood Zone Classification
Source: Based on the data from Ethiopian Geospatial Information Agency (2018)

1.6.2. Description of Livelihood Zones

Cereal and Enset LZ

As the name indicates, this is the LZ where cereal and enset are widely grown. It is the largest zone in the north and north-west part of Kembata Tembaro Administrative zone. Smallholder farmers reside in relatively limited landholdings, with high population density. It lies in the upper highland altitude bands, in the range of 2300-3028 masl, where rainfall in recent years is becoming erratic and, in some cases, experiencing drought especially during Belg season. The LZ covers Doyogena, Angecha, parts of Kacha Bira, Kedida Gamela, Tembaro and Damboya districts. The chief perennial crop of the zone is enset and annual cereal is wheat, both as a consumption and cash crop.

As indicated in Figure 1.3 below, the topography of the zone is a mixture of mountains, hills and plains, where mountainous land slope dominate. The vegetation coverage is moderate, dominated by enset (the main food crop), eucalyptus and some indigenous trees. Additional crops of the zone include wheat, barley, potatoes, beans and peas. Accordingly, products of enset and wheat, beans, peas and potatoes are the main crops exported from the livelihood zone. Maize is the main crop imported into the livelihood zone, mostly from Adilo and Halaba. From the last ten years onwards, there is an increasing trend of growing apple in few kebeles and wheat is the main cash crop used (sometimes sent to factories in Hossana and Addis Ababa) in all kebeles and there are few additional fruits and vegetables used as a cash crop in the zone.

Livestock and livestock products are generally sold for local consumption and are not exported from the zone. The main livestock types reared are cattle, sheep, horses and mules. Crop diseases are an on-going problem in this LZ affecting crops like enset, potato, wheat and barley. Increasing population is another threat for this LZ. According to agricultural researchers' classification, there are five agro-ecological regions in Ethiopia: moisture reliable cereal-based highlands, moisture reliable enset-based highlands, humid lowlands, drought prone highlands, and pastoralist area. Most smallholder farmers reside in the moisture reliable cereal-based highlands (i.e. 59 percent of total cultivated area) (ESSP II working Paper, 2011). CELZ fall in this category of classification. The nearest meteorological station located for this LZ is at Angacha.

Figure1.3: Picture Showing Enset and Cereal Farmland in Serera and Doreba Kebeles, Cereal and Enset LZ
Source: Researcher (Own picture) (Taken in June, 2018)

Kedida-Badewacho Coffee LZ

This LZ covers mainly Kedida Gamela and Kacha Bira districts. The main cash crop of this zone is coffee. Agro-ecologically it mainly lies on *woina dega* (mid-land), in the range of 1600-2200 masl, where rainfall in recent years is becoming erratic and, in some cases, experiencing drought, especially during Belg season. The zone is densely populated; and there is a shortage of cultivable land. This shortage has contributed to the over use of land and a continuous decline of soil productivity, coupled with climate change. In recent years, there is repeated occurrence of high heat wave during the flowering period of coffee, reducing the production and causing coffee berry disease.

The topography of the zone is a mixture of plains, hills and in some areas with mountains. The vegetation coverage is moderate, with enset (the main food crop) around the homestead and eucalyptus and some indigenous trees planted along the roads and riversides. The main crops of the zone, in addition to coffee, are: haricot bean, taro and sweet potato. Households obtain most of their cash income from coffee sales, other crops, livestock and livestock product (butter) sales. The main livestock types reared are cattle, sheep, goats and donkeys. Livestock are sold both for local consumption and nearby and far markets, including Shashemene and Addis Ababa. The nearest meteorological station is located at Durame.

Figure 1.4: Picture Showing Coffee Farm in Aze Deboa and Jore Kebeles, Kedida Badewacho Coffee LZ
***Source*: Researcher (Taken in April, 2018)**

Hadero Ginger Livelihood Zone

Zone Description

This LZ lies in the lower midland altitude bands, in the range of1500-2100 masl. The main woredas falling in this LZ include Hadero-Tunto, Tembaro and parts of Kacha Bira. This LZ extends south to Boloso Sore woreda of Wolayita and extends to Dawuro Administrative Zones. The zone is densely populated and there is a serious shortage of cultivable land. This shortage has contributed to the overuse of land and a continuous decline of soil fertility, coupled with frequent dry spells and declining livestock ownership, and in recent years has sought food aid regularly. The zone consists of rugged terrain and vast areas of unproductive land that do not support the cultivation of crops due to poor soil. Agro-ecologically, the zone stretches from *kolla* (lowland) to *woina dega* (midland), in the range of1500-2100 masl. The major cash crop for households in this LZ is ginger. Other crops grown include haricot bean, taro and sweet potato.

Cattle and goats are the main livestock types reared in the livelihood zone. There is a form of agreement for sharing cattle (and sometimes goats) whereby poor households care for the livestock of the rich in return for the skimmed milk and a share of the offspring. As a result of this type of agreement, all households in the zone keep cattle. Staple foods like maize and wheat are imported in most years from neighbouring livelihood zones. The major determinants of wealth in the Hadero Ginger Livelihood Zone are the number of cattle owned (including oxen) and land area cultivated. The nearest meteorological station for this LZ is located at neighbouring Boloso Sore district (Wolayita administrative zone), Areka.

Figure 1.5: Picture Showing Ginger Farm in Mugunja and Hachecho Kebeles, Hadero Ginger LZ
***Source*: Researcher (Taken in April, 2018)**

Badewacho-Alaba Maize LZ

It lies in the lower midland altitude bands, in the range of1400-1800 masl. Maize is the major food crop, and in years of good production, the zone supplies a large amount of green maize for nearby markets like Halaba, Shashemene and also to Addis Ababa. However, from the last ten years onwards, recurrent drought has affected the production. In addition to maize, teff, haricot beans, sorghum and finger millet grow in this livelihood zone. For the better-off farmers, livestock sales are the highest income earner. In recent years, there is an increasing trend of keeping more sheep and goats for selling as an important source of income. The land scape is flat and much of the area is deforested. Scattered indigenous trees and from the last ten years onwards, eucalyptus trees are increasingly dominating the remaining vegetation. The nearest meteorological station is located at Alaba Kulito.

Figure 1.6: Picture Showing Maize Farm in Adilo and Hamido Kebeles, Badewacho-Alaba Maize LZ
***Source*: Researcher (Taken in June, 2018)**

Halaba Mareko Lowland Pepper LZ

This LZ has a valuable cash crop that attracts migrant laborers from other zones. Population density is relatively sparse and its residents enjoy large land holdings in comparison to bordering livelihood zones. It lies in the lower midland altitude bands, in the range of 1400-1800masl. Livestock production, especially cattle, is important including for the poor through butter sales. Rain failure has affected production in recent years, but floods from the neighboring highlands are also a frequent problem although at the same time as causing damage they deposit fertile silt.

Households in this LZ mainly rely on annual crops and consequently any fluctuations in rainfall distribution during the meher season reduce food and cash incomes at household level. Because of recurrent drought, farmers in this LZ suffer relatively higher level of food insecurity, and reports indicate that almost for the last fifteen years, 20 percent of poor households required minimum food needs; hence, there is a challenge in maintaining viable livelihoods. The landscape of the zone is flat with short indigenous shrubs. Acacia and in recent years, Eucalyptus trees dominate the vegetation of the livelihood zone. Remote kebeles have a more dense vegetation cover. The main food crop is maize and the main cash crop is pepper and other crops include millet and sorghum. The sale of pepper is the most important source of income for all wealth groups. A decline in pepper production results in reduced cash income, making susceptible their livelihoods. The main livestock types reared are cattle, sheep, and donkeys. The nearest meteorological station is located at Alaba Kulito.

Figure 1.7: Picture Showing Pepper Farm in Megere and Gindela Kebeles, Alaba-Mareko Lowland Pepper LZ

***Source*: Researcher (Taken in June, 2018)**

1.6.3. Research Design

The study design employed for this study is cross-sectional, as it helps to provide a comprehensive explanation of perceptions, vulnerability and adaptation strategies of smallholder farmers to climate change. The study seeks to locate its epistemological position in comparative case study design. Hence, the study employed mixed methods (qualitative and quantitative) as the method is believed to be more appropriate to investigate the topic under discussion, encompassing comparative analysis at livelihood zone levels.

The approach further allows for triangulation across the results obtained from qualitative (Perceptions) and quantitative (trend analysis, LVI, CACI, etc) sources. Methodological triangulation; obtaining data from different sources, such as observations, documentations, household survey and interviews helps to harnesses diverse ideas about the same issue and assist in cross-checking the results and consequently helps to increase the validity and reliability of the findings and eases data analysis (Bryman, 2008). As one of the tools of empirical enquiry, the method is suitable for answering the 'how' and 'why' questions, in which research questions of this study includes question framed with along this line.

1.6.3.1. Sampling Techniques

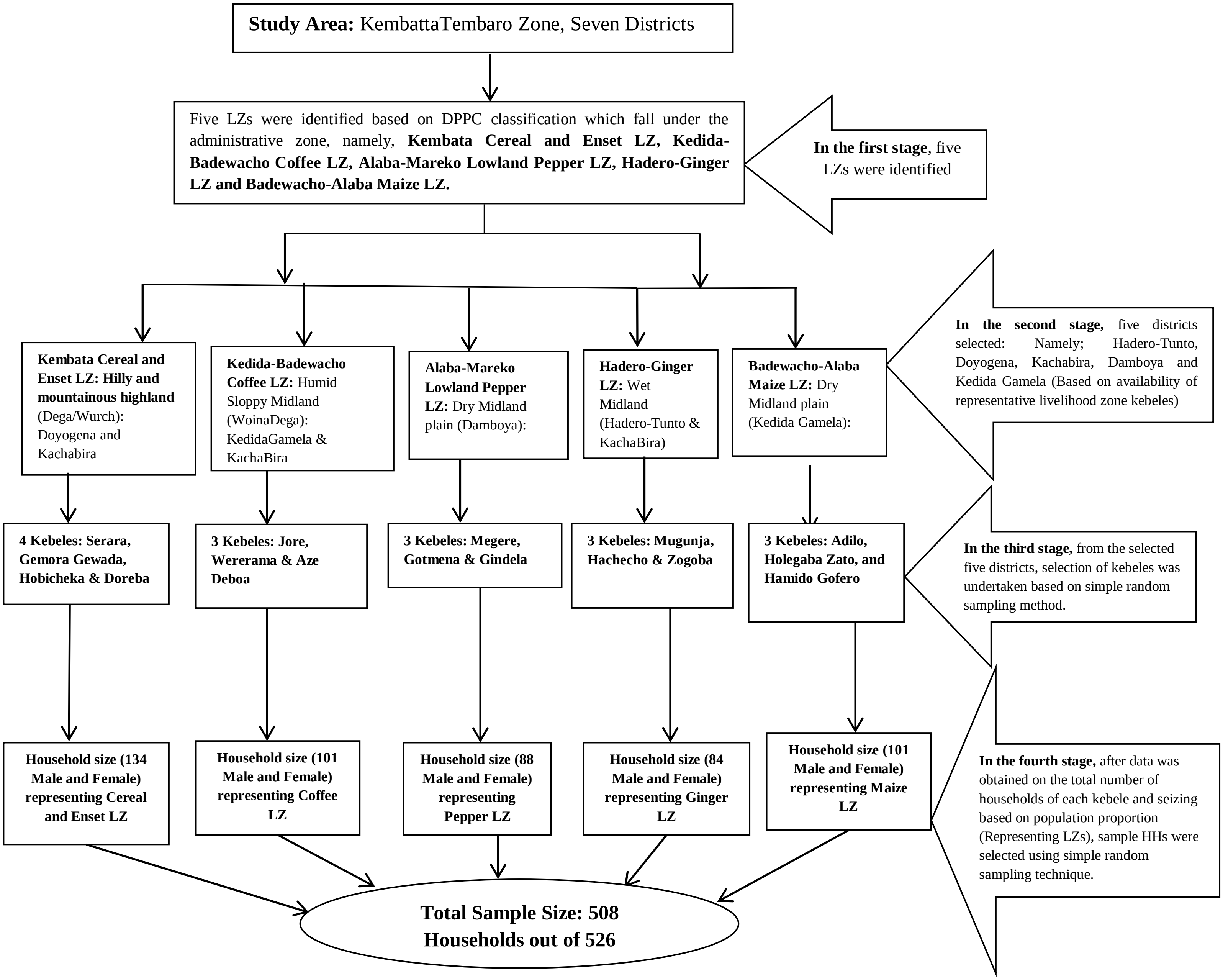
The survey was administered to samples taken by multistage sampling technique. In the first stage, five livelihood zones, namely, *Cereal and Enset LZ, Hadero-Ginger LZ, Kedida-Badewacho Coffee LZ, Badewacho-Alaba Maize LZ* and *Alaba-Mareko lowland Pepper LZs,* among forty LZs in SNNPRS were selected as the five LZs fall in the administrative zone, based on the prevailing occurrences of climate change and the consequences of repeatedly occurrence of production decline, population pressure, land fragmentation and also influenced by the familiarity of the researcher with the area. Hence, the sampling unit is the livelihood zones.

In the second stage, selection of districts that represent from each LZs is discussed as follows. The study area comprises of seven districts in its formal administrative boundary, namely, Kedida Gamela, Kacha Bira, Angacha, Danboya, Hadero-Tunto, Tembaro and Doyogena. Distribution of LZs across the seven districts is not proportional, i.e., it is difficult to divide the districts proportionally to each LZs as LZs do not normally follow the formal administrative boundaries. For instance, the majority of the districts including Angecha, Doyogena, and parts of Damboya, Kachabira, Hadero-Tunto and Kedida Gamela are categorized under *'Kembatta Cereal and Enset LZ'* (DPPC, 2005b). Accordingly, five districts, namely; Doyogena, Kachabira, Hadero-Tunto, Kedida Gamela and Damboya are selected. The districts were purposefully selected in such a way that they represent the specific livelihood zone and geographical settings. Angacha and Tembaro districts are not included, because Angacha district fall in Kembatta Cereal and Enset LZ (represented by Doyogena and parts of Kachabira districts) and Tembaro district belongs to Hadero-Ginger LZ (represented by Hadero-Tunto and Kachabira districts).

In the third stage, from the selected five districts, selection of kebeles was undertaken based on representativeness of the selected LZ, frequency of disaster, production trends, accessibility and in consultation with DAs and woreda experts. Each selected district consists of an average of 17 rural kebeles, and after all the kebeles are compared and contrasted, three and in some cases, four kebeles (in the case of CELZ) per livelihood zone were selected based on the above indicators.

In the fourth stage, after data were obtained on the total number of households of each kebele and seizing based on population proportion, sample households were selected using simple random sampling technique (see figure 1.8 below).

Figure 1.8: Multistage Sampling



Source: Own Construction

1.6.3.2. Sample Size Determination

In order to determine the sample size, the researcher used the formula set by Kotari (2004, p. 179) in the case of finite population, as follows:

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

Where, N the total household head of sample *kebeles, n* is the desired sample size, *P* is the approximate proportion of people, *e* is the tolerable error margin, as defined in 0.05 (i.e., 5% maximum discrepancy between the sample and the general population), *q*=1-p, z is the value of 1.96 (z=standard variate at a given confidence level), that is *t* value for 95% of the confidence level. Since the research sampling technique is multistage sampling to reduce the design effect, the sample size was multiplied by two. Accordingly, the sample size is 508. Distribution of sampled households and their distribution is presented in the following table.

Table 1.1 Distribution of Sampled Households across the five LZs

Name of LZ	District/s	Number of Sampled household heads	Male Household Heads (%)	Female Household Heads (%)
CELZ	Doyogena, Kachabira	134	87.31	12.69
CLZ	Kedida Gamela, Kachabira	100	83.17	16.83
GLZ	Hadero Tunto, Kachabira	84	89.29	10.71
MLZ	Kedida Gamela	101	86.14	13.86
PLZ	Danboya	88	76.14	23.86

Source: Household survey

1.6.3.3. Data Sources and Methods of Data Collection

The study used both primary and secondary data sources for analysis of the questions. Instruments for primary data collection included: household survey, key informant interviews, focus group discussions and field observations. Overall, a cross sectional household survey composed of both qualitative and quantitative methods was carried out using a standard structured questionnaire of both close and open-ended types of questions. Through the questionnaire, farmers were asked to provide information on socio-economic characteristics, vulnerability contexts, livelihood assets, climate change perceptions, adaptation and coping strategies, agricultural activities, institutional access and capacities.

Secondary data were obtained from statistical yearbooks, published and unpublished documents, local administrative records, studies conducted by NGOs, and various projects and programs conducted in relation with the topic. Zonal and district level reports were used from the respective Agriculture and Natural Resources Offices.

Specifically, data sources required for perception of smallholder farmers to climate change include both primary and secondary sources. The primary sources include household survey, key informant interviews and focus group discussions. A cross sectional household survey composed of both qualitative and quantitative information was carried out. Secondary sources include historical climate data on precipitation and temperature, which is based on gridded dataset (4km by 4km spatial resolution) of daily maximum and minimum temperatures, and daily total rainfall from 1984 to 2017. The gridded dataset combines with station data (rainfall and temperature) sourced from Ethiopian National Meteorological Agency (NMA) and used to support the findings from household survey, FGD and KII. Seasonal and annual rainfall was derived from the daily data of the four stations.

With regards to data sources required for Livelihood Vulnerability Index (LVI) analysis include from primary and secondary sources. The primary sources include household survey and FGD. Secondary sources utilized include zonal and district level reports, supported with researches, and projects undertaken by NGOs and/or individual researches.

The historical climate data on precipitation and temperature were sourced from four nearby stations from 1984 to 2017, (as shown in figure 1.9 below) namely: Angacha (located in Angacha district, with an altitude of about 2317 masl); Durame (located in Kedida Gamela district, with an altitude of about 2000 masl), Alaba Kulito (located in Halaba special district, with an altitude of about 1772 masl), and Areka (located in Boloso Sore district of Wolayita Zone, with an altitude of about 1752 masl), representing Cereal and Enset LZ, Kedida-Badewacho Coffee LZ, Alaba-Mareko Lowland Pepper LZ and Badewacho-Alaba Maize LZ, and Hadero-Ginger LZ respectively, was sourced from Ethiopian National Meteorological Agency (NMSA, 2018).

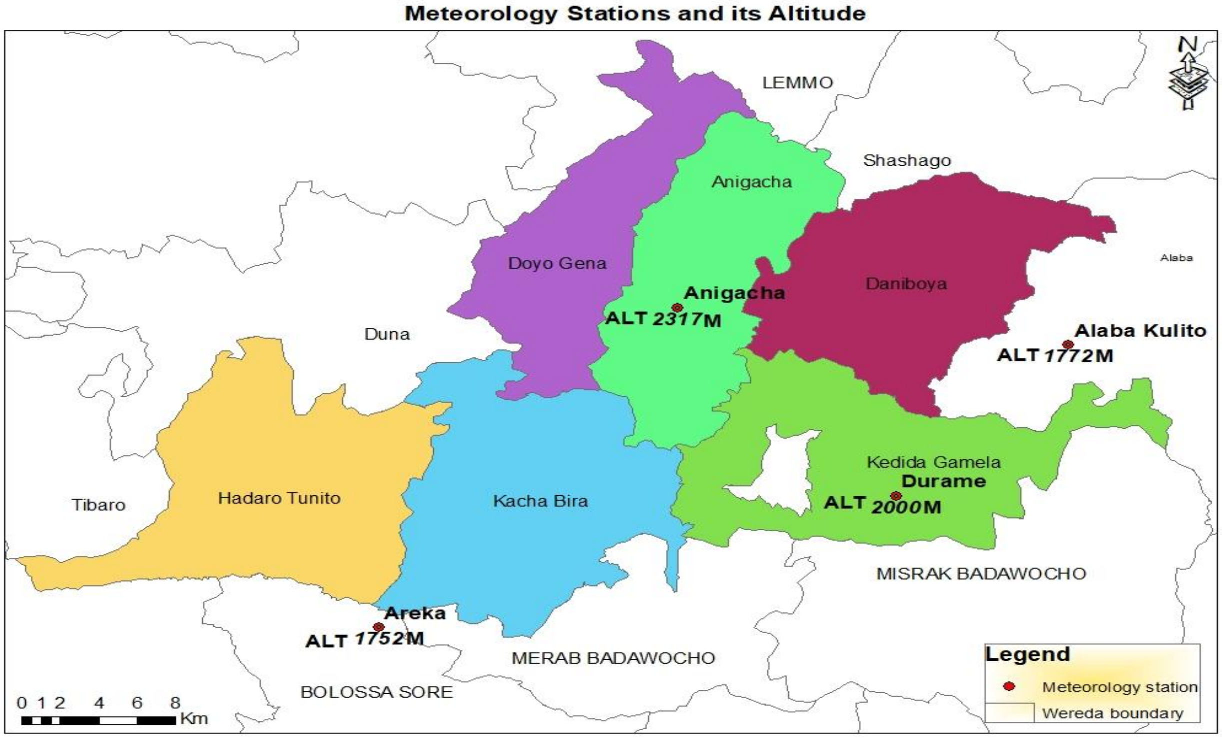


Figure 1.9: Location and Altitude Map of Meteorological Stations

Thirteen focus group discussions (3 FGDs in four LZs and 4 FGDs in CELZ) in the five LZs, each comprising ten to twelve elderly and experienced farmers, were purposefully selected based on the criteria of: (a) settlement in the area for ≥30 years, (as the degree and prevalence of climate change has increased in the last thirty years (Funk, et.al., 2012); (b) practice agricultural farming livelihoods for ≥30 years; (c) deep knowledge on local climate trends of their respected areas; and (d) local wealth breakdown of households (Rich, Medium and Poor, based on the classification used by district Agriculture Office) and in some cases, safety-net beneficiaries and graduates of the program in consultation with district experts and DAs.

1.6.3.4. Methods of Data Analysis

Description of Variables and Models

The dependent variable is perception to climate change; including for increase or decrease in rainfall duration, temperature, rainfall frequency, rainfall magnitude, rainfall intensity and rainfall duration. The explanatory variables (Independent variables) chosen for the analysis of factors affecting perceptions to climate change and perceived effect are: farming experience, sex of the household head, education of the household head, land vegetation cover, local institutional support, farm income, land slope, technology adoption, early warning information, access to extension service, indigenous knowledge, access to remittance, access to radio, access to mobile, water access, cultural connectivity and road access.

The variables identified for the perceptions of farmers to climate change include:

a) An increase in rainfall duration, an increase in rainfall frequency and an increase in rainfall magnitude.

b) A decrease in rainfall intensity and rainfall duration.

c) An increase in temperature and decrease in temperature.

Mann-Kendall test

In connection with perceptions of farmers to climate change trend analysis, Mann-Kendall's test was employed, which is widely used for the analysis of trend in climatologic and in hydrologic time series for increasing or decreasing trends. There are two advantages of using this test. First, it is a non- parametric test (which means it works for all distributions) and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. Hence, the nonparametric Mann–Kendall trend test is robust since trends in climatic series are rarely linear. The Mann-Kendall statistic S is:- $S = \sum_{i=1}^{n-1} \sum_{j=i-1}^{n} sgn(x_j - x_i)$

The application of trend test is done to a time series X_i, that is ranked from i=1,2,…n-1 and X_j, which is ranked from j=i+1,2,…n. Each of the data point X_i, is taken as a reference point which is compared with the rest of the data points X_j, so that:

$$\text{Sgn}\,(X_j - X_i) = \begin{cases} +1 \; if \; (X_j - X_i) > 0 \\ 0 \; if \; (X_j - X_i) = 0 \\ -1 \; if \; (X_j - X_i) < 0 \end{cases}$$

Where S is the Mann-Kendal's test statistics; $\boldsymbol{x_i}$ and $\boldsymbol{x_j}$ are the sequential data values of the time series in the years ***I*** and ***j*** (*j* >*i*). The true slope of the existing linear trend (as change per year) was estimated with the nonparametric Sen's method. The Sen's method uses a linear model to estimate the slope of the trend. It is given as,

$$f(t) = Qt + B$$

Where f (t) is the estimated rainfall amount at t year; Q is the slope; B is a constant.

Coefficient of Variation

The rainfall variability for representative meteorological stations was determined by calculating the coefficient of variation (CV) as the ratio of the standard deviation to the mean rainfall in a given period. CV is calculated to evaluate the variability of the rainfall. A higher value of CV is the indicator of larger variability, and vice versa which is computed as:

$$CV = \left(\frac{\text{Standard Deviation}}{\text{Mean}} \times 100 \right) \%$$

According to Hare (2003), CV is used to classify the degree of variability of rainfall events as less (CV< 20), moderate (20 < CV <30), and high (CV >30).

For vulnerability analysis, forty four context specific variables are used to capture the level of exposure to natural disasters and climate variability, adaptation capacity of households and their sensitivity to climate change (see table 1.2.). The formulation for LVI developed for this study is based on the livelihood vulnerability analysis technique developed by Hahn et.al., (2009), with replacements of some indicators to suit the local context of the study area. It makes use of nine major components, namely; Natural Disaster, Assets and Basic Services, Land and Water, Nutrition and Health, Skill and Knowledge, Socio-economic, Biophysical, Social and Institutional and Finance and Incomes.

Each profile is defined by a set of indicators and relationship with climate vulnerability. Selection of indicators was based on review of related literature, household survey, FGD with farmers, DAs, and key informant interviewers and my observation and experience in the study area. The components are further categorized under the five livelihood capitals; *Human, Social, Natural, Physical* and *Financial*. The indicators are developed based on a review of previous LVI studies conducted. The details of descriptions are indicated as follows.

Table 1.2: Livelihood Vulnerability Index (LVI) Capitals, Major Components, Sub-indicators and Hypothetical relationships

Determinants of Vulnerability	Capitals/ Disaster	Major components and Assigned Weights	Sub-indicators	Units	Hypothetical relationship	Assigned Weight for Sub-indicators
Exposure	Natural Disaster	Frequency of Natural Disaster and Climate Variability (9)	Frequency of natural disaster	Number of events	The more frequency in natural disaster, the higher exposure	**40**
			Increase in average annual temperature between 1984-2017	Changes over time, °C	The more increase in temperature, the higher exposure	**20**
			Increase in average annual rainfall duration between 1984-2017	Changes over time, mm	The more increase in rainfall, the higher exposure	**20**
			Vulnerability to the incidence of drought	Index	The more vulnerability to the incidence of drought, the higher exposure	**20**
	Physical	Infrastructure, assets and basic services (11)	Access to all weather roads	Hours	The more access to all weather roads, the less exposure	**15**
			Access to veterinary services	Hours	The more access to veterinary services, the less exposure	**12**
			Farm size	Hectare per HH	The higher farm size, the less exposure	**30**
			Livestock ownership	TLU	The higher livestock ownership, the less exposure	**10**
			Access to climate information	Frequency	The more access to climate information, the less exposure	**10**
			Access to early warning information	Frequency	The more access to early warning information, the less exposure	**8**
			Type of house	Percent	The more access to home with galvanized, cement and hut (thatched), the less exposure	**6**
			Ownership of pack animals (like donkey) for transport	Number	The more access to pack animals (transport), the less exposure	**4**
			Ownership of plough	Number	The more access to production means like plough, the less exposure	**5**
Sensitivity	Natural	Crop Land and water (13)	Land productivity	Index	The more percent of fertile land, the lesser sensitivity	**26**

			Access to grazing land	Index	The more access to grazing land, the lesser sensitivity	**15**
			Access to animal forage/pasture	Index	The more access to animal forage, the lesser sensitivity	**17**
			Access to water	Index	The more access to water (Potable and Irrigation), the lesser sensitivity	**15**
			Effect of post-harvest loss	Percent	The higher post-harvest loss, the higher sensitivity	**12**
			Effect of extinction of crop varieties	Number	The higher number of extinction of crop varieties, the higher sensitivity	**15**
Adaptive Capacity	**Human**	**Nutritional and health status (8)**	Access to Food	Index	The more access to food, the more adaptive capacity	**60**
			Health status	Index	The higher access to health, the more adaptive capacity	**40**
		Skills and knowledge (18)	Educational attainment of household head	Years	The more educated household head, the more adaptive capacity	**35**
			Skill upgrade	Number	The more diversified skill (Training access), the more adaptive capacity	**25**
			Technology adoption	Number	The more access to technology, the more adaptive capacity	**40**
		Socio-economic (10)	Farming experience	Years	The more farming experience in years, the more adaptive capacity	**35**
			Dependency ratio	Number	The more dependency ratio, the less adaptive capacity	**30**
			Off-farm activity	Birr	The more access to off-farm activity, the more adaptive capacity	**35**
	Natural	**Bio-Physical /Environmental (6)**	Land protected from degradation	Index	The more percent of degraded land, the less adaptive capacity (Land degradation index)	**15**
			Vegetation cover	Index	The more vegetation cover, the higher adaptive capacity	**15**
			Slope (topography) of cultivated land	Percent	The more percentage of good topography for cropping, the higher adaptive capacity	**20**
			Access to irrigation	Percent	The more access to irrigation, the higher	**30**

					adaptive capacity	
			Crop Diversification Index	Index	More crop diversity, higher will be adaptive capacity	**20**
	Social	**Social and Institutional (16)**	Access to social membership	Index	The more access to social membership, the higher adaptive capacity	**25**
			Cultural connectivity	Index	The more access to cultural connectivity, the higher adaptive capacity	**22**
			Trust and mutual support	Index	The more social help at times of shocks (Covariate and idiosyncratic shocks), the higher adaptive capacity	**10**
			Local institutional support	Index	The more access to get support from local institutions (iddir, equb,, etc), the higher adaptive capacity	**8**
			Access to indigenous knowledge	Percent	The more access to indigenous Knowledge (coping and adaptation), the higher adaptive capacity	**15**
			Traditional Weather Prediction	Percent	The more access to get traditional weather prediction, the higher adaptive capacity	**20**
	Financia l	**Finance and incomes (9)**	Access to credit	Percent	The more access to credit services, the higher adaptive capacity	**15**
			Access to remittances	Percent	The more access to remittance, the higher adaptive capacity	**17**
			Access to savings	Percent	The more access to get saving services, the higher adaptive capacity	**9**
			Access to money for emergency	Percent	The more access to get money for emergency, the higher adaptive capacity	**10**
			Subsidy from the government	Percent	The more access to get subsidy from the government, the higher adaptive capacity	**8**
			Farm income	Birr	The higher farm income, the higher adaptive capacity	**25**

The Livelihood Vulnerability Index (LVI) of each livelihood zone is then analyzed and finally description of the aggregate level of the degree of vulnerability of the study area was given. Since each of the sub-components is measured on a different scale, it is first necessary to standardize each as an index as:

$$index_{SLZ} = \frac{S_{LZ} - S_{min}}{S_{max} - S_{min}} \quad \text{……………………………………………………………..…Equation (1)}$$

Where, index $_{SLZ}$ refers to index standardized value for a given livelihood zone, S_{LZ} is the original sub-component for a given livelihood zone, and S_{min} and S_{max} are the minimum and maximum values respectively for each sub-component. After each is standardized, the sub-components were further averaged using equation (2) to calculate the value of each major component:

$$M_{LZ} = \frac{\sum_{n\, i=1} index_{SLZ_i}}{n} \quad \text{……………………………………………..Equation (2)}$$

Where, M_{LZ} is one of the nine major components for Livelihood Zone, index $_{SLZi}$ represents the sub-components indexed by *i,* that make up each major component and *n* is the number of sub-components in each major component.

Once, values for each of the nine major components for the Livelihood Zones are calculated, major components that make up each livelihood assets is averaged using the following equation (3) to obtain the Livelihood Vulnerability Index at Livelihood Zone level:

$$LVI_{LZ} = \frac{\sum_{i=1}^{5} W_{MLZi} M_{LZi}}{\sum_{i=1}^{5} W_{MLZi}} \quad \text{……………………………….……..…...…..… Equation (3)}$$

Which can be expressed as:

$$LVI_{LZ} = \frac{W_H H_{LZ} + W_N N_{LZ} + W_S S_{LZ} + W_P P_{LZ} + W_F F_{LZ}}{W_H + W_N + W_S + W_P + W_F}$$

Where, **LVI_{LZ}:** is the vulnerability index for one of the five livelihood assets of livelihood zone LZ, equals the weighted average of major components which form that livelihood asset; **W_{MLZ}:** the weights of each major component, are determined by the number of sub-components that makeup each major capital. Calculating the LVI-IPCC is an alternative method for calculating

LVI that incorporates the IPCC vulnerability which is used by Hahn, et.al., (2009). The LVI-IPCC diverges from LVI when the major components are combined. They are combined using the following equation;

$$CF_{LZ} = \frac{\sum_{i=1}^{n} W_{MLZi} M_{LZi}}{\sum_{i=1}^{n} W_{mLZi}} \quad \text{……………………………..………………….….. Equation (4)}$$

Where, CF_{LZ} is an IPCC defined contributing factor (i.e. Exposure, Sensitivity, or Adaptive Capacity) for Livelihood Zone LZ, W_{MLZi} is the weight of each major component, and M_{LZi} are major components for livelihood zone LZ, indexed by *i*, and *n* is the number of major components in each contributing factor. Once, exposure, sensitivity and adaptive capacity are calculated, the three contributing factors will be combined using the formula developed by Hahn et.al., (2009):

$$LVI - IPCC_{LZ} = (e_{LZ} - a_{LZ}) * S_{LZ} \quad \text{………………………..……………….…..… Equation (5)}$$

Where, $LVI - IPCC_{LZ}$ is the LVI for livelihood zone LZ, expressed using the IPCC vulnerability framework, ***e*** is the calculated exposure score for livelihood zone LZ, ***a*** is the calculated adaptive capacity score for livelihood zone LZ, and ***S*** is the calculated sensitivity score for livelihood zone LZ. And then the LVI-IPCC is scaled from -1 (denoting least vulnerable) to 1 (Denoting most vulnerable).

For Composite Adaptive Capacity Index (CACI) analysis, context specific variables were first categorized into seven main indicators: *human, natural, physical, financial, social, information accessibility* and *institutional and infrastructural*. Choice of indicators to represent the index for adaptive capacity is constrained by the fact that adaptive capacity itself has no tangible element. Adjustments were made to contextualize the index by adjusting the indicators that were not applicable to the study site. Here, *Institutional and Infrastructural* and *Information Accessibility* were added for enhancing the visibility of the composite index. Both main and sub-indicators were weighted by assigning relative score to all sub-indicators constituting each main indicator and also all the seven main indicators. For each main indicator of adaptive capacity, this study used a community self-assessment approach based on the community's perceived influence of indicators on farmers' capacity to adapt to climate change in weighting the indicators of adaptive capacity of farmers to climate change and variability through focus group discussion. This approach provides specific geographical settings based adaptive capacity of farmers for informed policy directives.

Table 1.3: Community-Based Weights of Adaptive Capacity Indicators

Capital Indicator	Weight / Score (%)	Sub-Indicator	Weight / Score (%)
Human Capital	**20**	Educational attainment of household head	18
		Skill upgrade	12
		Farming experience	14
		Health status	16
		Technology adoption	18
		Dependency ratio	22
			Total 100
Physical Capital	**22**	Type of house	12
		Farm size	30
		Access to Irrigation	20
		Ownership of plough	8
		Ownership of Donkey for transport	10
		Tropical Livestock Unit (TLU)	20
			Total 100
Financial Capital	**14**	Access to savings	9
		Access to Remittances	17
		Subsidy from the government	8
		Access to credit	15
		Access to money for emergency	10
		Farm income	25
		Off-farm activity	16
			Total 100
Natural Capital	**16**	Access to water	25
		Land productivity	16
		Access to animal forage/pasture	20
		Slope of cultivated land	8
		Land protected from erosion/degradation	14
		Land covered with (indigenous) vegetation	17
			Total 100
Social Capital	**12**	Access to social membership	20
		Cultural connectivity	18
		Access to indigenous knowledge	14
		Local institutional support	26
		Trust and mutual support	10
		Traditional Weather Prediction	12
			Total 100
Institutional and Infrastructural	**10**	Access to leaders	9
		Participation in Decision-making	16
		Access to all weather roads	24
		Access to veterinary services	14
		Access to electricity	8
		Access to improved varieties of seeds	17
		Access to early support for disaster	12
			Total 100

Information Accessibility	**6**	Climate information	30
		Access to radio	18
		Access to early warning	36
		Frequency of weather information	16
Total	**100**	**Total**	**100**

Source: Own construct

Given that each of the sub-indicators are measured on different scales, the first step in computing the Composite Adaptive Capacity Index was to normalize the sub-indicators to a common scale using equation (1):

$$index_{SLZ} = \frac{S_{LZ} - S_{\min}}{S_{\max} - S_{\min}} \quad \text{……………...………………………………………...…Equation (1)}$$

Where $Index_{sLZ}$ is one of the sub-indicators of one of the seven adaptive capacity indicators, S_{Lz} is the observed value for sub-indicator S, S_{Min} and S_{Max} are the minimum and maximum values respectively for the sub-indicator in the combined data. The second step involved multiplying the normalized value of each sub-indicator by the respective assigned sub-indicator score obtained from the community self-assessment. Thus,

$$Index_{si} = Index_s * S_w \quad \text{……………………..………………………………...………...…Equation (2)}$$

Where S_w is the assigned weight (in %) for the sub-indicator S, and $Index_{si}$ is the weighted index for sub-indicator S. The index for each main indicator of adaptive capacity was ascertained by summing the weighted indices of sub-indicators constituting the main indicator. This was done using equation

$$Index_{mi} = \sum_{i=1}^{N} Index_{si} \quad \text{…………....………………….…………………………...…Equation (3)}$$

Where $Index_{mi}$ is the computed index for one of the seven main indicators of adaptive capacity, N is the number of sub-indicators constituting the main indicator. Given that all indicators do not contribute equally to adaptive capacity; the main indicators were also weighted by multiplying the index for each main indicator of adaptive capacity by its community assessment score as presented in equation(4):

$$M_{wi} = Index_{mi} * M_w \quad \text{…………………….…………………………...…Equation (4)}$$

Where M_{wi} is the weighted index for main indicator M, and M_w is the assigned weight/score (%)

for main indicator M. The Composite Adaptive Capacity Index (CACI) for each district was than as curtained by summing the weighted indices of the seven main indicators. This is presented in equation (5):

$$\boldsymbol{CACI_{LZ}} = \sum_{i=1}^{7} \boldsymbol{M_{wi}} \text{ ………………………………………………..…Equation (5)}$$

Where, $\boldsymbol{CACI_{LZ}}$ denotes the Composite Adaptive Capacity Index for Livelihood zone, $\boldsymbol{LZ}$. The CACI is scaled between 0 (least adaptive capacity) to 1 (highest adaptive capacity).

Data Analysis Techniques

Data analysis technique employed for perception of smallholder farmers to climate change includes both qualitative and quantitative techniques. Qualitative techniques mainly include narrative analysis and content analysis of perceptions and feelings of FGD participants. Descriptive and inferential statistical techniques were employed to analyze data collected from both primary and secondary sources. Descriptive statistics were presented in the form of frequencies, cross tabulation, percentages, graphs and tables. Sen's estimator, Mann-Kendall's statistic test and coefficient of variation were used as descriptors of trend detection and compared with the perception of farmers in the study area. Binary Logistic Regression Model was used following stepwise inclusion of variables (identified from theory, literature and possibility of influence selected by the researcher), statistical tests of individual predictors are used. The statistical significance of individual regression coefficients is tested using the Wald and score chi-square statistic.

Binary Logistic Regression analysis of **predictors and perception to climate change:** logit perception to climate change with independent variables.

Binary Logistic Regression analysis **between predictors and perception to climate change:** logit perception to climate change: sex marstat farmexp roadaces landslop weathinfotimly culturconnect tradweathpredic physasetdonkey. In addition, Chi-square tests were also employed.

$$logit\left(\frac{\widehat{p}}{1-p}\right) \text{(perception to climate change)} = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \beta 4x4 \ldots + \beta 9x9$$

Where Bo is constant, B1, B2, B3, B4…Bn are coefficient for sex, marital status, farm experience, road access, land slope, timely weather information, cultural connectivity, traditional weather prediction, physical asset (donkey).

Table 1.4: Description of Variables for Perception to Climate Change

Variables	**Description**
Sex of the household head	Dummy, 1 = male, 0 = female
Marital status	1. Married; 2. Single; 3. Divorced; 4. Widowed
Farm experience	Continuous (years)
Road access	Dummy, 1 = yes, 0 = no
Education of the household head	1. None; 2. Primary (Grade 1-8); 3. Secondary (Grade 9-12); 4. Tertiary (College/University).
Land vegetation cover	Dummy, 1 = yes, 0 = no
Local institutional support	Dummy, 1 = yes, 0 = no
Farm income	Continuous (ETB)
Land slope	1.Flat; 2.Somewhat flat; 3.Highly slopping; 4.Mountaneous
Technology adoption	Dummy, 1 = yes, 0 = no
Access to extension service	Dummy, 1 = yes, 0 = no
Indigenous knowledge	Dummy, 1 = yes, 0 = no
Access to remittance	Dummy, 1 = yes, 0 = no
Access to traditional weather prediction	Dummy, 1 = yes, 0 = no
Access to radio	Dummy, 1 = yes, 0 = no
Cultural connectivity	Dummy, 1 = yes, 0 = no
Water access	Dummy, 1 = yes, 0 = no
Access to mobile	Dummy, 1 = yes, 0 = no
Social networks	Dummy, 1 = yes, 0 = no

With regards to data analysis techniques employed for Livelihood Vulnerability Index (LVI), two vulnerability measurement approaches developed by previous researches (LVI and LVI-IPCC) to identify vulnerable LZs, to understand factors contributing to their vulnerability at LZ level and prioritize the potential interventions. Hence, analysis of nine major components is undertaken, comparing LZs and analysis on exposure to climate change, analysis on sensitivity to climate change, and analysis on adaptive capacity to climate change was undertaken. Finally, aggregate vulnerability of LZs is analyzed and further mapped accordingly.

Different methods have been developed to measure a system's capacity to adapt to climate change. In any case, the type of method or index to be employed depends on the objective of the study. This study used a Composite Adaptive Capacity Index approach in computing the adaptive capacity as a measure of farmers' capacity to adapt to climate change and variability. According to Jones, et.al., (2010) and Vincent, (2007), index-based approach to adaptive capacity assessment and comparison is considered very insightful with regard to identifying the hotspots and supporting prioritization of international assistance for climate change adaptation. Rather than assuming equal weights for all adaptive capacity indicators or relying on macro-level rating of adaptive capacity indicators, this study used community' self-assessment approach in weighting the indicators of adaptive capacity of farmers to climate change through focus group discussion. This approach helps to identify specific livelihood zone based settings influential adaptive capacity indicators of farmers to climate change.

For analysis of factors influencing adaptation strategies of farmers to climate change, binary logistic regression analysis by using stepwise inclusion of twenty nine variables identified from theory, literature and possibility of influence selected by the researcher. Statistical tests of individual predictors at 25% (0.25) level of significance are used for further analysis. The statistical significance of individual regression coefficients is tested using the Wald and score chi-square statistic. At first, major factors that are expected to influence adaptation strategies of farmers to climate change were first analyzed by considering the relationship of each predictor variable with the outcome variable, i.e. identification of the statistically significant predictor variables and determining the direction of relationship with and contribution to the dependent variable is undertaken. Description of variables is given below in table 1.4 below.

Table 1.5: Description of Variables for Adaptation Strategies

Variables	Description
Sex of the household head	Dummy, 1 = male, 0 = female
Marital status	1. Married; 2. Single; 3. Divorced; 4. Widowed
Farm experience	Continuous (years)
Road access	1. Paved; 2. Partly paved; 3. Gravel; 4. Dirty; 5.No road
Off-farm	Dummy, 1 = yes, 0 = no
Perception to climate change	Dummy, 1 = yes, 0 = no
Education of the household head	1. None; 2. Primary (Grade 1-8); 3. Secondary (Grade 9-12); 4. Tertiary (College/University).
Land vegetation cover	Dummy, 1 = yes, 0 = no
Local institutional support	Dummy, 1 = yes, 0 = no
Farm income	Continuous (ETB)
Land slope	1.Flat; 2.Somewhat flat; 3.Highly slopping; 4.Mountaneous
Technology adoption	Dummy, 1 = yes, 0 = no
Access to extension service	Dummy, 1 = yes, 0 = no
Access to improved variety of seeds	Dummy, 1 = yes, 0 = no
Access to timely weather info	Dummy, 1 = yes, 0 = no
Access to early warning	Dummy, 1 = yes, 0 = no
Indigenous knowledge	Dummy, 1 = yes, 0 = no
Access to remittance	Dummy, 1 = yes, 0 = no
Access to radio	Dummy, 1 = yes, 0 = no
Dependency ratio	Continuous (number)

Access to saving	Dummy, 1 = yes, 0 = no
Access to leaders	Dummy, 1 = yes, 0 = no
Decision making	Dummy, 1 = yes, 0 = no
Access to mobile	Dummy, 1 = yes, 0 = no
Frequency of disaster	1. Four out of 5 years or more; 2. Three out of 5 years; 3. Two out of 5 years; 4. One out of 5 years; 5. Almost every year
Physical asset donkey	Dummy, 1 = yes, 0 = no
Water access	Dummy, 1 = yes, 0 = no
Cultural connectivity	Dummy, 1 = yes, 0 = no
Social networks	Dummy, 1 = yes, 0 = no

From the p-values of the output of individual predictor variables, analysis at 25% significance level variables are selected for further analysis and other variables were ignored and excluded from the model, i.e, multiple predictors' analysis is undertaken first to check whether the excluded variables in single predictor's analysis are significant in the inclusion of collection of variables. And then for binary logistic regression analysis of significance for p-value is less than 0.05 variables are selected for further analysis.

$logit\left(\frac{\widehat{p}}{1-p}\right)$ (Changing Timing of Farm Operations and Management) $= \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \cdots + \beta nxn$... **Equation (1)**

Where Bo is constant, B1, B2, B3…B24 are coefficient eduhh farmexp offarm perception to climate change acesimpvarity acesextserv weathinfotimly acesearlywarnin techadopt acesaving roadaces landslop indigknowlg locinstitsup Tradweathpredic dep_ratio farm_income Acesleaders Decisionmaking Culturconnect Physasetdonkey Physasetmobil Physasetradio Freqdisaster

$logit\left(\frac{\widehat{p}}{1-p}\right)$ (Diversification into Off-farm and Non-farm adaptation strategy) $= \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \cdots + \beta 16x16$...............................**Equation (2)**

Where Bo is constant, B1, B2, B3…B16 are coefficient for eduhh farmexp offarm perception to climate change acesimpvarity acesextserv weathinfotimly acesearlywarnin techadopt acesaving roadaces landslop indigknowlg locinstitsup Tradweathpredic dep_ratio farm_income Acesleaders Decisionmaking Culturconnect Physasetdonkey Physasetmobil Physasetradio Freqdisaster.

