Climate Change, Adaptation and Livelihood Changes in the Lake Tana Basin: Implications for Food Security and Poverty.

By

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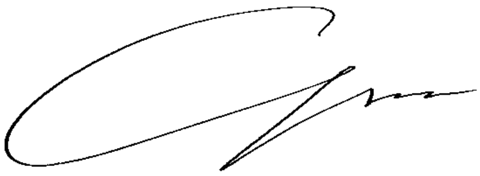
DECLARATION

Student number: 64078558

I, Naod Mekonnen Anega declare that: **Climate Change, Adaptation and Livelihood Changes in the Lake Tana Basin: Implications for Food Security and Poverty.**

is my own original work and all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.



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SUMMARY

The main objective of the thesis is to examine the effect of climate change and adaptation on livelihood pattern and the concomitant implications for poverty and food security.

The thesis uses a mixed-method research approach to address the study objectives. In this regard, the thesis applied various types of data collection techniques including household survey, focus group discussion, key informant interview, in-depth interview and participatory scenario development workshops.

The thesis reveals that there is a decline in rainfall and a rise in temperature in the Lake Tana Basin. In line with this, a time series analysis of the relationship between climate change variables and crop production showed that changes have occurred in the variables that have led to a reduction in crop production. In order to respond to this negative effects, community members have used various modern and traditional adaptation techniques.

Climate change and adaptation strategies have both brought about changes in livelihood pattern in the Lake Tana Basin. Accordingly, the study has assessed the effect of changes in livelihood pattern on food security and poverty. The result shows that the observed changes in livelihood pattern (caused by climate change and adaptation) have affected different components of poverty and food security.

And with regard to the components of livelihood assets, the thesis shows that almost all of them are under climate threat but with different levels of vulnerability.

Another finding is that the current adaptation strategies are not pro-poor. The result of a ranking exercise using local criteria shows that while afforestation, tree planning, shifting cultivation and modern irrigation ranked relatively at the top as pro-poor strategies, improved seeds and improved animal hybrids ranked lowest.

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LIST OF ACRONYMS AND ABBREVIATIONS

ARARI	Amhara Regional Agricultural Research Institute
m.a.s.l	Mean Sea level
BDU	Bahir Dar University
BoFED	Amhara National Regional State Bureau of Finance and Economic Development
BWI	Blue Nile Water Institute
CAPI	Computer Assisted Personal Interviewing
CS-PRO	Census and Survey Processing System
CGE	Computable General Equilibrium
CSA	Central Statistics Agency
CV	Coefficient of Variability
NMA	National Meteorological Agency
PFA	Potential Food Availability
SLF	Sustainable Livelihood Framework
DCGECE	Dynamic Computable General Equilibrium Model for Climate
EIWR	Ethiopian Institute of Water Resources
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GERD	Great Ethiopian Renaissance dam
GoE	Government Ethiopia
ICC	International Panel on Climate Change
KII	key Informant Interviews
LCDs	Least developing countries
LVI	Livelihood Vulnerability Index
MoARD	Ministry of Agriculture and Rural Development
NCT	Noticing, Collecting and Thinking
NCAP	National Climate Adaption Program
NMA	National Meteorological Agency
PCI	Precipitation Concentration Index
PSD	Participatory Scenario Development
SD	Standard Deviations
SLA	Sustainable Livelihood Approach
SSA	Sub Saharan African
UN	United Nations
UNISA	University of South Africa
IPCC	Intergovernmental Panel on Climate Change
IFAD	International Fund for Agricultural Development
WHO	World Health Organization
WFP	World Food Programme
UNICEF	United Nations International Children's Emergency Fund
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER 1: BACKGROUND

1.1. INTRODUCTION

Although structural changes and multifaceted development efforts in the past decades have helped to reduce poverty and improve food security conditions, there are still 696 million people who live in abject poverty globally (World Bank 2022:2). In addition, there 825 million people who suffer from hunger and malnutrition (FAO,IFAD, UNICEF, WFP & WHO 2022:8-9) . The implication is that a lot of work remains to be done to end extreme poverty and hunger in the coming decades. Moreover, without addressing these two important pillars of the global development agenda, achieving sustainable development goals is not plausible.

Climate change, among other factors, is threatening global efforts to end poverty and achieve food security. Unless proper actions are taken, climate change could make more than 100 million people fall into poverty by 2030 according to a recent estimate (Hallegatte, Fay & Barbier 2019:220). Furthermore, climate change coupled with global increase in population growth, rapid urbanization and water scarcity has already hampered the efforts to achieve the targets of sustainable development goals (United Nations 2018:3). This leads to the conclusion that climate change will continue to be one of the most pressing global challenges in the fight against poverty and food security.

Above all, climate change poses a danger for the agriculture sector which is the main and direct source of livelihood for more than 2.5 billion people who mostly live in rural areas (Ho & Shimada 2018:11). According to FAO (2021), changes in precipitation and the occurrence of droughts and floods are expected to diminish agricultural crop productivity, further exacerbating the food security and poverty conditions of millions of poor farmers (FAO 2021).

The effect of climate change on rural livelihood in general and poverty and food security in particular is more pressing in developing countries due to their climatic conditions, dependence on rain fed agriculture and their limited capacity to curb the possible negative impacts (Bandara & Cai 2014:452). For example, each Degree-Celsius increase in global mean temperature will on average reduce global yields of wheat by 6.0 percent, rice by 3.2 percent, maize by 7.4 percent, and soybean by 3.1 percent (Zhao, Liu, Piao, Wang, Lobell, Huang, Huang, Yao, Bassu, Ciais, Durand, Elliott, Ewert, Janssens, Li, Lin, Liu, Martre, Müller, Peng, Peñuelas, Ruane, Wallach, Wang, Wu, Liu, Zhu, Zhu, Z & Asseng 2017:927). This reveals that the agriculture sector which is the main source of livelihood for millions of farmers in least developing countries (LCDs) is more susceptible to the negative impacts of climate change.

In Sub Saharan Africa (SSA) where agriculture accounts for 80 percent of the economic sector and smallholders farming accounts up to 96 percent of overall crop production, climate change has become a major threat to the livelihoods and food security of millions of poor farmers. A recent study has indicated that there is a rising trend both in temperature and the sea-level which, by the end of this century, could adversely affect all forms of agricultural systems that millions of smallholder famers in the region depend on for their livelihoods (Serdeczny, Adams, Baarsch, Coumou,Robinson, Hare, Schaeffer, Perrette & Reinhardt 2017: 1590).

The case is no different for Ethiopia. Ethiopia still needs to address the issue of food insecurity and poverty in the face of climate change. A recent study indicates that food security affects nearly 45 percent of the 110 million people in the country (Mulu & Mengistie 2017: 2). In addition, the economic cost of hunger and food insecurity is estimated to be 16 percent of the Gross Domestic Product (GDP) (Mohamed 2017:89).

This clearly shows that meeting food requirements under a changing climate will remain one of the most important development challenges for the country in the years to come.

According to (Ethiopian National Meteorological Agency 2019), there will be temperature increases in Ethiopia in the range of 1.7 – 2.1^{0}C and 2.7 – 3.4^{0}C by 2050 and 2080 respectively. Thus, as is the case in other Sub Saharan African (SSA) countries, climate change will continue to threaten the economic growth of the nation in general and rural livelihoods in particular. In fact, the present day reality shows increasing temperatures and rainfall variability are already adversely affecting the agriculture sector in different parts of Ethiopia (Tirfi & Oyekale 2022:542 ;Taye 2021:2)).

A time series analysis of agricultural production and climate variables in Ethiopia indicates that the country's agricultural production is very sensitive to climate change and a slight deviation in climate parameters worsens food security conditions for millions of farmers (Abebe 2017:372). Moreover, recent estimate shows that the mean maximum and minimum temperature is expected to increase by 2.2 -2.7 and 1.4-1.7^{0}C in 2050, respectively (Taye 2021:2).

The situation is expected to exacerbate even more if proper measures are not taken (Zenebe, Jesper, Alemu & Atlaw 2014:31). In addition, studies indicate that Ethiopia has experienced droughts and food insecurity in the years of 1985, 1988, 1995, 1997 and recently in 2019 induced by rainfall variability (Taye 2021:5). Thus, the issue of climate change should be a top policy priority for the country.

In this respect, the Government of Ethiopia (GoE) has been undertaking various policy measures in response to climate change. The development objectives of the government show the commitment of the GoE to build a climate resilient economy and reduce poverty. For example, Ethiopia has designed and implemented the National Climate Adaption Program (NCAP) and the Green Economic Development Plan to make the agriculture sector and rural areas more resilient to climate change through sustainable farming. However, despite the efforts made, there exists only little evidence of success (Mekonnen, Tessema, Ganewo & Haile 2021:2).

1.2. STATEMENT OF THE PROBLEM

The Lake Tana Basin functions as an important source of livelihood in the Blue Nile Basin system that supports various socio-economic activities including but not limited to agriculture, fishery and livestock (Addisu,Yihenew, Getachew & Birhanu 2015 :4).

Against this background, the growth and transformation plan of Ethiopia (GTP) has designated the Lake Tana Basin as one of the development hot spots in the country (Goshu & Aynalem 2017:12). As a result, there have been various development activities in the basin including large scale agricultural intensification and mega energy development projects (Karlberg, Hoff, Amsalu, Andersson, Binnington, Karlberg, L.; Hoff, H. Amsalu, T. Andersson, K.; Binnington, T.Flores-López, F. de Bruin, A. Gebrehiwot, S.G. Gedif, B. zur Heide, F.Johnson, O. Osbeck, M. & Young 2015: 720).

However, studies indicate that this important basin is experiencing climate change which could threaten the present and future livelihoods of millions of farmers who mainly rely on the immediate ecosystem services of the basin to sustain life. It has been observed that temperature is generally in an increasing trend while rainfall is generally in a decreasing trend which could cause decline in water yield, crop production and livestock based activities (Addisu et al 2015 :4). Furthermore, research shows that the total water yield of the Lake Tana Basin declined by 6.5 percent due to climate change (Taye 2021:7). Another recent study by (Solomon, Adesola & Rao 2016:7) reveals that the Lake Tana Basin is highly susceptible to climate change induced shocks. Besides the challenges posed by climate change, the basin is faced with myriads others including but not limited to rapid population growth, land degradation, forest resource destruction, energy shortage and ecological damage (Goshu & Aynalem 2017:15).

On top of this, there exist at least three main competing interests over the use of resources: 1) the national government of Ethiopia has started constructing mega hydropower dams (including the Grand Ethiopian Renaissance Dam (GERD), 2) the regional government is conducting mega projects such as expanding recreational sites and constructing large scale irrigation, and 3) farmers depend on rivers in the basin for micro irrigation and fishing (Addisu, Fishsha, Gediff and Asemelash 2019:2).

There are a few studies that have attempted to study the relationship between climate change and adaptation and their impact on livelihood outcomes such as poverty and food security (Bandara & Cai 2017; Dube 2013; Deressa, Hassan & Poonyth 2005; Muluneh 2021; Makondo, Chola & Moonga 2014:394; Rahman, Toiba & Huang 2021; Urama Eboh & Onyekuru 2017). The finding from these studies imply that climate change generally reduces food production at smallholder's level and affects the poor. However, there are at least four major gaps in the existing literature.

These are:

1) Studies did not examine the implications of changes in livelihood pattern (change in different forms of assets because of climate change and adaptation) for poverty and food security. Consequently, studies so far have directly estimated the effect of climate change and adaptation on livelihood outcomes (poverty and food security) using statistical models (Biftu 2020; Rahel, Belay & Zaitchik;2021; Li, Sun & Mohiuddin 2022; Mekonnen, Tessema, Ganewo & Haile 2021; Sam, Abidoye & Mashaba 2020; Tadesse & Alemayehu 2019). Moreover, these recent empirical works also did not examine the impact of changes in livelihood pattern (caused by climate change and adaptation) on poverty and food security. The use of such models did not show the complex process in which climate change could affect poverty and food security. This thesis, however, follows a different approach by first examining changes in livelihood pattern (caused by

climate change and adaptation) and then exploring the implications of these changes for poverty and food security. The theoretical argument is climate change and adaptation would first bring changes in livelihood pattern before the effect is observed on livelihood outcomes such as poverty and food security. Thus, rather than a statistical estimation of the effect of climate change on poverty and food security, the thesis is interested in looking at the process and transmission channels (livelihood pattern change) through which climate change impacts livelihood outcomes (mainly poverty and food security).