$logit\left(\frac{\widehat{p}}{1-p}\right)$ ($Crop$ Diversification and Aforestation adaptation strategy) $= \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \cdots + \beta 15x15$...**Equation (3)**

Where Bo is constant, B1, B2, B3…B_n are coefficient for eduhh farmexp offarm perception to climate change acess to improved variety, access to extension service, weatherinfotimly acesearlywarnin techadopt acesaving roadaces landslop indigknowlg locinstitsup Tradweathpredic dep_ratio farm_income Acesleaders Decisionmaking Culturconnect Physasetdonkey Physasetmobil Physasetradio Freqdisaster

Table 1.6: Summary of Methods of Analysis

No	Objective	Data Type	Data Sources	Method of Analysis
1	Identify smallholder farmers' perceptions to climate change and its perceived effect on their livelihood;	Qualitative Quantitative Recorded	Survey questionnaire (Survey of perceptions of farmers on climate change), In-depth interview, KII, FGD (FGD on indigenous (Traditional) coping / adapting mechanisms), documents, Seasonality, Climatological data	Descriptive statistical analysis, Logistic Regression, Chi-square test, A Mann-Kendall trend and statistical test, Sen's estimator, and coefficient of variation
2	Investigate the extent and underlying causes of vulnerability of smallholder farmers to climate change in different livelihood zones;	Quantitative and Qualitative	Survey questionnaire, In-depth interview, KII, FGD (-FGD on livelihood zone based possible sources of livelihood vulnerability), Livelihood assets, Institutions, Vulnerability Indicators	-Livelihood Vulnerability Index (LVI) developed by Hahn et.al.,(2009). -IPCC vulnerability framework -Aggregate analysis on exposure to CC -Aggregate analysis on sensitivity to CC -Aggregate analysis on adaptive capacity to CC -Comparative analysis -Vulnerability mapping
3	Identify the strategies pursued by smallholder farmers in response to climate change and the levels of adaptive capacity to climate change,	Quantitative and Qualitative	Survey questionnaire, In-depth interview, KII, FGD,	-Descriptive statistics, -Composite Adaptive capacity index, -Logistic Regression, -Chi-square tests -Comparative analysis on Aggregate Adaptive Capacity

Source: Own construction

1.8. Ethical Considerations

In the course of the research process, ethical issues were considered in a number of ways. Research ethics require that the researcher must ensure the confidentiality of the research participants and protect them from any harm (Laws, et.al., 2003). First, the research process ensured the verbal consent of participants by rendering their voluntary involvement. Participants were interviewed only after they are asked and granted their full willingness to take part in the research. The fact that findings of the research might be presented to different stakeholders was clearly communicated. In order to dispel doubt, participants' queries in relation to the research were answered openly and honestly.

It is expected that in a society that becomes prone to shocks (social, economic, political and ecological), people may develop expectations for immediate outcome such as aid. Especially, in the year 2017, as I personally observed some of the study area kebeles, there was shortage of rainfall for Belg season, which is used to grow short seasonal crops that extends their food requirements until Meher season, increase their expectations for aids. The message that the study will not directly and instantly benefit participants was clearly conveyed alongside the possibility of indirect benefits that its findings will help contribute to knowledge about the area and the people with the view to attract the attention of policy makers and stakeholders for redress.

Confidentiality of participants was another issue that required serious consideration, which was ensured by handling personal data in a sensitive manner and confirmed to participants that the data is used only for the purpose of the research, and not to be shared for other persons or interested groups. In addition, the respondents anonymous in the study and their characteristics will not make it possible for the reader to search them up. It means that the identity of the respondents will not be known by anybody outside the research team. In addition, I ensured the confidentiality of respondents, particularly those who were affiliated with government offices and policies at various levels, by using pseudonyms in my records, and often refraining from audio-recording of the discussions to avoid any repercussions for them in the future. Besides to this, the household questionnaire has an introductory part that ensures the secrecy and all those sensitive information to be kept in secret, confirming that the information will only be used for the research project.

1.8. Structure of the Dissertation

The dissertation is a monograph type with six chapters. Chapter one presented background and research context, statement of the problem, research objectives and questions, scope and significance of the study, delimitation of the study and research methodology including description of the study area and ethical considerations. The second chapter critically reviews theoretical and empirical literature and establishes conceptual framework for the study. It discusses a range of concepts and discourses pertinent to this research, covering perceptions, vulnerability, adaptive capacity and adaptation to climate change. It also explains the reasons for the selection and utilization of Sustainable Livelihood Framework (SLF) to investigate the causes of vulnerability and the adaptive capacity of smallholder farmers to climate change. Chapter three presents and discusses the results of perceptions of smallholder farmers to climate change. Historical climate data are compared with perceptions of climate change and its perceived effects among smallholder farmers in different LZs. Chapter four is devoted for the analyses and discussions of vulnerability to climate change. Chapter five deals with smallholder farmers' adaptive capacity and adaptation strategies to climate change. The sixth chapter summarizes and makes recommendations of the findings.

Chapter Two: Literature Review

2.1. Introduction

The second chapter presents the review of related literature. It discusses a range of concepts and discourses pertinent to this research including the basic concepts related with climate change, perceptions about climate change; vulnerability theories, components and measurements; trends of climate change; adaptive capacity; livelihood and climate change adaptation. Synthesis of relevant and related empirical studies undertaken on perception to climate change, vulnerability and adaptive capacity and adaptation strategies are also highlighted. Finally, conceptual framework drawn from the theoretical and empirical perspectives is explained at the last section of this chapter.

2.1.1. Basic Concepts and Definitions

Climate: Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (IPCC, 2018).

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persist for an extended period, typically decades or longer (ibid).

Climate extreme (extreme weather or climate event): The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes' (ibid).

Climate projection: A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission / concentration / radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized (ibid).

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

Disaster: Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery (ibid).

Drought: A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. A period with an abnormal precipitation deficit is defined as a meteorological drought (ibid).

Early Warning Systems (EWS): The set of technical, financial and institutional capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. Dependent up on context, EWS may draw up on scientific and / or Indigenous knowledge (ibid).

Ecosystem services: Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food or fibre, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation (ibid).

Global warming: The estimated increase in global mean surface temperature (GMST) averaged over a 30-year period, or the 30-year period centered on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue (ibid).

Heat wave: A period of abnormally hot weather. Heat waves and warm spells have various and, in some cases, overlapping definitions (ibid).

Indigenous knowledge: Indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings (ibid).

Local knowledge: Local knowledge refers to the understandings and skills developed by individuals and populations, specific to the places where they live (ibid).

Mitigation (of climate change): A human intervention to reduce emissions or enhance the sinks of greenhouse gases (ibid).

Social-ecological systems: An integrated system that includes human societies and ecosystems, in which humans are part of nature (ibid).

Paris Agreement: The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC (ibid).

2.1.2. Perceptions about Climate Change

Climate change is affecting every country on every continent, disrupting national economies, costing people and affecting lives and livelihoods of millions of people. In the face of global climate change and its emerging challenges and unknowns, it is essential that decision-making for policies and actions be based on the local actors' knowledge, perceptions and responsive strategies. In recent years, there has been a growing awareness that formal scientific knowledge alone is inadequate in solving the climate crisis (Finuccare, 2009). As a result, the perceptions and knowledge of local and indigenous people has been increasingly recognized as an important source of climate knowledge, coping and adaptation strategies.

It seems from this reality that currently indigenous knowledge and perceptions are increasingly recognized as an underutilized resource in rural development. According to Jiri et.al., (2015); valuable local knowledge of relevance to climate change assessment is held by rural societies. These knowledge systems are transmitted and renewed by each succeeding generation, ensuring the wellbeing of people through environmental conservation and early warning systems for disaster risk management. Indigenous knowledge and perceptions provide the basis for decision-making. According to Maddison, (2006); and Juana et.al., (2013), awareness or knowledge about climate change is a pre-condition for mitigating or adapting to its adverse effects. The fact that climate has changed in the past and will continue to change in the future underlines the need to understand how farmers perceive and adapt to climate change.

Perception is, in general, the process of attaining awareness or understanding of a phenomenon including climate change. Over the millennia, local communities have relied heavily upon their Indigenous Knowledge (IK), to conserve their environment and deal with natural disasters. The communities, particularly those in hazard-prone areas, have developed a good understanding and knowledge of disaster prevention and mitigation, early warning, preparedness and response, and post disaster recovery. This knowledge is based on facts that are known or learnt from experience or acquired through observation and practice, and is handed down from generation to generation. Scholars have pointed out that many technological solutions to problems in rural communities have failed because they did not take into account local knowledge and practices.

In this regard, understanding how smallholder farmers perceive climate change and how they adapt to it is very important to the implementation of policies for sustainable agricultural and rural livelihood development. Such information is necessary to guide future adaptation strategies. In this regard, smallholder farmers' perception plays a big role for successful implementation of adaptation strategies to mitigate climate change impacts as agricultural practices concerned (Arsiso, et.al., 2017).

2.1.3. Indigenous Local Forecasting Knowledge

Indigenous or local predictions provide clues about aspects of climate that are most salient for farmers, and about the kinds of climate information farmers seek to mitigate agricultural risk. At the same time, they can help enhance the relevance of scientific forecasts by integrating them with locally specific observations. IPCC's fourth assessment report noted that "indigenous knowledge is an invaluable basis for developing adaptation and natural resource management strategies in respect to environment and other forms of change" (Parry et.al., 2007; p. 19). This recognition was reaffirmed at the 32nd Session of the IPCC in 2010, where it was stated that, "Indigenous and traditional knowledge may prove useful for understanding the potential for certain adaptation strategies that are cost-effective, participatory and sustainable" (IPCC, 2010). The indigenous observations and interpretations of meteorological phenomena have guided seasonal and inter-annual activities of local communities for millennia. This knowledge contributes to climate science by offering observations and interpretation at a much smaller spatial scale with considerable temporal depth, and by highlighting aspects that may not be considered by climate scientists (Mafongoya, and Ajayi, 2017).

Farmers' forecasts concentrate on number, type and timing of rainfall rather than total quantity, which is key in scientific forecasting. Currently, scientific forecasting is unable to predict duration, amount or distribution of rainfall. Hence, integration of scientific knowledge with local knowledge might allow some inferences in this regard. Therefore, combining the knowledge of local resource-dependent people with evidence provided by formal climatology analysis holds the potential to reduce uncertainty and increase the relevance of future assessments of vulnerability and climate change adaptation. Indigenous and traditional peoples develop adaptation measures based on their own observations and interpretation of climate variability and change (ibid).

2.1.4. Empirical Literature

In order to analyze the coping and adaptation strategies of smallholder farmers to climate change in a given LZ, assessing the perceptions of the local indigenous communities becomes a pre-requisite, as specific geographical areas and production systems shape and influence the perceptions of the peoples in different stages of life. Similarly, Maddison, (2006) and Juana et.al., (2013) indicated that awareness or knowledge about climate change is a pre-condition for mitigating or adapting to its adverse effects.

Various researchers use different techniques and models for assessing perceptions of smallholder farmers to climate change. For instance, in a research conducted by Wooldridge (2002); Probit model was used in the first stage to generate a sample selection correction term, referred to as the Inverse Mills' Ratio (IMR), and then used as an explanatory variable in the Truncated model. A study conducted by Elum, Modise, and Marr (2017) in South Africa, a one-way analysis of variance, percentage analysis and Garrett ranking techniques were applied to analyze the perception of farmers to climate change. A study conducted by Menike and Arachchi, (2016) in Sri Lanka employed descriptive analysis technique to examine how rural smallholder farmers in different agro-ecological zones perceive climate change. Similarly, a study conducted by Alam et.al., (2017) used descriptive analysis to explore the local knowledge of adaptation in response to the perceived impacts of climate change and climatic hazards in Bangladesh. Commonly what is indicated is that descriptive analysis and various models, like Probit were employed to assess the perception of farmers in different countries.

Empirical studies conducted in sub-Saharan Africa by various scholars, among others: Nhemachena and Hassan, (2007); Yesuf et.al., (2008); Gbetibouo, (2009); Apata et.al., (2009); Mertz et.al., (2009); Fosu-Mensah et.al., (2010); Akponikpe et.al., (2010); Mandleni and Anim, (2011); Bryan et al., (2011); Sofoluwe et.al., (2011); Nyanga et.al., (2011); Acquah-de Graft, (2011); Gandure et.al., (2013); Ogalleh et.al., (2012); and Juana et.al., (2013) in general revealed that the majority of farmers are aware that there is a significant change in climate change pattern, though the percentage varies across different countries.

Factors that affect perceptions to climate change vary across different countries and localities. Studies show that different socio-demographic factors affect the perception of climate change. For instance, Diggs (1991), Maddison (2006) and Ishaya & Abaje, (2008) showed that farming experience, which is most often associated with age, plays an important role in the perception of climate change. Studies by Sampei & Aoyagi-Usui, (2009) and Akter & Bennett, (2009) revealed that exposure to mass media increases the awareness and concern about the damage associated with climate change. Semenza et.al., (2008) indicated that individuals with higher incomes are more likely to know that climate is changing than individuals with lower incomes. Moreover, other factors such as gender, ethnic background, membership of environmental groups, newspaper readers (Leiserowitz, 2006), education, access to extension services, geographical site and soil types (Maddison, 2006; Gbetibouo, 2009) may all affect perceptions of climate change (Deressa et.al., 2011).

Different people value perception to climate change based on their specific cultural, religious and environmental settings. Similarly, Asrat and Simane, (2018); and Aemro et.al.,(2012) indicated that perceptions vary spatially, and are influenced by different socio-economic and environmental factors (Semenza et.al., 2008; Sampei & Aoyagi-Usui, 2009; Akter & Bennett, 2009; as cited in Deressa et.al., 2011). According to a study conducted by Debela et.al., (2015) in pastoral/agro-pastoral systems in southern Ethiopia, the result indicated that age, education level, livestock holding, access to climate information and extension services significantly affected perception levels. Debela et.al., (2015) further indicated that household size, production system, farm and non-farm incomes did not significantly affect perception levels of smallholder farmers.

On the other hand, a study conducted by Asrat and Simane, (2018) in Dabus watershed, North-West Ethiopia indicated that educational attainment, age of the head of the household, the number of crop failures in the past, changes in temperature and precipitation significantly influenced farmers' perception of climate change in wet lowland parts of the study area. In dry lowland condition, farming experience, climate information, duration of food shortage, and the number of crop failures experienced determined farmers' perception of climate change. Temesgen et.al., (2008) indicated that age of the household head, wealth, information on climate change, social capital and agro-ecological settings have significant effects on farmers' perceptions to climate change.

On the other hand, a study conducted in Blue Nile of the upper catchment based on Agro-ecological zone of Highland, Midland, and Lowland study undertaken by African Technology Policy Studies (2013), revealed that there was no statistically significant variation in perception of temperature across the three agro-ecological zones. This implies that the change in temperature occurred in all agro-ecologies and it was felt more or less equal by every farming community. On the other hand, a research conducted by Hadgu et.al., (2014) in three districts situated at different agro-ecological zones of Tigray region of Ethiopia using descriptive statistics results revealed that farmers who reside in the highland area perceived increase in temperature than the lowlanders, implying that agro-ecological settings contribute for difference in perception to climate change.

Similarly, Diggs, (1991) indicated that agro-ecological setting of farmers influences the perception of farmers to climate change, further stating that farmers living in drier areas with more frequent droughts are more likely to describe the climate change to be warmer and drier than farmers living in a relatively wetter area with less frequent droughts. A study conducted by Menike and Arachchi, (2016) also indicated that perception to climate change was influenced by agro-ecological zone and farmers in the hilly and windy areas perceive more changes in climate variables than those in other areas, which is in favor of the results of Diggs, (1991). Belay et.al., (2005) argued that in Ethiopia, lowland areas are drier with higher drought frequency than other areas. Thus, it is hypothesized that farmers living in lowland areas are more likely to perceive climate change as compared to farmers living in midland and highland area as cited in Deressa et.al., (2011).

Specifically, for countries like Ethiopia, where there are diverse traditions, beliefs and cultural norms, analyzing smallholder farmers' perception plays a big role for successful implementation of adaptation strategies to mitigate climate change impacts. According to Simane et.al., (2016), understanding local perceptions and adaptive behavior provides better insights and information relevant to a policy that helps to address the challenge of sustainable agricultural development in the face of variable and uncertain environments. In this research, descriptive statistical techniques, qualitative analysis, Logistic regression, Chi-square tests and trend analysis of climate variables were employed for comparative analysis across the five LZs.

In summary, assessment of perceptions of smallholder farmers to climate change is a pre-requisite for further requirements of employing appropriate adaptation strategies, which ultimately contributes for vulnerability reduction studies. In this research, livelihood zone-based approach of perception is employed. Livelihoods research, of its nature, is essentially carried out at micro-level, such as households or communities and livelihood zone briefly describes the main characteristics of the livelihood patterns in that zone, as it provides geographical orientation of livelihood systems. Hence, assessing the perceptions and adaptation strategies of smallholder farmers to climate change and variability at local level helps to contextualize the required strategies and specific support needs. In this regard local level, affordable and scalable solutions are critical in designing policies and strategies based on those contextual settings.

2.2. Climate Change, Vulnerability and its Components

2.2.1. Concepts of Vulnerability

One of the catchy words in the scientific literature of climate change, but has no universally accepted definition is vulnerability. Scholars from different fields of specialization have been conceptualizing vulnerability differently based on their objectives and the methodologies employed within their individual contexts. Given the varieties of concepts and approaches that scholars define and use the term vulnerability, different fields of research have developed their own approaches to vulnerability, often heavily influenced by their topical and disciplinary foci (Sumner and Mallett, 2013). This has created multiple frameworks for understanding vulnerability to climate change and its subsequent classification (Adger, 2006; Adger and Vincent, 2005; Eakin and Luers, 2006; Gallopín, 2006; Vincent, 2007). One key division comes between physical scientists and social scientists, the former typically defining vulnerability based on physical exposure to extreme events and their outcomes, with the latter stressing the importance of social structures and differential access to resources (Adger, 2006). There has also been some blending of these two schools of thought, where the assessment is based on both aspects of a hazard as well as the social structures that respond (Aogán, et.al., 2014).

The literature provides a vast variety of interpretations and alternative concepts of vulnerability. The concepts often originate from different academic disciplines and professional fields of practice and they often differ with regard to their unit of analysis (e.g. individual, household or region) and methods (Adger, 2006; Füssel and Klein, 2006; O'Brien et.al., 2007; Pearson and Langridge, 2008).

Nelson et.al.,(2010) pointed out that definitions of vulnerability should not be confused with conceptual frameworks. While definitions describe the components of vulnerability, conceptual frameworks give meaning to the definitions so that they can be analyzed according to the analytical context in a transparent and repeatable way. According to Deressa, Hassan, and

Ringler, (2008); the knowledge of the existing conceptual and methodological approaches can influence the choice of one of the methods, or a combination of existing methods, in analyzing vulnerability for a specific area of interest. It should also be clear that definition of vulnerability has a time dimension built into it. A consistent and transparent terminology helps to facilitate the collaboration between different researchers and stakeholders, even if there are differences in the conceptual models applied (Downing and Patwardhan, 2005; Füssel, 2007; Laroui and van der Zwaan, 2001; Newell et.al., 2005).

The recent IPCC, (2018) glossary defined vulnerability as the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (ibid). Within the literature on climate change and human vulnerability (i.e., vulnerability of individuals, communities, societies and human systems), climate change has been conventionally seen as the main driver of vulnerability.

This is evident for instance in the definition suggested by the Intergovernmental Panel on Climate Change. The widely used IPCC definition of the Fourth Assessment Report states that:

> *''vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity''* (IPCC, 2007 p. 21).

This definition has become the most widely used in the climate change vulnerability literature (Bassett and Fogelman, 2013; Füssel and Klein, 2006; cited in Räsänen, et.al., 2016), thus having a major influence on research. Vulnerability to climate change is multidimensional and is determined by a complex inter-relationship of multiple factors (Eakin and Luers, 2006; Turner, 2010).

From the above definitions, commonly mentioned concepts in connection with vulnerability include that vulnerability should not only be seen from the inside part of the event itself, rather there are external factors as well which contribute for it. In addition, system of the process, sensitivity, degree of exposure and capacity to adapt are very important key words that encompass the concept. For the purpose of this research, the definition used by the IPCC in the third assessment report was adopted, as it fits with the goal and objectives of this research. Hence, the term 'vulnerability' is conceptualized to refer to (1) exposure to climate change, (2) sensitivity to climate change and (3) the capacity to cope and adapt with climate change that smallholder farmers confront in pursuit of their livelihoods, as described here under.

1. **Exposure to Climate Change**

Climate change exposure is defined by the magnitude, character and rate of climate change in a certain geographic area. Exposure as a component of vulnerability is not only the extent to which a system is subjected to significant climatic variations, but also the degree and duration of these variations (Adger, 2006). Exposure is the nature and degree to which a system (People, property, or other elements present in hazard zones) is exposed to significant climatic variations and subject to potential losses today and in the future for the specific region or livelihood zone, in this research context. According to the Index for Risk Management, Ethiopia is ranked as high risk, with exposure to hazards including increase in floods, earthquakes and droughts respectively, which will increase conflict risk and human exposure (Irish Aid, 2018). Due to the lack of long-term and/or continuous meteorological records in many parts of the developing world, as well as the lack of scientific projections at more localized scales, scientific information is often insufficient for analyzing local exposure to climate change. As a result, scientific information must build upon and be complemented by an analysis of local-level climate observations through consultations with communities and other local actors who are on the frontlines of climate change.

2. **Sensitivity to Climate Change**

The other component of vulnerability to climate change is sensitivity. It is the degree to which exposed people, places, institutions and sectors are impacted, either positively or negatively, by disaster today and the degree to which they could be impacted in the future. Communities' sensitivity to climate change is the degree to which a community is adversely or beneficially affected by climate-related stimuli (IPCC, 2001b). It largely depends on the main livelihood activities of the community (including its dependence on livestock and rain-fed agriculture), its key livelihood resources, and the impacts of climate hazards on these key resources.

Exposure and sensitivity together describe the potential impact that climate change can have on a system. However, it has to be noted that even though a system may be considered as being highly exposed and/or sensitive to climate change, it does not necessarily mean that it is vulnerable. This is because neither exposure nor sensitivity account for the capacity of a system to adapt to climate change (i.e. its adaptive capacity), whereas vulnerability is the net impact that remains after adaptation is taken into account. Thus, the adaptive capacity of a system affects its vulnerability to climate change by modulating exposure and sensitivity (Yohe and Tol, 2002; Gallopin, 2006; Adger et.al., 2007).

3. Adaptive Capacity

The adaptive capacity of a community is ability to adjust to climate change, to moderate or cope with the impacts, and to take advantage of the opportunities. Adaptive capacity is often determined by a range of factors, processes and structures such as income, literacy, institutional capacity, social networks, as well as access to information, markets, technology, and services, (IPCC, 2007). One of the most important factors shaping the adaptive capacity of individuals, households and communities is their access to and control over natural, human, social, physical, and financial resources. As the availability of these resources and services is limited in many developing countries, their adaptive capacity in the face of climate change is correspondingly low compared to developed countries.

There are incidents of using coping capacity and adaptive capacity interchangeably in the climate change literature. However, there are differences for what capacity of condition, context and duration should be used. Literally, coping is “the use of available skills, resources, and opportunities to address, manage, and overcome adverse conditions, with the aim of achieving basic functioning of people, institutions, organizations, and systems in the short to medium term” (IPCC, 2014). According to IPCC (2018), coping capacity is the ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities to address, manage, and overcome adverse conditions in the short to medium term.

Nelson, et.al., (2007) and Smit and Wandel, (2006) explained the difference between coping and adaptive actions. Coping action tends to be used to describe shorter-term adjustments made to simply survive a disturbance, whereas adaptive actions describe longer-term, more sustainable adjustments. Alternatively, Engle (2011), stated that coping strategies relate to short-term measures taken by households to moderate the adverse impacts of climate variability on their livelihoods over a time frame usually less than one year. Coping actions are not adaptive in the sense that they do not support transformative change, that is, complete reorganization or transformation of current management (Murphy, et.al., 2015). Coping strategies are 'erosive' when they undermine future livelihood security (vander Geest & Dietz, 2004; Warner et.al., 2012).

However, coping ranges and adaptive capacity are not static; steps can be taken to increase the coping range, or conversely, decisions can erode a coping range (Smit and Wandel, 2006). Coping often focuses on the actions individuals or communities have taken in the past in response to a specific change or hazard. However, the usefulness of past responses in future adaptations is uncertain, as climate change may lead to fundamentally new conditions compared with those in the past. When a system is undergoing large-scale changes that exceed functional thresholds, coping is no longer effective; rather, the system and system elements must adapt to novel conditions (Murphy, et.al., 2015). In some cases, coping and adaptation strategies may exert greater pressure on households' abilities to withstand future vulnerabilities (Brown, et.al., 2007), and this can lead to maladaptation (Antwi-Agyei, et.al., 2017).

2.2.2. Empirical Literature on Adaptive Capacity

From the nature of the multidimensional and comprehensive characteristic of adaptive capacity of a system, it is very difficult to devise a specific, yet holistic formula for its analysis. It is from this reality that in the assessment of adaptive capacity, the scale of assessment, similar with vulnerability and adaptation, received significant attention. According to McCarthy et.al., (2001), adaptive capacity of a system is determined by an array of factors which are neither independent nor mutually exclusive but a result of a combination of these factors. It is important to recognize that macro-scale processes are fundamentally different from those operating at a smaller scale. An adaptation program designed for a small and relatively uniform community is unlikely to be readily transferred to a regional center with a diverse population and a broader income base.

Some researchers explore adaptive capacity in reference only to specific events, risks, or thresholds; while others are more concerned with what might be called a generic capacity to adapt (a broad capacity to adapt to many different kinds of changes) (Lemos, et.al., 2013; cited in Murphy, et.al., 2015). Adaptive actions respond to different needs at different scales (e.g., individual, community, region, and nation), and such actions are shaped by capacities at those scales.

In the fourth assessment report of IPCC, Adger, et.al., (2007) identified two dimensions of what constitutes adaptive capacity, namely, the generic and impact-specific dimensions. While the generic dimension of adaptive capacity looks at the ability of a system to respond to the general climate change stimuli, the impact-specific dimension as its name denotes the ability of the system to respond to a particular climate change stimulus. A third dimension, proposed by Schneiderbauer, et.al., (2013) is sector-specific dimension of adaptive capacity, which is related to the capacity of a particular economic sector within a model region to adapt to the general impacts of climate change (Abdul-Razak and Kruse, 2017). When assessing sector-specific adaptive capacity of smallholder farmers, social capital tends to determine the ability of local farmers to access labour resources.

The determinants of a system's adaptive capacity are highly contested. In the search for determinants and indicators of adaptive capacity, a growing critique has emerged arguing that indicators will differ depending on the scale of the adaptive unit being analyzed (Wilbanks and Kates, 1999; Adger and Vincent, 2005; Vincent, 2007). For instance, the characteristics of adaptive capacity within households will be significantly different than those for communities or for countries (Adger and Vincent, 2005; Vincent, 2007) and for individuals (Grothman and Patt, 2005). Yet, these forms of social organization are also nested, as nation-states consist of and govern communities and households, and communities are embedded in nation-states (Adger et.al., 2009).

Constraints identified for adaptive capacity in Kenya, South Africa, Ethiopia, Malawi, Mozambique, Zimbabwe, Zambia, and Ghana, in general, include poverty and a lack of cash or credit (financial barriers); limited access to water and land, poor soil quality, land fragmentation, poor roads, and pests and diseases (biophysical and infrastructural barriers); lack of access to inputs, shortage of labor, poor quality of seed and inputs attributed to a lack of quality controls by government and corrupt business practices by traders, insecure tenure, and poor market access (institutional, technological, and political barriers); and finally a lack of information on agroforestry/afforestation, different crop varieties, climate change predictions and weather, and adaptation strategies (informational barriers) (Barbier et.al., 2009; Clover and Eriksen, 2009; Deressa et.al., 2009; Bryan et.al., 2009; Roncoli et.al., 2010; Mandleni and Anim, 2011; Nhemachena and Hassan, (2008); Nyanga et.al., 2011; Vincent et.al., 2011a).

A variety of empirical methods have been used to assess adaptive capacity ranging from relatively quantitative to highly qualitative. Quantitative frameworks use surrogate indicators of adaptive capacity, the value of which they obtain from open sourced data or measure using surveys (Yohe and Tol, 2002; Luers, et.al., 2003; Brooks, et.al., 2005; Sietchiping, 2007; Lockwood, et.al., 2015; Abdul-Razak and Kruse, 2017; Agnes, et.al., 2017; Alhassan, et.al., 2018b).

Some have adopted the five capitals of Sustainable Livelihoods approach to poverty reduction as proxy indicators of adaptive capacity (Osman-Elsha, et.al., 2005; Cooper, et.al., 2008; Hahn, et.al., 2009; Defiesta and Rapera, 2014). Goldman and Riosmena (2013) assessed adaptive capacity in Tanzanian Maasai-land focusing on livestock keeping and found that adaptive capacity is unevenly distributed within communities. Other techniques include a study conducted in China by Hu and He, (2018) developed the evaluation index system of Urban Adaptive Capacity (UAC) based on the driver-pressure-state-impact-response model (DPSIR).

Commonly in most approaches, a mix of qualitative and quantitative data is used in the process of analyzing adaptive capacity to climate change. There are also variations in terms of identifying indicators, most often depending on the objective and research questions (context specific) identified by the researcher. According to Defiesta and Rapera, (2014) indicators used in recent times are largely based on the Sustainable Livelihood Framework, which comprises five assets, human, social, natural, physical and financial capitals from which livelihoods of people are built (Serrat, 2010; cited in Abdul-Razak and Kruse, 2017).

In the process of identifying indicators, Jones, Ludi, and Levine, (2011) argue that while the availability of assets is essential, asset-oriented approaches typically mask the importance of processes and functions in supporting adaptive capacity. They fail to capture the role of agency in adaptation, i.e. the behaviour, creativity and entrepreneurialism of the individuals and organizations within the system, as well as the role that historical and structural factors play in constraining or enhancing those agents' adaptive choices.

In connection with making visible the importance of processes and functions in supporting adaptive capacity, Levine, et.al., (2011) developed the Local Adaptive Capacity (LAC) framework, which characterizes adaptive capacity based on five elements: asset base; institutions and entitlements; knowledge and information; innovation; and flexible forward-looking decision-making and governance. The LAC framework is an improvement over capital-based approaches in that it examines the processes through which a system adapts, rather than just what it has that enables it to adapt. In this research, in addition to assets (Human, Social, Financial, Natural, Physical), indicators in relation with institutional and infrastructural, and information accessibility are taken in the indices in order to develop composite adaptive capacity index. The more varied the asset base, the greater is people's adaptive capacity and the level of security and sustainability of their future livelihoods.

2.2.3. Theoretical Constructs of Vulnerability to Climate Change

In the recent years, climate change studies have recognized that vulnerability is not only defined by the characteristics of the hazards, but rather by the emergent property of human-environmental systems that enable them to cope with changes, thereby linking vulnerability to their adaptive capacity (Vincent & Cull, 2010; Vincent, 2004; Adger & Kelly, 1999; Adger, 1999). There are different assessment approaches to vulnerability to climate change. Such differences in the approach have led to the coining of the terms 'biophysical' and 'social' vulnerability (Vincent, 2004; Brooks, 2003). As a 'starting-point', vulnerability is caused by numerous environmental and social processes, and exacerbated by climate change. In this approach, vulnerability is determined by the existing capacity to respond to that hazard. This approach puts vulnerability as the 'starting point' of analyses, a state that exists within a system before it encounters a hazard, therefore, refers to the present day vulnerability.

Viewing vulnerability as a starting point further allows for an understanding of how climate change impacts will be distributed and is used to identify how vulnerability can be reduced

(O'Brien et.al., 2009). In viewing vulnerability as a ‘starting-point’, climate change acts as a “magnifying glass” where populations that already exist at the margins of society are likely to experience climate change more acutely, which further prevents them from participating equally in any solution or accessing necessary adaptation measures (Lambrou & Paina, 2006; Masika, 2002; Skinner, 2011; Tanner & Mitchell, 2008).

In the starting point approach, emphasis is placed on “social vulnerability” concerning more with the social system. Social vulnerability approach recognizes that the physical phenomena are mediated by the particular human context in which they occur. Social vulnerability also helps to explain why some communities experience the hazard differently, even though they experience the same level of flooding or storm flow inundation. Cutter et.al., (2009) argues that critique of social vulnerability approach is the failure to examine the root causes of the social vulnerability and the failure to include the larger contexts within which such vulnerability exists.

While biophysical studies have contributed to our understanding of the physics of climate change and its impact on biophysical environments, it has less implications on policy making since variables like temperature and precipitation are not under the immediate control of the policy makers. In addition, the assessment of biophysical factors is not a sufficient condition for understanding the complex dynamics of vulnerability. It also neglects structural factors and human agency both in producing vulnerability and in coping or adapting to it. The approach overemphasizes extreme events while neglecting root causes and everyday social processes that influence differential vulnerability.

An integrated framework of both biophysical components (exposure and sensitivity) and the socio-economic component (adaptive capacity) has been employed by Piya et.al., (2012) along with sustainable livelihood framework. The study covers all three components of vulnerability and adopts rural livelihoods framework. Hence, some studies have, therefore, tried to form a compromise between the two approaches by considering an integrated approach for vulnerability assessments, combining social vulnerability (adaptive capacity) with the biophysical aspects of climate change (exposure and sensitivity) to give a complete picture of vulnerability (Nelson et. al., 2010b; Gbetibouo & Ringler, 2009; Cutter, 1996). The ‘hazard-of-place model’ by Cutter et.al., (2000) is a good example of integrated approach, in which both biophysical and socio-economic factors are systematically combined to determine vulnerability. The vulnerably mapping approach is another example in which both socio-economic and biophysical factors are combined to indicate the level of vulnerably through mapping (O'Brien et.al., 2004).

End-point analyses, on the other hand, tend to view vulnerability as a linear impact of hazards, referring to the exposure and sensitivity of natural environments to projected changes in climate, therefore, referring to the biophysical vulnerability. This approach is often criticized for taking humans as passive receivers of hazards, failing to account for the interactions of humans to cope with such hazards. Some analysts regard assessment of vulnerability as the end point of any appraisal, others as the focal point, and yet others as the starting point. And these different views carry considerable baggage regarding, amongst other things, levels of certainty and uncertainty, policy relevance and disciplinary focus. According to Kelly & Adger (2000), in 'end-point' analysis, one considers the residual impacts of climate change after adaptation efforts have been made.

2.2.4. Methods to Vulnerability Analysis

Unsurprisingly, the identification of metrics and standards for measuring vulnerability remains a significant challenge for the scientific community, and hence difficult to device a one size fits all type of formula. However, there are different approaches which researchers use, such as indicators, case studies, analogies, stakeholder-driven processes, and scenario-building methodologies, sometimes using mapping and geographic information system (GIS) techniques, based on their context, research objectives and type of data availability. It is generally accepted that measurement in vulnerability analysis and adaptive capacity is most effective when qualitative and quantitative methods and objective and subjective contexts are used in combination to inform, complement and address the research objectives.

Assessment of vulnerability to climate change mainly involves research into the exposure, sensitivity and adaptive capacity levels of a system, in this research context, in the presence of climate change. For any adaptation effort to be initiated in response to climate change impacts, vulnerability assessment is often the preliminary step, as it is considered as a pre-requisite for further analysis of adaptation and resilience. The most common methods for analyzing vulnerability to climate change employed in vulnerability literature are the econometric and indicator methods (Leichenko et.al., 2001).

2.2.4.1. Econometric method

This method uses household-level socio-economic survey data to analyze the level of vulnerability of different social groups. The method is divided in to three categories: vulnerability as expected poverty; vulnerability as low expected utility; and vulnerability as uninsured exposure to risk. All three share common characteristics in that construct a measure of welfare loss attributed to shocks (Hoddinott et.al., 2003).

This method was used by Temesgen et.al., (2009) to assess farmers' vulnerability to climate extremes in Ethiopia. They estimate the probability of the income of households falling below a poverty line, and classify vulnerable households as those with more than fifty per cent probability of falling below the poverty line. The authors are able to identify the share of vulnerable households in different agro-ecological zones, and differentiate between vulnerable households that are poor today and vulnerable households that are not poor today.

There are limitations to using econometric approaches to measuring vulnerability to climate change. The first limitation of this approach is based on observed data will have to rely on already observed climate variability to measure vulnerability to climate change. Second, point to high data requirements and that the form of the utility function must be assumed, as weaknesses of the economic approach (Sofie, 2012).

2.2.4.2. Indicator method

There is no agreed integrated metric for vulnerability to climate change, as vulnerability is a conceptual construct rather than a directly observable phenomenon. This lack of a single measure means that a combination or set of indicators is required to provide an accurate picture of both adaptation and vulnerability. These indicators vary depending upon the framework used, the research question at hand, the methodology employed, the context in which the research is undertaken and often the disciplinary paradigm of the researchers (Aogán, et.al., 2014). Most often, vulnerability indicators tend to be used in relation with sensitivity, exposure and adaptive capacity indicators. From the point of view of scientific innovation, the profusion of a diverse array of approaches to researching climate vulnerability is positive development (ibid).

The indicator method of quantifying vulnerability is based on selecting some indicators from a set of potential indicators and then systematically combining them to point out the levels of vulnerability. These levels of vulnerability may be analyzed at local, regional and global level (Adger, W.N., 1999; Leon-Vasquez et.al., 2003; Morrow, 1999). Two options are available for calculating the level of vulnerability using this method at any scale. The first is assuming that all indicators of vulnerability have equal importance and thus giving them equal weights (Cutter, et. al., 2000). The second method assigns different weights to avoid the uncertainty to equal weighting given the diversity of indicators used (O' Brien, et.al., 2004). In line with the second method, many methodological approaches have been suggested to make up for the weight differences of indicators.

In the context of sustainable livelihoods, vulnerability assessment is often undertaken through an indicator-based approach. Adger et.al., (2003) used an indicator-based approach to understand how various factors interact to explain vulnerability significantly. As per the conceptual framework developed by the authors, vulnerability cannot be defined in terms of singular indicators nor it is static; rather different factors combine differently in a specific context to determine a system's vulnerability in a dynamic way.

For indices, attempts are made to quantify each component through the development of indicators that can then be combined into an integrated index of vulnerability. Devising an index to measure vulnerability is helpful to compare similar systems and provide insights into the underlying processes and determinants of vulnerability that is of relevance to policy makers. The first step in constructing the index comprises of the selection of indicators, then weights are assigned to these indicators, and finally these indicators are aggregated to form an index. However, the methodology adopted in the choice of indicators is very crucial, since choice of wrong indicators may lead to a construction of an invalid index. Choice of indicators to represent the index for vulnerability is constrained by the fact that vulnerability itself has no tangible element. Much of the research on climate change vulnerability has utilized some kind of indicator methodology. This research also adopted Livelihood Vulnerability Index approach through integrating an array of various components and sub-indicators.

According to Vincent (2004), there are two approaches in the selection of indicators, data-driven and theory-driven. The selection of suitable indicators can best be done based on some theories that provide insight into the nature and causes of vulnerability. However, even theory-based deductive approaches are constrained by data-limitations due to which subjectivity enters in the process of indicator selection. The best option is to verify the representativeness of the theory-based indicators with insights gained from focus group discussion conducted at the local level (Luni, et.al., 2012). This approach was adopted while selecting the indicators used in this research. Murphy, et.al., (2015) also mentioned that most researchers rely on expert elicitation to weigh particular indicators, such as income, gender, or education, and then use the established index to rank or rate households, communities, or larger units, such as countries, according to their relative vulnerability or adaptive capacity.

In the context of vulnerability assessment, (Carter & Mäkinen, 2011) suggest that indicators are commonly drawn from a combination of the biophysical realm (primarily of exposure and sensitivity) and from socio-economic statistical sources (mainly describing adaptive capacity). Identifying indicators by themselves is not an end. Indicators form just one part of vulnerability assessments and that they should only be formulated once the purpose of the assessment and the conceptualization of vulnerability have been determined (Fritzsche et.al., 2014).

There are good reasons to continue indicator studies at some levels. Nelson et.al., (2010) distinguished between general vulnerability and specific vulnerability, pointing out that indicator research is helpful in understanding vulnerability more generally. The fundamental purpose of such work is to highlight deficiencies in adaptive capacity so that initiatives can be appropriately targeted to support capacity building where necessary. Adger, (2006) argued that targeting resources to specific groups or regions should be the primary purpose of indicator studies, while (Barnett, Lambert and Fry, 2008; Hinkel, 2011; cited in Murphy, et.al., 2015) suggested that indicators are only useful for identifying vulnerable entities when systems can be narrowly defined (particularly vulnerable people, regions or sectors) by a few variables or as starting points to future, more detailed inquiry.

In selecting indicators, it is very important to view scale and unit of measurement. Different researchers and institutions employ various scales of assessment to vulnerability, including continental, sub-continental, country, regional, zonal, agro-ecological, etc…levels. Many vulnerability assessments have focused on local or community scale, where vulnerable groups and coping strategies can be concretely identified (Stephen and Downing, 2001). In this research, livelihood zone is taken as the scale of assessment. Following on this, it is important to note that just as vulnerability is produced by the intersection of specific contextual drivers, vulnerability assessments are themselves also often conducted at the intersection of specific contexts, actors and interests. Because no two communities, landscapes, or local economies are the same, vulnerability assessments are likely to be most effective when tailored to a specific context.

The view of conducting vulnerability assessment at finer scale is supported by various scholars. For instance, Eakin and Luers, (2006) argue that households are often a convenient unit of analysis for vulnerability assessments that aim to differentiate a population in terms of sensitivity to a particular stressor and capacities to effectively respond. At the household level, vulnerability is often evaluated by assessing exposure (the physical relation of the household to a stressor) and sensitivities to the losses experienced (e.g., what the impact means for the household's function and survival), as well as by the households' ability to cope and adapt, or its ''adaptive capacity,'' prior to and after experiencing loss (Eakin et.al., 2012). Similarly, Aogán, et.al., (2014) stress that finer-scale analysis at a household or community level allows greater clarity on specific causes, interactions and outcomes of vulnerability. In addition, Eakin and Bojórquez-Tapia, (2008) also mentioned that local level assessments have the potential to recognize the context and system-specific dynamics of vulnerability determinants, which change according to the hazard.

2.3. Empirical Literature

From the nature of the term vulnerability and its relatedness to a specific context, place, time and the view of those who assess it has opened spaces for utilization of various methods by different scholars. Some of the most common approaches employed by various scholars are discussed as follows.

Yusuf and Francisco, (2009) in their study mapped vulnerability in south Asia with the conceptual frame work of vulnerability = f (exposure, sensitivity and adaptive capacity). In their analysis, indicator method vulnerability was employed by attaching different weight for different indicators and their proxies by using expert opinion polling method. They assessed exposure using information from historical records of climate related hazards.

Temesgen et.al.,(2008) in their study analysis of Ethiopian farmers' vulnerability change across seven regional states analyzed using integrated assessment approach. To analyze the overall vulnerability of farmers they calculated vulnerability as a function of adaptive capacity, sensitivity and exposure. By identifying indicators from the socio-economic and biophysical components, they run a principal component analysis method to determine the factor scores or relative weight of the selected indicator of each region. Methodologically similar, but different in scale to Temesgen, et.al., (2008), Abenet, (2010) has employed a local level comparative assessment of vulnerability to climate change among pastoral and agro-pastoral households in Yabello woreda of Oromia regional state using integrated vulnerability approach and vulnerability indicator method to assess the level of vulnerability.

Hahn et.al., (2009) have offered a replicable methodology which has been used by many researchers to determine vulnerability in different contexts (e.g. Pandey and Jha, 2012; Shah et. al., 2013; Panthi et.al., 2016, Adu et.al., 2017, etc.). The LVI was originally designed to provide development organizations, policy makers and planners with a practical tool to understand contributions of demographic, social and physical factors to climate vulnerability. This provides a flexible approach where development planners can refine and focus their analysis to suit the needs of each geographical location. In addition to the overall composite index, sectorial vulnerability indices can be segregated to identify potential areas for intervention (Hahn et.al., 2009). The LVI takes into consideration earlier methods of estimating the differential impacts of climate change. This index uses primary data from households and combines them with data obtained from secondary sources (Etwire et.al., 2013; Hahn et.al., 2009).

Pandey and Jha, (2012) used the livelihood vulnerability index approach for two communities in rural India in the Lower Himalayan region and provided a comparative analysis of the strengths of rural mountainous livelihoods. Similarly, Shah et.al., (2013) employed the livelihood vulnerability index for the case of two rural communities in wetlands of Trinidad and Tobago. Panthi et.al., (2016) applied the livelihood vulnerability methodology for the case of agro-livestock owners in three ecologically different districts in Nepal. Applying the same methodology for two communities in Ghana, Adu et.al., (2017) identified that both regions had different determinants of vulnerability.

In general, index-based analyses have certain precedence over other methodologies in that they rely on primary and secondary data as they are better designed to provide a localized viewpoint, giving context-based insight for local needs and adaptation responses required. As vulnerability is a socially constructed subject (Hinkel, 2011), studies based on primary data collection or those employing a mix of primary and secondary data are better posited to provide insight on socially determined drivers of vulnerability.

This research applied the IPCC Livelihood Vulnerability Index to study the vulnerability of smallholder farmers imposed by climate change in five livelihood zones in southern Ethiopia. The IPCC Livelihood Vulnerability Index offers a tested technique that has the ability to identify the determinants of vulnerability and at the same time possessing the capacity to compare scores among different units. It also allows contextualizing the choice of indicators to the local scenario. The power of providing household/community level analysis is also a positive feature of this methodology. In this research, the guidance from work done by Hahn et.al., (2009) and Panthi et.al., (2016) is adopted and applied to the specific context of the five livelihood zones in the study area.

Ethiopia belongs to one of those countries vulnerable to climate change. The Notre Dame Global Adaptation Initiative (ND-GAIN) Index ranks Ethiopia as the 36^{th} most vulnerable to climate change, of the countries it covered for 2015 (Irish Aid, 2017). In Ethiopia, there are studies conducted in different contexts and frameworks according to the researchers' interest. For instance, Tadege, (2007) indicated that causes for vulnerability of Ethiopia to climate change include very high dependence on rain-fed agriculture which is very sensitive to climate variability and change, under-development of water resources, low health service coverage, high population growth rate, low economic development level, low adaptive capacity, inadequate road infrastructure in drought prone areas, weak institutions, and lack of awareness. According to

Sisay, (2016), vulnerability of rural farm households in North Gonder is largely determined by variety of factors that include social, economic and natural factors and households living in areas having better access to education, livelihood strategy and social network have better adaptive capacity and lesser vulnerability to climate change impacts.

Deressa, et.al, (2008) indicated that the level of vulnerability of Ethiopian agriculture to drought is determined by both socio-economic and biophysical factors. The socio-economic factors most cited in the literature include the level of technological development, infrastructure, institutions, and political set ups and the biophysical attributes mainly include climatic conditions, quality of soil, and availability of water for irrigation (*Ibid*).

A study conducted by Dechassa et.al., (2016) in Didesa Sub Basin of Blue Nile River based on agro-ecological approach applied the Livelihood Vulnerability Index framed within the LVI-IPCC vulnerability framework through cross-sectional household survey complemented with secondary data of rainfall and temperature. For each agro-ecological zones, LVI and LVI-IPCC vulnerability score was calculated. The result shows that, each of these metrics varied systematically where the lowland agro-ecological zone is the most exposed zone, the highland is the most sensitive zone and the midland is the highest in adaptive capacity to climate variability and change.

Similarly, Alemayehu and Bewket, (2016) investigated vulnerability of smallholder farmers to climate change and variability in three districts located in different agro-ecological zones (AEZs) in the central highlands of Ethiopia using two vulnerability measurement approaches developed by previous researches (LVI and LVI-IPCC). The findings are supported by Teshome, (2016) who observed that farmers in the Kolla agro-ecological zone were more vulnerable to the effects of climate change and variability compared to those in the Dega agro-ecological zone. However, Tesso et.al., (2012) reported in a different manner and those farmers in the Dega agro-ecological zone were more vulnerable to the effects of climate change and variability due to land degradation and less experience in adaptation.

On the other hand, Simane et.al., (2016) reported that both farmers in the Dega and Kolla agro-ecological zones were more vulnerable than those in the Weyna Dega agro-ecological zone. From the findings of the studies conducted in Ethiopia, it is possible to state that even though different researchers use the same technique of composite LVI and LVI-IPCC, however, the findings are different in specific settings with similar agro-ecologies, indicating that context specific indicators influence the degree of vulnerability differently.

2.4. Trends of Climate Change in Ethiopia

Ethiopia is both topographically and climatically complex, with vastly different rainfall regimes across the country. The seasonality of rainfall in Ethiopia is complex with the number of rainy seasons and their importance in terms of percentage of total rainfall varying depending on location. Ethiopia's National Meteorological Agency (NMA) describes three seasons, the Belg rainy season from February to May (corresponding to the East African 'short rains'), the Kiremt rainy season from June to September, and the cool and dry Bega season from October to January. The Belg season is considerably more variable than the Kiremt, contributing to high vulnerability to shifts in rainfall in areas that are primarily dependent on the Belg rains (Cochrane and Singh, 2017).

Ethiopia's climate is influenced by diverse topographical and agro-ecological settings, as well as multi-decadal global oscillations, complicating long-term forecasting and climate models for rainfall. Historically, Ethiopia has been prone to extreme weather variability. Rainfall is highly erratic; most rain falls with high intensity and there is a high degree of variability in both when and where it falls. The current and expected impacts of climate change are influencing government policies and services indicating the need to integrate climate change mainstream frameworks in land use and land cover and land suitability changes. Especially in recent years, the variability is increasing in ways that pose unique challenges for the agricultural base of the country (Bewket, Radeny and Mungai, 2015; Suryabhagavan, 2017).

Looking forward, Global Climate Models have projected an increase of mean annual temperatures by between 1.4 and 2.9 ^{0}C by middle of the century (Conway and Schipper, 2011; cited in Cochrane and Singh, 2017). The Intergovernmental Panel on Climate Change found that reports from the Famine Early Warning Systems Network (FEWS NET) indicate that there has been an increase in seasonal mean temperature in many areas of Ethiopia (IPCC, 2014). According to the UNDP climate change country profiles, the average annual temperature in Ethiopia increased by 1.3^{O}C between 1960 and 2006 (McSweeney et.al, 2010). Daily temperature observations also show an increase in the average number of ‘hot’ days and ‘hot’ nights per year (Irish Aid, 2018).

ENSO (ElNiño Southern Oscillation) is one of the main predictable drivers of year-to-year rainfall variability in Ethiopia. During El Niño years, there is often reduced rainfall in northern Ethiopia during the main Kiremt season, while in southern parts of Ethiopia rainfall is typically enhanced from September to November (Jury, 2016; Gissilia et.al., 2004). During La Niña event, rainfall is enhanced during the Kiremt season, especially in the northern part of the country, and reduced from November to then extend to May in the southern part of the country (Wolde-Georgis, 2002). The Indian Ocean Dipole also effects rainfall in southern Ethiopia mainly during October to December (Shongwe, et.al., 2011; Marchant, et.al., 2007; cited in Cochrane and Singh, 2017). Hence, the changes in climate is also disrupting the seasonality, creating more complexities.

2.5. Livelihood and Climate Change Adaptation

2.5.1. Conceptualizing Livelihood

Livelihood perspectives have been central to rural development thinking and practice in the past decades, and still utilized in various contexts. A variety of definitions are offered in the literature, including, for example, *‘the means of gaining a living’ (Chambers 1995, VI) or ‘a combination of the resources used and the activities undertaken in order to live’.* A descriptive analysis portrays a complex web of activities and interactions that emphasize the diversity of ways people make a living.

Livelihood is at the heart of all scholarship that contributes to the present understanding of adaptive capacity in developing countries. Livelihoods perspectives start with how different people in different places live. IPCC, (2018) defines livelihood as the resources used and the activities undertaken in order to live. Livelihoods are usually determined by the entitlements and assets to which people have access. Such assets can be categorized as human, social, natural, physical or financial (ibid). Scoones and Wolmer (2003); cited in Scoones, (2009) argue that livelihood perspectives offer an important lens for looking at complex rural development questions. The standard definition of livelihood is that of Chambers and Conway (1992):

> *"A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base"* (Chambers and Conway, 1992:7).

2.5.2. Livelihoods and Climate Change Adaptation

In development studies and practice, the notion of 'adaptation' has itself been modified to focus on adaptable livelihood systems. Hence, livelihoods and climate change adaptation are very interrelated concepts demanding context specific investigation and analysis. Sustainable livelihood thinking considers the coping and adapting mechanisms that people use in response to the dynamic nature of the social-ecosystem that they live within, which are not typically captured in traditional climate change vulnerability assessments that focus on employment, production, markets, and forestry systems. Morton, (2007) argues that local responses to climate variability, shocks, and change have always been part of livelihoods. Livelihood based adaptation, therefore, is the recently demanding concept for understanding local climate change vulnerability contexts for ensuring sustainable livelihood system. Climate change increases the pressure on already vulnerable livelihoods, and particularly those that depend on natural resources. Recovery from losses and damages is more difficult for the most vulnerable people whose livelihood security depends on land and other natural resources.

Sonja, et.al., (2015) indicated that livelihood systems are an essential framework for human organization. They include social and economic networks, maintain cultural practices and enable upward socio-economic mobility over generations. According to Morgan et.al., (2012), methods for investigating community livelihoods lend insight into social-ecological resilience, adaptation and transformation under a changing climate. Increasing the chances for successful adaptation requires a sound understanding of how a given system functions, in response to the key driving climatic and non-climatic variables. This system understanding needs to be represented in the form of a causal model which establishes the relationships and interrelationships between different variables, and how risks are generated. As such, learning and developing understanding of how a given system functions will rely on the given community's overall livelihood system, collective experience and knowledge. As well, from vulnerability perspective the adaptive capacity of communities can be evaluated.

At this level, it is important to stress that a farmers' choices of adaptation strategies are shaped by livelihood needs and goals and cultural values. Livelihood adaptation, according to Susanna, and Naomi and Davies, (1997; p. 5) refer to:

> *'the dynamic process of constant changes to livelihoods which either enhance security and wealth or try to reduce vulnerability to poverty'*.

The process of livelihood adaptation can be positive (leading to greater security and sometimes more assets and wealth) or negative (leading to greater vulnerability and the loss of assets, which is irreversible in the worst cases). Livelihood systems include ex-ante risk reduction strategies, as well as ex-post survival and coping strategies. Positive forms of adaptation involve livelihood intensification (the expansion or strengthening of existing systems) and livelihood diversification (the adoption of new or more diverse strategies), while negative forms of adaptation may consist of more fundamental changes to basic subsistence (such as asset depletion, begging or prostitution) if the shock to existing livelihood systems is sufficiently severe.

There is no universally accepted definition of what counts as adaptation in practice. General definitions like the one proposed by the IPCC, (2018:542) puts explanation of adaptation in two systems, stating that adaptation in human systems is:

> *"the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities"*

And, adaptation in natural systems is:

> *"the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects"*.

In the context of climate change literature, adaptation is the process of adjusting to current or expected changes in climate and its effects. Pettengell, (2010:7) defines climate change adaptation as:

> *"actions that people and institutions make in anticipation of, or in response to, a changing climate. This includes changes to the things they do, and/or the way they do them"*.

Below et.al., (2012); and Wheeler et.al., (2013) state that adaptation refers to adjustments in human-environmental systems in response to observed or expected changes in climatic stimuli. Adaptation depends greatly on the adaptive capacity or adaptability of an affected system, region, or community to cope with the impacts and risks of climate change. Serraj and Pingali, (2019) argue that to be indigenous-based, adaptation practices need to be developed locally by the communities observing climatic phenomena. According to Cutter, (2016) farmers often adopt adaptations that are relatively short term in nature, rather than developing longer-term adaptive strategies.

Adaptations occur in something (i.e., who or what adapts?), which is called the “system of interest,” “unit of analysis,” “exposure unit,” “activity of interest,” or “sensitive system” (Carter et.al., 1994; Smithers and Smit, 1997a; Reilly and Schimmelpfennig, 2000; cited in Smit, and Pilifosova, 2001). Article 7 of the Paris Agreement provides an aspirational global goal for adaptation, of ‘enhancing adaptive capacity, strengthening resilience, and reducing vulnerability’ (UNFCCC, 2016). Even though climate change is a global problem, its impacts are experienced differently across the world. This means that responses are often specific to the local context, and so people in different regions are adapting in different ways. A rise in global temperature from the current 1°C above pre-industrial levels to 1.5°C, and beyond, increases the need for adaptation (Coninck et.al., 2018). Operationalizing adaptation in a set of regional environments on pathways to a 1.5°C world requires strengthened global and differentiated regional and local capacities (Vergara et.al., 2015).

Climate change adaptation is a continuous process requiring location-specific response. However, much of the documented information on impact of climate change and its associated variability is at the global level. According to FAO, (2011) there is an increasing need for a more organized body of information and knowledge at local and community levels on the location-specific impacts of climate change and variability on the agricultural-based livelihood systems (i.e. smallholder rain-fed agriculture, herders and agro-pastoralists, smallholder mixed-farming, etc) as well as on best practices and options to increase awareness and preparedness for adaptation to climate change.

Similarly, Dietz et. al., (2009) argue that large-scale governmental efforts to combat climate change that do not consider household-level actions and resources can undermine the inherent adaptive capacity of households or de-incentivize further protective measures taken by households (Barrett, 2006; Toole et.al., 2016). Because the decisions of individuals can have cumulative effects on communities and policy outcomes (Kane and Shogren, 2000; Head et.al., 2013; Elrick-Barr et.al., 2016), as a result, households are increasingly viewed as foundational social units for observing adaptation and resilience (Toole et. al., 2016).

Most sectors, regions and communities are reasonably adaptable to average changes to the local climate and do so on their own initiative (often referred to as ‘autonomous adaptation’), particularly if change is gradual. However, support is needed at both national and community levels to adapt and make informed transformations in response to changes in climate that may have no recent historical precedent, when local institutions may not have the necessary familiarity or the capacity to cope and adapt (Jones, et.al., 2010). Similarly, Fankhauser S., (2016) stresses that there are adaptation gaps and market imperfections which call for government interventions, especially in developmental states to facilitate the balance of livelihoods.

2.5.3. Types of Adaptation

The climate adaptation literature is rich in frameworks and concepts that relate to adaptation approaches and adaptation-related system characteristics, often with many overlapping and sometimes, with contesting definitions. Evidently stating, adaptation manifests itself in a number of forms, is undertaken by various agents and occurs at multiple scales. The IPCC and the Kyoto Protocol have also recognized adaptation in its different forms (Adger et.al., 2003) and agreed that some form of intervention is needed to support adaptation adoption in societies.

The concept is usefully disaggregated into various ways; mainly by timing, goal, motive and scale of its implementation and by the degree of planning involved. Adaptation can be autonomous or planned (Smit and Wandel, 2006); adaptation could also be classified into spatial scope in terms of being localized and widespread (Smit and Wandel, 2006; IPCC, 2001b); temporal scope as short-term versus long-term (Smit et.al.,1999; 2000; IPCC, 2001b); form (technological, behavioral, financial, institutional, informational) Smit et. al., (1999; 2000); and function/effects (retreat, accommodate, protect, prevent, tolerate, spread, change, restore) (Smit et. al., 1999; 2000; cited in Wardekker, 2011).

Accordingly, adaptations undertaken by individuals or communities can be classifies as:

Reactive or Anticipatory: Reactive adaptation takes place after the initial impacts of climate change have occurred; while anticipatory adaptation takes place before impacts become apparent. In unmanaged natural systems, adaptation is autonomous and reactive and is the means by which species respond to changed conditions, hence, there is no anticipatory adaptation. In these situations, adaptation assessment is essentially equivalent to natural system impact assessment.

Public (sometimes termed as Planned) or Private (Autonomous): The distinction is based on whether adaptation is motivated by public interest (government) or private (individual households and companies). The former is largely planned, seeking to facilitate sustainable and effective positive adaptation by the community as a whole; is the consequence of deliberate policy decision, based on the awareness that conditions have changed or are expected to change and that some form of action is required to maintain a desired state. Füssel, (2007) argues that adaptation to climate change is planned when the actions that are taken are meant to reduce risks and utilize new opportunities brought about by global climate change. For example, deliberate crops selection and distribution strategies across different agro-climatic zones, substitution of new crops for old ones and resource substitution induced by scarcity (Easterling, 1996).

The assessment of climate risk is a critical process in the adaptation planning process as enhanced understanding of the future dynamics of extreme weather events is a high priority for adaptation. The latter is generally associated with adaptation that occurs naturally by private actors without intervention of public agencies, in anticipation of the reaction to climatic shocks and stresses. Often, autonomous adaptation does not constitute a conscious response to climatic stimuli, but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. In general, proactive, long-term strategies are cheaper than reactive, short-term ones.

Park et.al., (2012) differentiated between incremental and transformational adaptation. Incremental Adaptation: is characterized by continued response to climatic risks within an existing system. It results in small incremental changes, generally aimed at enabling a person or community to maintain its functional objectives under changing conditions. According to IPCC (2018), incremental adaptation maintains the essence and integrity of a system or process at a given scale. In some cases, incremental adaptation can accrue to result in transformational adaptation (Termeer et.al., 2017; Tàbara et.al., 2018).

Transformational Adaptation: Adaptation that results in a change in the individual or community's primary structure and function, i.e., a process that results in change in the biophysical, social, or economic components of a system (Park et.al., 2012). IPCC, (2018) expressed it as adaptation that changes the fundamental attributes of a socio-ecological system in anticipation of climate change and its impacts. With the recent trend of climate change, there is a growing interest in the theory and practice of more 'transformational' approaches as a way of achieving larger step changes to meet climate change and development challenges.

Based on its approach, adaptation can also be "top-down" or "bottom-up". A "top-down" or impacts-first approach to adaptation, in contrast to "bottom-up" thresholds-first approach provides decision-relevant information (Carter et.al., 2007; Wilby & Dessai, 2010; cited in Bowyer, et.al., 2014). However, the classical "top-down" approach is not well suited to informing adaptation planning in practice. In contrast, according to Bowyer, et.al., (2014), the "bottom-up" approach seeks to understand the organizational context and causes of the way in which climate risks arise and why they are important and it is duly more grounded in the real-world of decision making, and thus may provide more decision-relevant information than a "top-down" approach. In this research, "bottom-up" approach is the focus as livelihood zone-based vulnerability and adaptation strategies are analyzed.

Indeed, it should be noted that adaptive actions are not necessarily positive. For instance, Jones, et.al., (2010) argue that short-term gains or benefits taken to adapt to changing shocks and stresses can in some cases lead to increased vulnerability in the long term, known as maladaptation. Maladaptive actions (Maladaptation) are actions that may lead to increased risk of adverse climate-related outcomes, including via increased GHG emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. According to IPCC (2018), maladaptation is usually an unintended consequence. Poor planning which only focuses on short-term solutions or which is incapable to assess longer-term consequences, will likely result in maladaptation, which in turn will increase the vulnerability of already vulnerable groups, and limit future choices by locking vulnerable people into cycles of dependence (IPCC, 2014).

Maladaptive actions undermine the long-term sustainability of livelihoods, resulting in downward trajectories, poverty traps, and exacerbated inequalities (Ziervogel et.al., 2006; Tanner and Mitchell, 2008; Barnett and O'Neill, 2010; cited in Olsson, et.al.,2014). Though adaptation helps reduce impacts and risks, however, adaptation has limits. Not all systems can adapt, and not all impacts can be reversed (IPCC, 2018). There are two adaptation limits based on the point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions, as ***hard adaptation limit*** and ***soft adaptation limit***. In hard adaptation limit, no adaptive actions are possible to avoid intolerable risks. In the context of soft adaptation limit, options are currently not available to avoid intolerable risks through adaptive actions (ibid).

2.5.4. Empirical Literature

From the conceptual overlapping and differences as well as complexities, measuring adaptation has opened space for employing various empirical methods to analyze the determinants of adaptation to climate change. Previous studies have employed various empirical methods to analyze the determinants of adaptations to climate change and choice of adaptation strategies. In the context of developing countries, studies on Ethiopia (Deressa et.al.,2009) and Pakistan (Abid, et.al., 2014) identified lack of information, lack of money, shortage of labour, shortage of land, and poor potential for irrigation as barriers to adaptation. Similarly, a comparative study of Ethiopia and South Africa identified the lack of access to credit in the latter and lack of access to land, information as barriers to adaptation (Bryan et.al., 2009).

By nature, farmers are more likely to adopt a mix of adaptation strategies to deal with a multitude of climate-induced risks and constrains than a single strategy. A short coming of most of the previous studies on modeling choice of climate change adaptation strategies is that they do not consider the possible inter-relationships between the various strategies (Yu et.al., 2008). These studies mask the reality faced by decision-makers who are often faced with alternatives that may be adopted simultaneously and/or sequentially as complements, substitutes or supplements.

Believably, most African farmers would easily adapt to changed climate if they had unfettered access to markets, new technologies, extension agents and credit services among other needs (Hassan and Nhemachena, 2008; cited in Deressa et.al., 2011; Elum, et.al., 2017). Most studies assessing the potential effects of climate change on African agriculture are regional or national and yet adaptation is place-based and needs the use of place-specific strategies (Fischer et.al., 2002; Hassan and Nhemachena, 2008; Kurukulasuriya and Mendelsohn, 2008; Lobell et.al., 2008; Seo et.al., 2009; Deressa et.al., 2011).

In Ethiopia, a study conducted by Belay et.al., (2017) in central rift valley of Ethiopia revealed that household demography, as well as positively by farm size, income, access to markets, access to climate information and extension, and livestock production are found the factors that shape smallholder farmers' adaptation strategies. According to a study conducted by Hadgu et.al., (2014) in three districts situated at different agro-ecological zones of Tigray region, revealed that farmers use change in crop type and/or variety, soil and water conservation practices, crop diversification, change in planting date and irrigation practices as climate change adaptation options. Similarly, a study conducted by Seid Sani, et.al., (2016) in Asosa district confirmed that sex, literacy status, farming experience, family size, land holding, access to credit, access to media, extension contact, farmer to farmer extension, farm income, off/non-farm income, livestock ownership, market distance and access to training have a statistically significant impact on climate adaptation strategies.

A study conducted by Ann-Karin Sørhaug (2011), noted that some of the most common adaptation strategies and coping mechanisms are crop diversification (Crop diversification is the most commonly used method to overcome climate changes in Ethiopia (Deressa et.al., 2009), mixing of crop cultivation and livestock breeding, tree planting, taking off-farm work, soil and water conservation, selling of assets, and use of new or suitable seed varieties. Education, wealth, age, household size, gender of head of household, and access to credit are among the factors that might contribute to explain different levels of adaptive capacity within these two communities. Commonly sharing elements with Deressa, et.al., (2009); Aemro et.al., (2012) indicated that sex of the household head, age of the household head, education of the household head, family size, livestock ownership, household farm income, non/off-farm income, access to credit, distance to market center, access to farmer-to-farmer extension, agro-ecological zones, access to climate information, and extension contact have a significant impact on choices of climate change adaptation. According to Bryan et.al., (2009), factors influencing Ethiopian farmers' decision to adapt include wealth, and access to extension, credit, and climate information. The analysis of barriers to adaptation to climate change in the Nile basin of Ethiopia also indicated that most of the constraints are associated with poverty (Deressa et.al., 2008). Belaineh et.al.,(2013) identified that sex, plot size and frequency of extension contacts have a significant and positive impact on crop based diversification coupled with soil and water conservation practices while family size, non/off-farm income and training have significant negative impacts.

In a different view, Yonkura (2015) noted that farm size has implications on vulnerability and adaptation to climate change in Sidama zone. According to Ginbo (2015), research conducted in the same study area, Sidama Zone, revealed that the main adaptation strategies used so as to reduce risks pertaining to climate change are use of modern varieties, crop diversification, varying planting and harvesting dates, and soil and water conservation. Empirical analysis indicates that household head's gender and education, household size, land size, agricultural extension services, access to market, credit and climatic information are key factors affecting household's decision regarding climate adaptations. Positive significant effect of household head education on climate adaptation strategies is consistent with the findings of Deressa et.al., (2008); Aemro et.al.,(2012); Seid Sani, et.al., (2016) and Di Falco et.al., (2011).

According to a research conducted in Wolayita Zone; Tessema, (2008) indicated that most households adapt climate change through diversifying their livelihoods, such as non-farm and off-farm activities in addition to farming. Petty trade being the most important source of off-farm income, and rural non-farm employment and seasonal wage labor has important contributions for livelihood diversification. The above findings indicate that adaptation to climate change deserves to be seen in the context of local communities' overall conditions as it varies from place to place.

Similarly, Di Falco et.al., (2011) found that adaptation levels among Ethiopian farmers vary depending on household size, as well as factors such as the availability of extension services and access to credit.

Although there is an increasing surge in interest surrounding adaptation approaches, however, the approaches in Ethiopia mainly tend to be dispersed and narrow in focus. Specifically, there remains wide and diverse knowledge gaps on adaptation to livelihood zone-based approach in densely settled enset farming system. Similarly, Few, et.al., (2015) noted that in Ethiopia, knowledge gaps exist in relation to the role and limitations of livelihood-based adaptations. According to Demeke et.al., (2011) and Kato et.al., (2011), most adaptation planning is developed by government stakeholders in a top-down fashion and simply implemented in communities, often in ways that is unfamiliar to them.

However, effective adaptation to climate change must be location-specific, and yet be contextualized to wider landscapes or ecosystems, taking into account diverse livelihood systems. Although both coordinated "bottom up" and "top down" strategies will be crucial in climate change adaptation (Hill and Engle, 2013; Bierbaum et.al., 2013), adaptive efforts are often more successful at smaller scales (Brooks and Adger, 2005; Estrada et.al., 2017). Adaptation to climate change should enable livelihood systems to be more resilient to the consequences of climate change. In this research, adaptation to climate change is assessed based on livelihood zone, as it provides a sampling frame for future on-the-ground assessments and inputs for policy makers.

2.6. Conceptual Framework

As stated in the methodological part of Chapter One, livelihood zone approach is used in this research for analysis. Recently, frameworks based on the concept of livelihood are widely used by researchers to document and analyze the processes by which individuals and households utilize the resources and the opportunities they have to make a living in a particular socio-economic and bio-physical context (Scoones, 1998; Carney, 1998; Ellis, 2000; Shanmugaratnam, 2008). Originally different communities, under specific geographical contexts, initially have their own indigenous knowledge, cultural norms and perceptions towards climate change, reflected and practiced in their local norms, proverbs and values. This indicates that the level of vulnerability of the local communities is affected by the above mentioned elements. Hence, the initial norms, practices and values through time with the changing climate is expected to reshape and hence demand to adjust the system of production which influences the amount and diversity of household assets, and eventually leads to affect livelihood outcomes, either positively or negatively.

In this study, Sustainable Livelihood Framework (SLF), which is one of the most widely used livelihoods frameworks in international development practice has been adopted. The rationale to apply sustainable livelihoods framework is that some of the key components of this study, such as vulnerability, institutions and policies and adaptation strategies are central to the framework. The strength of the framework lies in its focus on contextual/local factors that influence vulnerability, people-centered, provides a framework for analyzing both the key components that make up livelihoods and focus on livelihood assets (Bebbington, 1999; Leach et.al., 1999). In addition, the approach helps to understand better the complexity of systems, sources of vulnerability and strategies that people use to make a living (Carney et.al., 1999).

The framework further provides the basis for understanding how livelihood strategies can build adaptive capacity to enable people to better cope with change and diversify their activities to increase resilience to unforeseen future change. The framework, for example, helps to explain how livelihoods adapt to shocks, seasonality and economic or resource trends and how their vulnerability may be reduced, for example, through building social capital, increasing the flow of information about new technologies or by improving access to alternative grazing areas during drought (Adger, 2003a; Kelly and Adger, 2000; Smit and Pilifosova, 2001; Yohe and Tol, 2002; Ziervogel et al., 2006). The asset-based framework helps identify ways capital can be used to cope in the short term, or ways capital can be used to prepare for future problems (e.g., financial capital to purchase crop insurance) and/or how capital assets can be substituted to adapt to changing circumstances.

The framework recognises that different stakeholders are affected by climate change in different ways and have different capacities to adapt, depending on their reliance on and access to capital assets (e.g., Ziervogel et al., 2006). As a result, participatory, people-centred and action research approaches are often used in sustainable livelihood research and practice to build adaptive capacity to different and dynamic livelihood contexts.

Shocks emanate from environmental, social and economic factors. They include droughts, floods, harm to livestock or crop health, social crises, food shortage and inflation. Smallholder farmers are also vulnerable to ***seasonality*.** Agriculture in general and farming in particular is affected. The problem is pronounced for rain-fed farming where livelihoods depend on the amount and timing of rainfall.

The sustainable livelihood framework is based on understanding of people's access to assets that typically include natural, human, social, physical and financial capital. Other assets are increasingly being used in such analyses include information, cultural/traditional and institutional assets. Access to these assets are then analysed in relation to the context of that livelihood (e.g., climate, demography, history and macro-economic conditions), institutional and social processes (e.g., organisational arrangements and land tenure), and the livelihood strategies that are used (combinations of activities people choose to undertake to achieve their livelihood goals).

Human capital encompasses the abilities, experience, work skills and the good health that, when combined, allow populations to engage with different livelihood strategies and reach their own objectives. In the context of sustainable livelihoods ***social capital*** refers to the social resources which individuals rely on in order to achieve certain objectives relating to their livelihoods, such as relationships of trust, reciprocity and exchanges that facilitate co-operation, participation in more formal groups, and networks and connections. ***Natural capital*** is the term used to describe the stocks of natural resources from which further resources and services can be developed which may prove useful to livelihoods, such as land and soils, water, food production, and so on. It is obvious that natural capital is extremely important for those who earn part or all of their livelihoods from activities which rely on natural resources, such as crop or animal farming. ***Physical capital*** comprises the basic infrastructure and producer goods needed to support livelihoods, such as access to road and transport; access to water and sanitation; housing and safe buildings; and access to information (communication) are among others. ***Financial capital*** refers to the financial resources that people use to achieve their livelihood objectives. The definition used here includes flows as well as stocks and it can refer to consumption as well as production, such as credit, savings, pensions, payments for environmental services and remittances.

Important too are ***processes*** in the form of policies, legislation, rule of law, and power relations that determine the interactions between the structures and individuals (Kollmair and Gamper, 2002). The effectiveness of adaptation practices in particular depends on the social and institutional contexts in which they are pursued.

Livelihood strategies form another important component of sustainable livelihood framework. Households or communities pursue different options for pursuing livelihood goals.

Livelihood outcomes result from the application of livelihood strategies taking into account the assets that farmers have access and the vulnerability context and supported or obstructed by policies, institutions and processes. Examples of desirable outcomes include reduced vulnerability, adapting to climate change (adaptable livelihood), systems with boosted resilience (Resilient Livelihood, CRGE), increased wellbeing, protected livelihoods and improved environmental sustainability. As livelihood systems evolve over time, there are many complex interactions conceived among the various elements in this framework.

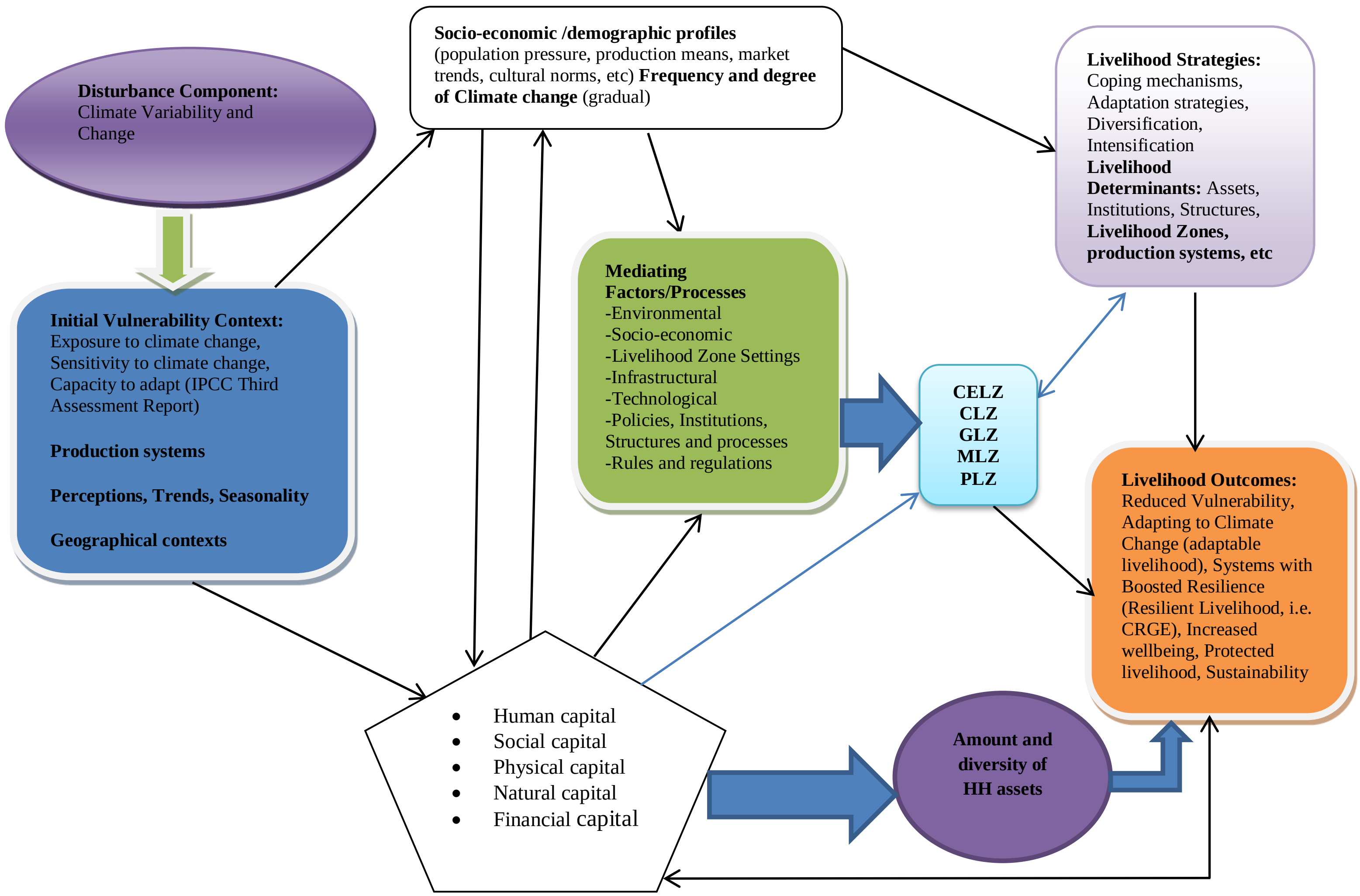


Figure 2.1: Conceptual Framework: Adapted from Sustainable Livelihood Framework (SLF), DFID (1999).

Chapter Three: Farmers' Perceptions of Climate Variability and Change

3.1. Introduction

This chapter is devoted to present the results and discusses the main findings of perception to climate change. The chapter begins with the results and discussion of socio-economic and demographic characteristics, including age, gender, education and farm size and further proceeds with perceived changes in climate supporting with trend analysis of secondary sources of data using graphs. The chapter further proceeds with analyzing perceived changes in climate, factors influencing perception to climate change and perceived effects of climate change on smallholder farmers' livelihood supporting with descriptive and qualitative analysis. Frequency tables and graphs are also used to visualize the results. Results are also compared with the findings of other related works. Finally, the chapter closes with summary.

3.2. Socio-economic and Demographic Characteristics

Demographic characteristics, nowadays, are becoming vital indicators for overall development programs. In general, the study area is known for being one of those densely populated areas at national and regional levels.

Table 3.1: Socio-economic and Demographic Characteristics of Households

Family Size by LZ					
Family Size	**Cereal and Enset LZ**	**Coffee LZ**	**Ginger LZ**	**Maize LZ**	**Pepper LZ**
Mean	7.98	9.50	9.62	8.40	6.76
Std. Dev.	1.89547	1.82	1.93	1.91	1.44
Min	3	5	6	5	4
Max	13	13	13	13	10
Total	**134**	**101**	**84**	**101**	**88**
Age of the Household Heads by LZ					
Mean	61.31	58.59	63.07	62.97	62.18
Std. Dev.	7.33	6.63	5.97	4.23	3.18
Min	41	45	36	55	56
Max	87	75	85	80	73
Total	**134**	**101**	**84**	**101**	**88**
Farming Experience of the Households Heads by LZ					
Mean	33.64925	34.0099	35.05952	33.46535	32.65909
Std. Dev.	4.506065	5.812908	5.315019	3.53713	5.145886
Min	22	25	25	28	25
Max	50	49	47	45	45
Total	**134**	**101**	**84**	**101**	**88**
Farm Income of Households by LZ					
Farm Income	**Cereal and Enset LZ**	**Coffee LZ**	**Ginger LZ**	**Maize LZ**	**Pepper LZ**
Mean	25275.63	28001.49	51625.71	27418.32	44380.68
Std. Dev.	17005.77	6234.976	20498.16	9028.487	15267.35

Min	15340	16500	24900	14400	26500
Max	45940	49400	83800	58400	96500
Total Obs.	**134**	**101**	**84**	**101**	**88**
Farm Size of Households by LZ					
	Cereal and Enset LZ	**Coffee LZ**	**Ginger LZ**	**Maize LZ**	**Pepper LZ**
Mean	.353	.496	.349	.652	.903
Std. Dev.	.201	.246	.210	.314	.326
Min	.112	.132	.121	.125	.25
Max	1.12	1.3	1	1.75	2
Total Obs.	**134**	**101**	**84**	**101**	**88**
Dependency Ratio					
	Cereal & Enset LZ	**Coffee LZ**	**Ginger LZ**	**Maize LZ**	**Pepper LZ**
Mean	1.290	.831	.839	.859	.899
Std. Dev.	1.034	.423	.362	.413	.528
Min	.2	.25	.285	.25	.25
Max	8	2.5	2	3.33	3
Total Obs.	**134**	**101**	**84**	**101**	**88**

Distribution of Sex of the Household Heads by LZ

Sex	**Cereal and Enset LZ**		**Coffee LZ**		**Ginger LZ**		**Maize LZ**		**Pepper LZ**	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Male	117	87.31	84	83.17	75	89.29	87	86.14	67	76.14
Female	17	12.69	17	16.83	9	10.71	14	13.86	21	23.86
Total	**134**	**100.00**	**101**	**100.00**	**84**	**100.00**	**101**	**100.00**	**88**	**100.00**

Educational Level of the Household Heads by LZ

Educational Level of the Household Head	**Cereal and Enset LZ**		**Coffee LZ**		**Ginger LZ**		**Maize LZ**		**Pepper LZ**	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
None	59	44.03	90	89.11	46	54.76	78	77.23	82	93.18
Primary (Grade 1-8)	61	45.52	8	7.92	28	33.33	22	21.78	6	6.82
Secondary (Grade 9-12)	14	10.45	3	2.97	6	7.14	1	0.99	-	-
Tertiary (College/University)	-	-	-	-	4	4.76	-	-	-	-
Total	**134**	**100.00**	**101**	**100.00**	**84**	**100.00**	**101**	**100.00**	**88**	**100.00**

Source: Household Survey

From the survey result, it is possible to state that Ginger LZ has the highest average family size of 9.6 household members and comparatively Pepper LZ has the least family size of 6.7. In Ginger LZ, the majority (58.33%) of the respondents follow Protestant religion, followed by Catholics (41.67%); whereas, in Pepper LZ, the majorities (53.47%) of the respondents follow Muslim religion and Protestant and Catholics represent 32.63% and 11%, respectively. According to FGD participants in Ginger LZ, having more children is a blessing from God, and believes that God will fulfill all the needs of our children. In this connection with family size, the result for dependency ratio indicates that Cereal and Enset LZ has the highest members of family, implying that family members whose age is in between 1 to 14 and above 64 is greater than family members whose age ranges in between 15 to 64. This result has implications in terms of family income through participation in diversifying livelihoods, basic services and asset accumulation. Although Ginger LZ has the highest score of family size, the dependency ratio is less as compared with Cereal and Enset, Maize, and Pepper LZs.

The participants further mentioned that in recent years, there is reluctance by youngsters to spend more time in agricultural activities, but rather in church services. Coffee and Ginger LZs are located in altitudinal ranging in between 1900-2200 masl and 1500-2100 masl, situated in south central and south western part of the administrative zone, respectively. Whereas, Pepper LZ is located in north eastern part of the administrative zone, with altitudinal range of 1600-1800masl, with relatively drier climatic conditions. The survey further revealed that from the total sample households, the mean age is 61.54 with minimum of 36 in Ginger LZ and maximum of 87 in Cereal and Enset LZ.

The survey also revealed that out of the total respondents, 53.14% of household heads' age ranges in between 60 to 70; 35.23% of household heads' age ranges in between 50 to 59. Only about5.11% of households' age ranges in between71 and 80. Further analyzing age distribution across different livelihood zones: 30.59%, 48.51%, 21.43%, 16.83%, and13.64% of household heads in Cereal and Enset, Coffee, Ginger, Maize and Pepper livelihood zones respectively range in between 36-59 years. In relation with the perception to climate change, age of households influences the experience of perceiving climate change.

In addition, 88.80%, 81.19%, 89.28%, 90.09% and 71.59% of household heads in Cereal and Enset, Coffee, Ginger, Maize and Pepper livelihood zones respectively have farming experience in the range of 30-49 years, creating a good opportunity to capture the trend of climate change. The age of the head of the household represents experience in farming and studies have indicated that experienced farmers are more likely to perceive climate change (Maddison, 2006; Ishaya & Abaje, 2008). Accordingly, the highest percent, 90% of farmers in Maize LZ fall in having farming experience of above 30 years, creating a good opportunity for perceiving the trend of climate change.

In relation with the farm income of respondents, the highest mean result was registered in Ginger LZ and the least was registered in Cereal and Enset LZ. Ginger LZ has a valuable cash crop, Ginger, which contributed for highest income in addition to other income sources. Besides to ginger, farmers in Ginger LZ enjoy cash income from tropical fruits like banana, avocado and mango. Ginger LZ has also the highest (89.29%) male headed households, as income earned by male headed households is generally higher than the counterparts' female headed households. In the context of Cereal and Enset LZ, although farmers in few areas are able to diversify their crops, income wise, the major crops used as cash, including enset products, wheat and barley do not have high market value as compared with ginger with the current market value.

With regards to sex of respondents, from the total farmers in the five livelihood zones, 85% of farmers are male headed households and 15% of them are female headed households. Across livelihood zones, Ginger LZ has the highest percentage of male headed households whereas Pepper LZ has the highest percentage of female headed households.

The other important socio-economic characteristic analyzed of the respondents was education level. It is known that education has its own role in terms of shaping the perceptions of farmers in terms of their day to day livelihood systems. According to the survey data, 93.18% of farmers in Pepper LZ could not attend any education program of primary, secondary or tertiary levels, whereas, about 55.97% of the Cereal and Enset LZ respondents have attended either 'primary' or 'secondary' schools. It is expected that education level of the head of the household has direct implications in terms of shaping the perception of farmers to climate change. This result is in coincidence with Maddison (2006); Gbetibouo (2009); and Leiserowitz (2006) implying that participation in education enhances the perception of the occurrence of climate change. From the table above, it is possible to state that most of the farmers in Pepper LZ (93.18%) belong to the group who didn't attend education, which will have an implication on their perception to climate change. Tertiary level of education (College/University) was attended by only 4.76% of farmers in Ginger LZ.

Schmidt and Thomas, (2018) indicated that urbanization and population density is significantly greater in the highlands compared to the lowlands. People living in the highland areas have greater market access to urban centers. While the average travel time to a city of at least 20,000 people in the highlands is approximately 3 hours, the average travel time to a city of at least 20,000 people in the lowlands is approximately 6 hours. This is for several reasons. First there are fewer cities in the lowland areas. While there are 96 cities of at least 20,000 people in the highlands, there are only 20 urban centers of this size in the lowlands. The lowland areas of Ethiopia also have a sparser transportation infrastructure compared to the highlands (ibid).

The other critical socio-economic characteristics of farmers in the study area are reflected by farm size, which is considered as the main source of livelihood asset. The study area in general is considered as one of the most densely settled areas both at regional and federal levels. The least mean value of farm size is registered in Ginger LZ, about 0.349 ha; the highest in Pepper LZ, registering about 0.903 ha per household. This is because Pepper LZ is attitudinally located in lower areas as compared with Ginger LZ which is located in midland areas in the range of 1500 to 2100 masl, where temperature is relatively higher and precipitation is relatively lesser. The farm size distribution in the above two LZs has exactly matched with family size distribution, which has implication in terms of land size. As depicted in Table 2 above; Ginger LZ has the highest family size of about 10 per household; whereas Pepper LZ has the least family size of about 7 per household.

3.3. Perceived Changes in Climate

The delay in the rainy season and the variation in seasonal distribution of rainfall have substantial impacts on agricultural production and livelihoods. The change in rainfall has direct causal relationships with a decline in the production of food and fodder supply to the livestock dependent communities. Key Informant Interviewees (KII) in the study area has already perceived that the climate is becoming hotter and the rains being less predictable and shorter. There is an increasing trend for climate change and rains do not come on the usual time and if they come, they are of short duration.

It is important to note that local perceptions of climate change have also management implications. The information from the FGD participants indicated that, in general, climate variability and change was broadly acknowledged across all livelihood zones, though the degree of change was perceived differently. All participants stated that these changes affected their overall livelihood system, the climate seasonality and also highlighted impacts on yields.

In the study area, farmers in various livelihood zones underscored that there is climate variability and change increasingly being felt and responded in various degree of extent and forms. While most indicators of climate change are commonly perceived in all livelihood zones (erratic rainfall, disruption of the timing of rain, i.e. late onset and early cessation, and decrease in rainfall amount and frequency), there are specific perceived indicators that households repeatedly felt in Cereal and Enset, Coffee and Hadero-Ginger livelihood zones being unpredictable nature of Belg season onset of rain, most often to the extent of jumping sowing dates for weeks. Similarly, a study conducted by Bewket, (2012) in central highlands of Ethiopia mentioned that there are changes in total amounts and temporal patterns of Belg season, which increased drought frequency.

According to Kembata Tembaro Zone Agriculture Office report (2017), Belg season covers 35-40% of the total zonal agricultural production. The report stated that because of failure of Belg season rain during the 2016/2017; about 84062 people were in need of support of food for their daily consumption needs. The late onset of rain during Belg season tended to extend the sowing dates for Meher crops (the main rainy season), affecting the post-harvest process as the rain tends to extend for extra weeks beyond the normal rainfall cessation calendar.

The participants of FGD in all LZs mentioned that there is frequent variation of rainfall distribution, affecting crop growth at the time of seed-bearing stage when in need of moisture. Farmers' perceptions and understanding of rainfall variability has significant importance in their livelihood's adjustments. Specifically, farmers in Ginger and Coffee LZs in the FGD raised the occurrence of erratic rain distribution during Belg season has significantly reduced their production and affected their cash income seriously. In addition, perception of respondents is in coincidence with secondary data analysis results of Belg season mean annual rainfall (1984-2017), obtained from National Meteorological Agency (see Fig. 3.1. below). These findings are in line with the findings of the other studies conducted (e.g. Hageback et.al., 2005; Maddison, 2007; Gbetibouo, 2009; Zampaligré et.al., 2014).

Assessing trends in rainfall characteristics based on past records and linking with the perception of communities who practice different production system is essential to develop appropriate adaptation strategies. Accordingly, based on the analysis of secondary data obtained from National Meteorological Agency from 1984-2017, it is possible to state that there is a great variation (within ten years, below 50 mm rainfall during 2007 in Areka station to about 600 mm rainfall during 2013 in Alaba kulito) of Belg season rainfall distribution affecting farmers' respective Belg season annual crop production in all LZs, indicating being erratic and reduction trend in amount. For instance, every year on average, there was -4.6206 mm of rainfall reduction (the highest) in Angacha station, affecting Belg season crop production in Cereal and Enset LZ, especially, moisture sensitive annual crops are affected directly through reducing their productivity and in some cases, leads to crop failure. Similarly, in Areka station, there was -3.2871 mm of annual rainfall reduction, which directly affects ginger crop production as the crop is planted normally during January-March Belg season, exactly fits with the stage when in need of moisture for germination/grows up.

Looking further the result indicates that during the last ten years, there was Belg season variation in Halaba station, indicating that major crops of maize and pepper production were exposed for crop failure. On the other hand, extreme variation in increased amount of rainfall occurred in 2003/04, about 570 mm rainfall was registered in Durame station and about 600 mm rainfall was registered in Halaba station during 2013 Belg season (see Fig. 3.1. below). The extreme variation in decline of rainfall, which occurred in 2011/12 is known for its severity, resulted in a wide range of negative impacts in the study area exposing many smallholder farmers for humanitarian assistance (Kembata Tembaro Zone Agriculture Office, 2017). In general, from the trend analysis, it is possible to state that frequent variation in the distribution of Belg rain existed in all LZs, disrupting the crop production system of short season, which is used mainly for household food consumption especially during the summer season.