2) The focus of climate change impact and adaptation studies has been on crop yields and crop production to the neglect of the other dimensions of poverty and food security indicators (Campbell, Vermeulen, Aggarwal, Corner-Dolloff, Girvetz, Loboguerrero, Ramirez-Villegas, Rosenstock, Sebastian, Thornton & Wollenberg 2016:34). Yet, climate change will have impacts on all dimensions of food security namely: availability, access, utilisation and stability, and can have impacts over the whole food system. Consequently, the impact of climate change adaptation on the dimensions of poverty (asset and consumption) and food security needs more investigation.

3) Significant portion of the existing literature on climate change and adaptation follows a non-livelihood approach and mainly focuses on one component of rural livelihood i.e. agriculture (Abdelaziz 2017; Ginbo 2022; Menhas, Umber & Shabbir 2016; Rojas-Downing, Nejadhashemi, Harrigan & Woznicki 2017; Urama, Eboh & Onyekuru 2017). And those that used the livelihood approach or framework did not apply the concept of livelihood pattern change in the analysis of climate change impact (Ali, Ghosh, Osmani, Hossain & Fogarassy 2021:5) Ateeq-ur-rehman et al., 2018; Piya, Maharjan and Joshi, 2019; Sheikh & Akter 2017). But even though agriculture could be the dominant source of livelihood, rural livelihood usually consists of different agricultural and non-agricultural strategies that

a typical rural household relies on to sustain life (Ali et al 2021; Ateeq-ur-rehman Siddiqui, Hashmi, Masud, Adeel, Muhammad, Khawaja, Syed, Karim 2018; Piya, Maharjan & Joshi 2019; Sheikh & Akter 2017). Thus, previous studies only tell part of the story by concentrating on the impact of climate change adaptation. However, the impact of climate change on rural livelihoods differ according to the ecology and the livelihood strategies (Dube 2013: 12). Therefore, the argument in this regard is that studies need to look deeper into the impact of climate change and adaptation within a livelihood context or framework.

4) Studies did not document well the pro-poorness of climate change adaptation strategies. The poor are the hardest hit group of society by climate change due to their reliance on subsistence farming and weak adaptive capacity (Li Sun,Li & Mohiuddin 2022:1; Lankes, Soubeyran and Stern 2022). As such, many efforts have been made (through designing climate change policies and programs) by international, national, regional and local governments to help farmers in the fight against climate change (Fawzy, Osman Doran & Rooney, 2020:2071). Nonetheless, there is little evidence to support whether climate change adaptation strategies are helping the poor in the fight against the negative impacts of climate change (Fischer 2020:689).

In order to fill the aforementioned research gaps, this study 1) examined the implications of changes in livelihood pattern (changes in different forms of assets because of climate change and adaptation) for poverty and food security, 2) assessed the implications of changes in livelihood pattern (change in different form of livelihood strategies because of either climate change or adaptation) for poverty and food security, 3) delves into the implications of climate change and adaptation for dimensions of poverty and food security, and 4) Investigated whether climate change adaptation strategies are pro-poor nor not.

To this end, the problem to be researched in this thesis has two aspects: 1) the Lake Tana Basin livelihood is under severe threat because of climate change, and 2) the gap in the existing literature needs to be filled in terms of explanations about the implications of change in livelihood pattern (due to climate change and adaptation) for dimensions of poverty and food security.

1.3. OBJECTIVES OF THE STUDY

1.3.1. General objective

The general objective of the study is to contribute the design for effective climate change policies that work for the poor in terms of fighting food insecurity and poverty.

The specific objectives of the study are:

1. Analyse the trend and relationship between climate change variables (temperature and rainfall pattern) and crop production in the Lake Tana Basin
2. Investigate how climate change and adaptation are changing livelihood pattern in the Lake Tana Basin
3. Analyse the level of livelihood vulnerability in the Lake Tana Basin
4. Investigate the implications of livelihood pattern change (caused by climate change and adaptation) for poverty and food security
5. Examine whether climate change adaptation strategies are pro-poor or not

1.4 RESEARCH QUESTIONS

1. Did the trend in climate change variables (temperature and rainfall) and crop production changed over the past 30 years?
2. Do climate change and adaptation alter livelihood pattern in the Lake Tana Basin?
3. What is the level of livelihood vulnerability in the Lake Tana Basin?

4. What are the implications of livelihood pattern changes (caused by climate change and adaptation) for poverty and food security?
5. Are climate change adaption strategies pro-poor?

1.5 SCOPE OF THE STUDY

Thematically, this study assesses the impact of climate change and adaptation on livelihood outcomes. Geographically, the study covers the immediate surroundings of the Lake Tana Basin (upper and lower basins). This basin was selected because it functions as an important source of livelihood for millions of farmers in the Nile basin food system.

1.6. SIGNIFICANCE OF THE STUDY

Climate change is one of the most pressing challenges for the majority of developing nations due to its serious repercussion on the livelihood of millions of poor farmers today and in the years to come. Currently climate change has become an undeniable scientific fact and policymakers, researchers and scientists are working to curb further damage on the environment and human beings. In this regard, the contribution of the thesis can be looked at from theoretical, empirical, academic and policy making perspectives.

This study aims to evaluate and examine how livelihood pattern is transforming because of climate change and adaptation and what this could mean for poverty and food security. Various studies have examined the effect of climate change on poverty and food security without first looking at changes in livelihood pattern (section 1.7 and chapter 2). The aim is to explain how climate change and adaptation alter livelihood pattern and then to look at the associated implications of this change in livelihood pattern for poverty and food security in order to provide an important theoretical contribution to climate change studies.

The study will also help policymakers to work on critical areas of the impact of climate change because On the other hand, appropriate policies and strategies are required to address the challenges of rural livelihoods in a changing climatic condition. Therefore, understanding the relationship between the phenomenon and rural livelihood pattern is of great importance for the formulation of effective climate policy to respond to the negative impact of climate change. In this endeavour, the study will help policy makers to work on critical areas of impacts of climate change.

In addition, the study makes a unique contribution to assessing the pro-poorness of climate adaptation strategies which. Assessing the pro-poorness of climate adaptation strategies is very important as the poor are at the centre of the development agenda. In this regard, the study identifies approaches and ways in which climate adaptation strategies can best work for the poor.

The other significance of the study comes from its in-depth coverage of the impact of climate change and adaptation strategies on the dimensions of food security and poverty (section 1.2 and chapter eight). This study helps policy makers to acquire a substantial understanding of the impact of climate change on poverty and food security which are the two important pillars of sustainable development goals. It also provides the required knowledge and evidence that may inspire policies, strategies and programs aimed at improving the poverty and food security conditions of farmers.

1.7. LIMITATION OF THE STUDY

The study follows the cross-sectional research design approach that makes it difficult to quantify and statistically measure effects related to time that are caused by climate change and adaptation on key livelihood outcomes such as poverty and food security. Moreover, due to the cross-sectional nature of the data, the time series data could not be linked or correlated with some of the major livelihood assets. Therefore, more emphasis was given to the experience, observation and perception of community members in the study area than statistical control methods. Second, since the thesis applied a cross-sectional research design, it did not apply the dynamic livelihoods approach to study the impact and implication of climate change and adaptation overtime.

1.8. ETHICAL CLEARANCE

Ethical clearance was obtained from University of South Africa (UNISA) on 11 February 2020 and the last functional date of the ethical clearance is 11 February 2023. The UNISA ethical clearance committee has approved the low risk nature of the study and the ethical clearance form approved by UNISA ethical clearance committee. The low risk category approved for the reason that the study because it involves only the exploration of the perception, knowledge and experience of members of the community with regard to the impact of climate change and adaptation in the Lake Tana Basin. Participants are asked to allocate only their time for the purpose of the study. As such there is no possibility of the participants being vulnerable to physical, psychological or social risks.

1.8.1 Ethical consideration

The researcher prepared a consent form using the standard set by UNISA. The researcher then translated the consent form into a local language (Amharic) for each of the study tools. Once the study started, the data collectors and the researcher briefly explained to the study participants what the objectives of the study are and that collected data shall be used for academic purpose only. After this explanation, the participants were given the prepared consent form which they signed (appendix A). However, for those who cannot read and write the researcher or the data collectors read the consent form aloud.

1.8.2 De-identification data to protect participants' privacy during further processing

For the household interviews, codes were prepared to identify each participant, thereby removing or modifying personal identifiers such as a person's name and address. The following two approaches were used to de-identify data and protect participants' privacy during further processing: 1) applying data modification or data reduction techniques: this includes for example, rounding – combining information that is likely to enable identification of an individual into categories, and 2) applying controls and safeguards in the data access environment (locking using passwords) and limiting access to information.

1.9 OUTLINE OF THESIS CHAPTERS

Chapter 1 introduces the reader to the background of the thesis and the problem to be researched. Moreover, this chapter presents the scope, limitations, objectives, research questions, significance and ethical clearance of the thesis.

Chapter 2 presents the theoretical and empirical reviews of the thesis. In the theoretical review, the focus is on understanding the complex relationship between climate change, poverty and food security. The empirical review presents evidence about their relationship and shows that gaps exist in the approaches of other climate change studies. The impact of climate change on livelihood pattern and the associated implications for poverty and food security are largely missing from the empirical literature. Moreover, most studies focus only on one dimension of food security (food production) and poverty (income), lacking a comprehensive analysis of the impact of climate change.

But the study at hand has selected and modified the Sustainable Livelihood Framework as a conceptual guide for the thesis to properly explore the chosen topic.

Chapter 3 discusses the research methodology of the thesis. The adopted methodology uses a mixed approach that is both qualitative and quantitative to address the objectives of the thesis. The qualitative approach helps to understand how communities are experiencing climate change and its resultant effect on dimensions of poverty and food security, which is one of the gaps mentioned in the problem statement. In parallel, the thesis used quantitative approach to measure the perception and extent of impact of climate change adaptation on some dimensions of food security and poverty (livelihood outcomes). Furthermore, the study used both primary and secondary data to address the key research questions. While the secondary data is used to provide scientific evidence for the existence of climate change in the study area, the primary data is used to assess the experience of the community. This allowed triangulation of data coming from different sources.

Chapter 4 provides the administrative, socio- economic, socio-cultural, climate and natural profiles of the Lake Tana Basin. The chapter shows that the basin serves as an important source of livelihood for millions of famers by providing social, cultural and economic services. This is important for understanding the bases of livelihood in the basin and later for examining the impact of climate change and adaptation on key livelihood outcomes (poverty and food security conditions) of the basin.

Chapter 5 presents time series analysis of the trend in climate change variables (rainfall and temperature) using secondary data from the National Meteorology Agency. It also presents the relationship between climate change and food production in the basin. This provides important empirical evidence for the anticipated change in climate variables such as rainfall and temperature, which has implications for poverty and food security.

Chapter 6 discusses and analyses the socio-economic profile and typologies of livelihood of the study participants through the household survey. The result shows that crop and livestock productions are the main livelihood strategies in the basin. The identification of livelihood strategies helped to analyse how climate change is impacting and transforming these livelihood strategies.

Chapter 7 analyses the impact of climate change and adaptation on the livelihood of the Lake Tana Basin system. The chapter deals with how climate change and adaptation are changing livelihood pattern (asset and livelihood strategies) in the basin. This is the main concern of the problem statement.

The chapter shows that climate change and adaptation have altered livelihood strategies in the basin. The chapter presents evidence for the impact of climate change and the appearance of new livelihood strategies. The livelihood vulnerability analysis shows that assets (natural, social, human and physical) are vulnerable to climate change. In addition, the study examines farmers' choice of climate adaptation strategies and the pro-poorness of climate adaptation strategies. According to the local criteria developed by the community members, climate adaptation strategies are not pro-poor due to cost, availability, access difficulty, barriers when applying for, requirement of high technical skills and lack of credit schemes.