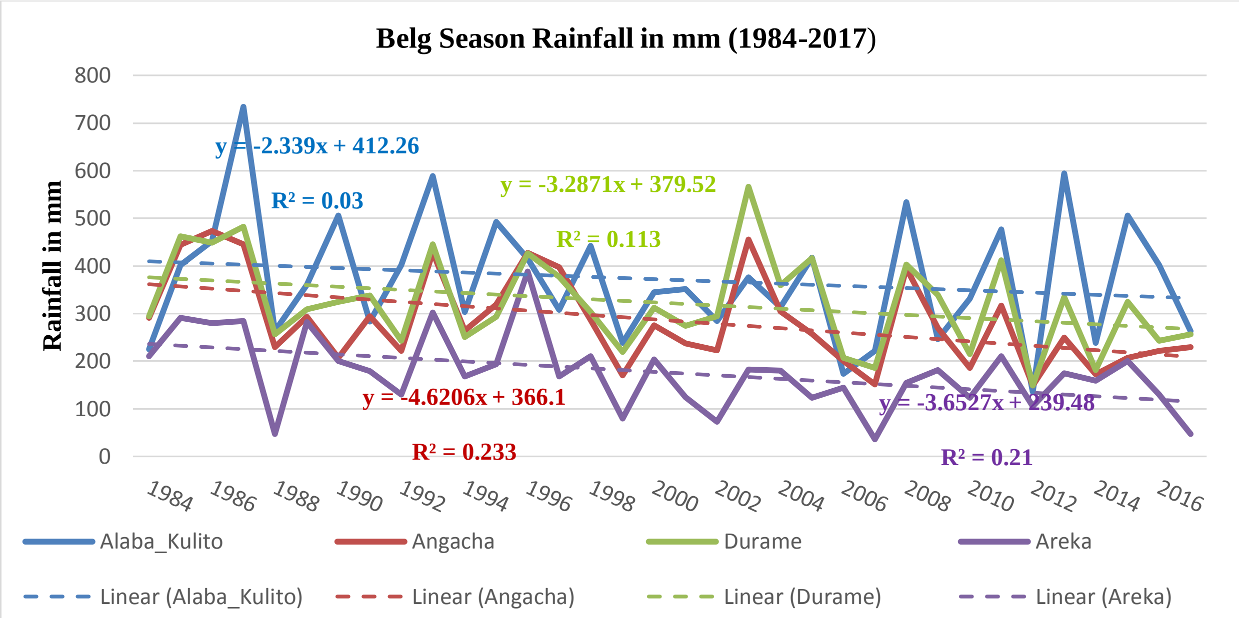


Figure 3.1: Belg Season Rainfall in mm (1984-2017)
Source: Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia (2018).

The result matches with the concerns of FGD participants raised from Ginger LZ, discussing that especially from the last ten years onwards, the Belg season for planting Ginger is becoming difficult. According to Kembata Tembaro Zone Agriculture Office report (2017), the 2016 Belg season harvests were below average, which has led to a significant reduction in household food access. Although the seasonal extreme variation in decline of trends of rainfall occurred in all LZs, commonly in 2006/7, 2011, 2014 and 2016/17 are those years registered the least rainfall amount, the leading being registered in Areka with less than 100 mm in 2007.

It is known that Ethiopia's diverse nature of altitude created for having different rainfall distribution across the country. Assessing the yearly kiremt season rainfall, which is the main agricultural season across the five LZs, contributes from 60 to 65 percent of the overall yearly production. Hence, trend analysis of kiremt season offers insights on the level of exposure of smallholder farmers who suffer from climate variability and extremes. The annual kiremt season mean rainfall distribution, which lasts from June to September/October, depicted using from the analysis of four nearest stations, in general, shows frequent variation and a decreasing trend in amount across the four stations, indicating that the main crop season, which they rely both for cash income and source of food is seriously affected.

The yearly kiremt seasonal increase in the amount of maximum rainfall was registered during 1985/86 in Areka station, registering about 1400 mm rainfall and the least during 2015/16, registering about less than 200 mm rainfall (see Fig.3.2. below), which caused serious disruption of livelihoods, exposing 84062 farmers for humanitarian assistance at zonal level (Kembata Tembaro Zone Agriculture Office, 2016). Station wise, trends of Angacha and Durame experienced on average -7 mm of rainfall reduction on every kiremt season for the last 33 years. The highest annual kiremt season rainfall reduction of about -13 mm was registered in Areka station, indicating that the main crop of Ginger production was put under pressure of serious moisture stress, affecting the overall production of the crop, in recent years leading to the extent of crop failure.

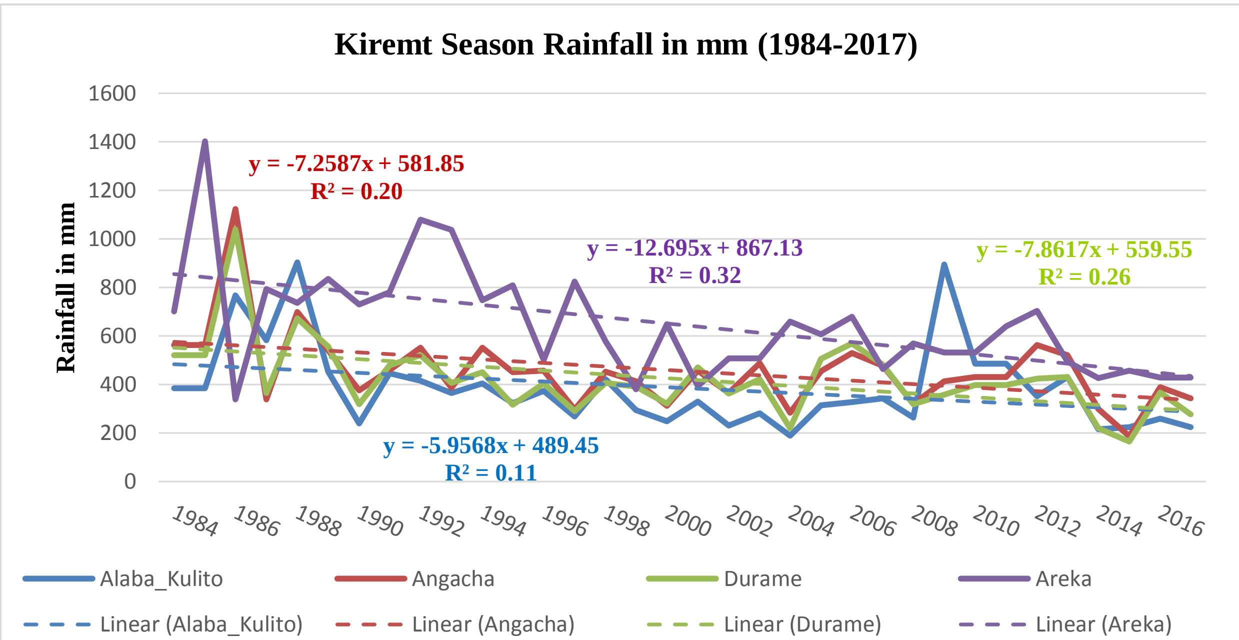


Figure 3.2: Kiremt Season Rainfall in mm (1984-2017)
Source: Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia (2018).

From the above seasonal trend analysis of rainfall, it is possible to state that in both seasons, the overall trend shows a reduction in amount and being erratic, indicating that smallholder farmers are leading in secured livelihood system.

The results from the historical analysis contribute to the wider argument of the general annual variability (no regular trend) and decrease of rainfall distribution. Similarly, the historical annual and seasonal variation in distribution of precipitation in the study area is in tandem with the analysis undertaken at country level (Bewket & Conway, 2007; Tadege, 2007; Evangelista et.al., 2013), indicating that there is variation in annual and seasonal rainfall distribution and difficult to predict. Extreme variation in annual mean rainfall will create favorable condition for the prevalence of crop diseases. The trend analysis depicted above also coincides with what the FGD participants in Coffee and Ginger LZs raised. In the discussion, participants underscored that because of variability of rainfall, extreme moisture conditions created expansion of bacterial diseases, exactly what they experienced in the two cash crops of Ginger and Coffee, Ginger and Coffee LZs. According to the participants, almost from the last ten years onwards, production of ginger and coffee is seriously threatened because of the occurrence of diseases, disrupting the overall livelihood system built for many decades.

Cognizant of this, farmers were requested whether they perceive long term changes in precipitation over the past thirty years. In the context of Maize and Pepper livelihood zones, the participants of FGD underscored that formerly drought occurs once in ten years, but from the last ten years onwards, there is occurrence of recurrent drought almost in two to three years' gap, exposing for crop failure, especially the main cash crop in Pepper LZ, pepper production in the last ten years has seriously decreased in production, affecting their cash income.

Table 3.2: Perception to Long-Term Changes in Climate Variables

		Livelihood Zones					Pearson chi2(4)	Pr
		Cereal LZ	Coffee LZ	Ginger LZ	Maize LZ	Pepper LZ		
		%	%	%	%	%		
Perception to long term mean increased in rainfall duration	Yes	35.82	25.74	22.62	20.79	4.55	29.8519	0.000
	No	64.18	74.26	77.38	79.21	95.45		
Perception to long-term changes in mean increased temperature	Yes	88.81	78.22	92.86	89.11	100.00	11.4571	0.022
	No	11.19	21.78	7.14	10.89	0		
Perception to long-term changes in mean decreased temperature	Yes	29.85	34.65	83.33	26.73	3.41	130.3583	0.000
	No	70.15	65.35	16.67	73.27	96.59		
Perception to long-term changes in mean increased in rainfall frequency	Yes	29.85	31.68	26.19	26.73	15.91	7.2257	0.124
	No	70.15	68.32	73.81	73.27	84.09		
Perception to long-term changes in mean increased in rainfall magnitude	Yes	35.07	29.70	17.86	26.73	71.59	66.0684	0.000
	No	64.93	70.30	82.14	73.27	28.41		
Perception to long-term changes in mean decreased in rainfall intensity	Yes	83.08	82.18	88.10	83.17	97.73	6.1550	0.188
	No	16.92	17.82	11.90	16.83	2.27		
Perception to long-term changes in mean decreased in rainfall duration	Yes	70.90	80.20	91.67	69.31	96.59	36.8536	0.000
	No	29.10	19.80	8.33	30.69	3.41		

Source: Household survey

From the survey result, it is possible to state that out of the five livelihood zones, the least and the highest percent of respondents, i.e. 4.55% of farmers in Pepper LZ and 35.82% of farmers in Cereal and Enset LZ perceived that there is long term mean increased in rainfall duration over the last thirty years. In connection with this, FGD participants in Cereal and Enset LZ underscored that especially from the last fifteen years on wards, the duration of the rain cessation period is getting extended from year to year, which formerly they did not experience.

Regarding the perception to long-term changes in mean increased in rainfall frequency, on average, about 74% of respondents from the five LZs replied that the rainfall does not frequently occur, whereas out of the five LZs, 31.68% respondents from Coffee LZ perceive that there is frequent occurrence of rainfall in their surroundings.

The result for the perception to long-term changes in mean increased in rainfall magnitude revealed that the highest percent, 71.59% of farmers in Pepper LZ perceive that the magnitude of the rain is increasing, whereas, the highest percentage, 82.14% of farmers in Ginger LZ perceive that the magnitude of the rain is decreasing. In terms of the altitudinal differences, Pepper LZ is attitudinally situated in the lower agro-ecological zone, as compared with other livelihood zones. Hence, as compared with other livelihood zones, decrease in precipitation will occur and the magnitude of rainfall is expected to be relatively high.

One’s perception to climate change is shaped by experiential and or indigenous knowledge of the climate as well as given the observed impacts of climate change. Understanding how local communities perceive and predict rainfall variability is key to communicating scientific weather forecasts. Just like scientific forecasts, indigenous forecasts rely on observation and interpretation of specific phenomena. Studies further show that the perception or awareness of climate change (Semenza et.al., 2008; Sampei & Aoyagi-Usui, 2009; Akter & Bennett, 2009) and taking adaptive measures (Maddison 2006; Hassan & Nhemachena, 2008) are influenced by different socio-economic and environmental factors. In this regard, it is important to note that social capital in the form of indigenous climate prediction plays an important role in preparing farmers for their farming activities and to get ready for the disaster, if the occurrence predicted. However, in the study area, the process of integrating the local indigenous knowledge with “scientific forecasts” is very weak. From FGD participants conducted in Maize LZ, one elderly farmer underscored that:

> *“...formerly about fifteen years ago, the rain most often comes from the side of east, but from the last ten to fifteen years onwards until now, sometimes the rain comes from the side of south. The rain that comes from the side of the south is perceived as serious and strong. From the last fifteen years onwards, in some years the direction of the rain being from the south, the rain is getting erratic and sometimes stops during peak time of sowing, even for one to two months. Hence, the rain is getting decreasing from year to year. This year, the rain is coming from the side of east and it looks good…”* ***(Adilo Kebele, Badewacho-Alaba Maize LZ).***

Regarding the perception of farmers to long-term changes in mean temperature, all respondents of Pepper LZ (100%) perceive that there is an increase in mean temperature, whereas 21.78%of farmers in Coffee LZ perceive that there is no increase in long term mean temperature. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation (Nelson et.al., 2009; cited in Appiah et.al., 2018).The International Panel on Climate Change (IPCC) indicated that there has been an increase in seasonal mean temperature in many areas of Ethiopia (IPCC, 2014).

In the context of projections for Ethiopia, there are cases where different results are indicated by different researchers and institutions. For instance, forecasts by Tadege, (2007) indicated that temperatures in Ethiopia will increase in the range of 1.7-2.1^{o}C by the year 2050 and 2.7-3.4 ^{o}C by the year 2080. Irish Aid, (2018) projected the mean annual temperature to increase by 1.1 to 3.1°C by the 2060s, and 1.5 to 5.1°C by the 2090s. Though the amount of projection is different, however, all projections commonly indicate substantial increasing trend.

Similarly, there is also an increasing trend of maximum temperature during kiremt season in all LZs. More specifically, the highest annual kiremt season maximum increase in temperature of about 0.081 ^{o}C was registered in Areka station, indicating that production of ginger, the main cash crop in Ginger LZ, is suffering with high temperature during the last 33 years. Looking at the trend in Alaba station, there was 0.0679 ^{o}C annual maximum increases in temperature for the last 33 years during kiremt season, indicating that crop production of maize and pepper, which are sensitive for higher temperature, was critically affected. The trend further shows that the maximum temperature of about 27 °C was registered in 1984, increasing the trend and reached about 32 °C during 2011/12 (see Fig. 3.3. below), which coincides with participants of FGD conducted in Maize and Pepper LZs.

In the context of Cereal and Enset LZ, as depicted in figure 3.2. above, there was 0.0276 °C yearly average increase in maximum temperature and -7.2587 mm annual rainfall reduction is registered at Angacha station from 1984 to 2017 (see Fig. 3.3.) during the same season, indicating that Meher season sensitive crop types for increased temperature and moisture stress were affected, leading for reduction in production and exposure for crop disease.

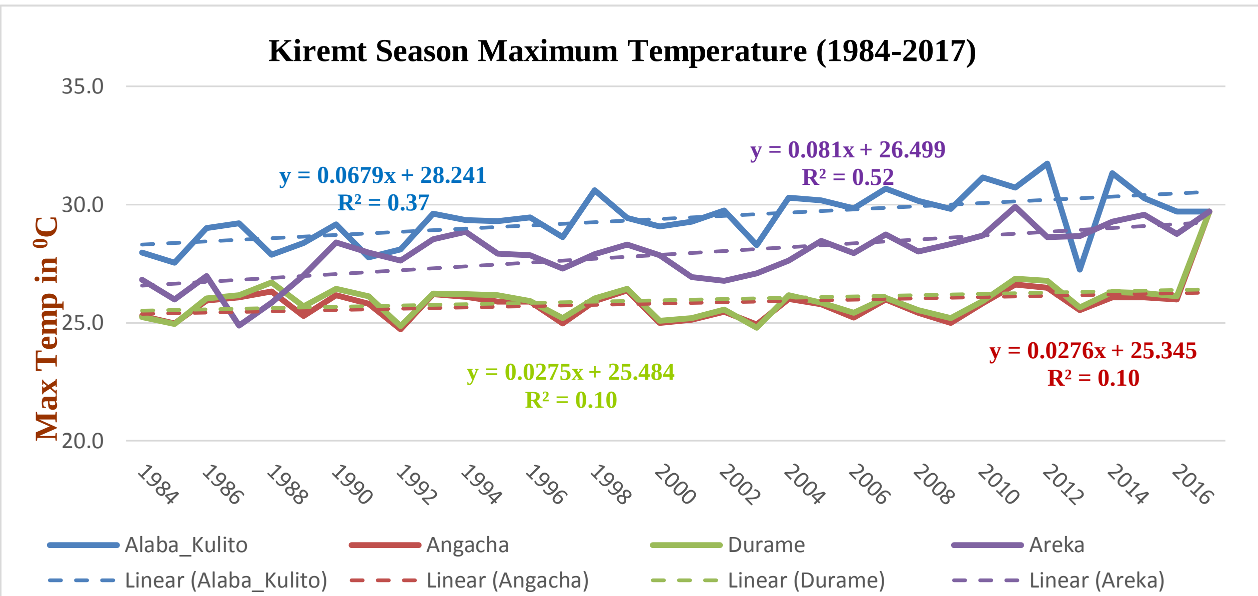


Figure 3.3: Kiremt Season Maximum Temperature (1984-2017)

Source: Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia (2018).

The perception of farmers to climate change was further supported by Mann-Kendal test, Sen's Slope Estimator and Coefficient of Variation. From the trend test, it is possible to state that Belg season trends in all stations revealed negative value, indicating that there is variability of rainfall with significant p-value of less than 0.1 was registered for Durame station.

Table 3.3: Seasonal Rainfall Trends for Meteorological Stations.

Stations	Kiremt season (June to August/Sept)			Belg season (Feb/March to May)		
	Trends (mm/year)	P-value	Sen's slope	Trends (mm/year)	P-value	Sen's slope
Alaba Kulito	0.56	0.67	-0.95	-1.4	0.91	-2.03
Angacha	0.19	0.31	0.81	-3.4	1.98	-3.03
Areka	-4.1	1.47	-4.12	-3.0	2.08	-2.92
Durame	-0.57	0.08*	-0.18	-1.67	0.84	-2.06

*=significant at p< 0.1

Source: Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

Looking specifically, Angacha and Areka stations have registered -3.4 and -3.0 mm/year reduction of rainfall during the Belg season, indicating how the Belg crops of wheat and ginger suffer from water stress, challenging the suitability of the land for growing the crops. Shortage of moisture also affects the production of respective moisture sensitive of both annual and perennial crops.

The variation of rainfall trend is also confirmed by Coefficient of Variation observed in stations. The coefficient of variation result revealed that there was less and moderate annual rainfall variation across the four stations, with the highest score in Alaba Kulito (30). Looking the seasonal rainfall variation, Alaba Kulito has experienced the highest variability of rainfall in kiremt season in the last 33 years, indicating that production of maize and pepper was negatively affected due to moisture variability; whereas Angacha, Areka and Durame stations have experienced moderate variation in Kiremt seasonal rainfall distribution. The main Kiremt season rainfall coefficient variation range was 41.1 in Alaba Kulito station and the least was in 22.7 in Angacha station.

Table 3.4: Annual and Seasonal Rainfall Variability (Coefficient of Variation) from 1984 to 2017

Stations	Annual		Kiremt season (June to August/Sept)			Belg season (Feb/March to May)		
	Mean	**CV**	**Mean**	**%**	**CV**	**Mean**	**%**	**CV**
Alaba Kulito	944.9	30.0	326.6	34.6	41.1	318.1	33.7	35.2
Angacha	906.6	18.1	396.4	43.7	22.7	266.4	29.4	35.1
Areka	910.2	24.5	591.5	64.9	24.1	160.5	17.6	46.8
Durame	914.1	19.6	366.2	40.1	24.6	293.2	32.1	34.1

Source: Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia (2018).

The result further indicated that in Belg season, all stations score fall under the highest variation in rainfall category, Areka station registered the leading (46.8) score. This indicates that Belg season crop production has seriously been affected, specifically production of Ginger, which is usually planted during February to March, is seriously affected because of the extreme variation in rainfall. In line with other studies in Ethiopia, Hadgu et.al., (2014) reported that high coefficient annual variation in main season was (CV 30%) and March to April (CV 50%) in northern Ethiopia.

3.4. Factors Influencing Perception to Climate Change

In analysing perception of farmers to climate change, it is very essential to assess the factors that affect the perception of farmers to climate change. For analysis of the factors influencing perception to climate change, first analysis of univariate logistic regression between predictor variables and perception to climate change was undertaken. From the p-values of the output of individual predictor's analysis at 25% significance level, some important predictor variables were ignored and excluded from the model. Hence, multiple predictors' analysis must be done to check whether the excluded variables in single predictor's analysis are significant in the inclusion of collection of variables. And then all the predictor variables are included and those which are significant and insignificant in the univariate analysis are identified.

Based on the results of univariate logistic regression, as indicated in table 3.5 below, out of the nineteen variables, five variables, namely, sex, traditional weather prediction, marital status, farming experience, and cultural connectivity are found to significantly influencing perceptions to climate change. Multiple logistic regression result indicated that Sex of the household head being male, traditional weather prediction, land slope and farming experience were found to be significant predictors of perception to climate change.

Table 3.5: Factors Affecting Perception to Climate Change

Multiple Logistic Regression Analysis		
Variable	**Adjusted OR 95%CI**	**P-value**
Sex	2.566 [.998, 6.598]	.050**
marstat	1.071 [.727, 1.580]	.728
farmexp	.932 [.886, .981]	.007***
roadaces	1.095 [.920, 1.302]	.307
landslop	.841 [.675, 1.048]	.021**
weathinfotimly	.749 [.458, 1.224]	.248
culturconnect	.611 [.283, 1.318]	.209
tradweathpredic	.405 [.179, .920]	.031**
physasetdonkey	1.157 [.715, 1.871]	.553
Constant 8.952	.117	

***=p<0.01; **= p< 0.05

Source: Household survey

The Logistic Regression result, as indicated in Table above, revealed that male headed farmers perceive climate variability and change revealed that male headed farmers perceive climate variability and change better than female farmers. Higher farming experience has a positive influence for farmers to perceive the occurrence of climate variability and change. The result also revealed that land slope influences perception to climate variability and change, i.e., farmers living around hilly mountainous areas perceive climate variability and change better than those living in flat areas. The result further revealed that farmers who practice traditional weather prediction perceive the existence of climate variability and change better than those who do not.

Another important element in analyzing perceptions of farmers to climate change is related with perception towards the causes of climate change, as it helps to strengthen the awareness level of farmers for further taking adaptation strategies. According to the participants of FGD in Cereal and Enset LZ, the change in climate is mainly because of clearance of indigenous tree species.

Table 3.6: Perception of the Causes of Climate Change

Perception of the cause/s of climate change?	**Perception of the cause/s of climate change by LZ**									
	Cereal		**Coffee**		**Ginger**		**Maize**		**Pepper**	
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
Human action	89	66.42	66	65.35	35	41.67	23	22.77	41	46.59
Natural process	7	5.22	6	5.94	7	8.33	16	15.84	12	13.64
Both human action and natural process	22	16.42	7	6.93	22	26.19	48	47.52	21	23.86
Wrath of God	14	10.45	19	18.81	17	20.24	14	13.86	11	12.50
I Don't know/I have no idea	2	1.49	3	2.97	3	3.57	-	-	3	3.41
Total	134	100	101	100	84	100	101	100	88	100

Source: Household survey

The result revealed that, the highest proportion (66.42%) of Cereal and Enset LZ farmers perceive that human action is the main cause of climate change and about 5% of households in this LZ perceive that climate change is mainly caused by the natural process. Whereas, comparatively the lowest percent (22.77%) of farmers in Maize LZ perceive that human action is the main cause of climate change. Interestingly, there is a notable coincidence between the perceptions of farmers towards the contribution of human action for climate change with their highest proportion of educational attainment of 56% in primary and secondary education, which might contribute for their perception of taking the role of human action as the main cause of changing climate. On the other hand, 47.52% of farmers in Maize LZ perceive that the main cause of climate change is because of both human action and natural process. About 20.24% of farmers in Ginger LZ perceive that the main cause of climate change is because of Wrath of God. In FGD held in Cereal and Enset, Coffee and Ginger LZ; participants who lived in the area more than thirty years mentioned that population pressure, increasing cover of the land with eucalyptus trees and clearance of natural indigenous tree species are the main causes of climate change.

3.5. Perceived Effects of Climate Change on Smallholder Farmers' Livelihood

In every livelihood context, the perception of the local communities influences the type and values of livelihood system they lead. From the survey analysis, it is possible to state that there are perceived effects of climate change felt in various degrees across different LZs.

For instance, the highest percent, 90.48% (76), of farmers in Ginger LZ perceived the effect of climate change to be felt as changed timing of rains, disrupting the normal sowing and cultivating season of the main cash crop, Ginger. Similarly, the highest percent, 92.86% (78) of farmers perceived the effect of climate change in the process of shortening growing season, affecting the productivity of the crop in the same LZ. The result is supported by Key Informant Interview (KII) and FGD held at Ginger LZ, indicating that from the last two years onwards, there is a gradual change of planting ginger from when it was usually planted during January to March (during the onset of Belg season rain), towards September/October, which is the cessation period of Meher season. The other most important perceived effect of climate change is in relation with the increasing trend of erosion and land degradation, with the highest percentage 96.27%, (129) of farmers in Cereal and Enset LZ. This is mainly because of the topographical hilly and mountainous nature of the LZ which contributed for the effect.

Table 3.7: Perceived Effects of Climate Change

Perceived Effects of Perception to Climate Change		Livelihood Zones					Pearson chi2(4)	Pr
		Cereal LZ	Coffee LZ	Ginger LZ	Maize LZ	Pepper LZ		
		%	%	%	%	%		
Perceived Effects (Negative Impacts) of climate change in changing timing of rains	Yes	79.85	78.22	90.48	75.25	71.59	10.5090	0.033
	No	20.15	21.78	9.52	24.75	28.41		
	Total	100.00	100.00	100.00	100.00	100.00		
Perceived Effects (Negative Impacts) of climate change by shortening growing season	Yes	77.61	85.15	92.86	79.21	86.36	10.7646	0.029
	No	22.39	14.85	7.14	20.79	13.64		
	Total	100.00	100.00	100.00	100.00	100.00		
Perceived Effects (Negative Impacts) of climate change by increasing frequency of drought and crop failure	Yes	99.25	94.06	97.62	95.05	100.00	10.1948	0.037
	No	0.75	5.94	2.38	4.95	-		
	Total	100.00	100.00	100.00	100.00	100.00		
Perceived Effects (Negative Impacts) of climate change by increasing frequency of post-harvest loss	Yes	91.04	77.23	69.05	100.00	95.45	55.0653	0.000
	No	8.96	22.77	30.95	-	4.55		
	Total	100.00	100.00	100.00	100.00	100.00		
Perceived Effects (Negative Impacts) of climate change in reducing potable water	Yes	100.00	92.08	98.81	97.03	100.00	27.6996	0.001
	No	-	7.92	1.19	2.97	-		
	Total	100.00	100.00	100.00	100.00	100.00		
Perceived Effects (Negative Impacts) of climate change in increasing erosion/land degradation	Yes	96.27	78.22	90.48	90.10	93.18	22.3625	0.000
	No	3.73	21.78	9.52	9.90	6.82		
	Total	100.00	100.00	100.00	100.00	100.00		
Perceived Effects (Negative Impacts) of climate change in extinction of some indigenous crops/crop varieties	Yes	100.00	96.04	96.43	98.00	100.00	12.3616	0.019
	No	-	3.96	3.57	2.00	-		
	Total	100.00	100.00	100.00	100.00	100.00		
Perceived Effects (Negative Impacts) of climate change in disappearance of natural vegetation cover	Yes	85.07	86.14	80.95	84.16	77.27	23.5151	0.006
	No	14.93	13.86	19.05	15.84	22.73		
	Total	100.00	100.00	100.00	100.00	100.00		
Perceived Effects (Negative Impacts) of climate change in declining of pasture land	Yes	100.00	89.11	71.43	97.03	88.64	55.4604	0.000
	No	-	10.89	28.57	2.97	11.36		
	Total	100.00	100.00	100.00	100.00	100.00		

Source: Household survey

In the context of Maize LZ, all farmers perceive the effect of climate change being felt as increased frequency of post-harvest loss, most often extending the normal rain cessation calendar and affecting the harvest of Meher season crops. With regards to the effects of extinction of indigenous crop varieties, all farmers in Cereal and Enset and Pepper LZ FGD participants underscored that there are perceived effect of climate change felt in the form of extinction of some crops and varieties. From the above table, it is possible to state that there is association between perceived effects of perception to climate change and livelihood zones. This result is in coincidence with FGD conducted in Pepper LZ, indicating the extinction of enset crop as one example of those crops undertaken slow extinction in the last thirty three years.

Table 3.8: Perception to Rank for Extinction of some Indigenous Crops

Perception to rank (order of severity) for extinction of some indigenous crops and crop varieties	Perception to rank (order of severity) for erosions / land degradation by LZ									
	Cereal & Enset LZ		Coffee LZ		Ginger LZ		Maize LZ		Pepper LZ	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Extremely severe (Disastrous)	92	68.66	54	53.47	47	55.95	38	37.62	64	72.73
Very severe(Critical)	28	20.90	28	27.72	16	19.05	29	28.71	15	17.05
Severe	9	6.72	10	9.90	11	13.10	24	23.76	8	9.09
Significant	1	0.75	2	1.98	7	8.33	10	9.90	1	1.14
Somewhat significant	4	2.99	3	2.97	3	3.57	-	-	-	-
Irrelevant	-	-	-	-	-	-	-	-	-	-
I don't know	-	-	4	3.96	-	-	-	-	-	-
Total	**134**	**100**	**101**	**100**	**84**	**100**	**101**	**100**	**88**	**100**

Source: Household survey

The extreme variation in climate expanded new pests and diseases like stalk borer, weed, and army worm. Specifically, in 2016, the emergence of an exotic and invasive polyphagous pest-FAW (***Spodoptera frugiperda***) has been reported in the zone (Kembata Tembaro Zone Agriculture Office, 2017), which prefers maize, has spreaded at alarming rate has affected maize production seriously. Farmers in Cereal and Enset LZ perceived (68.66%) that because of climate change, some of the indigenous crops and crop varieties are in the process of extinction (incompatible) from existence. This result has an implication in terms of the repeated occurrence of crop failure as indicated in zonal level report.

The process of climate change and extremes although created frequent crop diseases, on the other hand, has allowed them to adapt new crop types which formerly do not grow in high elevation areas, including coffee, root crops and fruits. They perceive that climate change has created some good opportunities in diversifying other crop types which formerly do not grow at all. According to Hassan & Deressa, (2009) some agro-ecological zones in Ethiopia can benefit from a slight increase in temperature during the right time of the season, whereas others will experience detriments. Likewise, change in precipitation will affect different agro-ecological zones differently.

One key informant interviewee from ***Doreba kebele*** (Cereal and Enset LZ) replied that….

"…In my view, from the last thirty years onwards, the amount of rain is getting decreasing…. especially during the last ten years, the rain is most often becoming erratic and pushing the Belg season to be late and affecting the Meher season (main cropping season) …mainly reducing the time to prepare the land for sowing the crops and also exposing the Belg matured crop to be sold at cheap market price in order to replace the Belg crop with the Meher one…. The crop varieties that we grow/use now are completely changed because of climate change…We use now new seed varieties…. In my view, the main cause for the change in climate is because of human action…. I believe that because of climate change, we have got opportunities…. now I'm able to grow coffee, avocado, apple, tomato, root crops like taro…and the productivity of the new crops is very good,….hence, the change of climate has helped me in this regard…".

The other higher percent of perceived farmers for extinction of some indigenous crops and crop varieties exist in Hadero-Ginger LZ, accounting about 56% of respondents. In this livelihood zone, according to the FGD participants, farmers are gradually changing their main source of cash crop from producing that of Ginger to widely growing tropical fruits, mainly banana, avocado, and mango. In this LZ, ginger is the main cash crop grown widely about eight years ago. But in recent years, because of climate change, the crop is affected by disease and farmers are not encouraged to plant the crop. From the last two years onwards, farmers are now changing the crop production system of ginger from that of rain fed to irrigation (Mugunja Kebele) as an option of adaptation strategy. In addition to this, from the last five years onwards, farmers grow various grass species along their degraded land and peripheries. According to the farmers who participated in FGD, besides to selling fruits, selling modern grass species is being used as an alternative coping strategy.

3.6. Summary

This chapter analysed smallholder farmers' perceptions to climate change. The study emphasizes the importance of understanding local perceptions of climate change in order to design effective adaptive measures at local LZ level. The results of this study showed that smallholder farmers in the study area, who live in different livelihood zones are well aware of climate change, as more than 97% of farmers interviewed perceived an increasing trend of temperature and a decreasing trend of precipitation. Farmers' perceptions of these trends an increasing trend of temperature and a decreasing trend of precipitation match fairly well with the local temperature and rainfall records obtained from National Meteorological Agency of the nearest four meteorological stations which are found in and bordering the five LZs. There is an indication of greater climate variability characterized by extreme weather events such as drought, shifts in the onset and cessation time of annual and seasonal rainfall. Although farmers are aware of climate change, there are differences in terms of perception towards the causes, effect, extent and rank of climate change across different livelihood zones. This calls for the need to contextualize the response mechanisms according to specific support needs of farmers in different livelihood zones of the study area.

In relation with factors influencing perception to climate change, the result revealed that sex, traditional weather prediction, marital status, farming experience, and cultural connectivity are found to significantly influencing perceptions to climate change. Perceived effects of climate change, although the percentage of perception varies across different LZs, among others include increasing frequency of post-harvest loss, reducing potable water, increasing erosion/land degradation, disappearance of natural vegetation cover and declining pasture land are statistically significant. In addition, changing timing of rains, shortening growing seasons, increasing frequency of drought and crop failure, extinction of some indigenous crops/crop varieties are also important to mention.

Chapter Four: Vulnerability of Smallholder Farmers to Climate Change

4.1. Introduction

This chapter is devoted to present the results and discusses the main findings of vulnerability to climate change. The chapter begins with presenting the findings of components of Livelihood Vulnerability Index (LVI) of each LZs and further proceeds with presenting the results of IPCC's Vulnerability Index (LVI-IPCC) by comparing the exposure, sensitivity and adaptive capacity of farmers in different LZs, and finally discusses the IPCC's Vulnerability Index using vulnerability mapping.

4.1.1. Vulnerability Components of Various Livelihood Zones: Compare and Contrast

As presented in Table 4.1. below, the major components of the LVI for each LZs are analyzed. The result revealed that Cereal LZ has the highest value of Natural Disaster (0.574), which is one of the influencing factors, in addition to Infrastructure, Assets and Services for exposure of farmers to climate change. In addition, the LZ has also the highest score in Skill and Knowledge (0.593) and Social and Institutional components (0.402); indicating with relatively better access to social membership, cultural connectivity, local institutional support, access to indigenous knowledge and trust and mutual support, which contributes for its higher adaptive capacity.

On the other hand, Cereal and Enset LZ registered the least score of Nutrition and Health (0.148). Pepper LZ has the least result in terms of Skill and Knowledge (0.496), which matches with the highest percentage (93.18%) of farmers who did not attend any education program of primary, secondary or tertiary levels, significantly reduces the capacity to adapt to climate change. whereas, the highest value (0.427) in terms of Biophysical component, which includes having better ratio of land protected from degradation, and having suitable slope (topography) of cultivated land. It is noted that Pepper LZ has the highest farm land size as compared with all LZs.

Having the highest human capital is critical in terms of building the adaptive capacity of farmers in the LZ. In the context of Assets and Basic Services, Coffee LZ has the highest result (0.429), for which access to off-farm activities contribute for registering higher assets, which helps to reduce vulnerability to climate change. With respect to Land and Water, which is the most critical component for sensitivity in all LZs, the least result is found in Ginger LZ (0.470), as there is the least farm size among the five LZs and the highest household size, which can contribute for higher sensitive to climate change.

Socio-economically, including farming experience and dependency ratio, Ginger LZ (0.372) has the highest result which can contribute for higher adaptive capacity. With regards to Assets and Basic Services, including livestock ownership, access to all weather roads, and access to veterinary services, Coffee LZ (0.429) has the highest result. This leads us to state that cash crop areas agro-ecologically located in midland areas have better result in socio-economically and having better assets and services, indicating that comparatively contributing for higher adaptive capacity. In addition, Ginger LZ has the highest result in terms of Finance and Incomes (0.334), for which the cash crop Ginger has contributed a lot, as the crop currently has higher market value, hence, influencing income from agriculture.

Better access to infrastructure, assets and basic services play critical role in reducing exposure of smallholder farmers to climate change. The highest score is registered in Coffee LZ (0.429), indicating that the LZ has better access to roads, access to climate information, type of house, ownership of pack animals and access to veterinary services; whereas Pepper LZ has the least score (0.316), indicating that the above assets and basic services are less owned and accessed for farmers, increasing their vulnerability to climate change.

The other component of LVI analyzed is access to land and water, which fall under sensitivity. It is beyond despite that land is the main source of livelihood, which has social, economic, and cultural values in smallholder agricultural livelihood system. If properly used and endowed with higher productivity and accessed with water, is capable of contributing greatly in reducing vulnerability to climate change. The analysis revealed that Maize LZ has the highest score of land and water, 0.529, indicating that the livelihood zone has better land productivity (which the flat topography of the land mainly contributes), better access to grazing land, as the livelihood zone has the second highest land size per household next to Pepper LZ, with 0.652 ha, and better access to animal forage have contributed for its highest score. On the other hand, Ginger LZ has the lowest score in Land and Water component, (0.470), indicating that it has the least average land size, 0.349 ha per household and with the highest household size of about 10 persons, which contributed for its least land holding size per household. In addition, with the continuous cultivation of the land, the productivity gets less from year to year, less access to grazing land and animal forage, which have contributed for the least score.

Among the nine components pertinent to indicate the level of vulnerability to climate change in the context of livelihood zones is socio-economic. In the assessment of sub-indicators selected for socio-economic profile is farming experience, dependency ratio and access to off-farm activity. The result revealed that Ginger LZ has the highest score, 0.372, whereas, Pepper LZ has the least score, 0.287, as compared with the five LZs. Specifically access to off-farm activity is better accessed for farmers in Ginger LZ as the livelihood zone has the highest family size of about 10. In addition, Ginger LZ has better access to small markets and towns in the nearby kebeles and the current higher market value of ginger as compared with pepper. Large family size is assumed to be the source of labor, skills and strong social capital to adapt to changing climate situation (Deressa et.al., 2011) and enable a household to accomplish various agricultural tasks especially at the peak seasons.

Access to Finance and Incomes is an important indicator of vulnerability status of households, which is represented in this study through access to credit, access to remittances, farm income, access to money for emergency, subsidy from the government and access to savings. Access to and availability of financial resources and stable income support the development of adaptive capacity (Yohe and Tol, 2002; Armitage, 2005; Engle and Lemos, 2007). Most climate change adaptation measures require some level of financial sacrifice, and access to credit/funds can increase farmers' capacity to adopt coping measures to recover from climate change risks. The result revealed that Ginger LZ has the highest score, 0.334, as the current higher market value of the crop contributed for its higher value; whereas, Maize LZ has the least score, 0.247, as this LZ rely on selling green maize which has relatively lower market value as compared with ginger, contributed for its less value.

Table 4.1: Major Components of LVI

Major Component/s	CELZ	CLZ	GLZ	MLZ	PLZ
Natural Disaster	0.574	0.481	0.502	0.492	0.465
Assets and Basic Services	0.331	0.429	0.383	0.327	0.316
Land and Water	0.478	0.507	0.470	0.529	0.493
Nutrition and Health	0.148	0.385	0.349	0.384	0.365
Skill and Knowledge	0.593	0.535	0.546	0.518	0.496
Socio-economic	0.291	0.313	0.372	0.354	0.287
Biophysical	0.387	0.410	0.343	0.419	0.427
Social and Institutional	0.402	0.314	0.377	0.286	0.334
Finance and Incomes	0.305	0.276	0.334	0.247	0.255

Source: Household survey

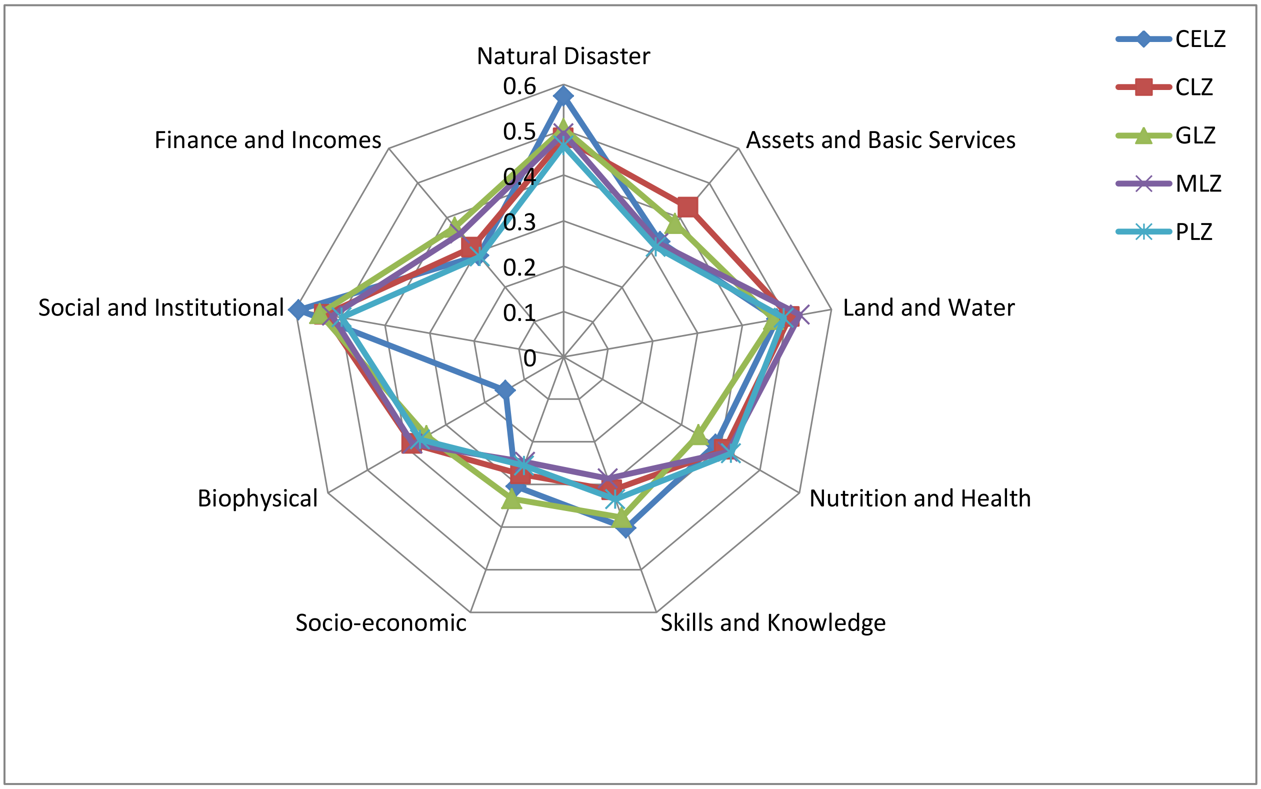


Figure 4.1: Vulnerability Spider Diagram of the Major Components of LVI

Source: Household survey

4.2.IPCC's Vulnerability Index (LVI-IPCC): Compare and Contrast

The LVI-IPCC was computed by grouping the nine major components into three categories namely; exposure (made up of two major components), sensitivity (one major component) and adaptive capacity (six major components) are represented in the vulnerability table as shown in Table 15. Index values should be interpreted as relative values to be compared within the study sample only. The LVI–IPCC is on a scale from -1 (least vulnerable) to 1 (most vulnerable). The overall LVI-IPCC result shows that Coffee LZ is the highest vulnerable to climate change, whereas, Ginger LZ is the least vulnerable. The result on the aggregate LVI-IPCC presents comparison among the various LZs indicating the presence of gaps in their production systems.

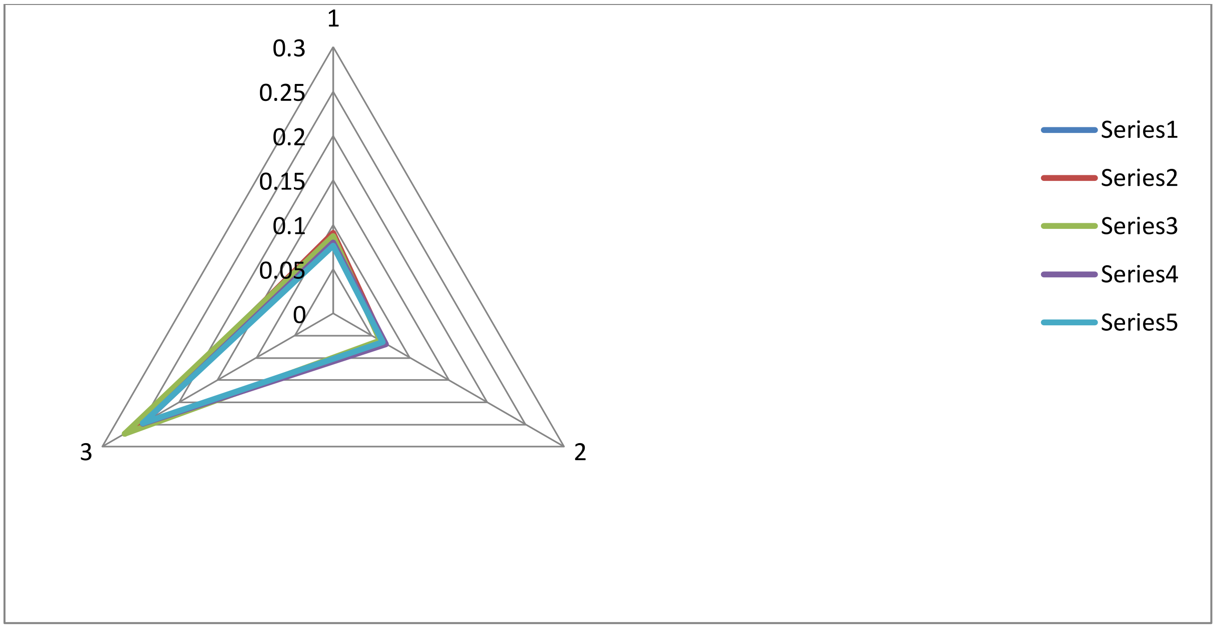
Table 4.2: IPCC Vulnerability Factors

IPCC Contributing Factors to Vulnerability	CELZ	CLZ	GLZ	MLZ	PLZ
Exposure	0.088	0.090	0.087	0.080	0.077
Sensitivity	0.062	0.065	0.061	0.068	0.064
Adaptive Capacity	0.264	0.254	0.270	0.247	0.245
LVI-IPCC	-0.1091	-0.1074	-0.1119	-0.1152	-0.1092

Source: Household survey

Very high exposure coupled with limited adaptive capacity made Coffee LZ as the most vulnerable among the five LZs. In the context of Ginger LZ, very high adaptive capacity and low sensitivity, coupled with medium level exposure to climate change has greatly contributed for its least vulnerability score.

To compare the findings of the research with those researches undertaken agro-ecologically, farmers in midland agro-ecological zone, but with respective specific assets, capabilities and access and ownership of intangible resources, livelihood zones located within the same agro-ecology are both highly vulnerable (Coffee LZ) and less vulnerable (Ginger LZ). On the other hand, Simane et.al., (2016) reported that both farmers in the *Dega* and *Kolla agroecological* zones were more vulnerable than those in the *Weyna Dega* agroecological zone.



1. **Exposure; 2. Sensitivity; 3. Adaptive Capacity**

Figure 4.2: Vulnerability Triangle Diagram of LVI-IPCC Contributing Factors
Source: Household survey

4.3.Vulnerability Mapping

The vulnerability mapping is an important tool that helps to take effective response actions to the adverse impacts of climate change through identification of vulnerable areas. The knowledge of vulnerability to climate change can assist decision makers in recommending adaptation measures and prioritizing resource allocation for specific areas as well as determining investments for adaptation to future impacts of climate change.

4.3.1. Exposure Index

Two components; namely, Frequency of Natural Disaster and Climate Variability and Infrastructure, Assets and Basic Services constitute the exposure contributing factor. The analysis result shows that Coffee LZ has the highest exposure result (0.090); indicating that the LZ has the highest score in terms of Natural Disaster and low score in Assets and Services, whereas, Maize LZ and Pepper LZ have very low levels of the score, the least being that of Pepper LZ, scoring 0.077 and that of Maize LZ is 0.080, indicating that the LZs have implications in terms of achieving higher results in Natural Disaster and lower score in Assets and Services. On the other hand, Cereal and Enset and Ginger LZs fall under medium level of exposure.

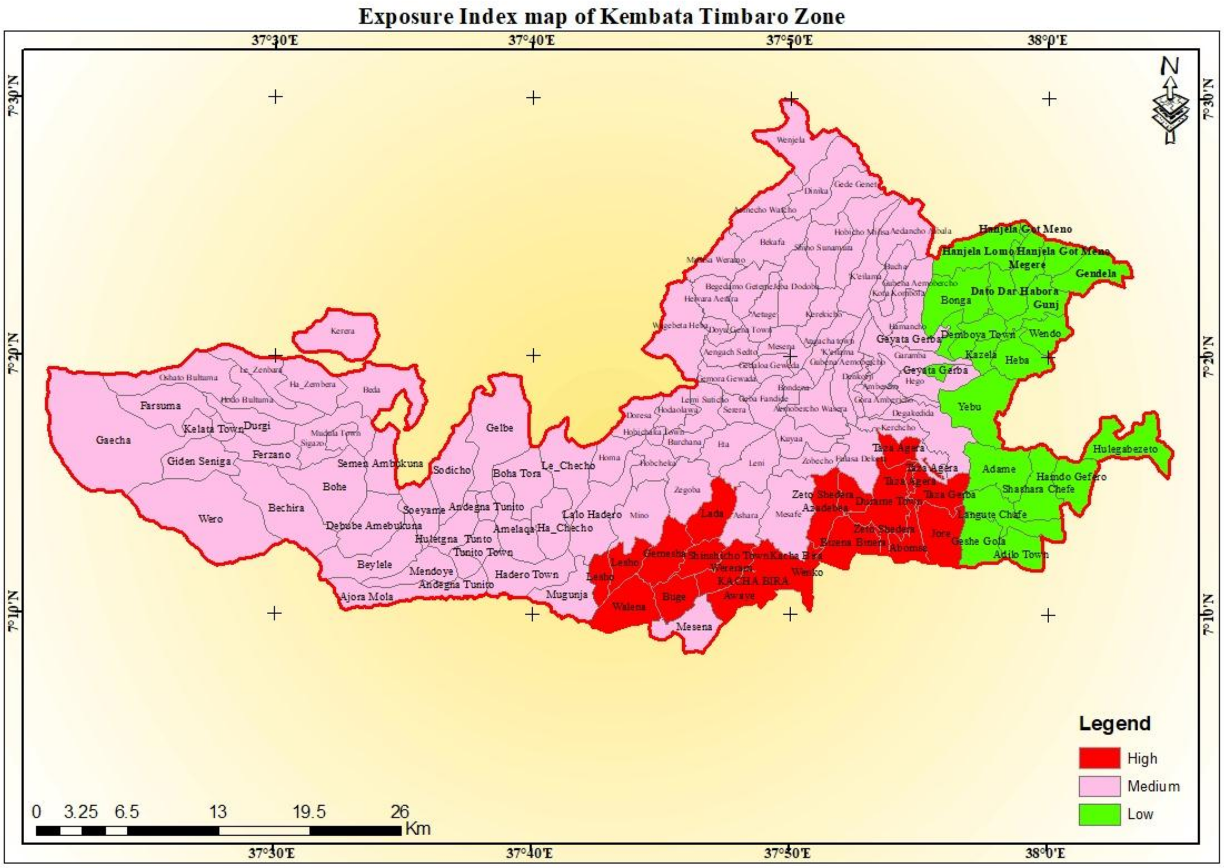


Figure 4.3: Exposure Index Map

Source: Own construction

4.3.2. Sensitivity Index

Results from the sensitivity analyses revealed that Ginger LZ and Cereal and Enset LZs scored 0.061 and 0.062, respectively, which fall under the low sensitive categories; Ginger LZ is the least sensitive to climate change; whereas, Maize LZ has the highest sensitivity score (0.068). This is because in Maize LZ, the sub-indicators for sensitivity, including less access to water, high effect of climate change on extinction of crop varieties and post-harvest loss have contributed for its higher value. The result is in coincidence with the findings of Gebre-egziabher, et.al., (2016), which is conducted in four major agro-ecological zones in the Nile Basin of Ethiopia by constructing composite vulnerability indices, indicating that drought-prone highland areas are the most sensitive zone to climate change. The area is characterized by higher frequency of drought, flooding and hailstorms, in addition to high temperature that is increasing over time.

Regarding sensitivity, even though population density is highest in Ginger LZ, the findings indicated that the LZ has the least score in sensitivity. From the generally known trend, agro-ecologically those moisture-sufficient highland areas tend to score least in terms of sensitivity; whereas, drought-prone areas tend to score higher in sensitivity to climate change. In a similar trend, Maize LZ has scored the highest in sensitivity score, which is characterized by higher frequency of drought, flooding and hailstorms, in addition, maximum temperature is increasing in this LZ over time. On the other hand, Pepper LZ and Coffee LZ fall under medium level sensitive LZs, with 0.064 and 0.065 score, respectively.

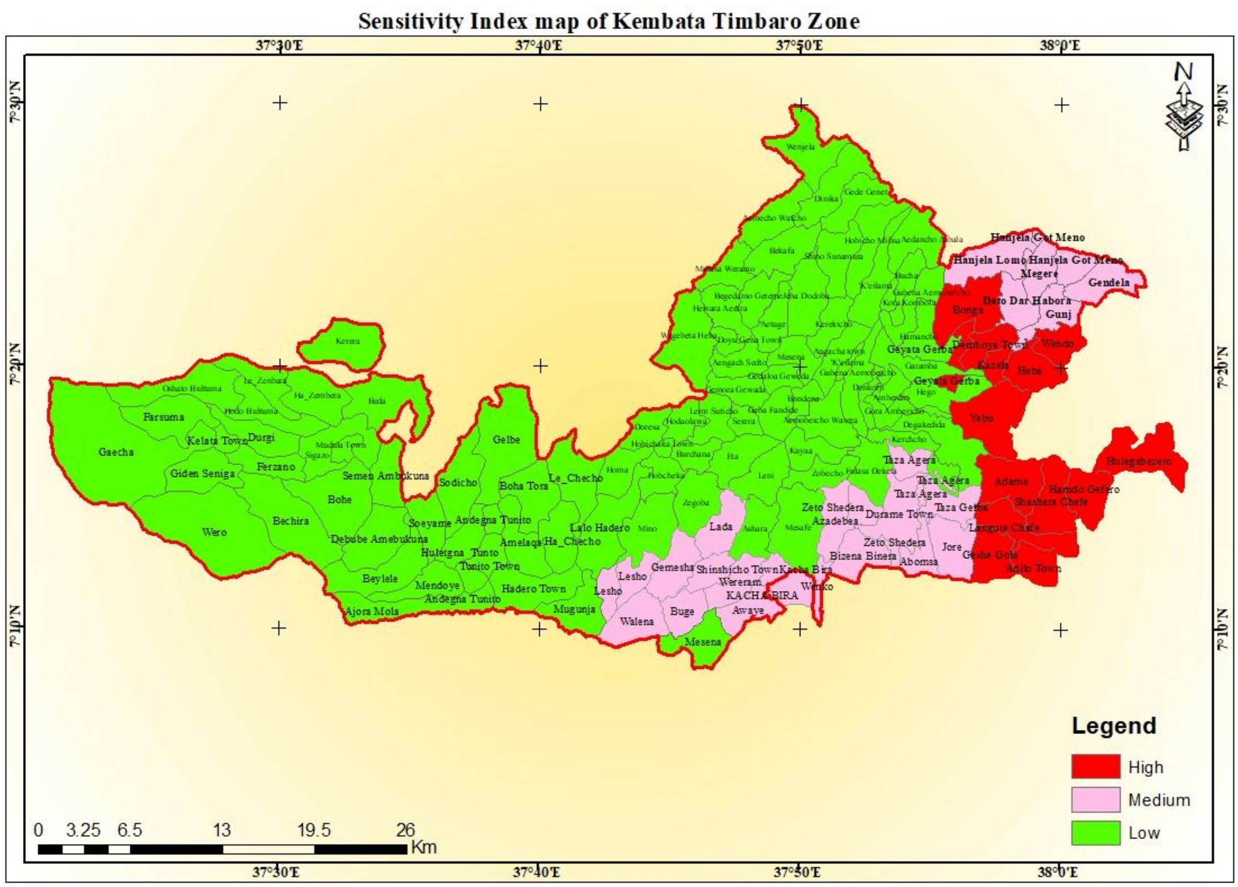


Figure 4.4: Sensitivity Index Map
Source: Own construction

4.3.3. Adaptive Capacity Index

Adaptive capacity is represented in the LVI-IPCC analysis through six major components, namely; Skills and knowledge, Socio-economic, Social and Institutional, Finance and Incomes, Bio-Physical/Environmental and Nutritional and Health Status. The analyses of indices for the five LZs indicated that Ginger LZ has the highest score of adaptive capacity, with 0.270, whereas Pepper LZ has the least adaptive capacity (0.245). The prime factor leading for Ginger LZ's highest adaptive capacity is the highest score in finance and income component, among others. On the other hand, Pepper LZ has the least adaptive capacity (0.245), with fewer score in crop diversification index, less score in educational attainment as indicated in table 3.1., technology adoption and access to social membership, among other sub-components.

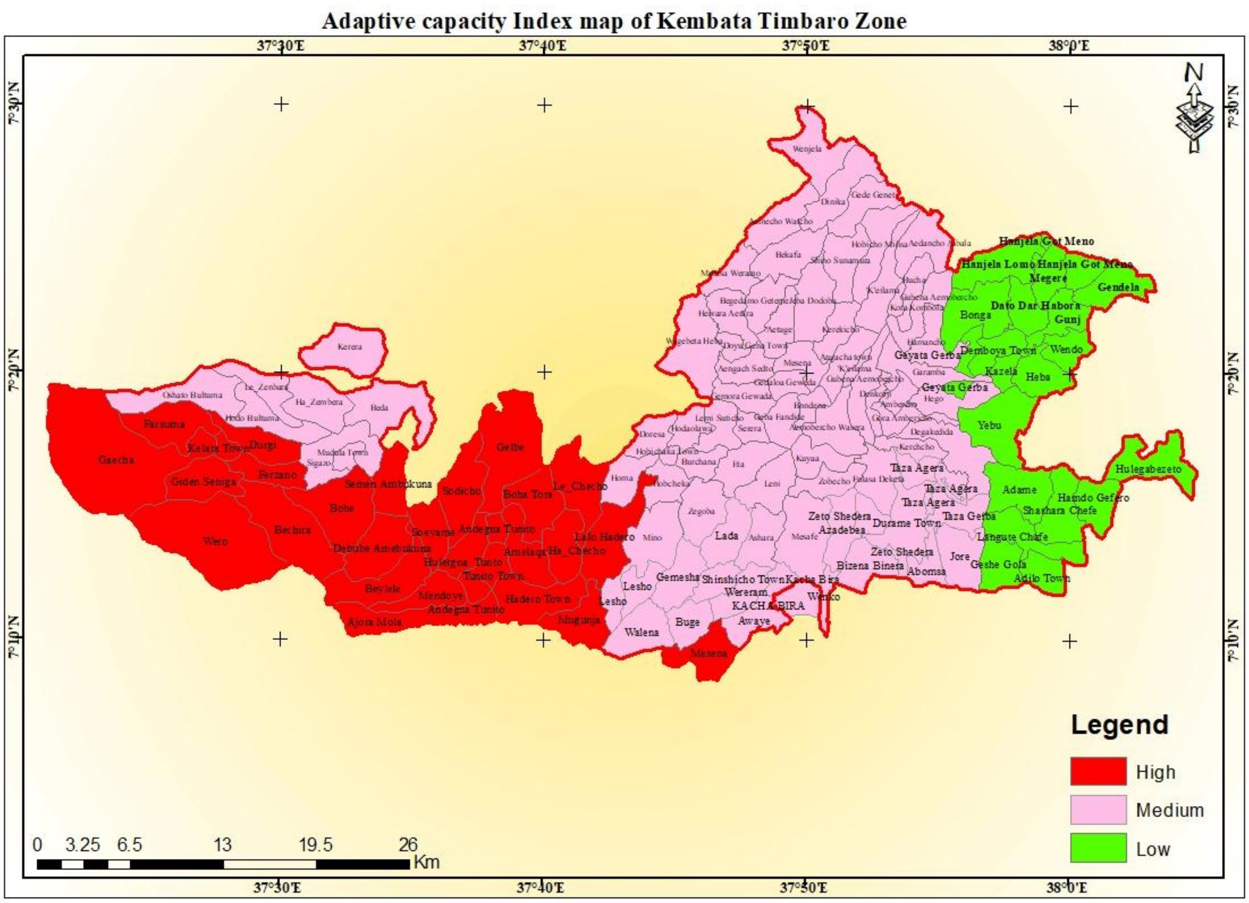


Figure 4.5: Adaptive Capacity Index Map
Source: Own construction

4.3.4. Aggregate Vulnerability Index

The aggregate vulnerability was mapped based on the potential contributing factors that are expressed by exposure, sensitivity, and adaptive capacity. The result implies that a higher adaptive capacity is associated with a lower vulnerability, while a higher potential impact is associated with a higher vulnerability. Contextually, the aggregate vulnerability index map revealed that Coffee LZ is the most vulnerable to adverse impacts of climate change, while Ginger LZ scored the lowest level of vulnerability because of potential low adverse impact and high adaptive capacity. Cereal and Enset and Pepper LZs fall under medium level of vulnerability.

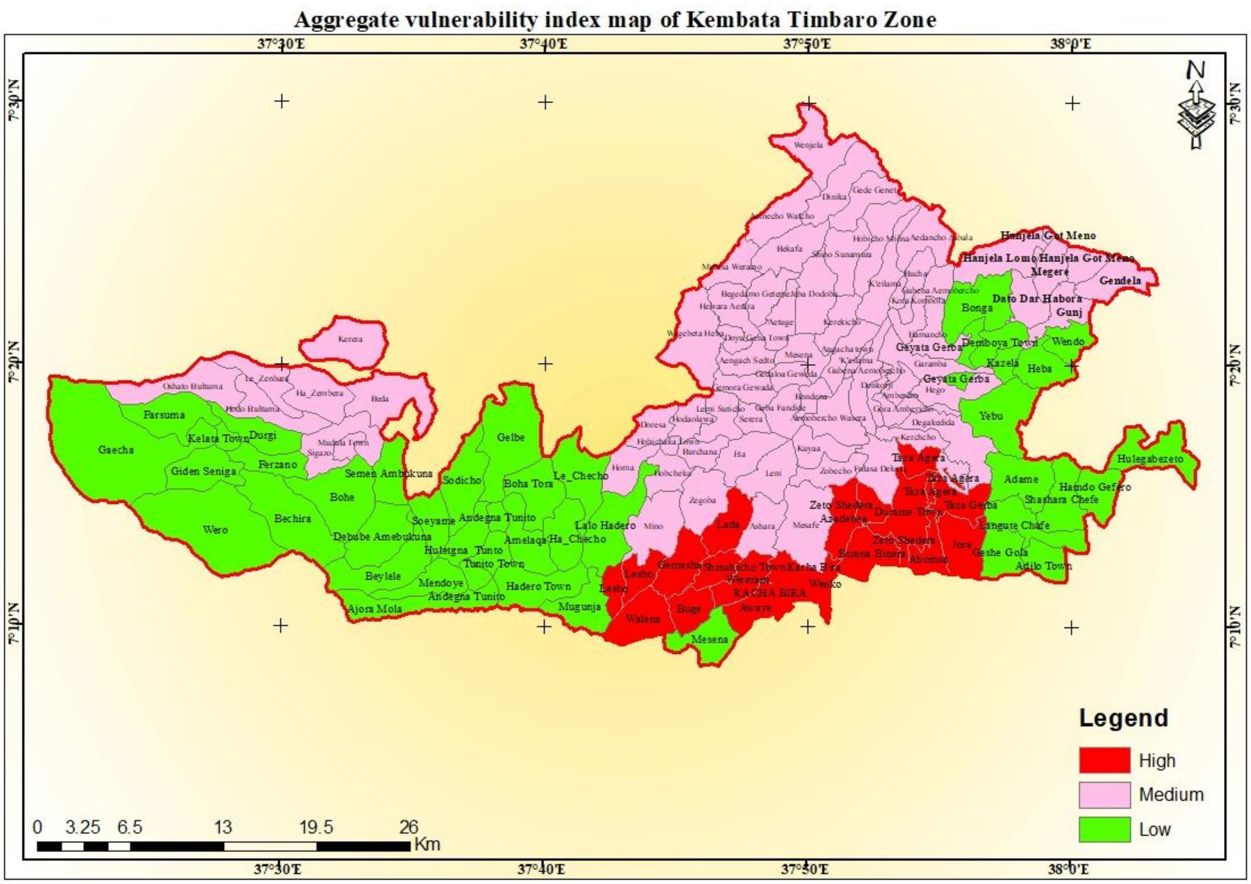


Figure 4.6: Aggregate Vulnerability Index Map
Source: Household survey

4.4. Summary

The chapter analyzed vulnerability of smallholder farmers to climate change and variability in five livelihood zones using the LVI and LVI-IPCC methodologies. Household level data about livelihood capitals and climate related variables were used to develop vulnerability indices and determine vulnerability patterns across the study area. Results of the vulnerability assessment confirmed that all the five livelihood zones are vulnerable to climate change. However, in relative terms, Coffee LZ is the most vulnerable to climate change, whereas, Ginger LZ (Agro-ecologically located in midland) is the least vulnerable to climate change. Cereal and Enset and Pepper LZs fall under the medium category of vulnerability level. Assessment of vulnerability is useful to identify and prioritize vulnerable areas and contributing factors for adaptation planning. Therefore, this study can inform policies to deliver better interventions for communities and smallholder farmers at the grassroots level.

Chapter Five: Adaptive Capacity and Adaptation to Climate Change

5.1. Introduction

This chapter is devoted to present the results and discussions of the main findings of levels of adaptive capacity of smallholder farmers to climate change and their adaptation strategies. The chapter begins with description of the perception for capacity to adapt and further discusses with the barriers affecting adaptive capacities in different LZs. In this chapter, efforts are made to discuss the capitals/components of adaptive capacity through comparing across the five LZs. The chapter further proceeds with discussing coping and adaptation strategies employed by farmers to climate change across the five LZs. Finally the chapter closes with summary.

5.2. Perception for Capacity to Adapt

Before undertaking detailed analysis on farmer's adaptive capacity to climate change using quantitative technique, it is very important first to assess the perceptions of farmers towards how they perceive their capacity to adapt, as perception influences both the coping and adaptation strategies farmers employ for the changing climate. The survey result indicated that the highest number (72%) of farmers in Coffee LZ perceive that they have the capacity to adapt to climate change; whereas, the least percent (45.52%) of farmers in Cereal LZ perceive that they have the capacity to adapt to climate change. Having a positive perception to adapt has an implication in terms of indicating their readiness to take decisions necessary for coping and adapting with the changing climate.

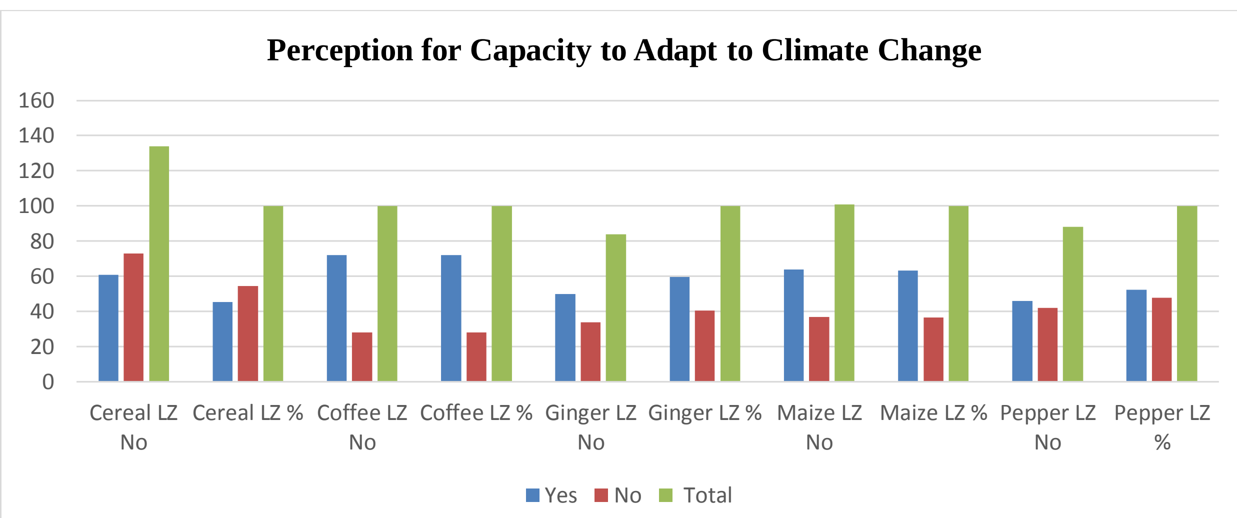


Figure 5.1: Perception for Capacity to Adapt
Source: Household Survey.

In the process of identifying perceptions of smallholder farmers to climate change, there are variables which significantly contribute for perception to capacity to adapt. The result revealed that access to savings, access to improved variety of seeds and fertilizer use have significantly contributing for perception to capacity to adapt; whereas, land productivity has marginal significant for perception to capacity to adapt (see table 5.1).

Table 5.1: Significance Test of Variables for Perception to Capacity to Adapt

Variables	Chi-square	p-value
Access to savings	13.1913	0.000
Land productivity	5.8128	0.055
Improved variety of seeds	5.2566	0.022
Fertilizer use	6.7142	0.035

Source: Household survey

More specifically provision for access to saving widens farmer's choice to engage in other off-farm and non-farm income generating activities. In general, strengthening access to savings, provision of improved varieties and enhancing access to fertilizer application are very important elements in terms of enhancing the perception for capacity to adapt.

5.3. Barriers Affecting Adaptive Capacities

Smallholder farmers in various geographical and socio-economic environments face different needs to enhance their adaptive capacity to climate change, as the negative impact of climate change differs from one LZ to the other according to the livelihood assets and capacities of the local communities. In this regard, farmers were requested to reflect the constraints that they face in the process of building their capacity to adapt. The highest percent (67.11%) of farmers in Maize LZ reason out that the main challenge to adapt to climate change is lack of human capital, such as skills, knowledge, and technologies helpful to reduce the impact of it (see figure 5.2. below). It is important to note here that human capital is the most important asset that can critically play great role in the process of adapting to climate change. In the context of social capital, 45.52% of farmers in Cereal LZ reason out that they lack social capital, which is helpful in building their adaptive capacity. With regards to financial capital, 23.26% of farmers in Coffee LZ perceive that they lack financial capital to build their adaptive capacity.

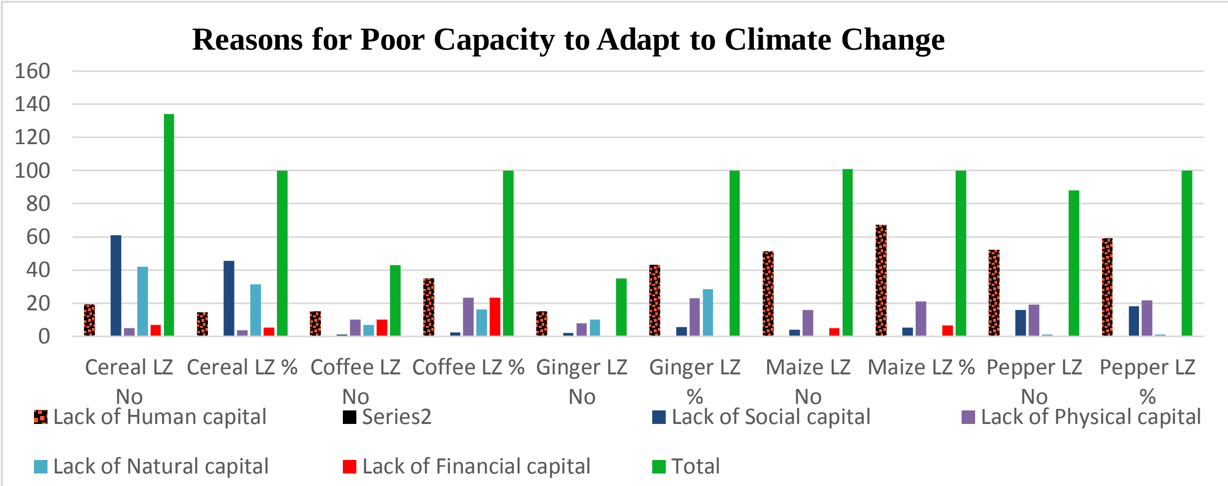


Figure 5.2: Reasons for Poor Capacity to Adapt to Climate Change
Source: Household Survey.

Serious shortage of natural and physical capital are registered in Cereal and Enset LZ, Coffee LZ and Ginger LZ; Maize LZ also scoring less in natural capital.

Besides to identifying the perceptions and the reasons for poor capacity to adapt to climate change, it is very important as well to assess the significance level of variables which contribute for recovering of farmers from climate change related disasters. As shown in table 5.2 below, the result revealed that frequency of disaster, land productivity, local institutional support, slope of cultivated land, health status, access to savings, technology adoption and applying skills are significantly contributing for the perception of farmers' capacity to recover from disaster. In addition, observed increased temperature, access to horse cart are marginally contributing for farmers' capacity to recover.

Table 5.2: Variables Contributing for Perception to Capacity to Recover

Variables	Chi-square	p-value
Frequency of disaster	32.1065	0.000**
Observed increased temperature	4.0728	0.044**
Land productivity	8.4220	0.015**
Access to donkey / horse cart	3.9951	0.046**
Institutional support	5.9715	0.015**
Land slope	55.8778	0.000**
Health status	14.6381	0.002**
Access to savings	9.8184	0.002**
Technology adoption	17.0779	0.002**

****indicate the existence of significant association at 0.05**
Source: Household survey

Hence, for improving the recovery capacity of farmers from climate change related disasters, it is very important to improve the land productivity, health status, access to savings at grass root level, enhancing the institutional support through the local government service provision including early warning information which can significantly help to recover from the disasters, and providing user friendly technologies which can easily be applied taking into account the local resources and capacities is very important.

5.4. Farmers' Capacity for Various Actions

In line with assessing the adaptive capacity of farmers to climate change, it is very important to assess how farmers act for various actions. In line with the objective of this research, four actions have been selected and further analyzed how do farmers assess their capacities, namely with: interpreting weather information, using weather information to plan, using weather information to decide what crop to plant/what to do, and their capacity in identifying variety of crops in the five LZs. Accordingly, in relation with weather information interpretation, 12% of farmers in Coffee LZ have good skill in this regard; whereas, more than half (57.43%) of farmers in Maize LZ have average capacity to interpret weather information.

On the other hand, 54.48% of farmers in Cereal LZ do not interpret weather information at all. In the context of using weather information to plan, 23.76% of farmers in Maize LZ have good capacity in using weather information to plan; whereas, 54.48% of farmers in Cereal LZ do not have the capacity in using weather information to plan; whereas, the highest percent (26.87%) of farmers in Cereal LZ have the capacity of identifying varieties of crops to plant. From the result, it is possible to conclude that the capacity of farmers to interpret weather information, using weather information to plan, using weather information to decide what crop to plant and identifying varieties of crops in general is below average.

Table 5.3: Assessment of Capacities for Various Actions

Assessment of capacities for various actions		**Distribution of Assessment of Capacities for Various Actions by LZ**									
		Cereal LZ		**Coffee LZ**		**Ginger LZ**		**Maize LZ**		**Pepper LZ**	
		No	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
Capacity to interpret weather information	No	73	54.48	28	28.00	33	39.29	37	36.63	40	45.45
	Poor	40	29.85	35	35.00	32	38.10	6	5.94	8	9.09
	Average	21	15.67	25	25.00	19	22.62	58	57.43	40	45.45
	Good	-	-	12	12.00	-	-	-	-	-	-
	Total	**134**	**100.00**	**100**	**100.00**	**84**	**100.00**	**101**	**100.00**	**88**	**100.00**
Capacity in using of weather information to plan	No	73	54.48	28	28.00	33	39.29	37	36.63	40	45.45
	Poor	31	23.13	27	27.00	20	23.81	5	4.95	3	3.41
	Average	28	20.90	44	44.00	31	36.90	35	34.65	42	47.73
	Good	2	1.49	1	1.00	-	-	24	23.76	3	3.41

	Total	**134**	**100.00**	**100**	**100.00**	**84**	**100.00**	**101**	**100.00**	**88**	**100.00**
Capacity in using weather information to decide what crop to plant/what to do	No	73	54.48	28	28.00	33	39.29	37	36.63	40	45.45
	Poor	5	3.73	22	22.00	5	5.95	4	3.96	7	7.95
	Average	46	34.33	48	48.00	43	51.19	28	27.72	35	39.77
	Good	10	7.46	2	2.00	3	3.57	32	31.68	6	6.82
	Total	**134**	**100.00**	**100**	**100.00**	**84**	**100.00**	**101**	**100.00**	**88**	**100.00**
Capacity in identifying variety of crops	No	73	54.48	28	28.00	33	39.29	37	36.63	40	45.45
	Poor	1	0.75	25	25.00	11	13.10	1	0.99	8	9.09
	Average	24	17.91	44	44.00	34	40.48	38	37.62	31	35.23
	Good	36	26.87	3	3.00	6	7.14	25	24.75	9	10.23
	Total	**134**	**100.00**	**100**	**100.00**	**84**	**100.00**	**101**	**100.00**	**88**	**100.00**

Source: Household survey

5.5. Description of Capitals/Components

Table 5.4: Description of Capitals/Component Index

Types of Capital / Component Index	**Livelihood Zones**					
		Cereal LZ	**Coffee LZ**	**Ginger LZ**	**Maize LZ**	**Pepper LZ**
Human Capital Index	Obs	134	101	84	101	88
	Mean	.3565252	.2999827	.3462642	.2861017	.3346943
	Std. Dev.	.1027224	.100576	.111721	.0922181	.0997207
	Min	.0581624	.0675641	.0575641	.0512821	.1258974
	Max	.6613676	.5616025	.6384615	.511282	.575641
Financial Capital Index	Obs	134	101	84	101	88
	Mean	.3119186	.3064877	.4071812	.3239191	.282994
	Std. Dev.	.1688082	.1625418	.1556535	.1634939	.1445665
	Min	.0023848	.0175056	.0289223	0	.0357723
	Max	.7116582	.7255611	.7186493	.7004445	.6700873
Natural Capital Index	Obs	134	101	84	101	88
	Mean	.2836816	.4129703	.3635516	.4043729	.3484659
	Std. Dev.	.1454091	.1898628	.1770052	.1842082	.1743719
	Min	0	.0266667	.0533333	.0533333	.0533333
	Max	.7133333	.9333333	.7366667	.8299999	.84
Social Capital Index	Obs	134	101	84	101	88
	Mean	.5989552	.539604	.5704762	.5106931	.5006818
	Std. Dev.	.1970965	.2012755	.2033568	.2063698	.2078118
	Min	.2	.1	0	0	0
	Max	1	1	1	.88	.88
Physical Capital Index	Obs	134	101	84	101	88
	Mean	.2896013	.3706081	.3169893	.3351905	.3781782
	Std. Dev.	.101746	.13931	.12787	.1189716	.1130945
	Min	.0906476	.1039002	.1139285	.1248594	.1495442
	Max	.6793919	.6719675	.5977547	.7201911	.7320181
Institutional and infrastructural index	Obs	134	101	84	101	88
	Mean	.4949254	.5551485	.532381	.4391584	.3244318
	Std. Dev.	.1575219	.1313173	.1428254	.1752114	.1725509
	Min	.06	.22	.22	.065	0
	Max	.835	.83	.84	.845	.705

Information Access Index	Obs	134	101	84	101	88
	Mean	.3227612	.2518812	.3426191	.2671287	.2719318
	Std. Dev.	.1444585	.10731	.1314802	.1383137	.1120022
	Min	0	0	0	0	0
	Max	.65	.49	.6	.67	.52

Source: Household survey

Physical Capital

Different researchers categorize physical capitals based on their contextual indicators. Physical resources refer to capital created by economic production processes, such as roads, machinery, and tools (Ellis, 2000). Physical resources, in this research context, consist of farm size, access to irrigation, ownership of plough, livestock ownership, type of house, ownership of donkey for transport, and farm situation. The findings revealed that Pepper LZ has the highest physical capital index (.3781), mainly supported by scoring the highest farm size of about 0.903 ha per household; and Cereal and Enset LZ has the lowest physical capacity index (.2896), mainly reflected by owning small farm size.

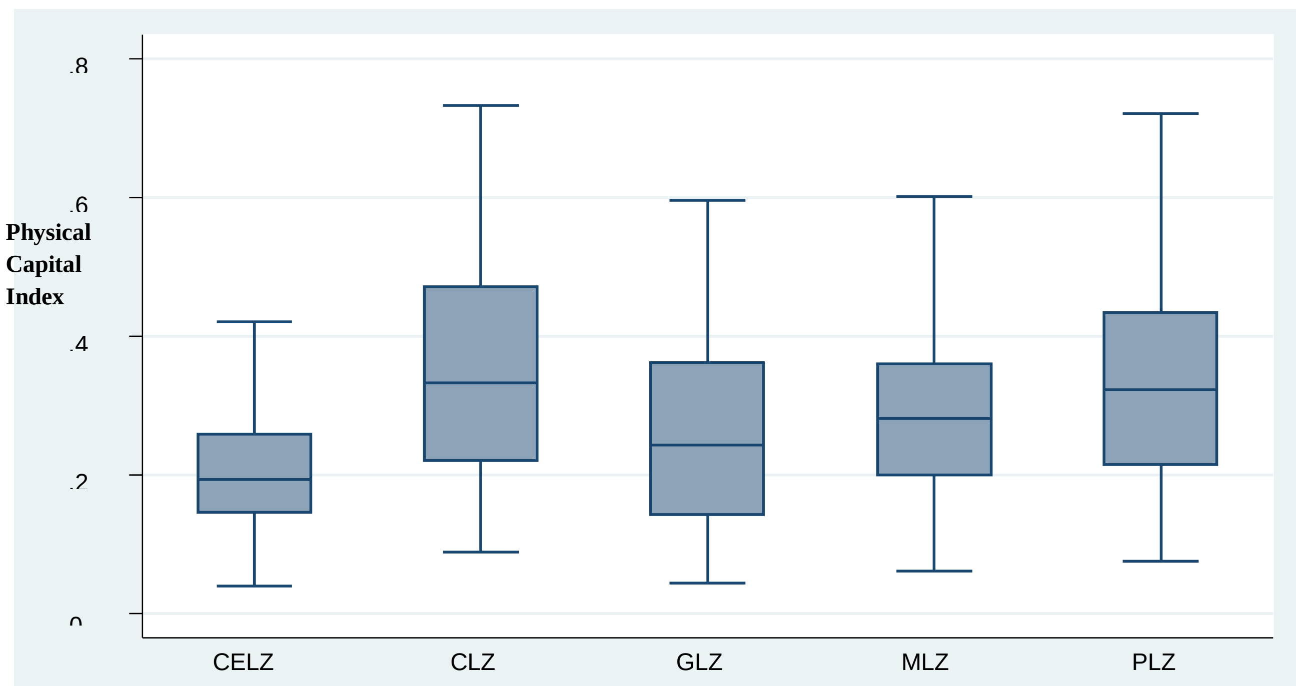


Figure 5.3: Physical Capital Index
Source: Household survey

Financial Capital

Financial resource as an indicator of adaptive capacity represents farmers' ownership of and access to financial wealth which is crucial for climate change adaptation. Most climate change adaptation measures require some level of financial sacrifice and access to credit/funds which can increase farmers' capacity to adopt coping measures to recover from climate change risks. In this research context, financial capital includes: access to remittances, access to savings, subsidy from the government, access to credit, access to money for emergency, farm income and off-farm activity.

The result revealed that Ginger LZ has the highest financial capital index (.4071), indicating that the LZ has better access to savings, remittances and off-farm engagement as compared with other LZs. In addition, income from the main cash crop, Ginger, has higher market value of money, which mainly contributed for greater value of the index; whereas, Pepper LZ has the least financial capital index (.2829), indicating that though market value of pepper is high, the LZ has less access to savings, remittances, credit, and off-farm engagement.

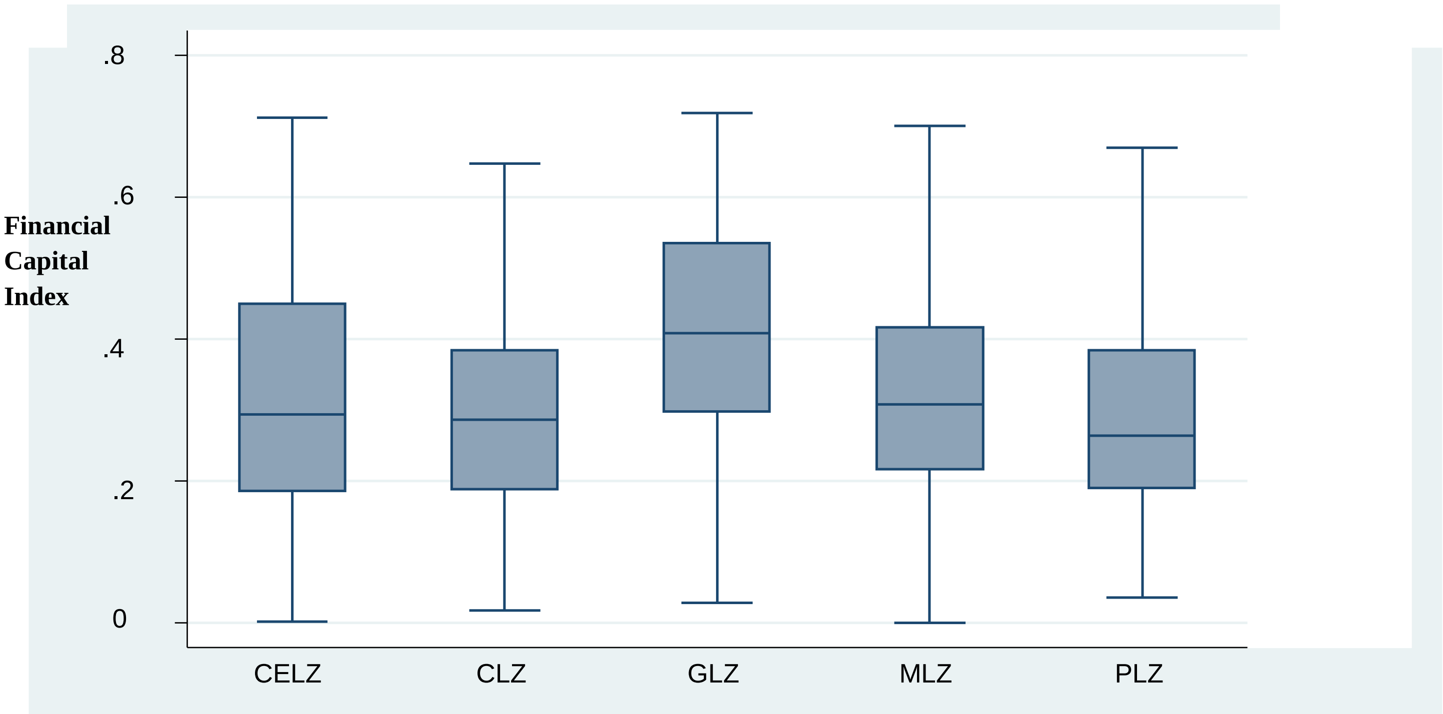


Figure 5.4: Financial Capital Index
Source: Household survey

Human Capital

Human resources refer to the availability of skills, expertise, knowledge, and human labor (Gupta et.al., 2010, Nelson et.al., 2010a), as well as good health and physical capability to undertake livelihood activities (Ellis, 2000). Studies have considered human resources in relation to the level of enthusiasm and optimism for natural resources management, good health and nutrition, willingness to change or innovate, and willingness to seek new information (Brown et.al., 2010, Morrison et.al., 2011, Park et.al., 2012). Longer farming experience, higher education and healthy human resource suggest more knowledge and skills for effective adaptation to climate related risks, hence, higher adaptive capacity. In this research context, human capital includes: farming experience, educational attainment of household head, health status, technology adoption, dependency ratio and skill upgrade. The index result revealed that Cereal and Enset LZ has the highest human capital index (.3565), which coincides with the highest percentage in educational attendance of 55.97%, better skill upgrade, health status, technology adoption; whereas, Maize LZ has the least score in human capital index (.2861), as the percentage of educational attainment of farmers 77.23% score ranks the third highest percentage in terms of lack of educational attendance, among others. The overall human capital index score for all LZs shows that it is less than 0.4, indicating that much has to be done in terms of technology adoption, skill upgrade and educational attainment.

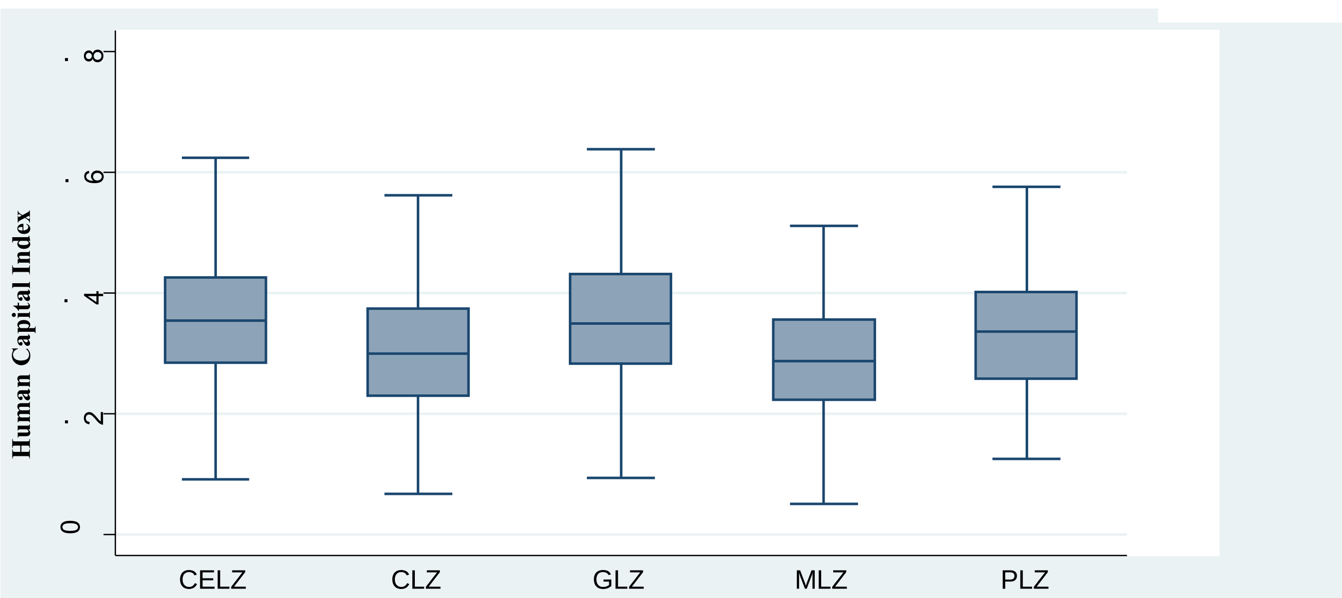


Figure 5.5: Human Capital Index
Source: Household survey

Natural Capital

Natural capital, as the name indicates, it generally refers to describe the stocks of natural resources from which further resources and services can be developed, such as land, water, soil, forests, etc. It is obvious that natural capital is extremely important for those who earn part or all of their livelihoods from activities which rely on natural resources, such as crop or animal farming. In this research context, natural capital includes: access to water, land productivity, access to grazing land, access to animal forage / pasture, slope of cultivated land, land protected from erosion/degradation and land covered with (indigenous) vegetation. From the aggregated index result, it is possible to state that Coffee LZ has the highest natural capital index score (.4129), as supported by better access to water and land protected from erosion, among others, whereas, Cereal and Enset LZ has the lowest index score (.2836), slope of cultivated land, which is mainly characterized by mountainous and hilly and lesser size of land protected from erosion have contributed for having very less natural capital index, among others. The overall index shows that except Coffee and Maize LZs, the rest LZs have index value of natural capital less than 0.4, indicating that much has to be done in improving land productivity and vegetation cover.