Chapter 8 examines the mechanisms through which climate change and adaptation affect the dimensions of poverty and food security in the Lake Tana Basin. The study shows that climate change and adaptation have affected dimensions of poverty and food security through their assets and livelihood strategies but not all dimensions have been impacted equally.

Chapter 9 provides conclusions and recommendations for each of the objectives mentioned in the thesis. The major findings of the thesis are: 1) climate change has affected livelihood pattern (altered livelihood assets/capital and strategies), 2) the key channels through which climate change and adaptation affect poverty and food security are changes in livelihood pattern, and 3) changes in livelihood pattern have implications for poverty and food security.

The appendices contain information concerning consent form (appendix A), participant information sheet (appendix B), study tools (appendix C), ethical clearance certificate (appendix D), certificate of translation (a Investigate whether climate change adaptation strategies are pro-poor nor not (appendix E), study tool (appendix F), time sheet used during the PSD**Error! Bookmark not defined.** (appendix G), Leopold matrix to identify the effect of climate change on livelihood (appendix H). Specifically, appendix F contains part of the translation of the study tool into Amharic. However, due to the length of the page (150 pages), the translated text is not included in the thesis. But it can be accessed from the researcher by email.

CHAPTER 2: THEORETICAL AND EMPIRICAL LITERATURE REVIEW

2.1 INTRODUCTION

As presented in chapter 1, the thesis would like to explain how livelihood pattern is changing in the Lake Tana Basin (as a result of climate change and adaptation) and the implications of this change for poverty and food security. This requires a theoretical and empirical understanding of the relationship among climate change, poverty and food security. At the outset, this chapter puts the whole thesis into a theoretical perspective by reviewing and incorporating the concepts, ideas, arguments and discussions that are related to climate change, livelihoods, food security and poverty.

The theoretical review (next section) defines climate change, poverty and food security and explains how these concepts have evolved over time. Moreover, it shows the underline relationship between climate change, poverty and food security. This helped to put the thesis into a theoretical perspective. For example, defining and conceptualizing climate change as a development issue makes the thesis to follow the human centred approach. The conceptualizing climate change as a development issue requires the thesis to follow a human-centred approach for three reasons. These are:

1) The thesis adopted the sustainable livelihood framework (SLF), which aims at understanding the way in which people develop and maintain their overall livelihoods (section 2.4, 2.5 and 2.6). Moreover, the SLF enable to examine how different shocks such as climate change related shocks affects livelihood and livelihood such as such as poverty and food security.

2) From methodological point of view, understanding development would require a human centred approach as it focuses on people's interpretation, experience and understanding of the issue under investigation such as climate change, food security and poverty (Chapter 3). In fact, the definitions of poverty

go beyond mere increase in income to encompass various aspects such as entitlement and capability.

3) The thesis goes beyond unidimensional analysis (only on income and food production) of the impact of climate change and adaptation on poverty and food security. Therefore, the thesis looks in to the different dimensions of the impact of climate change on poverty and food security, which includes (asset, consumption, food access and utilization) (Chapter 8 and chapter 2).

The chapter also explained the relationship between climate change and livelihood assets in the livelihood framework. This includes the physical, social, natural, financial and human capitals. The link between climate change and these key components of livelihood gives an important basis to answer some important research questions. For example, what is the implications of change in livelihood pattern (change in asset due to climate change) for different dimensions of poverty (asset, income and expenditure) and food security (food availability, food access, and food utilization)? Furthermore, the chapter discusses the relationship between climate change and the dimensions of poverty as well as that between the former and the dimensions of food security.

The chapter then presents the empirical review of on the relationship between climate change, poverty and food security. Specifically, the impact of climate change on poverty and food security is discussed. In the chapter, empirical researches on the impact of climate change on poverty and food security from different regions of the world are presented.

Finally, the chapter discusses the Sustainable Livelihood Framework as a guiding conceptual framework of the thesis. Here the thesis identifies the gap in this framework when applied to a climate change related study.

2.2 THEORETICAL REVIEW

In this section, the relationship between climate change, livelihood and livelihood outcomes (poverty and food security) is discussed from a theoretical perspective.

2.2.1 Definitions and concepts

2.2.1.1. Definitions of climate change

Studies on climate change have given various definitions to the climate change phenomenon. International Panel on Climate Change (IPCC) defines climate change as the change in climate variables such as temperature, precipitation and rainfall patterns due to natural factors or processes (IPCC 2012). In line with this definition, Seneviratne, Nicholls, Easterling Seneviratne, Nicholls, Easterling, Goodess, Kanae, Kossin, Luo, Marengo, McInnes, Rahimi, Reichstein, Sorteberg, Vera & Zhang (2012) define climate change as follows:

"A gradual change in temperature and changes in the frequency, extent and severity of climate and weather extremes, explained as a persistent change in the mean and variability of climate variables such as temperature, precipitation, rainfall, humidity and soil moisture".

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as:

*"A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". (*UNFCCC 2005).

This two definitions tend to consider climate change as long term changes in the statistical distribution of key weather variables and indicators like temperature, weather and precipitation (Rahman 2013:3), implying only the scientific aspect of climate change.

In the past fifteen years, there has been a paradigm shift from defining climate change only as a scientific fact to considering it as a development problem (Rahman 2013: 6). By implication, the focus in the beginning was on the scientific explanation of the causes of climate change and its impact. However, recent studies on climate change have shown that climate change is also a development problem. Here climate change is perceived as "*the main cause of the problem of 'underdevelopment' which results in hunger, food insecurity, poverty and physical disaster*". (Hallegatte, Fay & Barbier 2019:231).

In this thesis, climate change is considered as a development problem or agenda, not just a scientific fact. Thus, the thesis goes beyond the physical dimensions of the impact of climate change to incorporate the socio-economic aspects.

2.2.1.1.1. Measuring climate change impact

There are two major approaches to study the impact of climate change on rural livelihoods in general and agricultural production and productivity in particular. The most common approaches are: 1) statistical methods or simply model-based exploration (based on experimental and simulations analysis) (Mendelsohn 2005), and 2) qualitative method where the impact depends on observed changes by members of a community or personal experiences of members of households, for example through creating qualitative social scenarios (Res, Shackley & Deanwood 2003:74).

In the case of pure empirical analysis, the impact of climate change would yield known results where it affects agricultural livelihood in general and agricultural production and productivity in particular. In this regard, many studies have revealed that climate change hampers agricultural production and productivity (Bandara & Cai 2017:455; Deressa, Hassan and Poonyth, 2005; Makondo, Chola & Moonga 2014:340; Olabanj,Ndarana & Davis 2021:3; Thomas, Dorosh, & Robertson, 2019; Wei, Todd, Solveig & Solveig 2014:138). However, this approach fails to show how individuals are affected by climate change. But studies that uses personal experiences as well as perceptions of households or community members allows the systematic examination of community reported observations of climate change and its effect on various socio-economic factors (Maharjan & Maharjan 2018:95-96).

In this thesis, the qualitative approach is applied to evaluate the effect of climate change and adaptation on livelihood pattern and the implications of this effect for poverty and food security. This approach is selected because climate and livelihood represent a complex interaction (process) of various socio-economic activities which will be difficult to quantify using statistical models only. Moreover, the qualitative approach also tells a clearer the story of the changes in livelihood (due to climate change and adaptation) and the implications of these changes for poverty and food security.

2.2.1.2. Definitions of climate change adaptation

There are different ways of defining climate change adaptation based on the type of sector under consideration i.e. whether it is in the natural system or human system. Some of the key definitions are provided in the following paragraphs:

"The process of adjustment to actual or expected climate and its effects where in human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities".(IPCC 2014).

"The process of adjusting to new conditions, stresses and natural hazards that result from climate change and adaptation to climate change takes place in response to impacts experienced already as well as in anticipation of expected impact" (Schipper ,Krawanchid & Chanthy 2010).

"Adjustment in agricultural practices (modern and traditional) and processes in response to the possible negative impact of climate change on the agriculture sector of the economy". (Tarleton & Ramsey 2008:50).

“All changes an individual makes in order to adjust to a changing environment and climate” (Osberghaus, Elyssa & Pohl 2010: 2).

The above definitions show that adaptation to climate change is linked to changes in livelihood and these changes in livelihood could be expressed in terms of adjustment to new ways of life, adjustment in agricultural practices or any actions that individuals take to respond to the impact of climate change.

In this thesis, the definition by (Osberghaus, Finkel & Pohl 2010: 2) is used. Thus, the thesis will consider climate change adaptation as a change an individual makes in order to adjust to the possible negative impacts of climate change. Consequently, any self-initiated adjustment or change in the lifestyle of community members in response to climate change (whether it is an agricultural or non-agricultural practice) is considered as an adaptation strategy. In this regard, the focus will be on autonomous or private adaptation (Weldegebriel & Martin 2013:2).

Autonomous or private adaptation strategies can be measured by simply asking farmers whether or not they have applied or used adaptation strategies (Ho & Shimada 2018:17). Moreover, in this thesis, adopters are defined as those who have been using one or more agricultural practices for at least three years. The argument is that adaptation is not a one-time activity or action but rather something that requires continued effort and commitment.

2.2.1.3. The concept of food security

Early works on food security and poverty considered food security as only food availability (supply of food) that is related to food production alone (Hart 2009:371). By implication, food security measured by the level of food production by each respective household. However, there has been a major shift in the definition of food security after Sen’s introduction of the concept of entitlement in which he argues that food security is the ability of households to access food over time (Burchi & Muro 2016:10). The immediate implication is that food security goes beyond the physical supply of food and is associated with entitlement. The definition of food security provided by FAO is stated as follows:

“Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”. (FAO 1996).

As presented in figure 2.1, Opara (2013:327) has identified four dimensions of food security: 1) adequacy or availability of food, 2) stability, 3) accessibility to food and 4) utilization of food.

These four dimensions of food security are further explained as follows:

Food availability: the presence of adequate quantities of food at the household level as represented by production or productivity (Nicholson, Stephens, Kopainsky, Thornton, Jones, Parsons, Garrett 2021:2). This has been captured in the thesis by assessing how climate change and adaptation bring about change in crop production.

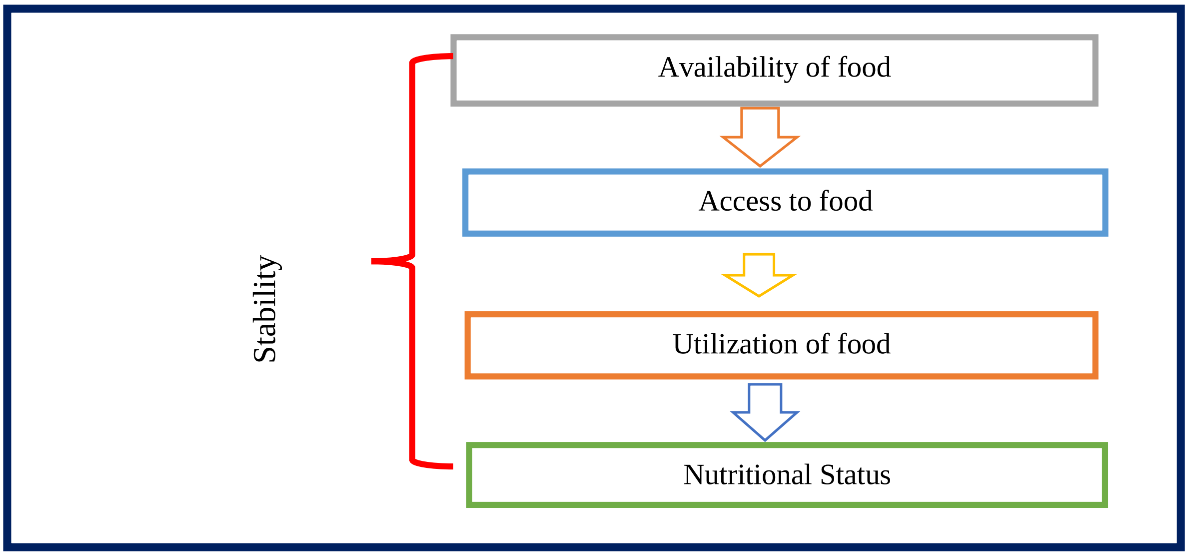
Food access: food access goes beyond food availability to consider procedures and institutions that manage distribution of available food (Andrew 2017:86). By implication, food access refers to the right to access adequate resources (entitlements) for obtaining food. In this thesis, this has been captured by assessing how climate change and adaptation alter the process of obtaining food in the geographical area being studied.