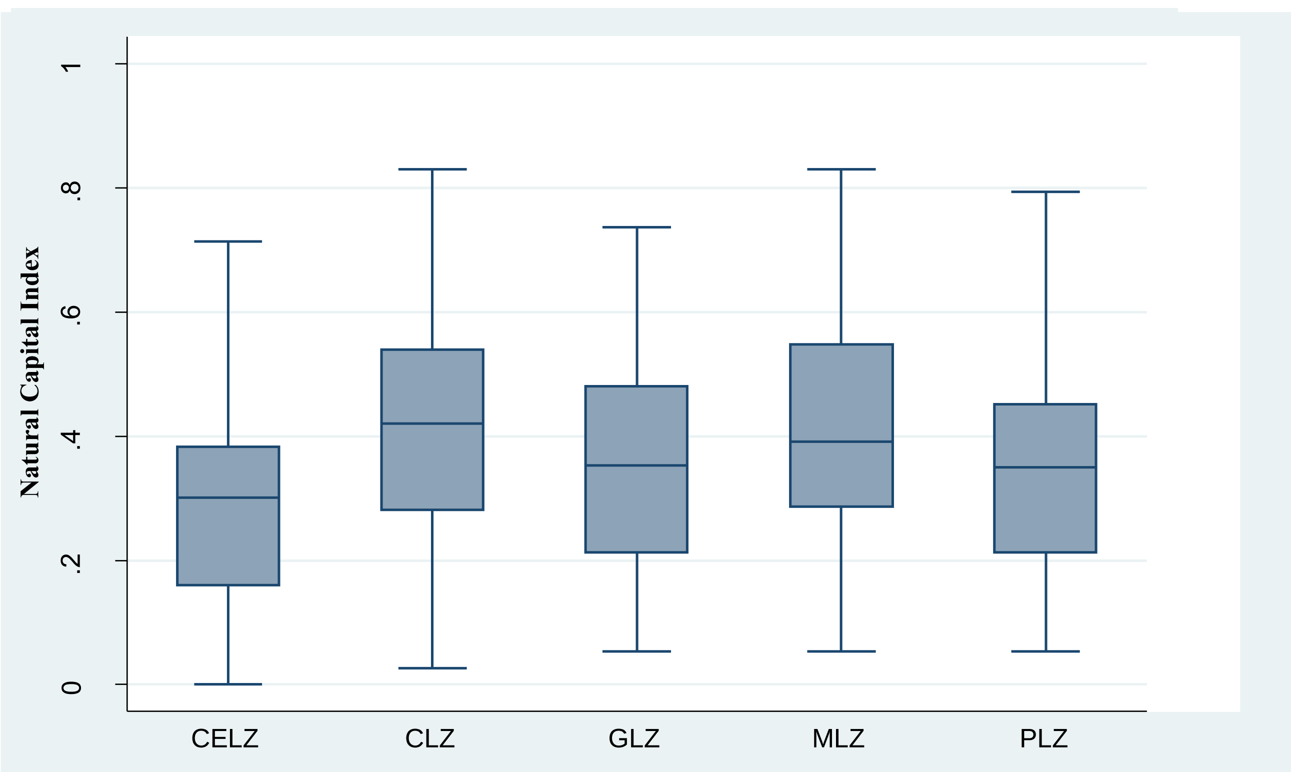


Figure 5.6: Natural Capital Index
Source: Household survey

Social Capital

Social capital broadly refers to a set of networks, agreements, and flows of information (Adger et.al., 2005). "It incorporates features of social organization such as trust, norms and networks that can improve the efficiency of society by facilitating coordinated actions" (Putnam et.al., 1993:167). Social capital is a lens for examining how social networks and social norms, including reciprocity, contribute to adaptive capacity (Pelling and High, 2005), particularly in coping with risk and environmental change (Adger, 2003a, Adger and Vincent, 2005). Social capital, in this research context, consists of access to social membership, cultural connectivity, access to indigenous knowledge, local institutional support, trust and mutual support, and traditional weather prediction. From the aggregated index result, it is possible to state that Cereal and Enset LZ has the highest social capital (.5989), expressed in the form of having better access to social membership, cultural connectivity, access to indigenous knowledge, local institutional support, trust and mutual support and traditional weather prediction; whereas, Maize LZ has the least social capital (.5006), for which the value for the above indicators is relatively low. In general, smallholder farmers in Maize and Pepper LZs (agro-ecologically lowland areas) have less social capital than farmers in Cereal and Enset, Ginger and Coffee LZs (agro-ecologically highland and midland).

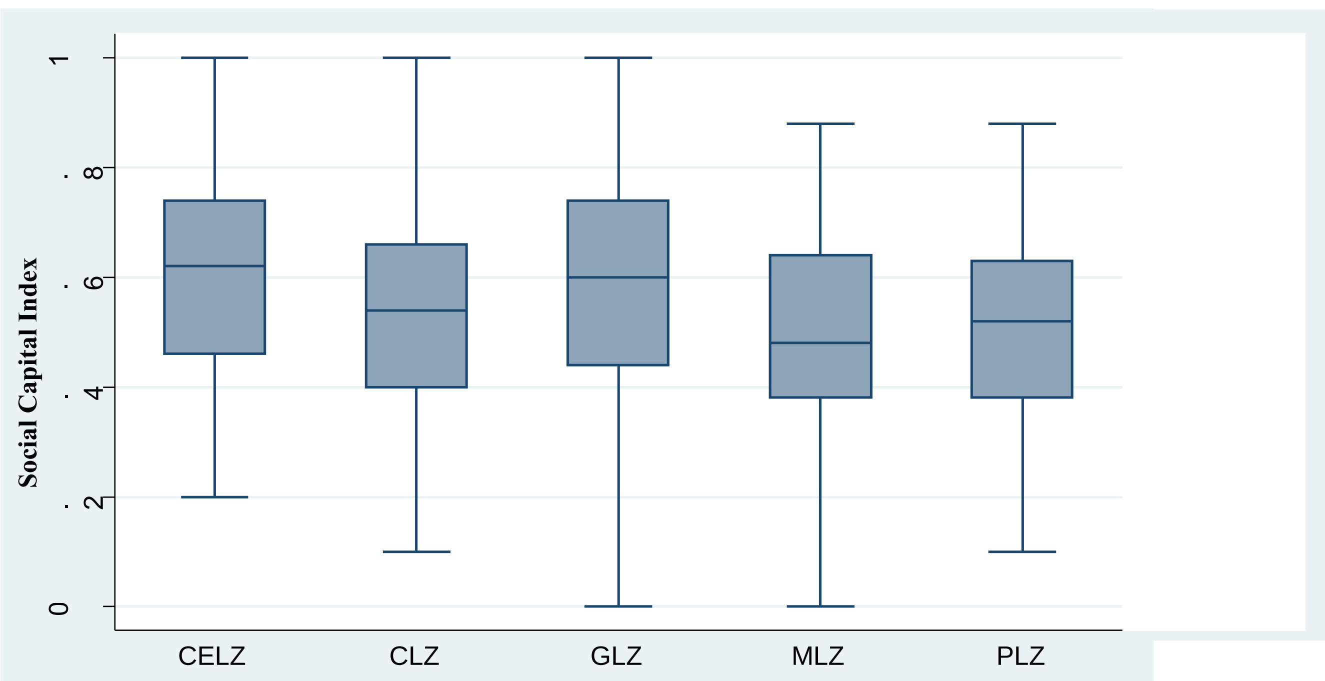


Figure 5.7: Social Capital Index
Source: Household survey

Information Accessibility

These include all the channels through which farmers can access requisite information to strengthen their ability to adapt to climate change, either directly from training, sources of climate information, or indirectly through interactions and knowledge-sharing with other farmers. The information accessibility indicator of farmers' adaptive capacity in this research consists of climate information, access to radio, access to early warning, and frequency of weather information. The result revealed that Ginger LZ has the highest score in information accessibility (.3426), which coincides with highest score in financial index contributing for access to buy and use electronic equipments like radio. On the other hand, Coffee LZ has the least score (.2518) in information accessibility. The result of the index revealed that the overall information accessibility is below 0.35, indicating that all farmers in the five LZs have very low access to climate information, which threatens their capacity to adapt to climate change, reducing their access to early warning information and increasing their exposure to climate change.

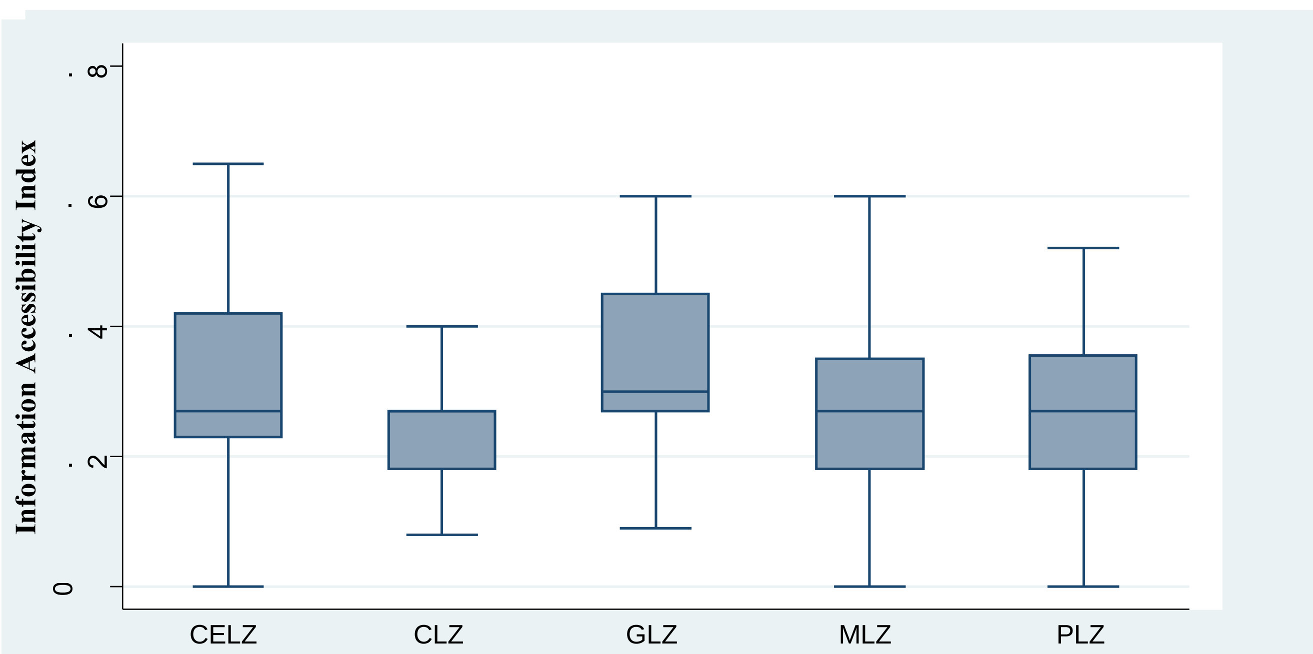


Figure 5.8: Information Accessibility Index
Source: Household survey

Institutional and Infrastructural

Institutional arrangements affect individuals' and communities' capacity to adapt (Ivey et.al., 2004; Engle, 2011). Actors engaged at all scales and levels of governance develop and implement adaptation policies, foster adaptive capacity, and undertake adaptive actions (Plummer, 2013). Rigidly hierarchical, poorly coordinated, or ill-informed governance can also be a barrier to adaptation (Engle and Lemos, 2010). Adaptive capacity demands that a governing body is intentional in its management of change and is able to rearrange internal processes and procedures in response to changing internal or external conditions (Gunderson et.al., 1995).

Ivey et.al., (2004) identified the extent of public participation in decision making and implementation as a dimension of adaptive capacity. Participation can build trust and shared understanding, which in turn can mobilize coordinated action and encourage the emergence of self-organized governance structures (Lebel et.al., 2006). Leadership has a major role in adaptive capacity for building trust, developing and communicating visions, managing conflict, linking different actors, societal levels, and knowledge systems, initiating partnerships, compiling and generating knowledge, and mobilizing support for change (Armitage, 2005, Pahl-Wostl et.al., 2007; Engle and Lemos, 2010; Gupta et.al., 2010; Plummer et.al., 2013). Leaders must also be able to generate and make the most of windows of opportunity when change becomes necessary (Folke et.al., 2005).

The institutional and infrastructural indicator of farmers' adaptive capacity in this research consists of access to leaders, participation in decision-making, access to all weather roads, access to veterinary services, access to electricity, access to improved varieties of seeds, and access to early support for disaster. The index result revealed that Coffee LZ has the highest institutional and infrastructural index (.5551), indicating that the LZ has better access to leaders, better participation in decision-making, better access to veterinary services and improved varieties of seeds/seedlings, access to all weather roads which contributed for its higher index; whereas, Pepper LZ has the least institutional and infrastructural index (.3244), indicating that the LZ has relatively less score in the above indicators. In general, LZs agro-ecologically located in midland and highland (Cereal and Enset, Coffee and Ginger LZs) have better institutional and infrastructural index as compared with those LZs which are situated agro-ecologically in lowland areas (Pepper and Maize LZs).

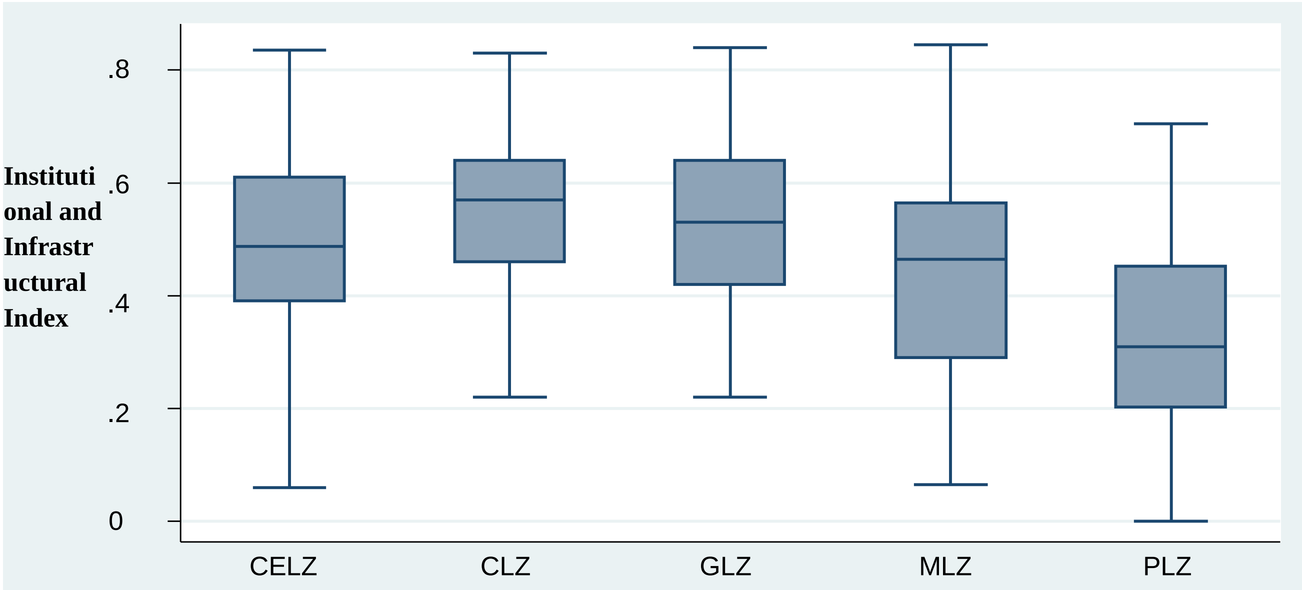


Figure 5.9: Institutional and Infrastructural Index
Source: Household survey

Composite Adaptive Capacity Index (CACI) of the seven components indicates that Ginger LZ has the highest composite adaptive capacity index, indicating that the aggregate index value of the above seven major components is relatively higher for the LZ. Agro-ecologically, Ginger LZ lies in midland areas. Comparatively, LZs located in midland areas (Coffee and Ginger LZs) have a score of higher composite adaptive capacity index; whereas, LZs located in lowland areas (Maize and Pepper LZs) have a score of relatively lower composite adaptive capacity index. In agro-ecological approach, the findings is in coincidence with Dechassa et.al., (2016) conducted in Didesa Sub Basin of Blue Nile River indicating that the midland has the highest adaptive capacity to climate change than the highlands and lowlands. Specifically, the result noted that chronic shortage of some form of assets, like: physical, natural, human and information accessibility, among others, are critically indicated of less than average in most LZs.

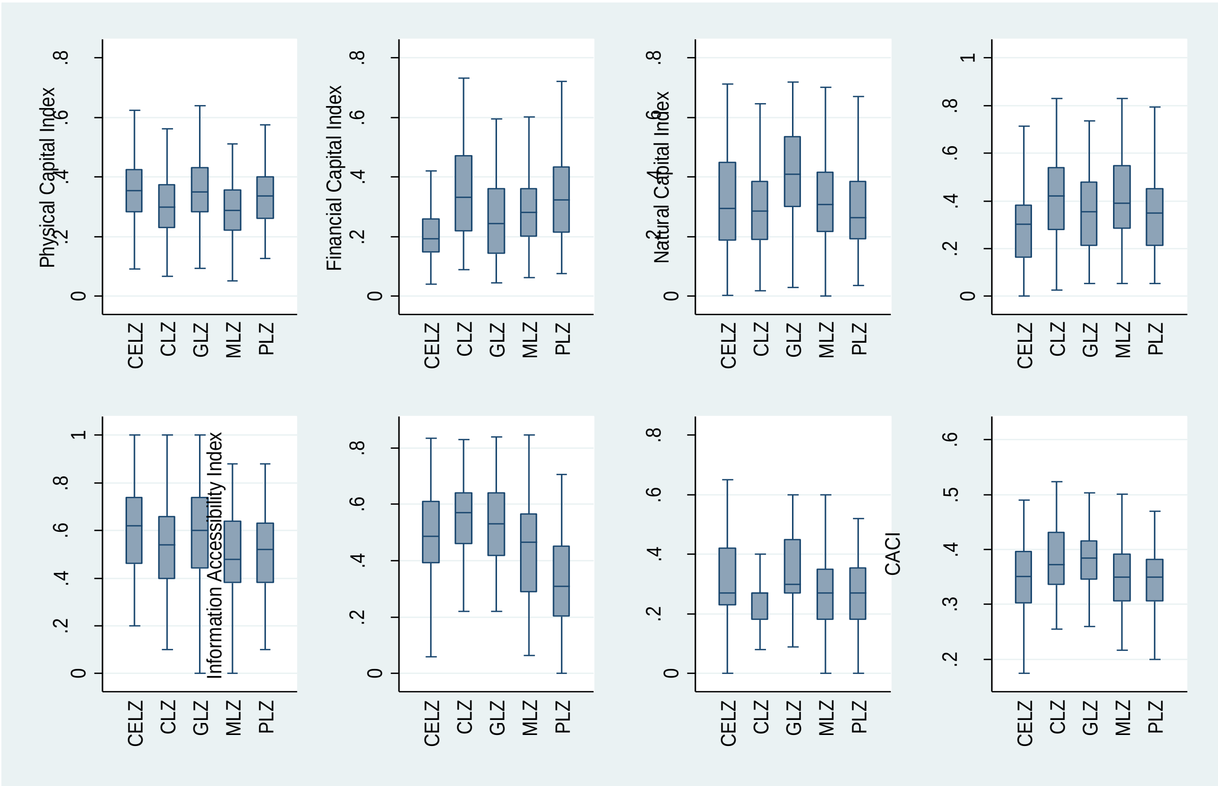


Figure 5.10: Composite Adaptive Capacity Index (CACI)
Source: Household survey

5.6. Coping and Adaptation Strategies

5.6.1. Coping Strategies

During times of difficulty households are forced to practice coping strategies in order to deal with the impacts of climate shocks. According to Berkes & Jolly, (2001), coping mechanisms are the actual responses to crisis on livelihood systems in the face of unwelcome situations, and are considered as short-term responses. The coping range of a system is not static and it responds to changes in economic, social, political and institutional conditions over time (ibid).

The result revealed that key coping measures identified include, but not limited to, *short term/seasonal labor migration, sale of enset and its products, rely on less preferred and less expensive food, selling more livestock than usual, selling of grasses/animal fodder, limit portion size at meals and sell of firewood/eucalyptus.* The results revealed that vital coping strategies (off-farm) reported include*: short term/seasonal labor migration, rely on less preferred and less expensive food and limit portion size at meals*. These coping strategies have been documented by other studies (e.g. Nyong et.al., 2007; Speranza et.al., 2010; Laube et.al., 2012; Antwi-Agyei et.al., 2014). The study further revealed that there are both common and specific coping strategies employed by farmers in different livelihood zones to cope and reduce the impact of climate variability and change.

Accordingly, in Cereal and Enset LZ, 47.04% of farmers use *sale of enset and its products* as the main coping strategy; 29.10% use *short term/seasonal labor migration* as an important coping strategy and the rest 23.88% *rely on less preferred and less expensive food*. The strategy of *'selling more livestock than usual'* is widely used coping strategy among Coffee, Maize and Pepper LZs. *Short-term/seasonal labor migration* is commonly used coping strategy in Cereal and Enset and Pepper LZs. In Coffee and Ginger LZs, 19.80% and 32.14% of farmers use *sell of firewood and eucalyptus* as their important coping strategies. *Selling of grasses/animal fodder* and *limit portion size at meals* are the only coping strategies employed by about 19.05% and 37.62% respondents in Ginger and Coffee LZs, respectively. In FGD conducted in the two LZs, participants stressed that there is an increasingly allocating more size of land for growing eucalyptus trees because of mainly economic issues. In Cereal & Enset and Maize LZs, 23.88% and 27.72% of respondents respectively use *relying on less preferred and less expensive food* as the third important coping strategy.

Table 5.5: Coping Strategies Employed by Farmers in different LZs

Livelihood Zones	Order of importance	Coping strategies	No	%
Cereal and Enset LZ	1st important	**Sale of perennial crops like enset products, fruits, etc**	**63**	**47.04**
	2nd important	**Short-term/seasonal labor migration**	**39**	**29.10**
	3rd important	**Rely on less preferred and less expensive food**	**32**	**23.88**
		Total	**134**	**100**
Coffee LZ	1st important	**Sell more livestock than usual**	**43**	**42.57**
	2nd important	**Limit portion size at meals**	**38**	**37.62**
	3rd important	**Sale of firewood (Eucalyptus trees), Plywood**	**20**	**19.80**
		Total	**101**	**100**
Ginger LZ	1st important	**Sale of perennial crops like enset, fruits, etc**	**41**	**48.80**
	2nd important	**Sale of firewood (Eucalyptus trees), Plywood**	**27**	**32.14**

	3rd important	**Sell of grasses/animal fodder**	**16**	**19.05**
	Total		**84**	**100**
Maize LZ	1st important	**Sell more livestock than usual**	**42**	**41.58**
	2nd important	**Consume seed stock**	**31**	**30.69**
	3rd important	**Rely on less preferred and less expensive food**	**28**	**27.72**
	Total		**101**	**100**
Pepper LZ	1st important	**Sell more livestock than usual**	**37**	**42.04**
	2nd important	**Short-term/seasonal labor migration**	**29**	**32.95**
	3rd important	**Reduce number of meals eaten in a day**	22	25
	Total		**88**	**100**

Source: Household survey

5.6.2. Adaptation Strategies

With the recent trend of recurrent climate change, the need for adaptation strategies is becoming a pressing issue. Adaptation involves long-term changes to the mix of activities required for subsistence, in order to reduce the vulnerability of livelihood systems. Being the first step in the adaptation process, timely and accurate perceptions are important determinants for farmers' intentions and the choice of adaptation methods (Deressa et.al., 2011). However, the development of these perceptions may depend on various socio-economic factors, access to institutional resources and agro-ecological settings. Underestimated or no perceptions may lead to maladaptation and may increase farmers' exposure to climate change impacts while the accurate perceptions may positively influence the adaptation process at farm level (Le Dang et.al., 2014; cited in Abid et.al., 2016).

With respect to their adaptation strategies, 41% of respondents in Coffee LZ use *agro-forestry* as an important adaptation strategy to climate change (See Table 5.6. below). In recent years, farmers in Coffee LZ are increasingly been encouraged to plant agro-forestry trees along with coffee plant to reduce the high heat wave during the timing of flowering. According to farmers, planting agro-forestry trees along with the coffee plant helps to enhance the productivity of the crop and reduce high heat wave and snow fall during extreme climatic conditions. Exceptionally, 7% of farmers in Coffee LZ practice *diversification into non-farm livelihood* as an alternative adaptation strategy; as non-farm livelihood serves as an alternative source of money, which may encourage them to perceive their capacity to adapt to the changing climate.

From the survey result, it is possible further to state that there are various adaptation strategies adopted by farmers in various livelihood zones. For instance, *change in cropping calendar/ timing of farm operations* is commonly practiced among the four livelihood zone farmers, except in Maize LZ. Specifically, the highest percentage (42.86%) of farmers in Ginger LZ practice this adaptation strategy in relation with the continuous occurrence of Ginger crop disease in the area in order to reduce and recover the prevalence of the disease. According to FGD participants raised during the discussion held in Ginger LZ, formerly the normal ginger planting period is during the late weeks of January, but from the last three years onwards, in order to reduce the prevalence of the disease, they are now planting the crop in October, almost during the cessation of Meher rain season. According to participants, change in cropping calendar has helped them a lot in reducing the prevalence of the disease and enhance productivity of the crop. Asfaw et.al., (2018), in a study conducted in Woleka sub-basin of north-central Ethiopia mentioned that stone/soil bund, changing the farming calendar and switching to short maturing varieties are the most widely practiced adaptations.

Table 5.6: Farmers' Adaptation Strategies to Climate Change

Adaptation Strategies of farmers for Changing Climate	**Distribution of Adaptation Strategies of Farmers for Changing Climate by LZ**									
	Cereal		**Coffee**		**Ginger**		**Maize**		**Pepper**	
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
Timing of farm operations / change in cropping calendar	44	32.83	13	13.00	36	42.86	-	-	14	15.9
Planting early maturing varieties	-	-	9	9.00	9	10.71	13	12.87	18	20.45
Change in cropping pattern	14	10.45	10	10.00	-	-	-	-	-	-
Small-scale irrigation (wetland cultivation)	3	2.24	-	-	-	-	8	7.92	-	-
Change in farm management practices	18	13.43	-	-	33	39.28	-	-	-	-
Plating high yielding varieties	17	12.69	-	-	-	-	-	-	-	-
Practicing crop rotation	-	-	8	8.00	-	-	5	4.95	7	7.95
Soil conservation /Terracing	4	2.99	-	-	-	-	-	-	-	-
Diversification into non-farm livelihood	-	-	7	7.00	-	-	-	-	-	-
Casual labour	4	2.99	-	-	-	-	-	-	-	-
Emphasis on livestock keeping instead of crops	-	-	-	-	-	-	10	9.90	-	-
Crop diversification and mixed cropping	5	3.73	6	6.00	-	-	-	-	-	-
Conversion of livestock capital into	3	2.24	-	-	3	3.57	-	-	-	-

physical capital / Reduce number of livestock										
Growing drought tolerant crops	-	-	-	-	7	8.33	6	5.94	11	12.50
Practicing agro-forestry / afforestation	-	-	41	41.00	-	-	10	9.90	4	4.55
Diversification into off-farm livelihood	4	2.99	6	6.00	-	-	-	-	-	-
Emphasize on small stocks (small animals)	-	-	-	-	-	-	43	42.57	-	-
Early planting	4	2.99	-	-	9	10.71	-	-	-	-
Flood control									7	7.95
Manure / compost use	-	-	-	-	-	-	-	-	3	3.41
Mulching	14	10.45	-	-	3	3.57	-	-	10	11.36
Rain water harvesting / Use Pond	-	-	-	-	-	-	6	5.94	14	15.9
Total	**134**	**100**	**100**	**100**	**84**	**100**	**101**	**100**	**88**	**100**

Source: Household survey

The survey also revealed that with the repeatedly occurrence of drought, exceptionally the highest percent (42.57%) of farmers in Maize LZ uniquely emphasize on *keeping small animals* like sheep, goat and poultry as an adaptation strategy. In FGD, participants discussed that managing the forage needs of small animals like sheep, goat, and poultry is much easier than managing the forage needs of cows, heifer, and oxen. In addition, in terms of income, it is better to keep small animals with higher number of heads as the animals mature in relatively short time as compared with larger animals.

Planting early maturing varieties is another adaptation strategy employed by farmers in all livelihood zones, except in Cereal and Enset LZ. This is because Cereal and Enset LZ is located in higher altitude, with relatively colder temperature and higher rainfall distribution, which contributes for sustaining the already established planting calendar. On the contrary, the rest of the four LZs, namely Coffee, Ginger, Maize and Pepper LZs are located in mid and lower altitude areas ranging from 1400-2300 masl, with frequently exposed for late onset and early cessation of rain, which contributes/pushes for planting early maturing varieties of crops. *Crop diversification and mixed cropping* is another adaptation strategy used by farmers in Cereal and Enset LZ and Coffee LZ. It is known that diversifying different crops and intercropping helps to minimize the shock, serving as an alternative source of food and income during the occurrence of disaster. The more crop diversification score, the higher adaptive capacity to climate change.

Based on the classification used by Ellis (2000), livelihood activities can be categorized into three; namely, on farm, nonfarm and off farm. Accordingly, adaptation strategies employed by farmers across the five LZs are categorized into on-farm, off-farm and non-farm adaptation strategies. On farm activities are activities which are directly related with agricultural production focused on both crop production and animal husbandry activities, intended to offset the negative effects of climate change/variability particularly droughts. Non-farm activities are activities that take place outside the agricultural sector including non-agricultural wage or salary employment and self-employment, rent income, transfers, and remittances. Off-farm adaptation strategies comprise strategies or actions that smallholder farmers carry out which are outside the farm, intended to moderate their vulnerability to negative effects of climate and ecological change/variability such as food/livelihood insecurity.

On-farm adaptation strategies employed by farmers include: timing of farm operations/change in cropping calendar, planting early maturing varieties, change in cropping pattern, small-scale irrigation (wetland cultivation), change in farm management practices, plating high yielding varieties, emphasis on livestock keeping instead of crops, practicing crop rotation, soil conservation /terracing, crop diversification and mixed cropping, growing drought tolerant crops, Practicing agro-forestry/afforestation, early planting, flood control, manure/compost use, mulching and rain water harvesting/use pond are the main on-farm adaptation strategies.

From the prevalence of the occurrence of changes in climate, farmers were asked what adaptation strategies employ mainly when they face less rainfall and drought condition across different LZs.

Table 5.7: Adaptation Strategies for Variable Rainfall Patterns

Adaptation Strategies for Variable Rainfall Patterns		**Adaptation Strategies for Variable Rainfall Patterns by LZ**									
		Cereal LZ		**Coffee LZ**		**Ginger LZ**		**Maize LZ**		**Pepper LZ**	
		No	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
Adaptation strategies when farmers face Less Rainfall Patterns	Use fertilizer	27	20.14	0	0	0	0	0	0	0	0
	Plant trees for shading	2	1.49	0	0	0	0	0	0	0	0
	Increase use of irrigation/ground water	17	12.69	26	25.74	23	27.38	5	4.95	37	42.05
	Change from crop to livestock management	11	8.21	8	7.92	9	10.71	6	5.94	9	10.23
	Diversify from farming to non-farming	46	34.32	17	16.83	12	14.29	27	26.73	23	26.14
	Pond	1	0.75	0	0	0	0	0	0	0	0
	Terracing	22	16.41	1	0.99	7	8.33	0	0	0	0
	Use quickly maturing/ripening variety s	0	0	47	46.53	29	34.52	63	62.38	13	14.77

	Flood control	2	1.49	0	0	0	0	0	0	0	0
	Afforestation	5	3.73	0	0	0	0	0	0	0	0
	Pray more or increase your ritual offer	1	0.75	0	0	0	0	0	0	0	0
	Cattle manure	0	0	2	1.98	4	4.76	0	0	0	0
	Reduce number of livestock	0	0	0	0	0	0	0	0	6	6.82
	Total	134	100	43	100	35	100	101	100	88	100
Adaptation strategies when farmers face No Rainfall / Drought Pattern	Reduce number of livestock	33	24.63	14	13.86	24	28.57	25	24.75	7	7.95
	Plant trees for shading	5	3.73	3	2.97	6	7.14	0	0	14	15.91
	Increase use of irrigation/ground water	25	18.66	37	36.63	21	25.00	37	36.63	9	10.23
	Change from crop to livestock management	31	23.13	14	13.86	7	8.33	0	0	14	15.91
	Diversify from farming to non-farming	34	25.37	9	8.91	20	23.81	27	26.73	17	19.32
	Pond	6	4.48	4	3.96	5	5.95	3	2.97	24	27.27
	Cattle manure	0	0	20	19.8	1	1.19	9	8.91	3	3.41
	Total	**134**	**100**	**43**	**100**	**35**	**100**	**101**	**100**	**88**	**100**

Source: Household survey

Using quickly maturing / ripening varieties is the highest percent share commonly practiced adaptation strategies, except in Cereal and Enset LZ, where the lion share of farmers in Maize LZ (62.38%) use the strategy. In addition, increasing use of irrigation/ground water, diversifying from farming to non-farming activities and changing livelihood activities from crop to livestock management are the most important adaptation strategies for less rainfall pattern commonly employed by farmers in different LZs according to their percentage importance, respectively. In the meantime, there are specifically employed adaptation strategies by farmers in different LZs. For instance, reducing number of livestock is a specific adaptation strategy for less rainfall pattern employed by farmers (6.82%) in Pepper LZ; using fertilizer, afforestation, using pond and flood controlling strategies are specifically employed by Cereal and Enset LZ farmers accounting 20.14%,3.73%, 1.49% and 0.75% of farmers, respectively. On the other hand, farmers in Coffee (1.98%) and Ginger (4.76%) LZs employ cattle manure as an important strategy for less rainfall pattern. From the result, it is possible to state that Cereal and Enset LZ farmers use the highest ratio of employing different adaptation strategies; whereas, farmers in Maize LZ employ the least ratio of different adaptation strategies for less rainfall pattern as compared with farmers in other LZs.

With respect to adaptation strategies farmers employ when they face drought condition, increase use of irrigation, diversify from farming to non-farming, reduce number of livestock and use of pond are the commonly employed strategies across all LZs. Specifically, the highest percentage of farmers in Pepper LZ (27.27%) use pond as the main adaptation strategy when they face drought. The highest percent of farmers in Cereal and Enset (25.37%) LZ employ diversification from farming to non-farming activities when they face drought; whereas, in Ginger LZ, the majority of farmers (28.57%) use reducing the number of livestock as an important adaptation strategy. In Coffee and Maize LZs, the highest percent of farmers, 36.63% in both LZs use increase use of irrigation as the most important strategy to drought. This is mainly because of access of the farmers in the LZs to use irrigation activities better than others. In terms to utilizing pond, the highest percent of farmers in Pepper LZ (27.27%) use the strategy, because of the relatively located in lowland areas and highly exposed to face recurrent drought conditions. This calls for the need to emphasize on creating access to irrigation activities for farmers across different LZs to adapt to drought conditions.

5.7. Factors Affecting Farmers' Adaptation Strategies to Climate Change

Identifying factors which affect adaptation strategies at grass root level offers insights in building the resilience capacity. Accordingly, three adaptation strategies, namely: changing timing of farm operations and management, Diversification into Off-farm/Non-farm activities and Crop Diversification and Afforestation are identified for analysis based on the frequency of choice and distribution across LZs.

In this section, dependent variable has been analysed using logistic regression models. The major factors that are expected to determine changing timing of adaptation strategy were first analysed by considering the relationship of each predictor variable with the outcome variable.

Table 5.8: Factors Influencing Changing Timing of Farm Operations Adaptation Strategy

Binary Logistic Regression Analysis		
Variable	**Adjusted OR 95%CI**	**P-Value**
eduhh	1.343432 [.9186074, 1.964723]	0.128
farmexp	1.060489 [1.016932, 1.105912]	0.006**
offarm	.9065369 [.5922241, 1.387666]	0.651
obscc30yrs	.8984633 [.5339127, 1.511926]	0.687
acesimpvarity	1.089277 [.5880088, 2.017869]	0.786
acesextserv	2.812723 [.2897932, 27.30018]	0.372
weathinfotimly	1.294738 [.8457384, 1.982109]	0.234
acesearlywarnin	.7689323 [.5814615, 1.016846]	0.065
techadopt	.7641612 [.5847915, .9985481]	0.049**
acesaving	.7691524 [.4760732, 1.242657]	0.284
roadaces	1.127783 [.956396, 1.329882]	0.153
landslop	2.231929 [1.717364, 2.900671]	0.000**
indigknowlg	1.094811 [.6995625, 1.713372]	0.692
locinstitsup	.9237638 [.5941475, 1.436242]	0.725

tradweathpredic	1.154382 [.4524039,2.945594]	0.764
dep_ratio	.9847776 [.6918944, 1.40164]	0.932
farm_income	1.000018 [1.000004,1.000031]	0.012**
acesleaders	.9747426 [.6349954,1.496268]	0.907
decisionmaking	1.155857 [.7390047, 1.807845]	0.526
culturconnect	.544576 [.2554565, 1.160914]	0.116
physasetdonkey	.7605887 [.4905836,1.179198]	0.221
physasetmobil	1.108734 [.6827525, 1.800494]	0.676
physasetradio	1.267327 [.6737558, 2.383826]	0.462
freqdisaster	1.100096 [.9094672,1.330681]	0.326

***=p<0.01; **= p< 0.05

Source: Household survey

And further analysing the variables selected for multivariate analysis at 0.05 level of significance for p-value is less than 0.05 indicated that farming experience, technology adoption, land slope and farm income are significantly influencing households for adopting ***changing timing of farm operations and management*** as an important adaptation strategy to climate change.

The second important adaptation strategy employed by farmers commonly across all LZs is Diversification into Off-farm/Non-farm activities.

Table 5.9: Factors Influencing for Diversification into Off-farm/Non-farm activities

Variable	Adjusted OR 95% CI	P-Value
Acesirrig	1.069415 [.5914327, 1.933692]	0.824
techadopt	1.597594 [1.110363, 2.298625]	0.012**
Acesaving	1.359411 [.7384626, 2.502493]	0.324
roadaces	.9980142 [.8187747, 1.216491]	0.984
landslop	.5478716 [.3806174, .7886222]	0.001**
indigknowlg	.6066275 [.3509144, 1.04868]	0.073
locinstitsup	.8095738 [.4736419, 1.383766]	0.440
tradweathpredic	.8047302 [.2843302, 2.277601]	0.682
farm_income	.9999945 [.999976, 1.000013]	0.560
aceselect	.2928317 [.1179865, .7267813]	0.008**
physasetdonkey	.6016709 [.3445263, 1.050741]	0.074
physasetmobil	.9047161 [.5206674, 1.572043]	0.722
physasetradio	.6882373 [.3663113, 1.293082]	0.246
eduhh	.844669 [.5042525, 1.414898]	0.521
freqdisaster	1.096155 [.8505353,1.412706]	0.478

***=p<0.01

Source: Household survey

The result for the analysis of the variables selected for binary logistic regression analysis at 0.05 level of significance for p-value is less than 0.05 indicated that three variables, as indicated in table 5.9 are; technology adoption, land slope and access to electricity are factors that significantly influence households for adopting ***diversification into off-farm/non-farm activities*** as an important adaptation strategy to climate change.

The third important adaptation strategy employed is Crop Diversification and Afforestation. The result of the analysis, as indicated in table 5.10 below, the result of the binary logistic regression analysis at 0.05 level of significance for p-value is less than 0.05 indicated that farming experience and land slope that significantly influence households for adopting ***Crop Diversification and Afforestation*** as an important adaptation strategy to climate change.

Table 5.10: Factors influencing Crop Diversification and Afforestation Adaptation Strategy

Binary Logistic Regression Analysis		
Variable	**Adjusted OR 95% CI**	**P-Value**
Farm_exp	.9548045 [.9157893, .9954818]	0.030**
Obscc30yrs	1.292156 [.7940313, 2.102773]	0.302
weathinfotimly	.6540042 [.4209829, 1.016007]	0.059
acesearlywarnin	1.261371 [.961257, 1.655183]	0.094
acesaving	1.112989 [.698003, 1.774698]	0.653
acesremitance	.8253738 [.5531003, 1.231679]	0.347
watraces	1.281295 [.8521801, 1.92649]	0.234
roadaces	.8750591 [.7470322, 1.025027]	0.098
landslop	.6866081 [.5458008, .8637412]	0.001***
locinstitsup	1.404439 [.9219773, 2.139368]	0.114
dep_ratio	.9683907 [.6734599, 1.392482]	0.862
farm_income	.9999889 [.9999757, 1.000002]	0.097
decisionmaking	.7952593 [.5245604, 1.205652]	0.281
aceselect	1.649471 [.7232899, 3.761639]	0.234
eduhh	.8434013 [.5782462, 1.230144]	0.376

***=p<0.01; **= p< 0.05

Source: Household survey

In conclusion, from the above Binary logistic regression analysis, factors significantly influencing/affecting households' adaptation strategies to climate change at 0.05 level of significance for p-value is less than 0.05 are: farming experience, technology adoption, land slope, farm income and access to electricity.

5.8. Summary

Capacity to adapt is a critical element in the vulnerability to climate change studies, as it is directly connected with the development level of a country. With the recently prevalence of climate change, the issue of building adaptive capacity of farmers is becoming a critical issue. The result indicates that in relation with weather information interpretation, 12% of farmers in Coffee LZ have good skill in this regard; whereas, more than half (57.43%) of farmers in Maize LZ have average capacity to interpret weather information. On the other hand, 54.48% of farmers in Cereal LZ do not interpret weather information at all. In the context of using weather information to plan, 23.76% of farmers in Maize LZ have good capacity; whereas, 54.48% of farmers in Cereal LZ do not have the capacity; whereas, the highest percent (26.87%) of farmers in Cereal LZ have the capacity of identifying varieties of crops to plant. From the result, it is possible to conclude that the capacity of farmers to interpret weather information, using weather information to plan, using weather information to decide what crop to plant and identifying varieties of crops in general is below average.

With regards to the capacity to use components, the findings further revealed that Coffee LZ has the highest physical capital index, and Cereal LZ has the lowest physical capacity index, mainly reflected by farm size and farm situation, which is mainly mountainous and hilly. With regards to financial capital, Ginger LZ has the highest financial capital index, indicating that income from the main cash crop, ginger has higher market value of money, which mainly contributed for greater value of the index; whereas, Pepper LZ has the least financial capital index. The index for human capital result revealed that Cereal and Ginger LZs have proportionally the highest human capital index, whereas Maize LZ has the least human capital index. Composite Adaptive Capacity Index (CACI) of the seven components indicates that Ginger LZ has the highest composite adaptive capacity index, whereas, Cereal LZ has the lowest composite adaptive capacity index. Coping and adaptation strategies that farmers employ also rely on local capacities and resources. There are both commonly shared and specific coping and adaptation strategies employed by farmers across different livelihood zones. Farming experience, technology adoption, land slope, farm income and access to electricity are factors significantly influencing farmers' adaptation strategies to climate change. Supporting adaptation, therefore, needs to go beyond simply supporting livelihood strategies and also needs to address institutional and policy constraints encountered in the adaptation process. Davies, (1993) stress that for adaptation strategies in order that they can be pursued over time, the strategies need to be environmentally sustainable and not damaging to the livelihoods of others. Hence, livelihood zone-based adaptation strategies which take into account the local geographical and socio-economic resources and capacities are critical to ensure resilient livelihood systems.

Chapter Six: Conclusion and Recommendations

6.1. Conclusion

This section concludes and recommends the key points considered in the study. In recent years, terms like perceptions, vulnerability and adaptive capacity to climate change are becoming powerful in light of climate variability and change analysis. The overall objective of the study was to explore smallholder farmers' perceptions, vulnerability and livelihood adaptation strategies of smallholder farmers to climate change in Kembata Tembaro Zone, Southern Ethiopia.

Accordingly, the study focused on three central themes to address the gaps of knowledge mentioned above. The first theme is the analysis of the perceptions of smallholder farmers to climate change; the second theme is the study of vulnerability to climate change; and the third theme is the study of adaptive capacity and adaptation to climate change.

On the basis of the first theme, the study emphasized the importance of understanding local perceptions of climate change in order to design effective adaptive measures at local LZ level. The results of the study showed that smallholder farmers in the study area, who live in different livelihood zones are well aware of climate change, as more than 97% of farmers interviewed perceived an increasing trend of temperature and a decreasing trend of precipitation. Farmers' perceptions of an increasing trend of temperature and a decreasing trend of precipitation matches well with the local temperature and rainfall records obtained from National Meteorological Agency of the nearest four stations, in and bordering the five LZs using Mann-Kendal test and Coefficient of Variation.

There is an indication of greater climate variability characterized by extreme weather events such as drought and flood, shifts in the onset and cessation time of seasonal rainfall. Although farmers are aware of climate change, there are differences in terms of perception towards the causes, perceived effect, extent and rank of climate change across different livelihood zones. Coping and adaptation strategies that farmers employ also rely on local capacities and resources. There are both commonly shared and specific coping and adaptation strategies employed by farmers across different livelihood zones, based on their socio-demographic, geographical and bio-physical settings. This calls for the need to contextualize the response mechanisms according to specific support needs of farmers in different livelihood zones of the study area.

Based on the second theme, the study analyzed vulnerability of smallholder farmers to climate change and variability in five livelihood zones using the LVI and LVI-IPCC methodologies. Household level data about livelihood capitals and climate related variables were used to develop vulnerability indices and determine vulnerability patterns across the study area. Results of the vulnerability assessment confirmed that all the five livelihood zones are vulnerable to climate change. However, in relative terms, Pepper LZ is the most vulnerable to climate change, whereas, Ginger LZ (Agro-ecologically located in midland) is the least vulnerable to climate change. In general, Pepper and Maize LZs, which are located in the lower agro-ecological zones, are the most vulnerable zones to climate change whereas livelihood zones agro-ecologically located in mid land and highland areas are relatively less vulnerable to climate change. Assessment of vulnerability is useful to identify and prioritize vulnerable areas and contributing factors for adaptation planning. Therefore, this study can inform policies to deliver better for communities and smallholder farmers at the grassroots level.

The last thematic area is related with assessing the capacity to adapt and adaptation strategies of farmers to climate change. The findings revealed that Coffee LZ has the highest physical capital index, and Cereal LZ has the lowest physical capacity index. With regards to financial capital, Ginger LZ has the highest financial capital index, indicating that income from the main cash crop, ginger has higher market value of money, which mainly contributed for greater value of the index; whereas, Pepper LZ has the least financial capital index. The index for human capital result revealed that Cereal and Ginger LZs have proportionally the highest human capital index, whereas Maize LZ has the least human capital index. The overall Composite Adaptive Capacity Index (CACI) of the seven components indicates that Ginger LZ has the highest composite adaptive capacity index, whereas, Cereal LZ has the lowest composite adaptive capacity index. In relation with adaptation strategies employed by farmers, the strategies are categorized into on-farm, off-farm and non-farm adaptation strategies. Farming experience, technology adoption, land slope, farm income and access to electricity are factors significantly influencing farmers' adaptation strategies to climate change. From the result, it is possible to conclude that most farmers use on-farm adaptation strategies to offset the negative effects of climate change. Hence the need to build the adaptive capacity of smallholder farmers is critical, based on the available local skills, technologies, and overall resources.

6.2. Recommendations

Based on the findings, the following recommendations are given:

- In terms of perceptions of climate change, a need exists to narrow the gap between scientific knowledge on climate change and farmers' understanding of the causes of climate change. Enhancing public awareness about physical causes of climate change goes some way to address the gap. Hence, strengthening of weather and climate services and improving use of agro meteorological services with focus on short term and long-term time scales to guide planning and investment.

- Investment in generating and disseminating accurate, timely and reliable weather and climate information is important to inform different adaptation and climate risk management plans and decisions regarding changes in climate. In this regard, there is a need to strengthen early warning systems for climate variability and change as well as resultant disasters. Exploring weather index based insurance schemes as part of climate risk management and reducing loss and damage will buffer development investments and livelihoods in the long run.