Utilization: consumption of food through adequate dietary sources (Nicholson et al 2021 :2). In this thesis, this has been captured by assessing how climate change and adaptation affect the dietary diversity of food consumption in the geographical area being studied.

Stability: the stability dimension of food security refers to the stability of the above three dimensions (availability, access and utilization) at all times including periods of extreme weather (Pangaribowo et al 2013). However due to the cross-sectional nature of the study, this component has not been captured in the thesis.

As presented in the thesis statement section, one of the gaps in the literature is lack of assessment of the multidimensional impact of climate change on food security.

Figure 2.1: Food security and nutrition



Source: Own (Aberman and Tirado, 2014)

2.2.1.4. The concepts and measures of poverty

There are various definitions of poverty depending on the school of thought and subject matter. For example, from economic sciences perspective, poverty is mainly defined as lack of income (Botchway 2013:86). Thus, the poor are those who do not have enough income to satisfy their basic needs.

However, from sociological perspective, poverty is linked to breakdowns in social, cultural and political structures of a society (Shildrick & Rucell 2015).

The concept of poverty has evolved over time. As such, recent works in the development literature adopt a broader definition to poverty. This broadest approach to poverty is the one articulated by Amartya Sen (1987) who argues that wellbeing comes from the capability to function in society. In this context, (Haughton & Khandker:2009) defines poverty as follows:

"Poverty arises when people lack key capabilities, and so have inadequate income or education, or poor health, or insecurity, or low self-confidence, or a sense of powerlessness, or the absence of rights such as freedom of speech".

The above definition of poverty paved the way for the development literature to go beyond a single dimension (mainly income based) definition of poverty and define poverty as a multidimensional phenomenon.

Moving on from the definition of poverty to how its measured, one categorization divides poverty measurements into subjective and objective methods. The subjective methods rely on experiences and opinions of individuals or community members (Jones &Tvedten 2019:158; Pradban & Ravallion:1998). These methods are important since what one understands by 'poverty' varies considerably based on locality and time period.

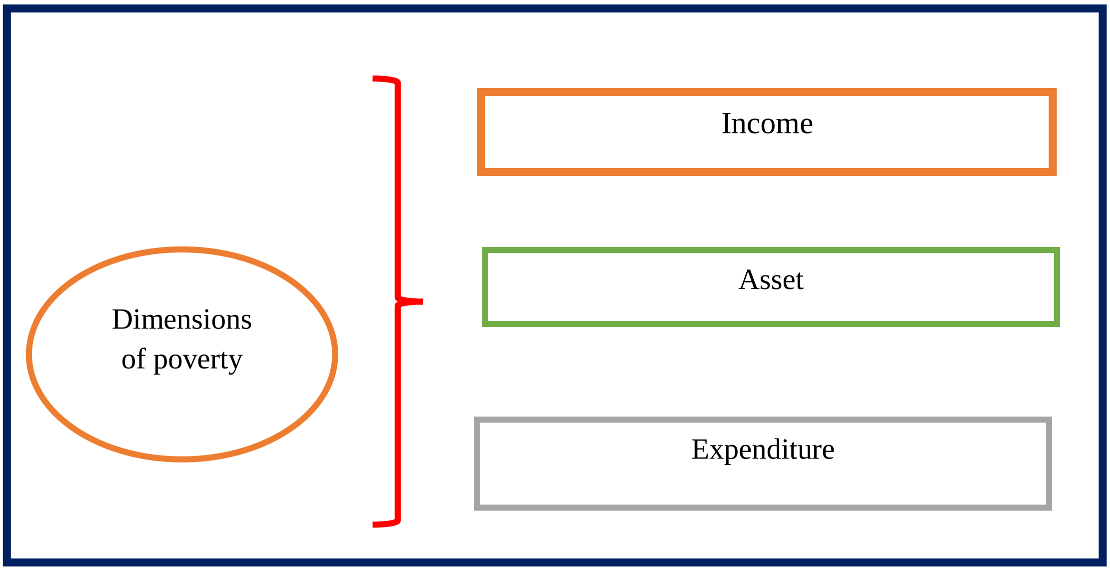
As to objective measurement methods, there are several approaches. As presented in figure 2.2, these include income, asset and consumption based measurements (Hjelm, Mathiassen & Wadhwa 2016:276-277). In the income and consumption approach, poverty is measured using the minimum income level required to meet basic needs or simply using the household per capita income (Waheed 2012:26) whereas the consumption approach uses the aggregate monetary value of household food consumption and non-food expenditure (Hjelm, Mathiassen & Wadhwa 2016:276). However, there are two major critiques of using the income and consumption approach as a measure of welfare or poverty. First, the income and consumption approach will not consider other important dimensions of poverty (as it does not indicate people's level of deprivation) and it cannot capture the individual experience and perceptions of wellbeing either (Greeley 1994:55). Robert Chambers agrees with this statement in his theoretical explanation of the deprivation trap. Chambers argues that the concept of poverty goes beyond quantitative measures such as income and expenditure which are important and common among development professionals but he stresses the need to include the analysis and views of the poor themselves about what poverty means to them (Ludi & Bird 2007).

Another way to measure poverty is through the use of number of assets owned by the households under study as proxy measure of poverty (Touray 2016).This approach is important when it comes to consideration of structural poverty which is a form of poverty that can pass from one generation to the next (Hjelm, Mathiassen & Wadhwa 2016:277).

In this thesis, the subjective poverty measurement method is used. This method is chosen because it provides a detailed account of how change in livelihood pattern (as a result of climate change and adaptation) affects livelihood outcomes such as poverty and food security.

However, to understand the disaggregated impact of climate change and adaptation on different dimensions of poverty, the concepts of income, asset and consumption are used in their qualitative forms. Hence, it is based on the perception and experience of the households which is self-reported than a statistically calculated values.

Figure 2.2: The three dimensions of poverty



Source: Own depiction

Livelihood outcomes: using the Sustainable Livelihood Framework as a conceptual foundation of this thesis, livelihood outcomes in the context of this study refer to poverty and food security. Thus, the study examines the implications of livelihood pattern change (as a result of climate change and adaptation) on these key livelihood outcomes (see section 2.5 and 2.6).

2.2.1.5. The concepts of livelihood and livelihood pattern change

As defined by Ellis (2000:290), the key concept of livelihood consists of the various assets (natural, physical, human, financial and social capital) and the access to these through socially or institutionally constructed channels that together determine the living conditions of the household and or individuals.

Natural capital: refers to various types of natural resources (e.g. land , water, and forests) that can be used by communities or households to secure their livelihood target (Sharifi & Nooripoor 2017:138). Natural capital can be measured using different proxy variables such as land size, access to water, access to forests or trees, number of oxen and soil fertility (Goh 2012).

Physical capital: refers to various basic economic and social infrastructures (for example: roads, machinery, water channels and hospitals) that communities and households use to facilitates livelihood activities (Sharifi & Nooripoor 2017:138). In line with this, physical capital can be measured using indicators such as distance to market, equipment, consumer durables, vehicles and transportation, water supply and sanitation facilities (Nawrotzki, Hunter & Dickinson 2014:3).

Human capital: refers to the demographic characteristics of households and individuals (for example: education, dependency ration, skills, knowledge, health, nutrition and labour) (Sharifi & Nooripoor 2017:138).

Financial capital: refers to the availability of endowments that are important to improve livelihood conditions (Sharifi & Nooripoor 2017:138).

Social capital: refers to the various social networks (e.g. membership in cooperatives, local associations and social networks) that are available for the community or households to pursue a decent life (Nawrotzki, Hunter & Dickinson 2014:3). Social capital is an important means of livelihood for rural communities of developing nations as it can fulfil both the economic and non-economic needs of communities (Vermaak 2006). The same author argues that there is much emphasis on the economic role of social capital to the neglect of its non-economic roles which are in fact key for rural communities in developing nations. As such, he argues that social capital should go beyond economic need.

In this thesis, the above definitions and concepts of capital/asset are used to understand the impact of climate change on livelihood and measure the vulnerability of livelihood to climate change in the Lake Tana Basin.

Livelihood pattern change: Livelihood pattern change is rarely mentioned in the literature. However, those that refer to it seem to associate the concept with livelihood diversification (Adzawla & Kane 2018; Asravor 2017: 1336; Makate, Wang, Makate, & Mango 2016:6; Mango, Makate, Mapemba, & Sopo 2018:2; Kassie, Kim & Fellizarjr 2017:5). More recently, for example, (Rulu & Rahu 2022 :33) refer to the term as switching away from traditional agricultural practices toward modern livelihood strategies. Nonetheless, in this particular thesis, the concept of livelihood pattern change is expanded to incorporate changes in any of the five components of livelihoods assets (natural, physical, human, financial or social capital) and livelihoods strategies. The assumption in this thesis is that in climate change and adaptation setting, both livelihood assets and strategies could be altered.

2.2.1.6. The definitions of vulnerability

The concept of vulnerability has different meaning in different disciplines in the academic literature. For example, disaster and risk management science mainly relate the concept of vulnerability to natural hazards (Agidew, Meta & Singh 2018:9) whereas ecological science associates vulnerability to environmental change (Teshome 2016:5). Economic and welfare science for its part associates the concept to long term impact on the welfare of rural communities (Smdlkn, Riederer and Foster 2009:31).

Several studies have adopted the concept of vulnerability based on the works of Roberts Chamber. Chamber (1993) argues that, *"Vulnerability is a lack of buffers against contingencies such as disasters and incapacity*" (Chamber 1983:103). This concept of vulnerability goes beyond explaining the idea in terms of only physical, social, and economic aspects. Thus, in this thesis, the concept of vulnerability provided by Chambers is adopted to contextualize the concept as the lack of capacity of rural communities to cope with and respond to climate change shocks.

2.2.2 Shift in climate change paradigms

When the paradigm of climate change shifts in terms of theorization, conceptualization and understanding, so does the focus of the associated impacts of the phenomenon. Thus, such a paradigm change has been accompanied by a shift in the views held about the impact of climate change which in turn has changed the direction of research and policy discussions on the topic.

According to Rahman (2013:11), there were at least three major shifts in climate change paradigm over the period1824 – 2012: 1) during the first paradigm(1824 – 1970), climate change was treated as only a scientific fact among researchers and policymakers, 2) during the second paradigm(1970 – 1990/2000), climate change was associated with “eco-centric” views and 3) during the third paradigm (1990/2000-2012), the focus of research shifted from “eco-centric” views to “anthropocentric” views.

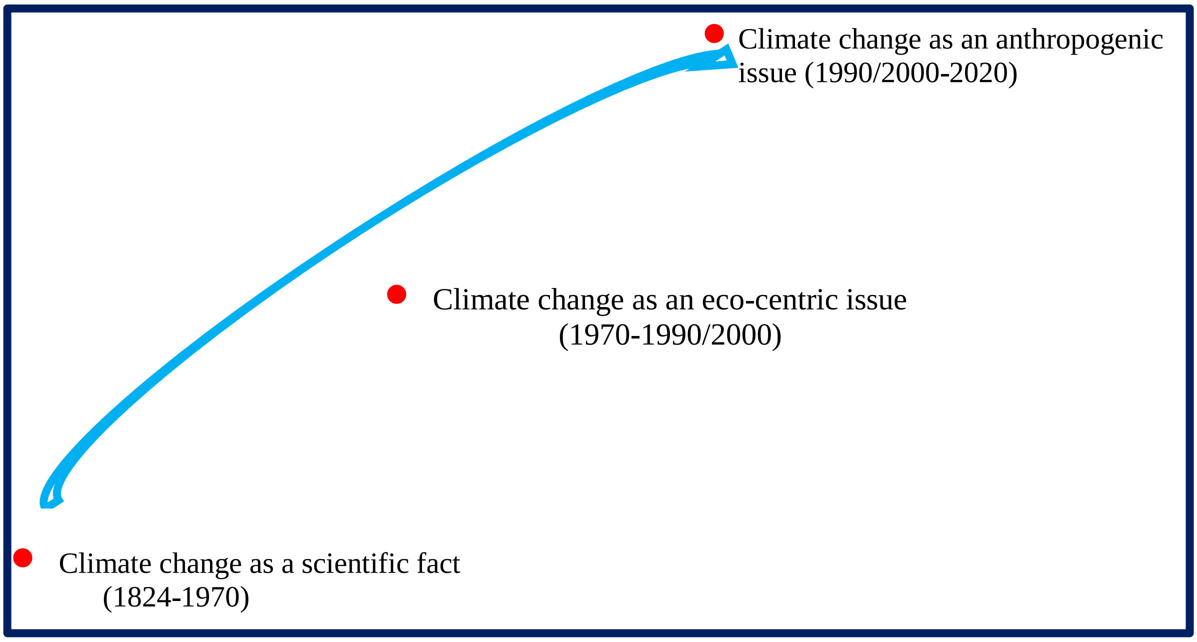
During the period when climate change was mainly considered a ‘scientific’ fact, studies on the impact of climate change focused on examining and explaining irregularities in the patterns of climate parameters. As a result, the dominant tendency was to treat climate change as only a scientific issue with no focus on its possible impacts on development in general and human wellbeing and livelihoods in particular.

During the second paradigm, the focus of climate change discourse shifted from its initial perspective of ‘an entirely scientific issue or fact’ to a perspective in which climate change was considered as the cause of environmental degradation, which can be referred to as a shift from “scientific fact’ to an ‘eco-centric’ view or approach (Rahman 2013:6). According to Dessai, Nuno & Katharine (2003:183), this change came about in the 1980s. The major focus of studies during this paradigm was on the exploration of the consequences of climate shocks on the natural environment including but not limited to forests, water resources and land. The outcome of this was that less focus was placed on the possible nexus between climate change and human wellbeing.

It was during this second paradigm that the Kyoto Protocol was ratified (1997). The Kyoto Protocol aimed at reducing GHG emission by an average of 5percent compared to its level in 1990 with the assumption that the reduction would be achieved over the 2008 – 2012 period (Cirman, Domadenik & Intriago 2009:30-31). Climate change, therefore, got an international recognition during this paradigm. Moreover, the main policy focus at this time was on the mitigation measures required to fight the impact of climate change (Weber 2016:324). Consequently, the main question asked was: what can we do to prevent environmental degradation?

During the latest paradigm, there has been a shift from 'eco-centric' to 'anthropocentric' views. The focus of scientific studies has moved from the impact of climate change on natural environment to that on various development issues (Cirman, Domadenik & Intriago 2009:35).

Figure 2.3: Major climate change paradigms



Source: Own depiction based on the discussion in section 2.2.2

Moreover, during the latest paradigm, climate change policy has shifted from being looked at only as a mitigation measure to being viewed as an adaptation measure that address the impact of climate change on human wellbeing. The Kyoto Protocol was enforced during this paradigm in 2005 (Cirman, Domadenik & Intriago 2009:33).

2.2.3. Livelihood and climate change

As presented in section 2.2.1 (see section 2.2.1.5), Vermaak(2006) stressed the need to reconceptualise the idea of social capital which is an important component of livelihood. The author argues that social capital should go beyond economic need and encompass other non-economic issues among rural communities. This is a clear indication that there is a need to rethink the livelihood framework for studies involving developing countries.

Human beings have depended heavily on their immediate environment to sustain their livelihood both in modern times and in early periods of civilization. Climate change, adaptation and livelihood conditions intertwine in many ways. Therefore, the main argument here is that studies on the impact of climate change and adaptation need to undertake their analysis from a livelihood perspective to understand the whole story of the relationship between people and climate change.

In this regard, as presented in the above section, livelihood refers to the means and mechanisms by which households sustain life and their different forms of assets (human, social, natural, physical and financial capital) as well as the institutions that allow them to access and utilize various resources. Climate change can affect and disturb the different components of assets and rural livelihood by compromising their quality and quantity. In the following subsections, brief discussions are presented on how climate change is related to each livelihood asset component.

Human Capital

Climate change will threaten human assets in the form of various adversities including but not limited to undernourishment, food insecurity and chronic hunger which mostly result from crop failure usually followed by inflation in food prices (Thakur & Bajangain 2019: 174).

Climate change could also directly affect human capital through its effect on health status. Climate change related shocks like heat waves, floods and vector borne diseases such as malaria could significantly threaten the conditions of millions of people in the years to come (Josh & Maharjan 2012:8). The implication is that climate related shocks could alter the human capital of a nation as well as households through its multiple effect and shocks.

Another climate-caused negative influence on human capital may come in the form of natural resources scarcity in rural agrarian systems (Connolly-Boutin & Smit 2016: 385). As explicitly discussed by the same authors, climate change could hamper investment by rural households on education as it constrains resource endowments that should be allocated for that purpose, limiting households' investment on human capital development.

The relationship between climate change adaptation and human capital can be also examined from the effect of climate change adaptation on the health status of household's members. That is households with high health problems are expected to have low labour force or capital as compared to households with no or minimum health problems or health related shocks and this will force them to allocate scare resource labour to treating illness which also compromise their effort in the fight against climate variability (Antwi-Agyei, Dougill, Fraser & Stringer 2013: 904). Consequently, health status or human capital status can hinder the effort of farmers in the process to adapt to the possible impacts of climate change.

Natural Capital

Rural livelihood security depends on adequate and sustainable access to natural resources. However, climate change will comprise both the quality and quantity (availability) of these resources (Ateeq-ur-rehman, Siddiqui, Hashmi, Masud , Adeel , Rameez, Khan, Dawood, Ali, Shah & Karim 2018:29). One way of identifying the relationship between climate change and rural livelihood is observing the impact of climate change on biodiversity.

Biodiversity serves as an important basis for livelihoods through the provision of various "ecosystem services", particularly to the rural population. It serves as an important natural capital for rural households by providing both non-market or non-consumptive use as well as market-oriented livelihood strategies (Kalaba, Chirwa, Syampungani & Ajayi 2010:463). Moreover, biodiversity has a prominent role in bringing about sustainable development (Ding 2011). However, climate change can result in biodiversity scarcity and the reduction in quality of ecosystem services which will undermine the livelihood of those who lead agro-ecology based lives (Dube, Moyo, Ncube & Nyathi 2016:259).

Climate change affects rural livelihoods through shocks such as droughts and floods which can bring post-harvest losses and decline in crop production and productivity (Aniah, Kaunza, Quacou, Abugre & Abindaw 2016:2). Thus, the negative impacts of climate change not only affect the general components of livelihoods systems but also the specific livelihood pathways and activities in which the rural communities rely on.

Climate change could undermine rural livelihoods by threatening components of agricultural biodiversity in many ways. Frison, Cherfas & Hodgkin (2011: 239) define agricultural biodiversity as follow:

> *"Agricultural biodiversity includes those components of biological diversity relevant to food and agriculture as well as the components of biological diversity that constitute the agro-ecosystem"*.

Climate change diminishes agricultural biodiversity by compromising the various components of biological diversity relevant to food, agricultural production and productivity (Jasrai 2013:2). This is evident as agricultural biodiversity can easily be influenced by weather and climate change variables (Moshefi & Bahojb-almasi 2015:635). The implication is that the degradation and dwindling of the biological components of natural resource would worsen the food security conditions of the rural communities.

Climate change also threatens natural resources like fresh water which is an important resource both for agricultural and drinking purposes and the impact of climate change on fresh water can be more pronounced in the tropical areas of the globe due to the fact that there is decline in both precipitation and rainfall and increase in temperature (Abdelaziz 2017:2). Hence, the argument here is climate change potentially bring change in the way of life and livelihood that is to say climate change can bring a shift in the way life has been going for centuries.

Climate change could also affect the various characteristics of soil including but not limited to its physical, chemical, and biological properties, leading to land degradation which could alter the agricultural landscape and reduce agricultural production and productivity (Kumar & Das 2014:9). These changes in agricultural production and soil characteristics further can threaten rural development in general and livelihoods in particular due to the obvious reasons that most rural communities and households depends on agricultural income for their livelihood.

Social Capital

Climate change can influence and change social capital in many ways in rural livelihood. However there is little information or evidence on the impact of climate change and the theoretical relationship between climate change with respect to social capital (Thakur & Bajangain 2019:173). Still, there could be many possible paths through which climate change can influence social capital both at national and households level. For example, the impact of climate change can directly affect social activities or functions. In rural settings, heavy rainfalls can separate rural areas for extended period of time, which of course hampers social interactions in the community. In fact social interactions, which are very important in every rural livelihood activity, will be halted if there are climate related shocks such as floods (Thakur & Bajangain 2019:174).

Social capital also plays an important role when it comes to climate change adaptation among rural communities. Some authors argue that climate change adaptation involves social and cultural processes in certain rural communities (Wolf 2011). In fact, according to (Yaméogo, Fonta & Wünscher 2018: 1), there are two mechanisms in which social capital can be associated to adaptation decisions of rural farmers namely: cognitive and structural social capital. While structural social capital is associated with different forms of social organizations and networks, cognitive social capital deals with norms and values of a given community (Yaméogo, Fonta & Wünscher 2018:2).

Physical Capital

Climate change adversely affects various physical infrastructures or physical capital including but not limited to rural roads, storage and marketing infrastructures, houses, productive assets and electricity grids (Singh 2012:10). The physical assets of rural communities are key in maintaining stable livelihoods in general and economic activities in particular. Thus, understanding the relationship between climate change and these socio-economic infrastructures would help to make proper rural policy interventions and design adaptation strategies. In the following sub section, the relationship between climate change and physical capital indicators such as rural roads, storage facilities and energy access presented.

The impact of climate change on rural transport systems, for example, can be hamper rural mobility and accessibility (Chakwizira 2019:3). Rural infrastructure is more susceptible to climate change impacts due to its high exposure to environmental conditions and damage to such infrastructure deprives the rural population any associated socio-economic benefits (Chinowsky, Amy, Niko & Ken 2015:49). Climate related socks such as floods can damage rural roads and paths and lead to the decline of agricultural services and products, resulting in fewer visits to health facilities by members of the community, fewer visits by clinic staff to members of the community and increased absenteeism from school (Chakwizira 2019:5).

2.2.4. Climate change and poverty

Climate change can have an influence on key livelihood indicators namely: poverty and food security conditions. However, the paths linking climate change with livelihood are far more complex to understand as livelihood encompasses the physical, social, financial, human and natural dimensions which have interwoven interactions and nonlinear relationships. Despite the fact that climate change and rural livelihood show a complex pattern, there are clear lines of impacts which could be of a direct or indirect nature.

The immediate or direct impact of climate change on rural livelihoods can be understood through its effect on the agriculture sector which is considered to be the main source of income and food for the resource constrained farmers (Burke & Lobell 2010:29). The argument in the climate literature indicates that the agriculture sector is the most sensitive sector to the negative impacts of climate related shocks than any other economic activity or sector (Barbier & Hochard 2018:235). Accordingly, the sensitivity of the sector to climate change could exacerbate the conditions of the poor as it directly affects their income level and food production (Taiy & Birech 2015:84). This is evident as climate change directly affects agricultural production and productivity (Gregory, Ingram and Brklacich, 2005; McSweeney, 2005 cited in (Barbier & Hochard 2018:235).

Climate change reduces agricultural production which in turn reduces the income of poor or subsistence farmers (Hertel & Rosch 2010:357). The same author argues that the effect of climate change on the farm income of the poor is exacerbated when the expenditure on food accounts for a significant proportion of total income. An economic theory referred to as “Engle’s law” states that generally there is an inverse relationship between share of food expenditure and the level of income (Martins 2010: 37). Thus, the implication is that the rural poor allocate significant shares of their income for food and as stated by (Hertel and Rosch 2010:358), this leads to climate change reducing their income massively, creating an unbreakable vicious cycle of poverty.