- Policies should encourage smallholder farmers' awareness and skill upgrading towards climate change. Policies should take into account the livelihood zone settings and socio-economic environment which are appropriate and fit with the sustainability paradigm while implementing new technologies that enhance agricultural productivity. Obtaining scientific evidence regarding the seasonal and annual rainfall and temperature variability and associating the information with the perception of farmers in the study area provides credible information for decision makers and end users. Consequently, future policy should focus on the local livelihood system of different farmers, according to which farmers perceive and act in their localities to address grass root level coping and adaptation capacity gaps.

- A programmatic approach to climate change adaptation is needed that goes beyond agriculture to ensure productivity and connectivity at grass root micro-scale level. In this regard, development programmes should systematically integrate climate change adaptation and support complementary livelihood and adaptation goals as well as promote environmental protection measures. In terms of sustainable development and climate change, policies need to anchor on the principles of sustainable livelihoods. Hence, government policies should strengthen the existing coping and adaptation strategies practiced by farmers across different LZs and support the adoption of adaptation technologies that fits with the local level priority needs that have the potential to reduce damages at livelihood zone level, among others, provision of improved varieties, modern water harvesting technologies and resource conservation and management practices.

- Adaptation to climate change is essential to ensure sustainable livelihood opportunities for rural smallholder farming households. In this regard, increased adoption of adaptive agricultural technologies has the potential to decrease the negative effects of climate change on agricultural production and productivity. In the study area, one of the critical factors influencing smallholder farmers' adaptation to climate change is technology adoption. Recent research findings also show that existing heat and drought tolerant agricultural technologies have the potential to counteract the decline in yields associated with climate change for some of the main staple crops. Hence, extension projects should promote alternative easier-to-adapt technologies for crop-livestock-land integration. The applicability of these technologies greatly supports to build resilient rural livelihoods. In this regard, increased investment in adaptive technologies for the wide variety of crops and farming systems is needed in the study area to reduce vulnerability to climate variability and change.

- Intensifying and diversifying land use with high-valued crops and creating access to improved varieties are a requirement for increasing per capita agricultural production in the study area. Because of land shortage, farmers intensify cultivation by a continuous succession of crops leading to nutrient depletion and decline in organic matter. Hence, the introduction of improved varieties or selection of disease resistant cultivars and expansion of cash crops production (such as coffee, ginger, apple, garlic, etc) could help much in improving the livelihoods of the households. Indigenous varieties used for many decades are becoming difficult to use with the currently changing climate. Thus, planners and decision-makers must work together with policy makers pertaining to bring fundamental structural changes which prevail in the study area, including: demographic dynamics, high level of dependence on land-based agricultural livelihood, low level of rural livelihood diversification and low level of urbanization and industrialization. Hence, encouraging potential combinations of on-farm, non-farm and off-farm livelihood strategies that can reduce pressure on the small farm size is very important.

References

Abdul-Razak, M., & Kruse, S. (2017). The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. *Climate Risk Management*, *17*, 104-122.

Abenet, (2010). A Composite Analysis of Vulnerability to Climate Change between Pastoral and Agro-pastoral Households: A Case Study in Yabello Woreda of Oromia Regional State. MA Thesis. Institute of Development Research, Addis Ababa University.

Abid, M., Scheffran, J., Schneider, U. A. and Ashfaq M., (2014). Farmers' perceptions of and adaptation strategies to climate change and their determinants; the case of Punjab province, Pakistan. Earth Syst. Dynam. Discuss., 5, 1359–1406. doi:10.5194/esdd-5-1359-2014.

Abid, M., Schilling, J., Scheffran, J., & Zulfiqar, F. (2016). Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan. *Science of the Total Environment*, *547*, 447-460.

Acquah-de Graft, H. (2011). Farmers' perceptions and adaptation to climate change: a willingness to pay analysis. Journal of Sustainable Development in Africa, 13, 5:150-161.

Adger, D. (2006). Combinatorial variability. *Journal of linguistics*, *42*(3), 503-530.

Adger, W. N. (2003a). Social capital, collective action, and adaptation to climate change. *Economic Geography* 79: 387-404.

Adger, W. N., & Kelly, P. M. (1999). Social vulnerability to climate change and the architecture of entitlements. *Mitigation and adaptation strategies for global change*, *4*(3-4), 253-266.

Adger, W. N., & Vincent, K. (2005). Uncertainty in adaptive capacity. *Comptes Rendus Geoscience*, *337*(4), 399-410.

Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., o'Brien, K., Pulhin, J., ... & Takahashi, K. (2007). Assessment of adaptation practices, options, constraints and capacity. *Climate change*, *2007*.

Adger, W. N., Huq, S., Brown, K., Conway, D., & Hulme, M. (2003). Adaptation to climate change in the developing world. *Progress in development studies*, *3*(3), 179-195.

Adger, W. N., Lorenzoni, I., & O'Brien, K. L. (Eds.). (2009). *Adapting to climate change: Thresholds, values, governance*. Cambridge University Press.

Adger, W.N., (1999). Social vulnerability to climate change and extremes in coastal Vietnam. World Development 27, 249–269.

Adger, W.N., N.W. Arnell, and E.L. Tompkins, (2005). Successful adaptation to climate change across scales. Global Environmental Change, 15(2), 77-86.

Adu DT, Kuworno JKM, Anim-Somuah H, Sasaki N., (2017). Application of livelihood vulnerability index in assessing smallholder maize farming households' vulnerability to climate change in Brong-Ahafo Region of Ghana. Kasetart J Soc Sci 39:22–32.

Aemro T., H. Jema and K. Mengistu, (2012). Climate change adaptation strategies of smallholder farmers: the case of Babile district of East Hararghe zone of Oromiya regional state of Ethiopia. Journal of Economics and Sustainable Development, 3 (14): 1-12.

African Technology Policy Studies Network, ATPS (2013). Farmers' Perception and Adaptive Capacity to Climate Change and Variability in the Upper Catchment of Blue Nile, Ethiopia [Bewket Amdu, Azemeraw Ayehu, Andent Deressa], ATPS WORKING PAPER No. 77.

Agnes M. Sorre, Alice Kurgat, Richard Musebe, and Benard Sorre (2017). Adaptive Capacity to Climate Change among Smallholder Farmers' in Busia County, Kenya. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS). e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 10, Issue 11 Ver. I (November 2017), PP 40-48).

Akponikpè, P. I., Johnston, P., & Agbossou, E. K. (2010, August). Farmers' perception of climate change and adaptation strategies in Sub-Saharan West-Africa. In *2nd International Conference: Climate, Sustainability and Development in Semi-arid Regions August* (Vol. 1620, No. 2010, p. 134147).

Akter, S. & Bennett, J. (2009). Household Perceptions of Climate Change and Preferences for Mitigation Actions: the Case of the Carbon Pollution Reduction Scheme in Australia. Environmental Economics Research Hub Research Report No. 19. Canberra, Australia: Australian National University.

Alam, G. M., Alam, K., & Mushtaq, S. (2017). Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Climate Risk Management*, *17*, 52-63.

Alemayehu, A. and Bewket, W. (2016). "Local climate variability and crop production in the central highlands of Ethiopia." *Environmental Development*, 19: 36–48.

Alhassan, S. I., Shaibu, M. T., Kuwornu, J. K. M. & Damba, O. T., (2018b). Assessing smallholder women farmers' adaptive capacity to climate change and variability in the Northern Region of Ghana: A Composite Index Approach. ICCCSDA 2017 Special Issue: Environment, Technology and Sustainable Development. Journal of Energy and Natural Resource Management. Vol 1, pp.: 1-9.

Ann-Karin Sørhaug, (2011). *Climate change impacts and adaptations among ethiopian farmers: case studies of Hagere Selam, Tigray, and Kofele, Oromia* (Master's thesis, Universitetet i Agder; University of Agder.

Antwi-Agyei, P., Kumasi, T. C., & Obiri-Danso, K. (2017). Small-holder farmers' climate change adaptation practices in the Upper East Region of Ghana. *Environment, Development and Sustainability*, 1-18.

Antwi-Agyei, P., Stringer, L.C., Dougill, A.J., (2014). Livelihood adaptations to climate variability: insights from farming households in Ghana. Reg. Environ. Change, 14 (4), 1615e1626.

Aogán, D., A., Chesterman, S., Crane, T. A., Tamás, P. A., & Ericksen, P. J. (2014). A systematic review of local vulnerability to climate change: in search of transparency, coherence and comparability.

Apata, T. G., Samuel, K. D., & Adeola, A. O. (2009). *Analysis of Climate Change Perception and Adaptation among Arable Food Crop Farmers in South Western Nigeria* (No. 1005-2016-79140).

Appiah O., Alfred C.K. Akondoh, Rhoda Kromoh Tabiri and Amos Annan Donkor, (2018). Smallholder farmers' insight on climate change in rural Ghana. Cogent Food & Agriculture (2018), 4: 1436211.

Armitage, Derek (2005). Adaptive capacity and community-based natural resource management. Environmental Management 35 (6): 703-715.

Arsiso, B. K., Tsidu, G. M., Stoffberg, G. H., & Tadesse, T. (2017). Climate change and population growth impacts on surface water supply and demand of Addis Ababa, Ethiopia. *Climate Risk Management*, *18*, 21-33.

Asfaw, A., Simane, B., Hassen, A., & Bantider, A. (2018). Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin. *Weather and climate extremes*, *19*, 29-41.

Asrat, P., & Simane, B. (2018). Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological Processes*, *7*(1), 7.

Bahal'okwibale, P. M. (2017). *Mainstreaming climate-related disaster risk reduction in agriculture and food sectors in eastern Africa: analytical report*. Food and Agriculture Organization (FAO).

Balew S, Agwata J, Anyango S., (2014). Determinants of adoption choices of climate change adaptation strategies in crop production by small scale farmers in some regions of Central Ethiopia. Journal of Natural Science Research. 4(4):78–93.

Barber, D. G., Galley, R., Asplin, M. G., De Abreu, R., Warner, K. A., Pućko, M., ... & Julien, S. (2009). Perennial pack ice in the southern Beaufort Sea was not as it appeared in the summer of 2009. *Geophysical Research Letters*, *36*(24).

Barnett, J., and O'Neill, S.J., (2010). Maladaptation. Global Environ. Change 20 (2), 211–213.

Barnett, J., Lambert, S., & Fry, I. (2008). The hazards of indicators: insights from the environmental vulnerability index. *Annals of the Association of American Geographers*, *98*(1), 102-119.

Barrett, S. (2006). Climate treaties and" breakthrough" technologies. *American Economic Review*, *96*(2), 22-25.

Bassett, T. J., & Fogelman, C. (2013). Déjà vu or something new? The adaptation concept in the climate change literature. *Geoforum*, *48*, 42-53.

Bebbington, A. (1999). Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. *World development*, *27*(12), 2021-2044.

Belaineh, L., Yared, A. and Woldeamlak, B. (2013), "Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, West Hararghe, Ethiopia", Asian Journal of Empirical Research, Vol. 3 No. 3, pp. 251-265.

Belay, A. John W. Recha, Teshale Woldeamanuel and John F. Morton (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agriculture & Food Security, 6(1), 24.

Belay, K., Beyene, F. & Manig, W. (2005). Coping with drought among pastoral and agro-pastoral communities in eastern Ethiopia. Journal of Rural Development 28, 185–210.

Below, T. B., Mutabazi, K. D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., & Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change*, *22*(1), 223-235.

Berkes, F. and Jolly, D. (2001). 'Adapting to Climate Change: Social-Ecological Resilience in a Canadian Western Arctic Community'. Conservation Ecology 5(2): 514-532.

Bewket, W. (2012). Climate change perceptions and adaptive responses of smallholder farmers in central highlands of Ethiopia. *International Journal of environmental studies*, *69*(3), 507-523.

Bewket, W., Radeny, M. A., & Mungai, C. (2015). Agricultural adaptation and institutional responses to climate change vulnerability in Ethiopia.

Bewket, Woldeamlak, and Declan Conway, (2007). "A note on the temporal and spatial variability of rainfall in the drought-prone Amhara region of Ethiopia." *International Journal of Climatology: A Journal of the Royal Meteorological Society* 27.11: 1467-1477.

Bierbaum R, Smith JB. Lee A, Blair M, Carter L, Chapin SF, III, Fleming P, Ruffo S, Stults M, McNeeley S, Wasley E, Verduzco L. (2013). A comprehensive review of climate adaptation in the United States: more than before, but less than needed. *Mitigation and adaptation strategies for global change*, *18*(3), 361-406.

Bowyer, P., Bender, S., Rechid, D., Schaller, M. (2014). Adapting to Climate Change: Methods and Tools for Climate Risk Management, Climate Service Center, Germany.

Brooks, N., & Adger, W. N. (2005). Assessing and enhancing adaptive capacity. *Adaptation policy frameworks for climate change: Developing strategies, policies and measures*, 165-181.

Brooks, N., (2003). Vulnerability, risk and adaptation: a conceptual framework. Working Paper 38, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich.

Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global environmental change*, *15*(2), 151-163.

Brown, H.C.P., J.N. Nkem, D.J. Sonwa, and Y. Bele, (2010). Institutional adaptive capacity and climate change response in the Congo Basin forests of Cameroon. Mitigation and Adaptation Strategies for Global Change, 15(3), 263-282.

Brown, O., Hammill, A., & McLeman, R. (2007). Climate change as the ‘new’security threat: implications for Africa. *International affairs*, *83*(6), 1141-1154.

Bryan, E., C. Ringler, B. Okoba, C. Roncoli, S. Silvestri, and M. Herrero, (2011). Adapting Agriculture to Climate Change in Kenya: Household and Community Strategies and Determinants. Presented at George Washington University, Washington, DC, USA, 19 May 2011, International Food Policy Research Institute (IFPRI), Washington, DC, USA, 30 pp.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental science & policy*, *12*(4), 413-426.

Bryman, A. (2008). Why do researchers integrate / combine / mesh / blend / mix / merge / fuse *quantitative* and qualitative research. *Advances in mixed methods research*, 87-100.

Carney, D., ed. (1998). Sustainable rural livelihoods: what contribution can we make? London: DFID.

Carney, D., et al. (1999). Livelihood approaches compared: a brief comparison of the livelihoods approaches of the UK Department for International Development (DFID), CARE, Oxfam and the

Carter, T. R., & Mäkinen, K. (2011). Revised title Approaches to climate change impact, adaptation and vulnerability assessment: towards a classification framework to serve decision-making.

Carter, T.P., M.L. Parry, H. Harasawa and N. Nishioka, (1994). IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations. London: University College London.

Carter, T.R., R.N. Jones, X. Lu, S. Bhadwal, C. Conde, L.O. Mearns, B.C. O’Neill, M.D.A. Rounsevell, and M.B. Zurek, (2007). New assessment methods and the characterisation of future conditions. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 133–171.

Chambers, R. (1995, VI). 'Poverty and Livelihoods: Whose Reality Counts?' Discussion Paper 347. Brighton, UK: Institute of Development Studies.

Chambers, R. and G. Conway, (1992:7). Sustainable rural livelihoods: practical concepts for the 21st century. IDS discussion paper, 296. Brighton: IDS.

Clover, J., & Eriksen, S. (2009). The effects of land tenure change on sustainability: human security and environmental change in southern African savannas. *Environmental Science & Policy*, *12*(1), 53-70.

Cochrane, L., & Singh, R. (2017). Climate services for resilience: the changing roles of NGOs in Ethiopia. *London: BRACED*.

Coninck de, H., Revi, A., Babiker, M., Bertoldi, P., Buckeridge, M., Cartwright, A., Dong, W., (2018). Strengthening and implementing the global response.

Conway, D., and Schipper, E.L.F.(2011). Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. Global Environmental Change, 21(1): 227-237.

Conway, G. (2009). The science of climate change in Africa: impacts and adaptation. *Grantham Institute for Climate Change Discussion Paper*, *1*, 24.

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferaw, B. and Twomlow, S. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change. Agriculture, Ecosystems and Environment 126: 24-35.

CSA (Central Statistical Agency), (2013). "Population Projection of Ethiopia for All Regions at *Woreda* Level from 2014 – 2017''. The Federal Democratic Republic of Ethiopia, Addis Ababa.

Cutter, S. L., (1996). Societal responses to environmental hazards. International Social Science Journal, 48, 525- 536. doi:10.1111/1468-2451.00053

__________ (2016). The changing context of hazard extremes: Events, impacts, and consequences. *Journal of Extreme Events*, *3*(02), 1671005.

Cutter, S. L., Emrich, C. T., Webb, J. J., & Morath, D. (2009). Social Vulnerability to Climate Variability Hazards: A Review of the Literature. Final Report to Oxfam America. Columbia: Hazards and Vulnerability Research Institute, University of South Carolina.

Cutter, S.L., J.T. Mitchell, and M.S. Scott, (2000). Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. Annals of the Association of American Geographers 90(4): 713-737.

Davies, S. (1993). Are coping strategies a cop out?. *IDS bulletin*, *24*(4), 60-72.

Debalke (2014). Economics of Farmers' Choices of Climate Change Adaptation Strategies: Evidence from North Shoa Zone of Amhara Region, Ethiopia. LAP LAMBERT Academic Publishing.

Debela Nega, Caroline Mohammed, Kerry Bridle, Ross Corkrey and David McNeil (2015). Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. SpringerPlus, 4:236

Dechassa C, Simane B, Alamirew B, Azadi H, (2016). Agro-ecological based small-holder farmer's livelihoods vulnerability to climate variability and change in Didesa sub Basin of Blue Nile River, Ethiopia. Acad. J. Agric. Res. 4(5): 230-240.

Defiesta, G. D., & Rapera, C. L. (2014). Measuring Adaptive Capacity of Farmers to Climate Change and Variability: Application of a Composite Index to an Agricultural Community in the Philippines. *Journal of Environmental Science and Management*, *17*(2).

Demeke, A.B., Keil, A. and Zeller, M. (2011) 'Using panel data to estimate the effect of rainfall shocks on smallholders food security and vulnerability in rural Ethiopia', Climate Change, 108: 185–206.

Deresa TT, Hassan RM, Ringler C, Alemu T, Yesuf M, (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Chang 19:248–255.

Deresa TT, Hassan RM, Ringler C., (2011). Perception of and adaptation to climate change by farmers in the Nile Basin of Ethiopia. Journal of Agricultural Science 149(1):23–31.

Deressa, T. T., & Hassan, R. M. (2009). Economic impact of climate change on crop production in Ethiopia: Evidence from cross-section measures. *Journal of African economies*, *18*(4), 529-554.

Deressa, T., Hassan, R. M., & Ringler, C. (2008). *Measuring Ethiopian farmers' vulnerability to climate change across regional states*. Intl Food Policy Res Inst.

Dessalegn Rahmato, (1996, 92). 'Resilience and Vulnerability: Enset Agriculture in Southern Ethiopia', in Tsedeke Abate, C. Hiebsch, S. A. Brandt and Seifu Gebre-Mariam (eds), *Enset Based Sustainable Agriculture in Ethiopia (83-104)*. Addis Ababa: Institute of Agricultural Research.

Dessalegn Rahmato, (2007: 13). *Development Interventions in Wollaita, 1960s–2000s: A Critical Review*. Monograph No.4, Addis Ababa: Forum for Social Studies.

Di Falco, S., M. Veronesi, and M. Yesuf, (2011). Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia. *American Journal of Agricultural Economics* 93(3): 829-846.

Diao, X. (2010a). Economic importance of agriculture for sustainable development and poverty reduction: The case study of Ethiopia. Paper presented at the OECD Global Forum on Agriculture: Policies for Agricultural Development, Poverty Reduction and Food Security, Paris, 29-30 November 2010.

Dietz, T., Gardner, G., Gilligan, J., Stern, P., and Vandenbergh, M. (2009). Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. Proc. Natl. Acad. Sci. U.S.A. 106, 18452–18456. doi: 10.1073/pnas.0908738106

Diggs, D. M. (1991). Drought experience and perception of climatic change among Great Plains farmers. *Great Plains Research*, 114-132.

Downing, T. E., and Patwardhan, A., (2005). Assessing vulnerability for climate adaptation. Adaptation policy frameworks for climate change: Developing strategies, policies and measures, pp. 67-90.

DPPC (Disaster Prevention and Preparedness Commission), (2005a). *Livelihood Profiles. Regional Overview*, Addis Ababa: LIU.

_______ (2005b). *SNNPR Livelihood Profile: Hadiya-Kambata Cereal and Enset Zone Report*, Addis Ababa: LIU.

DRMFSS (Disaster Risk Management and Food Security Sector), (2010). *An Atlas of Ethiopian Livelihoods*, Addis Ababa: MOARD.

Eakin H, Benessaiah K, Barrera JF, Cruz-Bello GM, Morales H., (2012). Livelihoods and landscapes at the threshold of change: disaster and resilience in a Chiapas coffee community. Reg Environ Change 12(3):475–488. doi:10.1007/s10113-011-0263-4.

Eakin, H., & Bojorquez-Tapia, L. A. (2008). Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change*, *18*(1), 112-127.

Eakin, H., & Luers, A. L. (2006). Assessing the vulnerability of social-environmental systems. *Annu. Rev. Environ. Resour.*, *31*, 365-394.

Easterling, W. E. (1996). Adapting North American agriculture to climate change in review. *Agricultural and Forest Meteorology*, *80*(1), 1-53.

Ellis, F. (2000). 'Rural Livelihoods and Diversity in Developing Countries', New York: Oxford University Press.

Elrick-Barr, C. E., Smith, T. F., Preston, B. L., Thomsen, D. C., & Baum, S. (2016). How are coastal households responding to climate change?. *Environmental Science & Policy*, *63*, 177-186.

Elum, Z. A., Modise, D. M., & Marr, A. (2017). Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. *Climate Risk Management*, *16*, 246-257.

Engle, N. L. (2011). Adaptive capacity and its assessment. *Global environmental change*, *21*(2), 647-656.

Engle, N., & Lemos, M. (2007). Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. Global Environmental Change. (20),4-13.

Engle, N.L. and Lemos, M.C. (2010). Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. Global Environmental Change 20, 4–13.

Estrada, F., Botzen, W. W., & Tol, R. S. (2017). A global economic assessment of city policies to reduce climate change impacts. *Nature Climate Change*, *7*(6), 403.

Ethiopian Panel on Climate Change (2015). *First Assessment Report, Working Group II Agriculture and Food Security*, Ethiopian Academy of Sciences.

Etwire, P. M., Al-Hassan, R. M., Kuwornu, J. K., & Osei-Owusu, Y. (2013). Application of livelihood vulnerability index in assessing vulnerability to climate change and variability in Northern Ghana. *Journal of Environment and Earth Science*, *3*(2), 157-170.

Evangelista, P., Young, N., & Burnett, J. (2013). How will climate change spatially affect agriculture production in Ethiopia? Case studies of important cereal crops. *Climatic change*, *119*(3-4), 855-873.

Fankhauser, S. (2016). *Adaptation to climate change*, Centre for Climate Change Economics and Policy Working Paper No. 287; Grantham Research Institute on Climate Change and the Environment Working Paper No. 255; London School of Economics, London, UK.

FAO, (2011). The state of the World's Land and Water Resources for Food and Agriculture (SOLAW)—Managing Systems at Risk; Food and Agriculture Organization of the United Nations: Rome, Italy; London, UK.

FAO, (2018). Climate–Smart Agriculture. Food and Agriculture Organization of the United Nations (FAO).

FDRE (2010). Growth and Transformation Plan (GTP); Ministry of Finance and Economic Development: Addis Ababa, Ethiopia.

______ (2011). Ethiopia’s Climate-Resilient Green Economy (CRGE): Green Economy Strategy. Federal Democratic Republic of Ethiopia, Addis Ababa.

_______ (2011). Ministry of Agriculture. Federal Democratic Republic of Ethiopia, Addis Ababa.

_______ (2015). Federal Democratic Republic of Ethiopia, Ministry of Environment and Forest. *Ethiopia’s Second National Communication to the United Nations Framework Convention on Climate Change* (UNFCCC), Addis Ababa.

_______ (2016). Growth and Transformation Plan (GTP) 2015/16-2019/20. National Planning Commission, FDRE.

_______ (2018). National Meteorological Service Agency (2018). Temperature and rainfall data of Kembata Tembaro Zone (unpublished document).

_______ (2019). Ethiopia’s Climate Resilient Green Economy: National Adaptation Plan. Federal Democratic Republic of Ethiopia.

Few, R., Satyal, P., McGahey, D., Leavy, J., Budds, J., Assen, M., Camfield, L., Loubser, D., Adnew, M., and Bewket, W., (2015). Vulnerability and Adaptation to Climate Change in Semi-Arid Areas in East Africa. ASSAR Working Paper, ASSAR PMU, South Africa, 111 pp.

Finucane, M. (2009). ‘Why science alone won`t solve the climate crisis: managing the climate risks in the Pacific.’ *Asia Pacific Issues* 89: 1–8.

Fischer G, Mahendra Shah and H.V. Velthuizen (2002). ‘Climate Change and Agricultural Vulnerability. A special report prepared by the International Institute for Applied Systems Analysis as a contribution to the World Summit on Sustainable Development, Johannesburg.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.*, *30*, 441-473.

Fosu-Mensah, B., Vlek, P., & Manschadi, M. (2010). Farmers' Perceptions and Adaptations to Climate Change: A Case Study of Sekyedumase District in Ghana. A contributed paper presented at World Food Systems Conference in Tropentag, Zurich: 14th -16 September, 2010.

Fritzsche K, Timmermeyer N, Wolter M, Michiels NK., (2014). Female, but not male, nematodes evolve under experimental sexual coevolution. Proc. R. Soc. B 281: 20140942. http://dx.doi.org/10.1098/rspb.2014.0942

Funk, C., J. Michaelsen, and M. Marshall, (2012). Mapping recent decadal climate variations in precipitation and temperature across Eastern Africa and the Sahel. In: Remote Sensing of Drought: Innovative Monitoring Approaches [Wardlow, B.D., M.C. Anderson, and J.P. Verdin (eds.)]. CRC Press, Boca Raton, FL, USA, pp. 331-358.

Füssel and R. J. T. Klein, (2006). Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. Climatic Change (75): 301-329.

Füssel, H. (2007). Vulnerability: A Generally Applicable Conceptual Framework for Climate Change Research. Global Environmental Change 17(2): 155-167.

Gallopín, G. C. (2006), ‘Linkages between vulnerability, resilience, and adaptive capacity’, Global Environmental Change, 16(3): 293-303.

Gandure, S., Walker, S., & Botha, J. J. (2013). Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. *Environmental Development*, *5*, 39-53.

Gbetibouo, G. A., & Ringler, C. (2009). *Mapping South African farming sector vulnerability to climate change and variability: A subnational assessment* (pp. 2-4). International Food Policy Research Institute (IFPRI) and Center for Environmental Economics and Policy in Africa (CEEPA).

Gbetibouo, G.A. (2009). Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa. IFPRI Discussion Paper 00849. Available: http://www.ifpri.org/sites/default/files/publications/rb15_08.pdf.

Gebreegziabher Z., Mekonnen A., Deribe R., Boka, J., and Abera S., (2016). Mapping Vulnerability to Climate Change of the Farming Sector in the Nile Basin of Ethiopia: A Micro-level Perspective. Environment for Development: Discussion Paper Series. EfD DP 16-19.

Gissila, T., Black, E., Grimes, D. I. F., and Slingo, J. M., (2004). Seasonal forecasting of the Ethiopia summer rains'. International Journal of Climatology 24: 1345-1358. doi: 10.1002/joc.1078

Goldman, M.J. and Riosmena, F. (2013). Adaptive capacity in Tanzanian Maasailand: Changing strategies to cope with drought in fragmented landscapes. Global Environmental Change 23, 588–97.

Grothmann, T., & Patt, A., (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. Global Environmental Change, 15(3), 199–213.

Gunderson, L.H., Holling, C.S., Light, S.S. (Eds.), (1995). *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. Columbia University Press, New York, NY.

Gupta, V. K., Misra, A. K., Gaur, R. K. (2010). Growth Characteristics of *Fusarium spp*. Causing wilt disease in *Psidium guavaja* L. in India. *J. Plant. Protect. Res*.**50**:452-462.

Hadgu, G., Tesfaye, K., Mamo, G., & Kassa, B. (2014). Analysis of farmers' perception and adaptation methods to climate variability/change in Tigray region, Northern Ethiopia. *Res. J. Agr. Env. Sci*, *1*(1), 15-25.

Hageback, J., Sundberg, J., Ostwald, M., Chen, D., Yun, X., & Knutsson, P. (2005). Climate variability and land-use change in Danangou watershed, China—Examples of small-scale farmers' adaptation. *Climatic Change*, *72*(1-2), 189-212.

Hahn, M., A. Reiderer, and S. Foster, (2009). The Livelihood Vulnerability Index: A Pragmatic Approach to Assessing Risks from Climate Variability and Change: A Case Study in Mozambique. Global Environmental Change 19: 74-88.

Hameso S., (2018) Farmers and policy-makers' perceptions of climate change in Ethiopia, Climate and Development, 10:4, 347-359, DOI: 10.1080/17565529.2017.1291408

Handino, M. L. (2014). *'Green famine'in Ethiopia: understanding the causes of increasing vulnerability to food insecurity and policy responses in the Southern Ethiopian highlands* (Doctoral dissertation, University of Sussex).

Hare, W. (2003). Assessment of knowledge on impacts of climate change-contribution to the specification of art. 2 of the UNFCCC: Impacts on ecosystems, food production, water and socio-economic systems.

Hassan R. & Nhemachena, C. (2008). Determinants of African farmers' Strategies for Adapting to Climate Change: Multinomial Choice Analysis. African Journal of Agricultural and Resource Economics, 2(1), 83- 104.

Hassan, R. M. and Tadesse Deressa, (2009). Economic impact of climate change on crop production in Ethiopia. Journal of African economies, 18(4): 529-554.

Head, L., Farbotko, C., Gibson, C., Gill, N., & Waitt, G. (2013). Zones of friction, zones of traction: the connected household in climate change and sustainability policy. *Australasian Journal of Environmental Management*, *20*(4), 351-362.

Headey, D., A. S. Taffesse, and L. You., (2014). "Diversification and Development in Pastoralist Ethiopia." *World Development* 56:200–213.

Hill, M., & Engle, N. L. (2013). Adaptive capacity: tensions across scales. *Environmental Policy and Governance*, *23*(3), 177-192.

Hinkel, J. (2011). Indicators of vulnerability and adaptive capacity: Towards a clarification of the science policy interface. Global Environmental Change 21:198-208.

Hoddinott, J., and A. Quisumbing, (2003). Methods for Microeconometric Risk and Vulnerability Assessments. Social Protection Discussion Paper Series No. 0324. Social Protection Unit, Human Development Network. Washington, DC: World Bank.

Hu, Q., & He, X. (2018). An integrated approach to evaluate urban adaptive capacity to climate change. *Sustainability*, *10*(4), 1272.

IMF, (2016). International Monetary Fund: Briefing note. Building resilience: International Monetary Fund.

IPCC, (2001b). Climate change 2001: Impacts, adaptation, and vulnerability. Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

________ (2007 p. 21). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (Eds.). Cambridge, UK: Cambridge University Press, pp. 976.

_______ (2010). Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties. Jasper Ridge, CA, USA. IPCC Cross-Working Group Meeting on Consistent Treatment of Uncertainties.

_______ (2013). Summary for Policymakers, Technical Summary and Frequently Asked Questions. In *Climate Change 2013: The Physical Science Basis.* Part of the Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, T.F. Stocker and others, eds. Cambridge, United Kingdom: Cambridge University Press.

_______ (2014). Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press.

_______ (2018). *Global warming of 1.5°C.* An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva, Switzerland: World Meteorological Organization.

Irish Aid, (2017). ETHIOPIA CLIMATE ACTION REPORT FOR 2016. Resilience and Economic Inclusion Team.

________ (2018). Ethiopia Country Climate Risk Assessment Report. Irish Aid, Resilience and Economic Inclusion Team, Policy Unit.

Ishaya, S. & Abaje, I. B. (2008). Indigenous people's perception of climate change and adaptation strategies in Jema's local government area of Kaduna State, Nigeria. Journal of Geography and Regional Planning 1,138–143.

Ivey, J. L., J. Smithers, R. C. de Loe, and R. D. Kreutzwiser, (2004). Community capacity for adaptation to climate-induced water shortages: Linking institutional complexity and local actors. Environmental Management 33(1): 36-47.

Jiri, O., Mafongoya, P., & Chivenge, P. (2015). Smallholder farmer perceptions on climate change and variability: A predisposition for their subsequent adaptation strategies. *Journal of Earth Science & Climatic Change*, *6*(5), 1-7.

Jones, L., Ludi, E., & Levine, S. (2010). Towards a characterisation of adaptive capacity: a framework for analysing adaptive capacity at the local level. *Overseas Development Institute, December*.

Juana J, Kahaka Z, Okurut F., (2013). Farmers' perceptions and adaptations to climate change in sub-Sahara Africa: a synthesis of empirical studies and implications for public policy in African agriculture. J Agric Sci.; 5:121–135.

Jury, M.R. (2016). Determinants of southeast Ethiopia seasonal rainfall.Dynamics of Atmospheres and Oceans, 76(1): 63-71.https://doi.org/10.1016/j.dynatmoce.2016.08.004

Kane, S., & Shogren, J. F. (2000). Linking adaptation and mitigation in climate change policy. In *Societal adaptation to climate variability and change* (pp. 75-102). Springer, Dordrecht.

Kato E, Kinoshita T, Ito A, Kawamiya M, Yamagata Y., (2011). Evaluation of spatially explicit emission scenario of land-use change and biomass burning using a process-based biogeochemical model. Journal of Land Use Science, 8, 1–19.

Kelly, P.M., and W.N. Adger., (2000). Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation. Climatic Change 47: 325-352.

Kembata Tembaro Zone Agriculture Office (2016). Kembata Tembaro Zone Wereda Basic Data (Amharic Version, Unpublished report). Durame.

Kembata Tembaro Zone Food Security Coordination and Disaster Prevention Office (2017). Annual report for the year 2016/17 (Amharic Version, Unpublished report). Durame.

Kollmair, M., & Gamper, S. (2002). The sustainable livelihoods approach. *Zurich: University of Zurich*.

Kotari, C. R. (2004). Research Methodology, Methods and Techniques; 2ndE. D. *New Age*.

Kurukulasuriya, P., & Mendelsohn, R. (2008). Crop switching as a strategy for adapting to climate change. *African Journal of Agricultural and Resource Economics*, *2*(311-2016-5522), 105.

Lambrou, Y., & Paina, G. (2006). Gender: The missing component of the response to climate change: Food and Agriculture Organization of the United Nations (FAO) Rome.

Laroui, F., and B.C.C. van der Zwaan, (2001). Environment and multidisciplinary. Three examples of avoidable confusion‖, Integrated Assessment, Vol. 3, pp. 360-369.

Laube, W., Schraven, B., Awo, M., (2012). Smallholder adaptation to climate change: dynamics and limits in northern Ghana. Clim. Change 111 (3), 753e774.

Laws, S., Harper, C. and Marcus, R. (2003). Research for Development: A Practical Guide, London: Sage

Le Dang, H., Li, E., Nuberg, I., & Bruwer, J. (2014). Understanding farmers' adaptation intention to climate change: A structural equation modelling study in the Mekong Delta, Vietnam. *Environmental Science & Policy*, *41*, 11-22.

Leach, M., R. Mearns and I. Scoones (1999). Environmental entitlements: dynamics and institutions in community-based natural resource management. World Development, 27(2), 225–47.

Lebel, L., J. M. Anderies, B. Campbell, C. Folke, S. Hatfield-Dodds, T. P. Hughes, and J. Wilson. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. Ecology and Society 11(1): 19.

Leichenko, R. M., and K. L. O'Brien. (2001). The dynamics of rural vulnerability to global change: The case of Southern Africa. *Mitigation and adaptation strategies for global change* 7(1): 1–18.

Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic change*, *77*(1-2), 45-72.

Lemos, M.C., Agrawal, A., Eakin, H., Nelson, D.R., Engle, N.L. and O. Johns (2013). Building adaptive capacity to climate change in less developed countries. In: Asrar, G.R. and J.W. Hurrell, Eds. Climate Science for Serving Society: Research, Modeling, and Prediction Priorities. Dordrecht, The Netherlands, Springer.

Leon-Vasquez. M., West, T., and Finan, J. (2003). A comparative assessment of climate vulnerability: Agriculture and ranching on both sides of the US-Mexico border. Bureau of Applied Research in Anthropology, University of Arizona, USA.

Levine, S., Ludi, E., & Jones, L. (2011). Rethinking support for adaptive capacity to climate change. *Oxfam Policy and Practice: Climate Change and Resilience*, *7*(5), 49-97.

Lobell, D.B., M.B. Burke, C. Tebaldi, M.D. Mastrandrea, W.P. Falcon, and R.L. Naylor, (2008). Prioritizing climate change adaptation needs for food security in 2030. Science, 319(5863), 607-610.

Lockwood, M., C. M. Raymond, E. Oczkowski, and M. Morrison, (2015). Measuring the dimensions of adaptive capacity: a psychometric approach. Ecology and Society 20(1): 37.

Luers, A.; Lobell, D.; Sklar, L.; Addams, L.; Matson, P. (2003). A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. Glob. Environ. Chang. 13, 255–267.

Luni Piya, Niraj Prakash Joshi, Keshav Lall Maharjan (2012). Vulnerability of rural households to climate change and extremes: Analysis of Chepang households in the Mid-Hills of Nepal. Paper Presented at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil.

Maddison, D. (2006). The Perception of and Adaptation to Climate Change in Africa. CEEPA Discussion Paper No. 10. Pretoria, South Africa: Centre for Environmental Economics and Policy in Africa.

________ (2007). *The perception of and adaptation to climate change in Africa*. The World Bank.

Mafongoya, P.L. and Ajayi, O.C. (editors) (2017). Indigenous Knowledge Systems and Climate Change Management in Africa, CTA, Wageningen, The Netherlands, 316pp.

Mahoo, H., Radeny, M. A., Kinyangi, J., & Cramer, L. (2013). Climate change vulnerability and risk assessment of agriculture and food security in Ethiopia: Which way forward?.

Mandleni, B., & Anim, F. D. K. (2011). Perceptions of cattle and sheep farmers on climate change and adaptation in the Eastern Cape Province of South Africa. *Journal of Human Ecology*, *34*(2), 107-112.

Marchant, R., Mumbi, C. Behera, S. and Yamagata, T. (2007). The Indian Ocean dipole: the unsung driver of climatic variability. East Africa. Afr. J. Ecol., 45: 4–16.

Masika, R. (2002). Gender, development, and climate change: Oxfam.

McCarthy, J., O.F. Canziani, N.A. Leary, D.J. Dokken, and C. White (Eds), (2001). Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

McSweeney, C., New, M. and Lizanco, G. (2010). UNDP Climate Change Country Profiles: Ethiopia. p. 27. UNDP.

McSweeney, C., New, M., Lizcano, G., & Lu, X. (2010). The UNDP Climate Change Country Profiles: Improving the accessibility of observed and projected climate information for studies of climate change in developing countries. *Bulletin of the American Meteorological Society*, *91*(2), 157-166.

MEFCC (2018). FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA, MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE. NATIONAL REDD+ STRATEGY (2018 - 2030), Addis Ababa, Ethiopia.

Menike, L. M. C. S., & Arachchi, K. K. (2016). Adaptation to climate change by smallholder farmers in rural communities: Evidence from Sri Lanka. *Procedia food science*, *6*, 288-292.

Mertz, O., C. Mbow, A. Reenberg, and A. Diouf, (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. Environmental Management, **43(5)**, 804-816.

Morgan, E., R. M. O'Riordan, T. C. Kelly, and S. C. Culloty, (2012). Influence of disseminated neoplasia, trematode infections and gametogenesis on surfacing and mortality in the cockle Cerastoderma edule. Dis. Aquat. Org. 98:73–84.

Morrison, M., E. Oczkowski, and J. Greig., (2011). The primacy of human capital and social capital in influencing landholders' participation in programmes designed to improve environmental outcomes. Australian Journal of Agricultural and Resource Economics 55:560-578.

Morrow, B.H. (1999). Identifying and mapping community vulnerability. Disaster, 23 (1). Retrieved from: www.ncbi.nlm.nih.gov/pubmed/10204285

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the national academy of sciences*, *104*(50), 19680-19685.

Murphy, Daniel J.; Wyborn, Carina; Yung, Laurie; Williams, Daniel R., (2015). Key concepts and methods in social vulnerability and adaptive capacity. Gen. Tech. Rep. RMRS-GTR-328. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 24 p.

Naomi Hossain and Susanna Davies (1997). LIVELIHOOD ADAPTATION, PUBLIC ACTION AND CIVIL SOCIETY: A REVIEW OF THE LITERATURE. IDS Working Paper 57.

Nelson DR, Adger WN, Brown K., (2007). Adaptation to environmental change: contributions of a resilience framework. *Ann Rev Environ Resour*, 32:395–419.

Nelson, G.C,. M. W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes,R. Valmonte-Santos, M. Ewing, and D. Lee., (2009). *Climate Change: Impact on Agriculture and Costs of Adaptation*. Food Policy Report No. 21. Washington, DC: International Food Policy Research Institute.

Nelson, R., Kokic, P., Crimp, S., Martin, P., Meinke, H., Howden, S. M., et al. (2010b). The Vulnerability of Australian Rural Communities to Climate Variability and Change: Part II - Integrating Impacts with Adaptive Capacity. Envrionmental Science and Policy, 13, 18 - 27.

Nelson, R., Kokic, P., Crimp, S., Meinke, H., & Howden, S. M. (2010). The vulnerability of Australian rural communities to climate variability and change: Part I—Conceptualising and measuring vulnerability. *environmental science & policy*, *13*(1), 8-17.

Newell, B., C.L. Crumley, N. Hassan, E.F. Lambin, C. Pahl-Wostl, A. Underdal, R. Wasson (2005). A conceptual template for integrative human-environment research‖, Global Environmental Change, Vol. 15,pp. 299-307.

Nhemachena, C. & Hassan, R. M., (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(311-2016-5521), 83-104.

________ (2007). Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No.00714. International Food Policy Research Institute, Washington D.C.

Niang, I., Ruppel, O.C., Abdrabo, M.A., Essel, A., Lennard, C., Padgham, J. and Urquhart, P. (2014). Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Nyanga, P.H., Johnsen F.H, Aune J. B and Kalinda T.H., (2011). Smallholder Farmers' Perceptions of Climate Change and Conservation Agriculture: Evidence from Zambia. Journal of Sustainable Development Vol. 4, No. 4; pp 73 – 85.

Nyong, A., Adesina, F., Osman Elasha, B., (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitig. Adapt. Strat. Glob. Change 12 (5), 787e797.

O'Brien, K., Eriksen, S., Schjolden, A., & Nygaard, L. (2009). What's in a word? Conflicting interpretations of vulnerability in climate change research.

O'Brien, K., Eriksen, S., Lynn, P.N. and A. Schjolden, (2007). Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy* 7(1):73-88.

O'Brien, K., R. Leichenko, U. Kelkar, H. Venema, G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard, and J. West, (2004). Mapping Vulnerability to Multiple Stressors: Climate Change and Globalization in India. *Global Environmental Change* 14: 303-313.

OECD (2013), "OECD DAC Statistics on Climate-related Aid", OECD, Paris.

Ogalleh, S.A., C.R. Vogl, J. Eitzinger, and M. Hauser, (2012). Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya. Sustainability 4(12): 3302.

Olsson, L., M. Opondo, P. Tschakert, A.Agrawal, S.H. Eriksen,S.Ma, L.N.Perch, and S.A. Zakieldeen, (2014). Livelihoods and poverty. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability.PartA:Global and SectoralAspects.Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on

Climate Change Cambridge University Press, Cambridge, United Kingdom and NewYork, NY, USA, pp.793-832.

Osman Elsha, B. et.al., (2005) Sustainable livelihood approach for assessing community resilience to climate change: case studies from Sudan. Washington, DC: Assessments of Impacts and Adaptations to Climate Change (AIACC).

Oxfam Media Briefing (2017). *A climate in crisis: How climate change is making drought and humanitarian disaster worse in East Africa*: Ref: 01/2017.

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007). Social learning and water resources management. Ecology and Society, 12(2), 5.

Pandey, M.K. & Jha, A., (2012). 'Widowhood and health of elderly in India: Examining the role of economic factors using structural equation modelling', International Review of Applied Economics 26(1), 111–124. http://dx.doi.org/10.1080/026921 71.2011.587109

Panthi, J., Aryal, S., Dahal, P., Bhandari, P., Krakauer, N. Y., & Pandey, V. P. (2016). Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal. *Regional environmental change*, *16*(4), 1121-1132.

Park, S.E., N.A. Marshall, E. Jakku, A.M. Dowd, S.M. Howden, E. Mendham, and A. Fleming, (2012). Informing adaptation responses to climate change through theories of transformation. Global Environmental Change, 22, 115-126.

Parry, M.L. Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E., eds. (2007). Contribution of Working Group II to the Fourth Assessment Report of the International Panel on Climate Change (Eds M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson). Cambridge, UK and New York: Cambridge University Press.

Pearson, L. and Langridge, J. (2008). Climate change vulnerability assessment: Review of agricultural productivity. CSIRO, Climate Adaptation Flagship Working paper No.1.

Pelling M, & High C., (2005). Understanding adaptation: What can social capital offer assessments of adaptive capacity? Glob Environ Change 15:308–319.

Pettengell, C. (2010). Climate Change Adaptation: Enabling People Living in Poverty to Adapt. Oxfam GB, Oxford.

Piya, Luni, Maharjan, Keshav Lall, and Joshi, Niraj Prakash (2012). Perceptions and Realities of Climate Change among the Chepang Communities in Rural Mid-Hills of Nepal. Journal of Contemporary India Studies: Space and Society, Hiroshima University, Japan.

Plummer, R. (2013). Can adaptive co-management help to address the challenges of climate change adaptation?. *Ecology and Society*, *18*(4).

Plummer, R., D. R. Armitage, and R. C. de Löe, (2013). Adaptive co-management and its relationship to environmental governance. Ecology and Society. 18(1): 21.

Putnam, R., R. Leornardi and R. Nanetti., (1993). Making democracy work: civic traditions in modern Italy. Princeton, NJ: Princeton University Press.

Räsänen , A, Juhola , S , Nygren , A , Käkönen , M , Kallio , M , Monge Monge , A & Kanninen, M (2016). 'Climate change, multiple stressors and human vulnerability: a systematic review ' Regional Environmental Change, vol. 16, no. 8, pp. 2291-2302.

Reilly, J. & Schimmelpfennig, D. (2000). Climatic Change, 45: 253.

Roncoli, C., B. Okoba, V. Gathaara, J. Ngugi, and T. Nganga, (2010).Adaptation to Climate Change for Smallholder Agriculture in Kenya: Community-Based Perspectives from Five Districts. IFPRI Note, International Food Policy Research Institute (IFPRI), Washington, DC, USA, 4 pp.

Sampei, Y. & Aoyagi-Usui, M. (2009). Mass-media coverage, its influence on public awareness of climate-change issues, and implications for Japan's national campaign to reduce greenhouse gas emissions. Global Environmental Change 19, 203–212.