Examining the impact of climate change on the environment also provides a good insight to understand the potential influence of climate change on rural livelihoods. This is apparent as rural farmers depend heavily on the mercy of the environment for their livelihoods and climate change can indirectly impact their livelihoods by affecting rural land and water use (Barbier & Hochard 2018:236). In addition, climate change also intrudes in the livelihoods of the poor by preventing rural communities' access to energy in their immediate surrounding (Emerta 2013). In this regard, since access to energy is key for both cooking and economic production purposes, its shortage can worsen the living conditions of the poor.

Climate change also affects the rural poor as they have the least capacity to cope with the various negative impacts of climate change in comparison to the relativity well to do households (Urama, Eboh & Onyekuru 2017:2). Thus, the argument here is poor households more likely affected by the negative impacts of climate change. Moreover, as the cost of adaptation is very high and poor people are constrained by subsistence farm income, the uptake of climate smart technologies and climate change strategies that could reduce the negative effects is low (Mendelsohn 2012:7).

Climate change will reduce quality and quantity of natural resource as well as good and services coming from the natural resources (Hertel & Rosch 2018:356). This has an important implication for rural communities whose livelihoods mainly depends on the immediate natural environment for their livelihood and income hence anything that goes wrong in the natural environment will affect the poor directly and hence their livelihood.

Another fact is that climate change can affect the course of an individual's movement out of poverty. This is evident by the fact that climate change affects poor households' wealth through its effect on agricultural production and productivity by reducing income from crop sales (Hallegatte, Fay & Barbier 2018:219). The implication is that climate change will hamper a poor farmer's efforts to accumulate more assets, preventing any possibility of exiting poverty.

The effect of climate change on food availability and food prices affects the welfare of the poor. Climate change directly affects food availability since it reduces food production and productivity, making the poor even poorer (Hertel & Rosch 2018:358). Moreover, the same author argued that climate change would also affect food price (as it leads to increase in food price) and this will reduce farmer's welfares, as they incur additional cost to buy food. Thus, climate change generally can compromise the conditions of the poor as it can result in loss of asset, loss of key livelihoods strategies, hamper agricultural production and productivity, loss of natural resources (Josh & Maharjan 2012:13).

2.2.5 Climate change and food security

2.2.5.1 Paradigm shifts in food security within the context of development theories

The classical view on food security comes from the seminal work of Thomas Malthus in 1789, which is commonly referred to as the Malthusian approach. The population growth aspect in his approach examines the imbalance between population increase (geometric growth) and food production (arithmetic growth) (Burchi & Muro 2012). According to Malthus, population growth outpaces food production, resulting in food shortage. Thus, according to this approach, food security is mainly an issue of food supply (Hart 2009: 371). This view remained the major theoretical foundation of the subject until 1970. Thus, many studies assumed that hunger, starvation and famine were caused by food production failure alone (Weber 2016: 323). The main policy prescription that comes out of the population and food analysis of the Malthusian approach is that more food should be produced while reducing the rate of population growth (Burchi & De Muro 2016:11).

The Malthusian approach to food security was replaced by the income approach around 1976 (Burchi & Muro 2012:11). The main argument here is that in the real world, economic activities are dependent on one another, bearing a complex interaction that produces a complex system which can be termed as an economic system that goes beyond the agriculture sector and encompasses various other sectors such as trade, industry and manufacturing (Burchi & Muro 2012). Food security is not an agricultural issue alone but rather involves food trade wherever food import is possible. The policy implication of this approach is that countries at macro level and households at micro level should enhance national and personal income respectively (through economic growth) so that they can afford to buy food from where it is least expensive. Therefore, what matter is the level of income and not production alone because if adequate food is not available locally, it can be imported. And from households perspective, if households cannot produce enough food, they can buy from the local market (Nawrotzki, Hunter & Dickinson 2014:3).

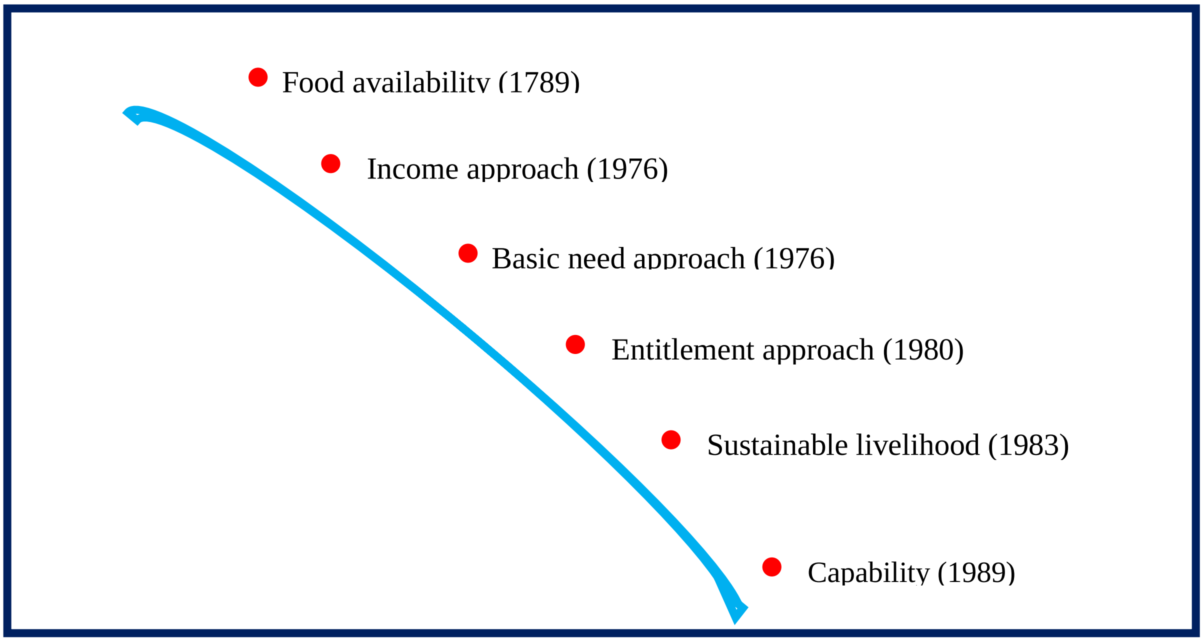
The basic needs approach is another important paradigm that tried to define and conceptualize food security. In this approach, the focus of development is on meeting the minimum or basic requirements that are needed to sustain life. The approach was popularized when member states of the ILO declared in 1976:

“Strategies and national development plans and policies should include explicitly as a priority objective the promotion of employment and the satisfaction of the basic needs of each country's population.”

In light of this, food security made it to the list of key items that are considered to be essential for development (Burchi & Muro 2012). The policy implication of the basic needs approach is that economic opportunity such as employment should be promoted to satisfy basic requirements. This approach did not stay long in the academic discussion. The main critics to this approach mentioned that it discourages motivation to work and reduces saving, productivity and investment at household level as it only focuses on meeting current need of consumption or welfare (Schutte 2018). It basically sacrifices long-term growth and development goals for short-term needs or consumption. However, food security is still considered here as a supply issue alone to the neglect of other dimensions of food security.

Figure 2.4 provides the change in food security paradigms over the past many years. It shows that food security paradigms passed through various concepts from food availability (1789) to the capability approach (1989).

Figure 2.4: Major food security paradigms



Source: Own summary from the discussion in section 2.2.5.

However, a major shift took place in the concept of food security with the introduction of the entitlement approach in the 1980s. This approach argues that food security is the ability of households to access food over time (Burchi & Muro 2012). It was popularised by the seminal work of Amartya Sen. Sen argues that starvation does not always stem from insufficient food production; rather hunger and famine can occur even if there is surplus production of food in one region (Elahi 2006: 541). Sen further argues that the main cause of famine and hunger is entitlement failure (decline of people's capabilities to buy food or to produce it) which could be the result of various unfavourable changes in variables such as increase in the price of food, decline in wages, falling cash crop prices and so forth (Rubin 2009: 621). The immediate implication is that the concept of food security goes beyond the physical supply or presence of food and encompasses the issue of entitlement to properly address or fight hunger and starvation.

Another important development in the food security paradigm is the emergence of the concept of sustainable livelihood. However, this approach does not deal with food security specifically but instead addresses development in general. The seminal work of Chamber and Conway introduced this approach in 1992 (Manlosa,Hanspach, Schultner, Dorresteijn & Fischer 2019:168). The sustainable livelihood served as a general approach to poverty and development for several years. This theory places people at the centre of the development agenda and argues that livelihood outcomes such as food security are achieved by combining household capital assets, institutions or agencies as well as different livelihood strategies (Burchi & De Muro 2016:12). The main argument of this approach is that food insecurity results either from household failure to secure access to various forms of assets or from the inability of intermediary agents or institutions to deliver what is expected of them (institutional failure)(Moroda, Tolossa & Semie 2018:3).

Conversely, food security can be achieved when household have access to the various components of assets (social, natural, financial, human and physical) and there exists a functional institution that work towards creating the enabling environment to help people achieve better livelihood outcomes such as food security. In addition, the sustainable livelihood approach has contributed to three key concepts in food analysis: 1) vulnerability: which has to do with exposure to internal and external shocks that threaten the food security conditions of households, 2) sustainability: which has to do with recovering from shocks, 3) coping strategies: which refers to various activities that a particular household performs to respond to shocks that brought a decline in food availability (Burchi & De Muro 2016:11). The same authors argue that the policy implication of this approach is that it is crucial to set up institutions that can create the enabling environment for people to secure livelihood outcomes such as food security.

The sustainable livelihood approach was followed by the capability approach. Jean Drèze and Amartya Sen first mentioned the concept of capability in their seminal work titled '*Hunger and public action' in* 1989 (Burchi & De Muro 2012:12). The authors argue that food security should go beyond food access or physical food supply, which has been the main concern of the basic need and sustainable livelihood approaches, and need to include what is called food utilization which has to do with nutritional achievements (Burchi & De Muro, 2016:15). Moreover, the capability approach introduced food as a human right that resulted in the expansion of the food security analysis framework to include political, social and cultural policies and economic arrangements that influence people's lives in general and food capability in particular (Gombert, Douglas, Carlisle & Karen 2017:148). The same authors argue that because of the focus on people's right and freedom to secure food, the policy focus of the capability approach can be generalised as making human rights work for the poor.

2.2.5.2 Recent development in the concept of food security

The concept of food security by now has been well developed into a more comprehensive and wide-ranging theory. For example, according to the definition of the FAO (1996),

"Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".

The main implication of the above definition is that the concept of food security should go beyond its physical availability and encompass social, institutional and economic aspects. Along the same line of argument, food security involves and implies at least four basic dimensions: 1) adequacy or availability, 2) stability of supply, 3) accessibility, and 4) utilization (Opara 2013: 327). The following discussion looks at each of these components of food security (see section 2.2.1.3 for the conceptual definitions as applied in this thesis).

Food availability refers to the economic, physical, and social access to the resources needed to acquire food. It has to do with the supply of food at the right time so that no one would fall short of food anywhere anytime (Leroy, Marie, Ruel , Frongillo, Harris & Ballard 2015:169). The same author defines food availability, access and utilization as comprising of quantity (the existence of adequate supply of food and energy), quality (the provision of essential nutrients or nutritional values), safety (the provision of safe and healthy food), cultural acceptability and preferences (culturally relevant and socially acceptable food).

In addition, food utilization can further include nutrition, food safety and quality, clean water, and sanitation (Opara 2013: 327). Consequently, it can be deduced that food insecurity could result if one or more of any of the four key dimensions fails to be fulfilled (Jones, Ngure, Pelto & Young 2013 :482). In this thesis, the implications of change in livelihood pattern (caused by climate change and adaptation) is examined from these dimensions of food security.

In section 2.2.8, a detailed theoretical discussion is presented on how climate change is associated with these four dimensions of food security.

2.2.6. Reflection on the similarity and differences of various food security theories

All the food security paradigms presented in section 2.2.5 have emphasised the need to address the issue of lack of food and almost all of them view food security as an important development challenge. However, the basis for all the food security paradigms (income, basic need, entitlement, sustainable livelihood and capability approaches) in their theorization of the concept of food security is the food availability paradigm in which the main concern has been the adequate supply of food. Thus, without availing the food itself first, it will not be plausible to think of the other demand and supply sides of food security. It is, therefore, clear that all the food security paradigms have stressed the need to maintain adequate food supply, which is the quantity dimension of food security. Moreover, all the paradigms have contributed to the development of the concept of food security in its present form which encompasses the four dimensions namely: food availability, access, stability and utilization.

On the other hand, there are also some differences among the food security paradigms when it comes to the policy focus or prescriptions towards achieving food security. The Malthusian approach suggests the need for national policies to focus on producing more food (food availability) and reducing the rate of population growth to balance global food supply and demand. The income approach suggests that countries at macro level and households at micro level should focus on maintaining high levels of income to buy food from where it is least expensive. The basic need approach implies that economic opportunities such as employment should be promoted to satisfy basic needs such as food, shelter and clothes. The entitlement approach indicates that polices need to go beyond the physical supply or presence of food and encompass the issue of entitlement to properly address and fight hunger and starvation. The policy focus of the sustainable livelihood approach is on making institutions work for the poor. Finally, but importantly, the policy focus of the capability approach is on making human rights work for the poor.

Another difference between the food security paradigms is their focus on the different dimensions of food security. For example, while the Malthusian, the basic needs, entitlement and sustainable livelihood approaches focus on food availability and access dimensions of food security, food utilization has been the main concern of the capability approach. In this respect, the capability approach emphasises the need to go beyond food supply or production and include a more robust understanding and analysis of food security.

2.2.7. Climate change paradigms shift and the food security policies

In this subsection, we reviewed the position of food security in climate change paradigms as reflected in terms of food policy and food security theories. It is clear that climate change paradigms have shifted in the past 150 years with different policy and research focus across a different of fields of studies. The argument here is that the shift in climate change paradigms has influenced the way climate change impact is understood and how food and climate policies are enacted. The discussion here focuses on the position of food security policy in each of the climate paradigms considered. Thus, the question at hand is what was the focus of food and climate policies during the time of each climate change paradigm?

The first climate change paradigm is the scientific paradigm that treated climate change as only a scientific fact. In this paradigm, there was little or no focus to the nexus between climate change and food security. As such, policymakers, researchers, development practitioners and the global community gave little attention to the consequences of climate change (Weber 2016: 321). During this era, food and climate policies seemed to lag behind in dealing with the possible impacts of climate change on food security. The world was not ready to investigate the impact of climate change at this time.

In this paradigm, there is no clear climate policy aimed at addressing the impact of climate change on food security (Burchi & De Muro 2016:16). Despite these however, World Food Conference of 1974 reflected the need to address food security by defining food security as "*Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices"* (UN 1974) cited in (Burchi & De Muro 2016:21).

The argument would be during this paradigm climate change was assumed only as scientific fact with no clearly established nexus between one or more components of food security. On the other hand, dDuring the second paradigm, climate change perspectives shifted from a pure scientific fact to eco-centric views of climate change (Weber 2016: 322). The focus was now on the impact of climate change on environmental degradations and there was a consensus that climate change was a cause of environmental deterioration. This change in perspective led to the formulation of climate change polices that included mitigation measures to reduce the impact of climate change on the environment. However, the food policy focus remained the same as before.

There was also an effort to link climate change with food production or food supply. The argument was climate change could result changes in the spatial and temporal distribution rainfall and hence causing decline in food production. The main gap in this period was lack of deeper insight and understanding on the nexus between climate change and other dimensions of food security. Thus, policy makers, researchers and development practitioners at large seem to miss the nexus between climate change and the different components of food security. In this context, the main argument would be policy prescription missed the nexus between climate change and the other components of food security. Thus, there was no major shift in the focus of food policy in the context of climate change. But during the third paradigm, climate change perspectives shifted from eco-centric views to anthropocentric ones. The focus was now on the nexus between climate change and development issues in general and human wellbeing in particular. In this paradigm, many efforts have been made to explain the connection between climate change and different food security components. Thus, the correlation between climate change and food security went beyond food production or food availability. Now there is at least a general recognition and explanation about the nexus between climate change the different component food security indictors, namely food availability, food access, food utilization and nutritional security (Burke & Lobell 2010).

In fact, it has now been recognized that changes in climate change parameters can affect one or more of the food security components either directly or indirectly (Tripathi, Durgesh, Chauhan, Niraj & Singh 2016: 356). However, it should also be clear that while the nexus between climate change and food availability or food supply is better explained and well researched in this paradigm, the literature on the nexus between climates change and the other components of food security is still scanty. Thus, we still have little information how climate change and the other dimensions of food security are related and the consequences this for development in general and the poor in particular.

Discussion of the climate change paradigms and the position of food security in each of the paradigms is summarized in table 2.1. The table shows that food security has evolved over the course of time in line with the change in climate paradigms.

Table 2.1: Climate change paradigms and the position of food security policy

Climate change paradigm	Climate policy focus	Food policy
Scientific fact	No clear policy	Food supply
Eco-centric	Mitigation	More food supply
Anthropogenic	Adaptation	Food access Food availability Food utilization Nutritional security

Source: Our summary of the discussion in section 2.2.7

2.2.8 Nexus between food security and climate change: Recent developments

Recent researches on climate change and food security have shown how climate change affects food production systems and food security in many ways and dimensions ranging from a direct effect on crop production to indirect effects on different components of food systems such as changes in agricultural markets, commercialization and food prices (Gregory, Ingram & Brklacich, 2005: 2139). Many authors agree on the negative impact of climate change on rural livelihood outcomes (including poverty and food security) (Antwi-Agyei, Quinn, Adiku, Codjoe, Dougill , Lamboll, & Dovie, 2017:213: Serdeczny et al 2016: 1585). We can now discuss the impact of climate change on food security from the perspective of the different components of food security.

Food Availability and Climate Change : Climate change reduces precipitation and disturbs rainfall patterns which directly impact agricultural production (food availability) both at national as well as household levels (Abdelaziz 2017:1). This is evident especially in tropical and temperate regions where high temperatures and inadequate rain often limit crop productivity (Tripathi, Chauhan, Kumar & Singh 2016:357). Thus, climate change could explain the challenges to meet food supply and this has an important implication given the fact that population is increasing without further increase in food production and productivity.

In the same line of argument, climate change can directly affect agriculture and agricultural availability as climate can results in both temporal and spatial variations in rainfall patter and temperature which brings change in local cropping pattern and farming (Edame, Ekpenyong Fonta & Ejc 2011: 205; Hossain, Setu & Rahman 2014:5). In this regard, (Edame et al 2011: 205) further argued climate hamper food distribution by affecting ability to store and transport infrastructure (for example due to floods) at local level which again affects access to market.

The other dimension of relation between climate change and food availability or productions comes from the fact that climate change can increase the frequency of climate-related disasters and shocks such as floods and droughts which have direct adverse impacts on crop production and hence food security (Islam & Andrea 2017:38). This is one of the direct and physically observed impact of climate change on these components of food security. Moreover climate change can potentially affect traditional forms of exchange of food that is food exchange can take place at the lowest level where traditionally people borrow or exchange food in the form of gift which this has remained an important source of food during food supply flux(Singh 2012). It is now clear that climate change alter food supply at household level and by implication if supply of food declines, it will limits households engagement in traditional food exchange activities (Singh 2012). Thus, climate change can affect the mechanisms of traditional access to food, which reflect change in livelihood pattern (social capital).

Global and local food availability could be affected by climate change as climate change has an effect on both agricultural crop productivity and land covered by crop (Burke & Lobell 2010:29). In this regard, food supply shortage due to declines in agricultural productivity would lead to increases in food prices while increased climate variability would bring stress on food price volatility (FAO 2016). Thus, the effect of climate change related shocks on agricultural crop productivity could explain the link between climate change and food security. Moreover, we can argue that both food supply shortfalls and price volatility would hamper food security condition both in terms of food access and in terms of utilization.

Food access and climate change : Climate change can bring decline in income growth of farmers and increase in the price of agricultural products in general and food in particular (Hossain, Setu & Rahman 2014:5). The decline in income and increase in food price hamper the conditions of the poor to access food at the required level, as the inflation of food will affect the poor and vulnerable group of the society whose significant proportion of income allocated to buy foods. Climate change can affect poor farmers' access to food in many ways. In this regard, Burke and Lobell (2010:29) have presented the following argument:

> *"Determining the effects of climate change on food access for a given household requires addressing the role of climate change in relation to three basic questions: how households earn their income? what the nature of their exposure to food prices are? and how well integrated their local food markets are with global markets?".*

Now we can look at the implications each of these three basic questions:

1) How do households earn income? Rural farmers are highly dependent on agriculture for their livelihood and on top of this, they need to wait for rainfall to grow their crops (Hossain, Setu & Rahman 2014:5). Moreover, agriculture is the most sensitive economic sector when it comes to the impacts of climate change for the obvious reasons that climate change alters the temporal and spatial distributions of rainfall and precipitations. These temporal and spatial variations in rainfall pattern adversely affect crop growth and as a result the generated income from agricultural products declines. If their amount of income is compromised, then famers will have less money to buy food from the local market during drought seasons or low agricultural production period. Now, we can argue that the extent to which a given household is dependent on agriculture can explain one of the possible links between climate change and food security (Burke & Lobell 2010:30).

2) What is the nature of their exposure to food prices? The level of exposure to food prices varies depending on the wealth status of farmers or households. Wealthy households are less likely to be affected by increases in food prices. On the other hand, poor households are easily affected by price hikes as they have less livelihood options and income sources. Moreover, (Burke & Lobell 2010:29) argues that rural communities are affected by climate change as net buyers of food.

3) How well is their local food market integrated with the global market? Climate change affects agriculture crop productivity but this impact on can vary spatially, for example, due to variations in agro-ecological status. Food markets that are well integrated with the global market are likely to withstand climate change pressures since the impact of the

phenomenon is rarely uniform throughout the world. There is bound to be areas that have been spared from climate change's impact that are able to send produce to other locations. However, it is unrealistic to expect the local markets that poor farmers access to be well networked with global markets. Consequently, these farmers will find themselves highly exposed to food insecurity as a result of climate change.

Food utilization and climate change : Depending on how food utilization is defined climate change can have a potential effect on food utilization (Aberman & Tirado 2014:1). The two major ways in which climate change can influence food utilization are health and diet (Burke & Lobell 2010: 14.). While the health components involve the impact on food and water safety as well as infections that hamper the uptake of essential nutrients by the body, the diet components have to do with the nutrient content of the food that farmers grow. Climate change will likely reduce agricultural yields, change the types of crops that are grown, and decrease the nutrient content of crops (Aberman & Tirado 2014:1-2).

Climate change can also affect food utilization indirectly by affecting food allocation in households. The premise is that climate change can reduce food production and the per capita food availability at household level. Furthermore, other studies indicate the existence of gender differentiated impact of climate change among communities (Goh 2012). It can be argued that vulnerable groups of communities and households (children and females) will be affected by food rationing as adult males are assumed to need more food (Singh 2012). Moreover, the effect on climate change on nutritional security is mostly felt indirectly, through its effect on income and capacity to purchase a diversity of food that is essential for the wellbeing of society (Aberman & Tirado 2014:5).

Climate change also affect food production systems and food security in many ways and dimensions that ranges from a direct effect on crop production to indirect effects on different components of food systems like changes in agricultural markets, commercialization and food prices (Gregory, Ingram &

Brklacich 2005: 2139). This is specially the case in rural areas of developing countries where the majority relies on the mercy of the environment and small-scale rain fed agriculture for livelihoods (Antwi-Agyei et al;2017:213; Serdeczny et al. 2016: 1591) argued that the effect of climate change on agriculture and food production could explain the impacts of climate change on rural livelihoods outcomes and incomes. Thus, theoretically, the impact of climate change on food security viewed from its impact on the different components of food security.

Climate change has a direct effect on precipitation patterns which directly impact and affect agricultural production which could result in decline crop yields which is an important indicator of food security (food availability) both at national level as well as at household level (Abdelaziz 2017:1). Thus, climate change could explain the challenges to meet food supply and this has an important implication given the fact that population is increasing without further increase in production and productivity.