Schmidt, E., and T. S. Thomas, (2018). Cropland expansion in Ethiopia: Economic and climatic considerations for highland agriculture. Ethiopia Strategy Support Program (ESSP) Working Paper 127. Addis Ababa: International Food Policy Research Institute.

Schneiderbauer, S., L. Pedoth, D. Zhang, and M. Zebisch, (2013). Assessing adaptive capacity within regional climate change vulnerability studies—An Alpine example. Natural Hazards 67: 1059–1073.

Scoones, I. (1998). Sustainable rural livelihoods: a framework for analysis.

________ (2009). Livelihoods perspectives and rural development. *The journal of peasant studies*, *36*(1), 171-196.

Scoones, I. and Wolmer, W. (eds), (2003). 'Livelihoods in crisis: new perspectives on governance and rural development in southern Africa', IDS Bulletin, Vol 34 No 3.

Seaman, J. A., Sawdon, G. E., Acidri, J., & Petty, C. (2014). The Household Economy Approach. Managing the impact of climate change on poverty and food security in developing countries. *Climate Risk Management*, *4*, 59-68.

Seid S., H. Jema and G. Degye, (2016). Climate Change Adaptation Strategies of Smallholder Farmers: The Case of Assosa District, Western Ethiopia. Journal of Environment and Earth Science: vol. 6(7):103-109.

Semenza, J. C., Hall, D. E., Wilson, D. J., Bontempo, B. D., Sailor, D.J. & George, L. A. (2008). Public perception of climate change voluntary mitigation and barriers to behaviour change. American Journal of Preventive Medicine 35, 479–487.

Seo SN, Mendelsohn R, Dinar A, Hassan R, Kurukulasuriya P (2009). A Ricardian analysis of the distribution of climate change impacts on agriculture across agro-ecological zones in Africa. Environ. Resour. Econ. 43:313-332.

Serraj R., and Pingali P., (2019). Agriculture & Food Systems to 2050: Global Trends, Challenges and Opportunities Vol. 2. Food and Agriculture Organization of the United Nations, Italy.

Serrat, O. (2010). *Knowledge solutions: Tools, Methods, and Approaches to Drive Development Forward and Enhance Its Effects* (Vol. 382). Asian Development Bank.

Seyoum Yunkura (2015). Perceptions, vulnerability and adaptation to climate change in Ethiopia: the case of smallholder farmers in Sidama: PhD Dissertation, University of East London, UK.

Shah KU, Dulal HB, Johnson C, Baptiste A., (2013). Understanding livelihood vulnerability to climate change: applying the livelihood vulnerability index in Trinidad and Tobago. Geoforum 47:125–137. doi:10.1016/j.geoforum.2013.04.004

Shanmugaratnam,N. (2008).'The Dynamics of Livelihoods in a War Zone: Mapping Socio-Economic Change in Eastern SriLanka.' In *Between War and Peace in Sudan and SriLanka.* N. Shanmugaratnam (ed.) Oxford: James Currey: 117-148.

Shongwe, M. E., van Oldenborgh, G. J. and van den Hurk, B. (2011). Projected changes in mean and extreme precipitation in Africa under global warming. Part II: East Africa. J. Climate, 24: 3718–3733.

Sietchiping, Remy, (2007). Applying an Index of Adaptive Capacity to Climate Change in North-Western Victoria, Australia. Applied GIS, Vol. 2(3), pp. 16.1–16.28.

Simane B., Benjamin F. Zaitchik, and Jeremy D. Foltz, (2016). "Agroecosystem specific climate vulnerability analysis: application of the livelihood vulnerability index to a tropical highland region." *Mitigation and Adaptation Strategies for Global Change* 21: 39-65.

Sisay T., (2016). Vulnerability of Smallholder Farmers to Climate Change at Dabat and West Belesa Districts, North Gondar, Ethiopia. J Earth Sci Clim Change 7: 365. doi: 10.4172/2157-7617.1000365.

Skinner, E. (2011). Gender and Climate Change: Overview Report. In G. a. C. Change (Ed.): Institute of Developmental Studies.

Smit, B., & Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development*, *8*(9), 9.

Smit, B., Burton, I., Klein, R. J. T. and Street, R. (1999). The science of adaptation: a framework for assessment, Mitigation and Adaptation Strategies for Global Change, 4, 199-213.

Smit, B., Burton, I., Klein, R.J.T. and J. Wandel, (2000). An anatomy of adaptation to climate change and variability. *Climatic Change* 45:223-251.

Smit, B., Burton, I., Klein, R.J.T., Street, R., (1999). The science of adaptation: a framework for assessment. Mitigation and Adaptation Strategies for Global Change 4, 199–213.

Smit, B., Pilifosova, O., (2001). Adaptation to Climate Change in the Context of Sustainable Development and Equity. Chapter 18 in Climate Change 2001: Impacts, Adaptation, and Vulnerability— Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Smit. B., and J. Wandel, (2006). Adaptation, Adaptive Capacity and Vulnerability. Global Environmental Change 16: 282-292.

Smithers, J. and B. Smit. (1997a). 'Human adaptation to climatic variability and change.' Global Environmental Change, 7(2): 129-146.

Sofie S. (2012). Measuring vulnerability to climate change – Why markets matter. Paper submitted for the Nordic Conference in Development Economics UMB School of Economics and Business Norwegian University of Life Sciences, Norway.

Sofoluwe, N. A., Tijani A. A., and Baruwa, O. I. (2011). Farmers' perception and adaptation to climate change in Osun State, Nigeria. African Journal of Agricultural Research Vol. 6(20), pp. 4789-4794.

Sonja Ayeb-Karlsson, Thomas Tanner, Keesvan der Geest and Koko Warner, (2015). Livelihood resilience in a changing world – 6 global policy recommendations for a more sustainable future.WORKING PAPERUNU-EHS PUBLICATION SERIES No. 22.

Speranza, C.I., Kiteme, B., Ambenje, P., Wiesmann, U., Makali, S., (2010). Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni district, Kenya. Clim. Change 100 (2), 295e315.

Stephen,L. and Downing,T.E. (2001). Getting the scale right: a comparison of analytical methods for vulnerability assessment and household level targeting. *Disasters*, **25** (2),113-135.

Sumner Andy and Richard Mallett, (2013). Capturing Multidimensionality: What does a Human Wellbeing Conceptual Framework Add to the Analysis of Vulnerability? Social Indicators Research, Vol. 113, No. 2, POVERTY, VULNERABILITY AND RESILIENCE IN A POST-2015 WORLD, pp. 671-690)

Suryabhagavan, K.V., (2017). GIS-based climate variability and drought characterization in Ethiopia over threedecades.Weather and Climate Extremes.

Tàbara, J.D., J.Jäger, D. Mangalagiu, and M.Grasso, (2018). Defining transformative climate science to address high–end climate change. *Regional Environmental Change*, 1–12, doi:10.1007/s10113–018–1288–8.

Tadege, A., (2007). Climate Change National Adaptation Program of Action (NAPA) of Ethiopia: http://unfccc.int/resource/docs/napa/etho1

Tanner, T. and Mitchell, T. (eds.), (2008). 'Poverty in a changing climate', IDS Bulletin, 39(4): 1-144.

Tazeze A, Haji J, Ketema M., (2012). Climate change adaptation strategies of smallholder farmers: the case of Babilie district, East Harerghe Zone of Oromia regional state of Ethiopia. J Econ Sustain Dev.;3(14):1–12.

Temesgen D, Claudia,R., Mahmud, Y., Rashid. M, and Tekie, A., (2008). Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. IFPRI. Discussion Paper No 00798 Washington, DC.

Temesgen Deressa, R.M. Hassan, C. Ringler, Tekie Alemu and Mahmud Yesuf (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change, 19: 248-255.

Termeer, C. J., Dewulf, A., & Biesbroek, G. R. (2017). Transformational change: governance interventions for climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and Management*, *60*(4), 558-576.

Teshome M., (2016). Rural households' agricultural land vulnerability to climate change in Dembia-woreda, Northwest Ethiopia. J Environmental System Research 5: 14.

Tessema, A. J. (2008). *Livelihood adaptation, risks and vulnerability in rural Wolaita, Ethiopia*. Noragric, Department of International Environment and Development Studies, Norwegian University of Life Sciences.

Tesso G, Emana B, Ketema M., (2012). Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia. 3(6):871–88.

Tesso, G., Ketema, M. & Emana, B., (2012b). Adaptation to climate change and its impact on food production in North Shewa zone, Ethiopia. Adv. Agri. Sci. Eng. Res. 2, 285 - 298.

Toole, S., Klocker, N. & Head, L. (2016). Re-thinking climate change adaptation and capacities at the household scale. Climatic Change: an interdisciplinary, international journal devoted to the description, causes and implications of climatic change, 135 (2), 203-209.

Tsegaye Gatiso, (2015). Effectiveness of Climate Change Adaptation Strategies: Household-Level Evidence from Ethiopia. *Journal of Economics and Sustainable Development*, *6*(19), 99-110.

Turner, B.L. (2010). Vulnerability and Resilience: Coalescing or paralleling approaches for sustainability science? In: Global Environmental Change, 2010 20:4, 570-576.

UNDP, (2015). Human Development Report 2015. Work for Human Development 1 UN Plaza, New York, NY 10017, USA.

UNFCCC, (2016). Implementation of technology action plans of developing countries. Bonn: United Nations Framework Convention on Climate Change.

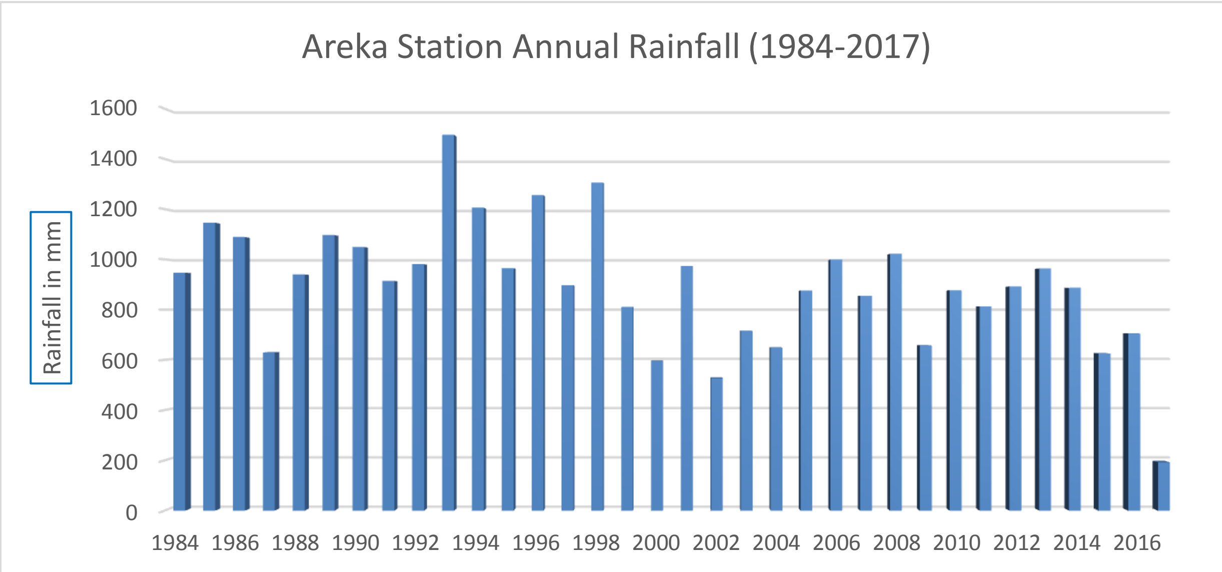
United Nations, (2016). World Economic and Social Survey 2016: *Climate Change Resilience: An Opportunity for Reducing Inequalities,*Department of Economic and Social Affairs, United Nations, New York, 2016.

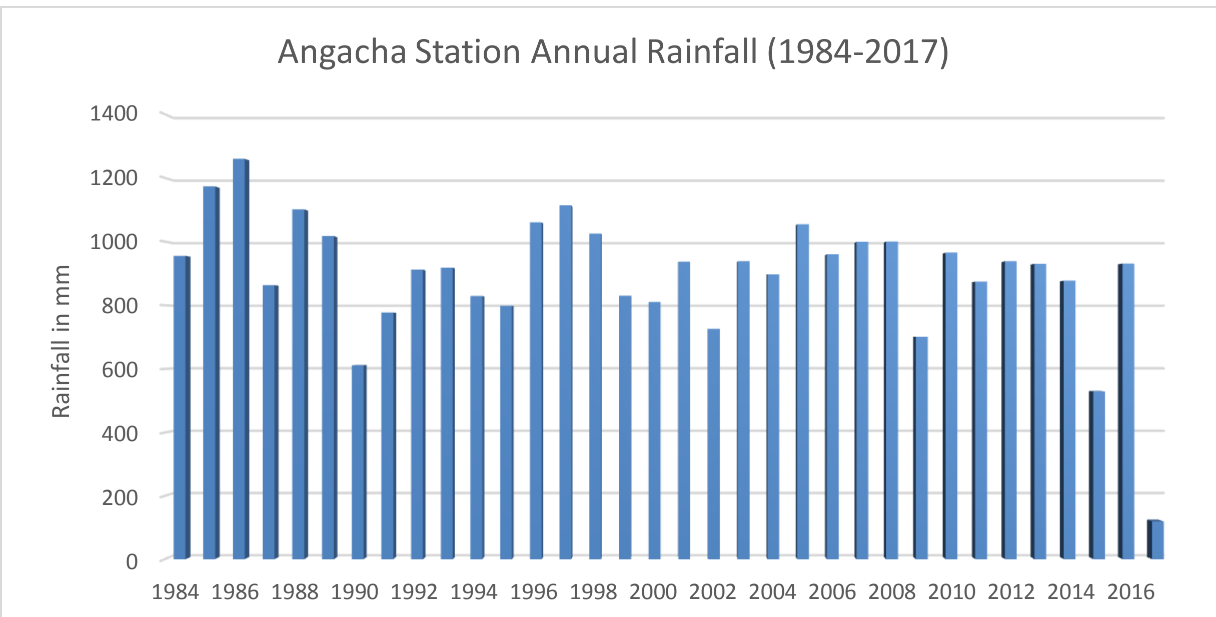
United Nations, (2017). World Population Prospects: The 2017 Revision. Department of Economic and Social Affairs, Population Division. New York: United Nations.
van der Geest, K. and T. Dietz, (2004). A literature survey about risk and vulnerability in drylands, with a focus on the Sahel. In: The Impact of Climate Change on Drylands: With a Focus on West Africa [Dietz, A.J., R. Rueben, and J. Verhagen (eds.)]. Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 117-146.
Vergara, W., Rios, A.R., Galindo, L.M., & Samaniego, J. (2015). Physical damages associated with climate change impacts and the need for adaptation actions in Latin America and the Caribbean. In W.L. Filho (Ed.) Handbook of climate change adaptation (pp. 479-491). Berlin: Springer-Verlag Berlin Heidelberg.
Vincent, K. (2004). Creating an Index of Social Vulnerability to Climate Change for Africa. Technical Report 56. Norwich, U.K.: Tyndall Centre for Climate Change Research, University of East Anglia.
________ Uncertainty in Adaptive Capacity and the Importance of Scale. Global Environmental Change 17(1): 12-24.
Vincent, K., & Cull, T. (2010). A Houshold Social Vulnerability Index (HSVI) for Evaluating Adaptation Projects in Devleoping Countries. Paper presented in PEGNet Conference 2010, Policies to Foster and Sustain Equitable Development in Times of Crises, Midrand, 2nd-3rd.
Vincent, K., A. Joubert, T. Cull, J. Magrath, and P. Johnston, (2011a). Overcoming the Barriers: How to Ensure Future Food Production under Climate Change in Southern Africa. Oxfam Research Report, Oxfam GB for Oxfam International, Oxford, UK, 59 pp.
Wardekker, J.A. (2011). Climate change impact assessment and adaptation under uncertainty. PhD dissertation. Utrecht University, Utrecht.
Warner, K., K. van der Geest, S. Kreft, S. Huq, S. Harmeling, K. Kusters, and A. De Sherbinin, (2012). Evidence from the Frontlines of Climate Change: Loss and Damage to Communities despite Coping and Adaptation. Policy Report No. 9, United Nations University-Institute for Environment and Human Security (UNUEHS), Bonn, Germany, 85 pp.
WEF, (2018). Global Risks 2013. Geneva: World Economic Forum.
Wheeler, S., Zuo, A., & Bjornlund, H. (2013). Farmers' climate change beliefs and adaptation strategies for a water scarce future in Australia. *Global Environmental Change*, *23*(2), 537-547.
Wilbanks, T. and R.W. Kates, (1999). Global change in local places: How scale matters. Climatic Change 43:601-628.
Wilby, R. L. & Dessai, S. (2010). Robust adaptation to climate change. *Weather*, 65**,** 180-185.
Wolde-Georgis, T. (2002).The impacts of cold events on Ethiopia (pp.158-167).InLa Nina anditsImpacts: Facts and Speculation, edited by M.l H.Glantz.United Nations University.
Wooldridge, J.M. (2002). Econometric Analysis of Cross Section and Panel Data. Cambridge, MA: MIT Press.World Bank (2010) Economics of adaptation to climate change: Ethiopia. The World Bank Group, Washington, DC, p. 124.
World Bank (2010) Economics of adaptation to climate change: Ethiopia. The World Bank Group, Washington, DC, p 124
Yesuf, M., S. Di Falco, C. Ringler, and G. Köhlin, (2008). Impact of Climate Change and Adaptation to Climate Change on Food Production in Low-income Countries:

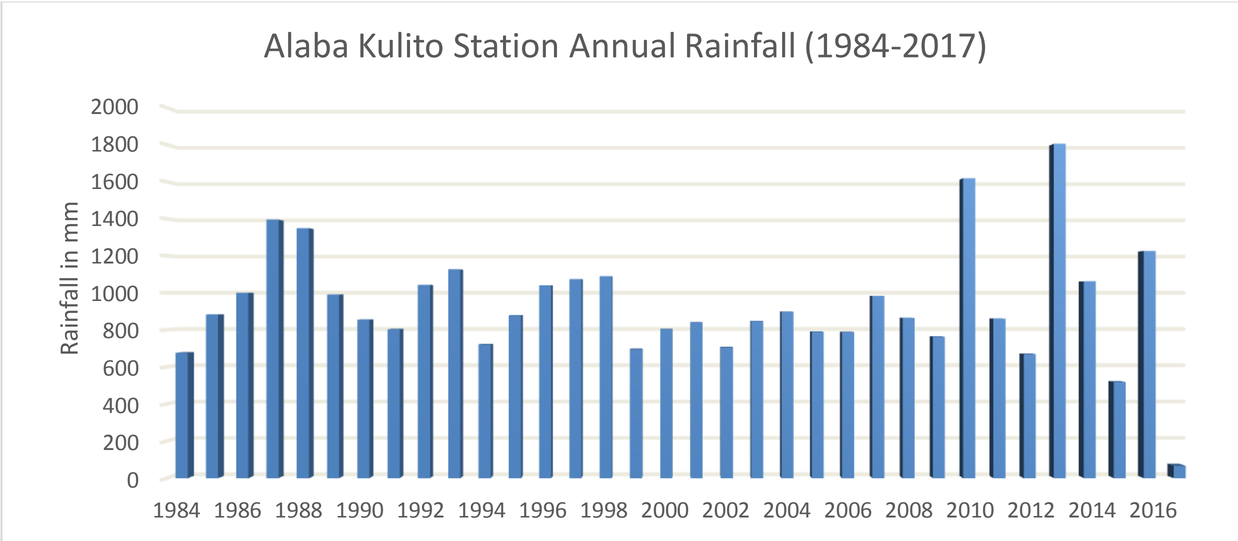
Household Survey Data Evidence from the Nile Basin of Ethiopia. IFPRI Discussion Paper 00828. International Food Policy Research Institute, Washington, DC.
Yohe, G.; Tol, R. (2002). Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Glob. Environ. Chang. 12, 25–40.
Yu, L., Hurley, T., Kliebenstein, J. and Orazen, P. (2008). "Testing for complementarity and substitutability among multiple technologies: the case of US Hog farms", Working Paper No. 08026, Iowa State University, Department of Economics, Ames, IA.
Yusuf, A. A., & Francisco, H. (2009). Climate change vulnerability mapping for Southeast Asia.
Zampaligré, N., Dossa, L. H., & Schlecht, E., (2014). Climate change and variability: perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso. *Regional environmental change*, *14*(2), 769-783.
Ziervogel, G., Nyong, A., Osman, B., Conde, C., Cortés, S. and Downing, T. (2006). Climate Variability and Change: Implications for Household Food Security. AIACC Working Paper No. 20. International START Secretariat. Washington, District of Columbia. 34pp.

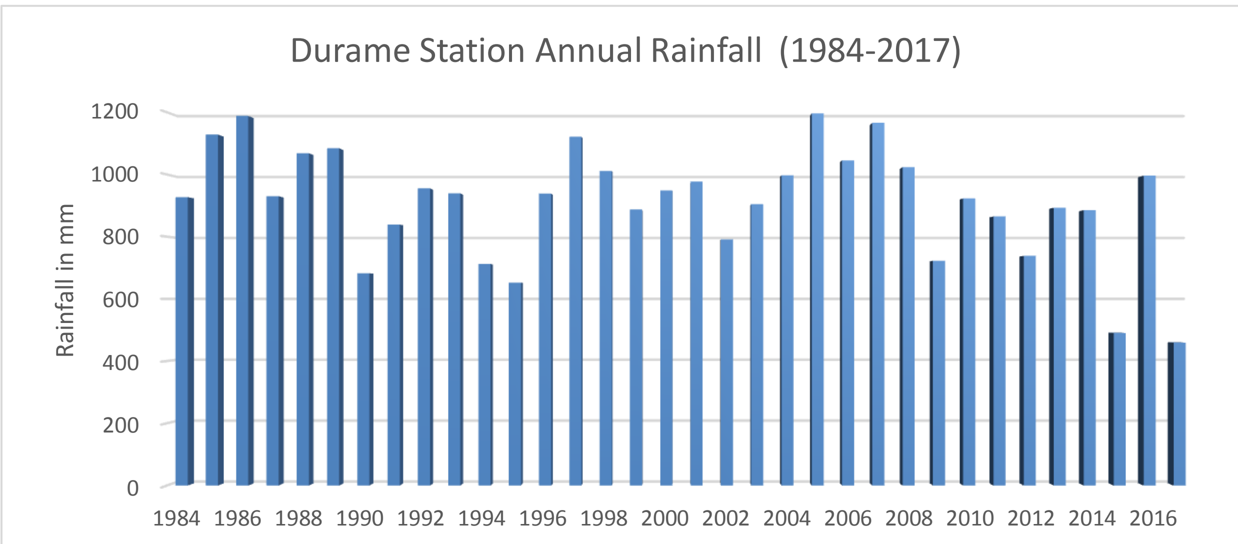
Annexes

Annex 1: Stations' Annual Rainfall

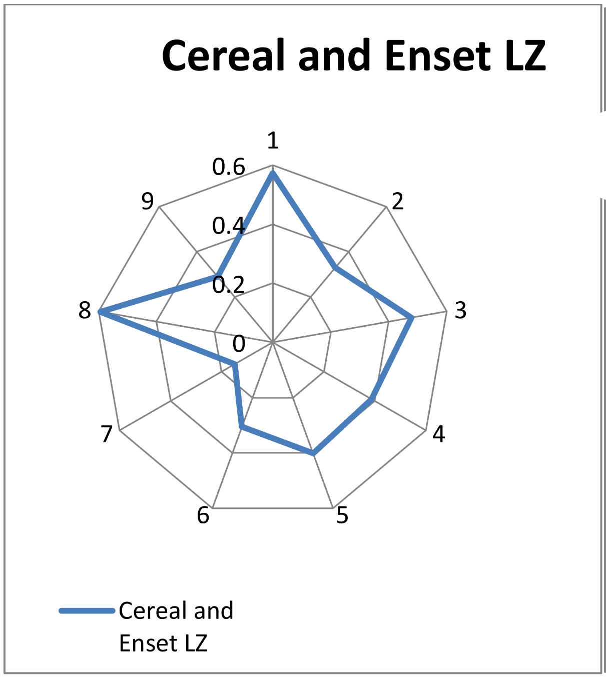


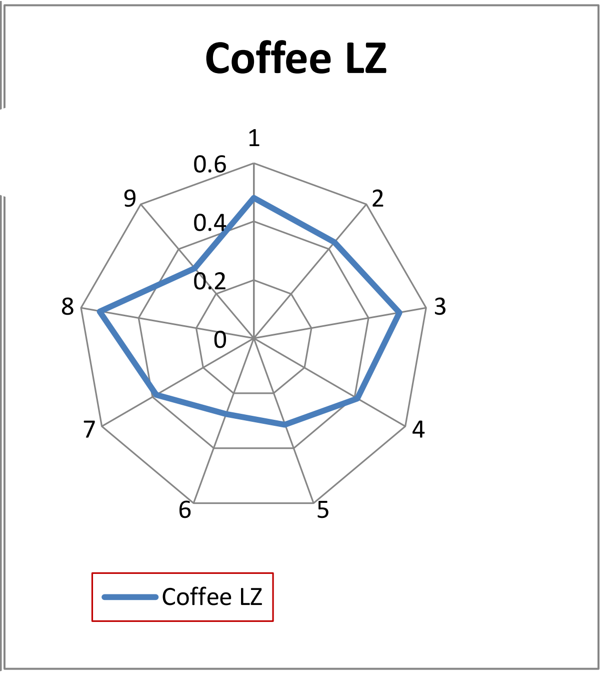


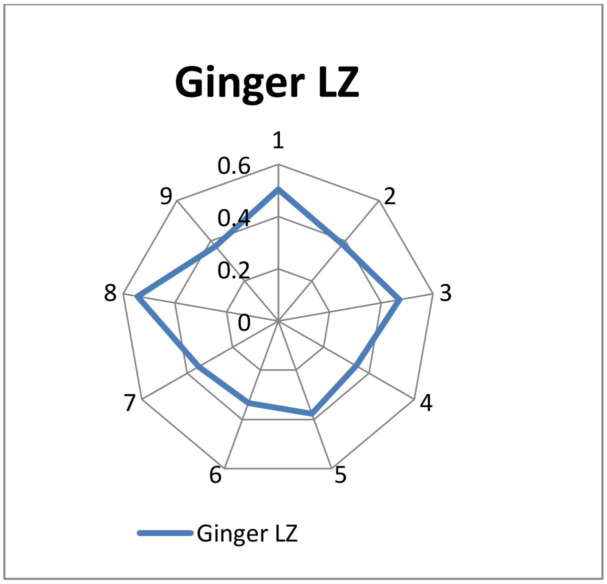

Alaba Kulito Station Annual Rainfall (1984-2017)
Rainfall in mm
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

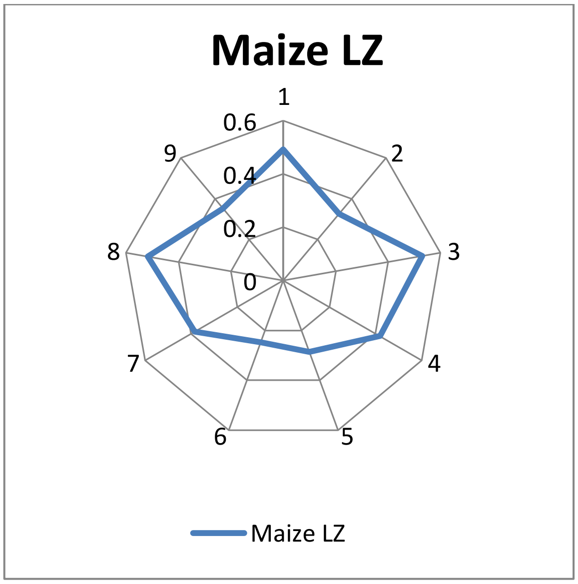

Durame Station Annual Rainfall (1984-2017)
Rainfall in mm
1200
1000
800
600
400
200
0
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

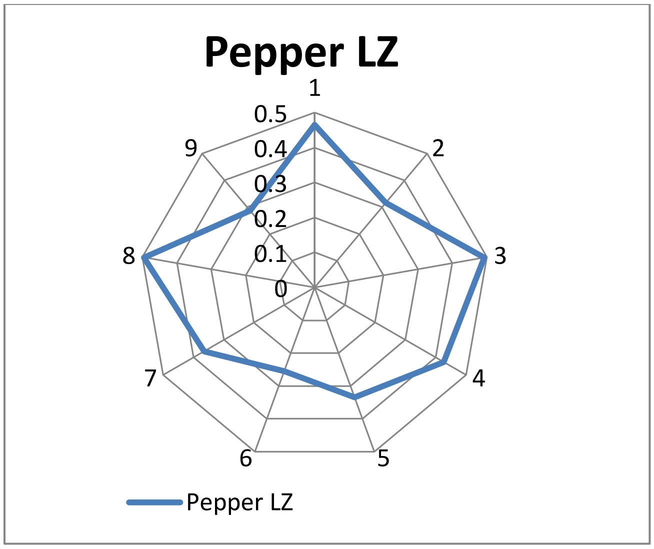
Annex 2: Vulnerability Spider Diagram of Each LZ











Annex 3: Multinomial Logistic Regression (MLR) of Adaptation and Coping Strategies

```
Multinomial logistic regression                     Number of obs      =
508
                                                    LR chi2(115)       =
415.59
                                                    Prob > chi2        =
0.0000
Log likelihood = -659.51291                         Pseudo R2          =
0.2396
```

adaptstrat1	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Timing_of_farm_operations_Change						
eduhh						
Primary(grade1-8)	.4225628	.3197361	1.32	0.186	-.2041085	1.049234
Secondary(garade9-10)	.5675797	.5599794	1.01	0.311	-.5299598	1.665119
Tertiary(college,university)	18.06126	5123.945	0.00	0.997	-10024.69	10060.81
relign						
Catholic	.7930193	.6436089	1.23	0.218	-.468431	2.05447
Protestant	.051868	.5762174	0.09	0.928	-1.077497	1.181233
Muslim	-1.818918	.7252074	-2.51	0.012	-3.240298	-.3975373
sex						
Femal	.1325842	.419547	0.32	0.752	-.6897128	.9548812
offarm						
No	.4695091	.2927688	1.60	0.109	-.1043072	1.043325
landproduc						
Decreasing	.1438522	.3911099	0.37	0.713	-.622709	.9104135
Remain the same	-1.745406	.8658529	-2.02	0.044	-3.442447	-.0483659
acesirig						
No	-.6334404	.3397595	-1.86	0.062	-1.299357	.032476
acesimpvarity						
No	.2625952	.4823493	0.54	0.586	-.6827922	1.207982
acesextserv						
No	19.94998	3818.561	0.01	0.996	-7464.293	7504.193
skilupgrad						
No	.5599634	.3[illegible]	.82	0.069	-.0426928	1.16262
techadopt						
high	-.0964931	.513[illegible]	[illegible]	0.851	-1.103361	.9103745

medium	-.093857	.4971341	-0.19	0.850	-1.068222	.8805081
low	-.1655629	.6266386	-0.26	0.792	-1.393752	1.062626
very low	-3.207051	1.365707	-2.35	0.019	-5.883788	-.5303138
acesaving						
Yes	-.1297447	.3030677	-0.43	0.669	-.7237466	.4642571
acesremitance						
Yes	-.2468071	.2873108	-0.86	0.390	-.809926	.3163117
acescredit						
Yes	1.853692	1.119025	1.66	0.098	-.3395569	4.046941
No	1.463721	1.119718	1.31	0.191	-.7308863	3.658328
watraces						
No	.2995078	.2952989	1.01	0.310	-.2792674	.878283
_cons	-2.020991	1.436651	-1.41	0.160	-4.836775	.7947936
Planting_early_maturing_varietie						
eduhh						
Primary(grade1-8)	-.4892892	.3880019	-1.26	0.207	-1.249759	.2711806
Secondary(garade9-10)	-2.066996	1.115318	-1.85	0.064	-4.252979	.1189868
Tertiary(college,university)	.0425064	7886.868	0.00	1.000	-15457.93	15458.02
relign						
Catholic	.7292935	.9437364	0.77	0.440	-1.120396	2.578983
Protestant	.5824449	.8727167	0.67	0.505	-1.128048	2.292938
Muslim	-.2166834	.9431998	-0.23	0.818	-2.065321	1.631954
sex						
Femal	-.2745398	.4951415	-0.55	0.579	-1.244999	.6959197
offarm						
No	.1864195	.3261513	0.57	0.568	-.4528254	.8256644
landproduc						
Decreasing	.0713081	.4037213	0.18	0.860	-.7199711	.8625873
Remain the same	-.3136714	.9388227	-0.33	0.738	-2.15373	1.526387
acesirig						
No	-.0448819	.3760784	-0.12	0.905	-.781982	.6922181
acesimpvarity						
No	.9165118	.4552132	2.01	0.044	.0243104	1.808713
acesextserv						
No	2.231389	5882.939	0.00	1.000	-11528.12	11532.58
skilupgrad						
No	.4040695	.3371411	1.20	0.231	-.256715	1.064854
techadopt						
high	.138679	.7154274	0.19	0.846	-1.263533	1.540891
medium	.7825675	.6562224	1.19	0.233	-.5036048	2.06874
low	1.125931	.7796434	1.44	0.149	-.4021416	2.654005
very low	-16.65061	2630.853	-0.01	0.995	-5173.028	5139.727
acesaving						
Yes	2.022628	.4256676	4.75	0.000	1.188334	2.856921
acesremitance						
Yes	-.283603	.3194177	-0.89	0.375	-.9096502	.3424443
acescredit						
Yes	-.4092378	.5937037	-0.69	0.491	-1.572876	.7544
No	-.820398	.6131978	-1.34	0.181	-2.022244	.3814475
watraces						
No	.0807583	.3248111	0.25	0.804	-.5558598	.7173765
_cons	-2.470229	1.384453	-1.78	0.074	-5.183707	.2432501
Change_in_cropping_pattern	(base outcome)					
Growing_drought_tolerant_crops						
eduhh						
Primary(grade1-8)	-.2038307	.4553645	-0.45	0.654	-1.096329	.6886672
Secondary(garade9-10)	.4005747	.8903026	0.45	0.653	-1.344386	2.145536
Tertiary(college,university)	18.56098	5123.945	0.00	0.997	-10024.19	10061.31
relign						
Catholic	-1.144209	.80[illegible]	1.42	0.157	-2.727135	.4387173

Protestant	-1.460797	.6392126	-2.29	0.022	-2.713631	-.2079638
Muslim	.1456569	.6439224	0.23	0.821	-1.116408	1.407722
sex						
Femal	.5328709	.4534203	1.18	0.240	-.3558165	1.421558
offarm						
No	.5494246	.3781876	1.45	0.146	-.1918095	1.290659
landproduc						
Decreasing	-.0654417	.4237453	-0.15	0.877	-.8959673	.7650839
Remain the same	-.7669861	.9109964	-0.84	0.400	-2.552506	1.018534
acesirig						
No	.3830278	.5763743	0.66	0.506	-.7466451	1.512701
acesimpvarity						
No	.3742844	.5728457	0.65	0.514	-.7484725	1.497041
acesextserv						
No	17.15647	3818.561	0.00	0.996	-7467.087	7501.399
skilupgrad						
No	.235718	.3621696	0.65	0.515	-.4741213	.9455574
techadopt						
high	.5566134	.7171236	0.78	0.438	-.848923	1.96215
medium	.9461113	.7089681	1.33	0.182	-.4434408	2.335663
low	.3892644	.8922478	0.44	0.663	-1.359509	2.138038
very low	1.461505	1.034273	1.41	0.158	-.5656325	3.488642
acesaving						
Yes	-.8418749	.4526738	-1.86	0.063	-1.729099	.0453494
acesremitance						
Yes	-.0438602	.3470523	-0.13	0.899	-.7240702	.6363497
acescredit						
Yes	-.477008	.6614737	-0.72	0.471	-1.773473	.8194567
No	-.3712583	.6590161	-0.56	0.573	-1.662906	.9203895
watraces						
No	-1.141222	.3948602	-2.89	0.004	-1.915133	-.3673099
_cons	-.6911184	1.355261	-0.51	0.610	-3.347381	1.965145
Small_scale_irrigation__wetland						
eduhh						
Primary(grade1-8)	-1.174966	.5007667	-2.35	0.019	-2.156451	-.1934816
Secondary(garade9-10)	-.7946499	1.15479	-0.69	0.491	-3.057997	1.468698
Tertiary(college,university)	.819274	8427.139	0.00	1.000	-16516.07	16517.71
relign						
Catholic	1.395849	.9769985	1.43	0.153	-.5190331	3.310731
Protestant	-.0252104	.8486959	-0.03	0.976	-1.688624	1.638203
Muslim	-.2833482	.8833884	-0.32	0.748	-2.014758	1.448061
sex						
Femal	-.2910827	.6107845	-0.48	0.634	-1.488198	.9060329
offarm						
No	.0697849	.4081329	0.17	0.864	-.7301408	.8697107
landproduc						
Decreasing	-.5085553	.436909	-1.16	0.244	-1.364881	.3477706
Remain the same	-17.10432	2236.154	-0.01	0.994	-4399.885	4365.677
acesirig						
No	-.2124201	.4399538	-0.48	0.629	-1.074714	.6498736
acesimpvarity						
No	.4119412	.6372466	0.65	0.518	-.8370392	1.660922
acesextserv						
No	5.128565	5729.946	0.00	0.999	-11225.36	11235.62
skilupgrad						
No	.6225775	.4166629	1.49	0.135	-.1940667	1.439222
techadopt						
high	-.0218638	1.[illegible]	[illegible]02	0.987	-2.63739	2.593662
medium	2.060104	1.12[illegible]	1.82	0.068	-.1527863	4.272994

low	2.298501	1.22204	1.88	0.060	-.0966531	4.693655
very low	-15.61545	2944.42	-0.01	0.996	-5786.573	5755.342
acesaving						
Yes	.491966	.4489142	1.10	0.273	-.3878896	1.371822
acesremitance						
Yes	-.0631481	.3817489	-0.17	0.869	-.8113623	.685066
acescredit						
Yes	-1.609372	.5355623	-3.01	0.003	-2.659055	-.5596895
No	-4.321058	.745319	-5.80	0.000	-5.781856	-2.860259
watraces						
No	.0384275	.3918979	0.10	0.922	-.7296784	.8065333
_cons	-.501924	1.635409	-0.31	0.759	-3.707266	2.703418
Mulching						
eduhh						
Primary(grade1-8)	.1249666	.4506216	0.28	0.782	-.7582354	1.008169
Secondary(garade9-10)	-.9026308	1.127523	-0.80	0.423	-3.112536	1.307274
Tertiary(college,university)	18.64409	5123.945	0.00	0.997	-10024.1	10061.39
relign						
Catholic	.6544987	.9287171	0.70	0.481	-1.165753	2.474751
Protestant	-.4953975	.8762685	-0.57	0.572	-2.212852	1.222057
Muslim	-.8447847	.9733318	-0.87	0.385	-2.75248	1.062911
sex						
Femal	.6059072	.5237828	1.16	0.247	-.4206883	1.632503
offarm						
No	.2019202	.4019188	0.50	0.615	-.5858261	.9896666
landproduc						
Decreasing	.5174284	.5634468	0.92	0.358	-.586907	1.621764
Remain the same	.4879617	.9335328	0.52	0.601	-1.341729	2.317652
acesirig						
No	.125156	.4788867	0.26	0.794	-.8134447	1.063757
acesimpvarity						
No	1.074622	.524309	2.05	0.040	.0469952	2.102249
acesextserv						
No	17.72993	3818.562	0.00	0.996	-7466.513	7501.973
skilupgrad						
No	.1921119	.4064418	0.47	0.636	-.6044995	.9887232
techadopt						
high	-.3432628	.7099601	-0.48	0.629	-1.734759	1.048233
medium	-.0949704	.6587714	-0.14	0.885	-1.386139	1.196198
low	.19691	.814423	0.24	0.809	-1.39933	1.79315
very low	-.5602177	1.137115	-0.49	0.622	-2.788923	1.668488
acesaving						
Yes	1.178998	.462297	2.55	0.011	.2729129	2.085084
acesremitance						
Yes	.3729106	[illegible]	0.93	0.350	-.4093982	1.155219
acescredit						
Yes	-.3691453	.8070493	-0.46	0.647	-1.950933	1.212642
No	-.7258502	.8216815	-0.88	0.377	-2.336316	.8846159
watraces						
No	-.1405592	.4082564	-0.34	0.731	-.940727	.6596087
_cons	-2.237316	1.529667	-1.46	0.144	-5.235408	.7607758

copingtyp	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
crop_sell						
eduhh	.0975676	.2357877	0.41	0.679	-.3645677	.559703
sex	-.117417	.4168741	-0.28	0.778	-.9344753	.6996413
acesirig	-.0473148	.3887254	-0.12	0.903	-.8092026	.714573
acesearlywarnin	.2918361	.2259813	1.29	0.197	-.151079	.7347513
techadopt	1.755361	.2188657	8.02	0.000	1.326392	2.18433
skilupgrad	.2833	.3179977	0.89	0.373	-.339964	.9065641
acesremitance	.0800721	.3078507	0.26	0.795	-.5233042	.6834484
acescredit	-.1811223	.286878	-0.63	0.528	-.7433929	.3811484
acesocialmemb	1.597951	3930.977	0.00	1.000	-7702.975	7706.171
roadaces	-.3532554	.1127373	-3.13	0.002	-.5742164	-.1322944
watraces	-.452812	.3053608	-1.48	0.138	-1.051308	.1456843
indigknowlg	.1159099	.3526153	0.33	0.742	-.5752035	.8070233
locinstitsup	-.1759725	.3120515	-0.56	0.573	-.7875823	.4356372
_cons	-6.701024	3930.977	-0.00	0.999	-7711.274	7697.872
consum_seed_stock						
eduhh	-.9486656	.4004139	-2.37	0.018	-1.733462	-.1638688
sex	-.3435488	.5513421	-0.62	0.533	-1.42416	.7370619
acesirig	-.6043328	.4510711	-1.34	0.180	-1.488416	.2797504
acesearlywarnin	.4393495	.283705	1.55	0.121	-.116702	.9954011
techadopt	1.577057	.2937965	5.37	0.000	1.001227	2.152888
skilupgrad	.5355241	.4323352	1.24	0.215	-.3118374	1.382886
acesremitance	.7042412	.4064998	1.73	0.083	-.0924837	1.500966
acescredit	-3.226997	.3876416	-8.32	0.000	-3.986761	-2.467234
acesocialmemb	-12.07461	2324.966	-0.01	0.996	-4568.924	4544.775
roadaces	-.2647456	.15006	-1.76	0.078	-.5588577	.0293666
watraces	-.6371968	.4042556	-1.58	0.115	-1.429523	.1551297
indigknowlg	.0175615	.4430519	0.04	0.968	-.8508043	.8859274
locinstitsup	-.1970173	.4069167	-0.48	0.628	-.9945595	.6005248
_cons	11.78757	2324.967	0.01	0.996	-4545.064	4568.639
seasonal_migration						
eduhh	-1.281558	.4283273	-2.99	0.003	-2.121064	-.4420522
sex	-1.034258	.581024	-1.78	0.075	-2.173044	.1045286
acesirig	-.7300302	.4306688	-1.70	0.090	-1.574126	.1140651
acesearlywarnin	.7833531	.2846476	2.75	0.006	.2254541	1.341252
techadopt	1.740856	.2729193	6.38	0.000	1.205944	2.275768
skilupgrad	.3052643	.4006698	0.76	0.446	-.4800341	1.090563
acesremitance	.9147285	.3903726	2.34	0.019	.1496123	1.679845
acescredit	-2.153509	.345287	-6.24	0.000	-2.830259	-1.476758
acesocialmemb	4.037127	4534.147	0.00	0.999	-8882.729	8890.803
roadaces	-.6406732	.1481065	-4.33	0.000	-.9309566	-.3503898
watraces	-.9183887	.3885154	-2.36	0.018	-1.679865	-.1569126
indigknowlg	-.1916588	.4135846	-0.46	0.643	-1.00227	.6189521
locinstitsup	-.341293	.3863168	-0.88	0.377	-1.09846	.4158739
_cons	-3.954238	4534.148	-0.00	0.999	-8890.721	8882.812
livestok_sell						
eduhh	-1.616971	.4825536	-3.35	0.001	-2.562759	-.6711833
sex	-.2115151	.4284701	-0.49	0.622	-1.051301	.6282708
acesirig	1.003993	.5207817	1.93	0.054	-.0167209	2.024706
acesearlywarnin	.1263934	.2135946	0.59	0.554	-.2922443	.5450312
techadopt	.5722218	.2060585	2.78	0.005	.1683546	.976089
skilupgrad	.5237057	.3503943	1.49	0.135	-.1630546	1.210466
acesremitance	.4999747	.3310007	1.51	0.131	-.1487748	1.148724
acescredit	-.1974663	.3078539	-0.64	0.521	-.8008487	.4059162
acesocialmemb	.3861078	4561.912	0.00	1.000	-8940.797	8941.569
roadaces	-.2217225	.1166041	-1.90	0.057	-.4502624	.0068173

```
         watraces |   .2843856   .3353908     0.85   0.396    -.3729682    .9417394
      indigknowlg |  -.3300965   .3455723    -0.96   0.339    -1.007406    .3472129
     locinstitsup |  -.1125557     .33476    -0.34   0.737    -.7686732    .5435618
            _cons |  -3.329579   4561.912    -0.00   0.999    -8944.513    8937.854
------------------+----------------------------------------------------------------
rely_lessexp_food |
            eduhh |   .3193112   .2555582     1.25   0.211    -.1815737    .8201961
              sex |  -.3677441   .4877485    -0.75   0.451    -1.323714    .5882254
         acesirig |   .3517091   .4657351     0.76   0.450    -.5611149    1.264533
   acesearlywarnin |   .2446384    .258126     0.95   0.343    -.2612794    .7505561
        techadopt |   1.289758   .2272457     5.68   0.000     .8443648    1.735151
       skilupgrad |   .5412552   .3759612     1.44   0.150    -.1956152    1.278126
    acesremitance |   .8419882   .3545025     2.38   0.018     .1471761      1.5368
       acescredit |  -.0784126   .3247993    -0.24   0.809    -.7150075    .5581823
    acesocialmemb |   .3679707   4712.913     0.00   1.000    -9236.772    9237.508
         roadaces |   .1643137   .1410703     1.16   0.244    -.1121791    .4408064
         watraces |   .1531562   .3498752     0.44   0.662    -.5325866     .838899
      indigknowlg |   .1094092   .4077275     0.27   0.788    -.6897221    .9085405
     locinstitsup |   -1.03916   .3479785    -2.99   0.003    -1.721185   -.3571345
            _cons |  -8.159263   4712.913    -0.00   0.999      -9245.3    9228.981
------------------+----------------------------------------------------------------
Others            |  (base outcome)
```