Global and local food availability could be affected by climate change as climate change has an effect on both agricultural crop productivity and land covered by crop (Burke & Lobell 2010:31). In this regard, food supply shortage due to declines in agricultural productivity would lead to increases in food prices while increased climate variability would bring stress on food price volatility(FAO 2016). Thus, the effect of climate change related shocks on agricultural crop productivity could show the link between climate change and food security. Here it the argument would be both food supply shortfalls and price volatility would hamper food security condition in terms of both food access and utilization.

On the other hand, there are four dimensions of food security that could explain the relationship between climate change and food security. These are; i) availability of food, ii) accessibility, iii) food utilizations and, iv) nutritional security. In the following sub section, a detailed discussion presented on how climate change is associated to these four dimension of food security.

Food availability and climate change: climate change can directly affect agriculture and agricultural availability (trends in food productions, quantity of produced, food storage, food process, and distributions) as climate can results in both temporal and spatial variations in rainfall patterns and temperature and hence change in local cropping pattern and farming (Edame et al 2011:205) (Hossain, Setu & Rahman 2014:5).

Moreover climate change can potentially affect traditional forms of exchange of food that is food exchange can take place at the lowest level where traditionally people borrow or exchange food in the form of gift which this has remained an important source of food during food supply flux (Singh 2012). It is now clear that climate change alter food supply at household level and by implication if supply of food declines and can limits households to engage in traditional food exchange activities (Singh 2012). Thus, climate change affects indirectly affect traditional access to food that can reflected change in livelihood pattern (social capital).

Food access: Climate change can bring decline in income growth of farmers and increase in the price of agricultural products in general and food in particular (Hossain, Setu & Rahman 2014: 6). The decline in income and increase in food price hamper the conditions of the poor to access food at the required level, as the inflation of food will affect the poor and vulnerable group of the society whose significant proportion of income allocated to buy foods.

Food utilization: Depending on how food utilization is defined climate change can have a potential effect on food utilization (Aberman & Tirado 2014:1). The two major ways in which climate change can have influence on food utilization are health and diet (Lobell, Burke, Tebaldi, Mastrandrea, Falcon & Naylor 607). While the health components involve the impact on food and water safety as well as infections that hamper the uptake of essentials nutrients by the body, the diet components involve or reveals the impact on nutrient content of the food that farmers grow. Moreover, climate change will likely reduce agricultural yields, change the types of crops that are grown, and decrease the nutrient content of crops(Aberman & Tirado 2014:2).

Climate change can also affect food utilization indirectly by affecting amount of food allocation in the households. For example, climate have a potential impact on food allocation at household’s level in rural areas as well as urban areas (Singh 2012). The premise is that since climate change can reduce food availability or production until household’s ration food among family members. Furthermore, other studies indicated the existence of gender differentiated impact of climate change among communities (Goh 2012). The authors described that since vulnerable groups such as women and children have little say (men’s are highly favoured in some communities) they are likely to have less share during food ration at household. Moreover, it should also be noted that the effect of climate change mostly be felt indirectly through its effect on income and capacity to purchase a diversity of food (Singh 2012). This show that is while climate change directly affects agricultural production (i.e. food availability) and food access it has an indirect impact on food utilization and nutritional security (Rashid, Umber & Shabbir 2016: 549).

2.3 LITERATURE REVIEW OF EMPIRICAL STUDIES

This subsection mainly focuses on empirical studies that reveal the interaction between climate change and livelihood. The theoretical review has shown that climate change can affect livelihood, poverty and food security (section 2.2.7, 2.2.8). In fact, in rural community settings, agriculture and natural environment are the main sources of livelihood, making the impact of climate change clearly visible.

In this regard, the empirical review starts the discussion by presenting the empirical evidence for the impact of climate change on livelihood vulnerability. In addition, the empirical section looks into the impact of climate change on livelihood outcomes such as poverty and food security.

The empirical review also covers the impact of climate change adaptation on poverty and food security. In addition, the review seeks to understand how livelihoods assets and strategies are changing because of climate change related shocks and examines how different livelihoods paths can be impacted by climate change. It also explores the implications of this impact for poverty and security. While presenting this information, any important analysis that a referenced study could have carried out but did not is pointed out.

2.3.1 Livelihood vulnerability and climate change

(Antwi-Agyei, Dougill, Fraser & Stringer 2013: 903) conducted livelihood vulnerability analysis using livelihood vulnerability index in two rural communities in Ghana. The result shows that even within the same agro-ecology, households experience different degrees of vulnerability mainly because of socio-economic characteristics like asset, gender, and access to capital. Moreover, they found out that climate change’s impact on livelihood assets varies based on the type of asset (social, financial, natural, human or physical). This implies that there is a need to examine the various components of assets to identify and quantify the most sensitive part of asset/capital to climate related shocks. As such, this thesis uses the livelihood vulnerability index to estimate the impact of climate change on various forms of assets and identifies the most vulnerable component (chapter 7).

(Piya, Maharjan & Joshi 2019) studied the effect of climate change on livelihoods in developing countries. The result of their investigation shows that climate change caused a disaggregated impact on livelihoods. Thus, while agricultural labourers benefited from an increase in global food price, households with limited assets were disadvantaged and livelihood routes or patterns were shifting from farming to a more diversified one. This is important when it comes to examining livelihood pattern change due to climate change. However, (Piya, Maharjan & Joshi 2019) did not examine the impact of livelihood pattern change or its implications for poverty and food security, which is indeed the main interest of this thesis.

The empirical literature also shows the need to examine climate vulnerability across space and time to come up with sound and context-specific policy interventions. A policy prescription as 'one size fits all' might not work when it comes to climate change as its impact varies across time, region, gender, etc. For example, (Abeje, Tsunekawa, Haregeweyn, Nigussie, Adgo, Ayalew, Tsubo, Elias, Berihun, Quandt, Berihun & Masunaga 2019:2) studied the disaggregated level of climate vulnerability in three different agro-ecologies of Ethiopia using a composite vulnerability index. The result of the analysis shows that communities with similar exposure to climate variability and droughts had vulnerability levels that depended on their adaptive capacity and sensitivity to indicators. The same study shows that the adaptive capacity of households was determined by their participation in community-based organization and their lack of income diversification.

Along the same line of argument, (Amuzu, Amos, JalSlow, & Sidat 2018:35) signalled the need to design context-specific climate intervention strategies by assessing the vulnerabilities of two different livelihood systems. The authors argue that the level of vulnerability to climate change varies across study areas. More specifically, while the human capital related subcomponents of livelihood are more vulnerable to climate change in one part of the study area, natural and institutional components were found to be more vulnerable in the other parts. Therefore, the result shows the need to consider context-specific climate intervention strategies.

2.3.2 Impact of climate change on food security and poverty

In addition to its impact on those who are already poor, climate change also affects people's general movement into and out of poverty (Hallegatte, Fay & Barbier 2018 : 217). The same authors found out that households that were hit by droughts in the past were more likely to be poorer than those that were not (Hallegatte, Fay and Barbier 2018 :225). The implication is that climate change forces the poor to stay in the cycle of poverty. Though this thesis is a cross-sectional study (household's data collected at one specific time), there is a need to examine and treat time as important factor to examine the impact of climate change shocks on livelihood outcomes such as poverty and food security. In this thesis, the recall method is used to capture the time dimension of the effect of climate change and the occurrence of past climate change shocks in the Lake Tana Basin.

(Bandara & Cai 2014: 451–465) estimated the impact of climate change on food prices and food security in South Asia using the method of dynamic Computable General Equilibrium (CGE). The result of their analysis reveals that climate change had a significant negative effect on food production and prices in all countries considered for the study because climate change reduced agricultural productivity in the regions. Although the result has been presented as an important finding for food policy, the authors did not present cases that show variations across economies, agricultural systems and nations.

Wei, Todd, Solveig & Solveig (2014: 33–140) estimated the relationship between crop productivity and key climate change variables specifically precipitation and temperature changes using a panel dataset collected for the period 1980 – 2008 in China. The result of their analysis indicates that while rise in temperature increased the productivity of wheat and rice by 1.3percent and 0.4 percent respectively, it reduced maize yield by 12percent. The authors argue that climate change impact on agricultural production would not be an issue in China if positive impacts of other socio-economic factors continue to be strong. However, their conclusion and analysis only focused on food availability to the neglect of the other components (food access, utilization and stability) thus tells only part of the story.

Kabubo-mariara, Mulwa & Falco(2016:1289-1304) estimated the effects of climate variables (long term average rainfall and temperature) on food and nutrition security in Kenya using panel datasets. The quantitative analysis shows the existence of non-linear effects of climate variables on the probability of food and nutrition being secure. Methodologically, even though using panel data would help climate analysis to look into the effect of time which is not possible in the case of cross-sectional data, their study did not contextualize the transmission process through which climate change adaptation affects food and nutrition security.

2.3.3 Impact of climate change adaptation on food security and poverty

Ahmed et al (2016: 311–321) empirically investigated the impact and cost of climate change adaptation on food security using the Dynamic Commutable General Equilibrium Model for Climate and the Economy (DCGECE) with an assumption of 5 and 20 per cent over time. The result of the analysis reveals the presence of the effect of climate change adaptation on Malaysia's agricultural sector. This study however did not show the micro level perspective and policy implications of the estimated aggregate model to households.

Abid, Schneider & Scheffran (2016:261-254–266) estimated the impact of climate change adaptation on food productivity and income of rural communities in Pakistan. The authors used the matching technique to estimate the effect of climate change adaptation on food productivity and crop income. The study reveals that adapting to climate change had a significant positive effect on food productivity and net crop income. The authors argue that these would indirectly affect the food security status of rural households. However, the authors only saw the supply side of food production to the neglect of the other dimensions of food security.

Lopez-ridaura, Frelat, Mark, Valbuena, Krupnik & Jat (2018: 57–68) studied the impact of climate change adaptation on food security status and livelihoods of smallholder farmers in rural India. Prior to their estimation, they applied a multivariate statistical method to distinguish between different farming systems and applied a food security indicator in form of households' Potential Food Availability (PFA). They used scenario-based analysis to examine the impact of the adaptation of better agricultural practices (for example: conservation agriculture and improved livestock husbandry) on households' PFA.

Interestingly, the results indicate that compared to livestock interventions, conservation agriculture has a better potential to boost households' PFA.

Tesso, Mengistu & Bezabih (2012: 285–298) studied how adaptation to climate change affects food security conditions of rural households in Ethiopia using cross-sectional data collected from 452 households. A two stage least square technique and the Cobb-Douglas production function was used as estimation model. The analysis reveals that while climate change had a serious impact on crop production, adaptation to climate change probably improved food production. However, this analysis did not isolate the effect of other variables on food production besides climate change adaptation. Thus, they did not address the attribution problem.

Difalco, Ronesi & Esuf (2011:1) studied the major reasons that explain climate adaptation impacts on households' food security status through agricultural productivity in Ethiopia using switching regression model. The finding indicates that climate change adaptation made poor farmers better off if they used any one of the available adaptation strategies. In another study, Smith and Pilifosova (2001:27), found out that adaptation strategies determined the food security conditions of poor rural households by altering the conditions of agricultural productivity. Nevertheless, they did not show the extent of the effects of climate adaptation strategies on other dimensions of food security.

2.4. THE SUSTAINABLE LIVELIHOOD FRAMEWORK

The theoretical foundation of the Sustainable Livelihood Framework (SLF) can be traced back to the emergence of what has been termed as an 'intentional' approach to development (Morce & McNamara 2013:5). This approach is the counterpart to the other form of development known as immanent. The same authors describe, using Cowen and Shenton (1998) as their main reference, the immanent development theory as one that views development mainly as being driven by exogenous factors such as technological advancement, development in arts and sciences and globalization (Morce & McNamara

2013:5). On the other hand, the intentional approach to development views development as a focused process in which governmental and non-governmental actors exert efforts to reduce negative livelihood outcomes such as poverty and food insecurity.

SLF was introduced in the context of the intentional development approach where development practitioners were looking to maximize aid effectiveness for the poor (Morce & McNamara 2013:2). SLF is also rooted in the concepts of entitlements, capabilities and achievements and classification of poverty (Scoones 2002) as it takes a broader view of poverty, recognizing its multi-dimensionality (Money Metric Approach). As discussed in the previous sections, according to (Ellis 2000:290), the concept of livelihood consists of multiple dimensions of assets (natural, physical, human, financial and social) and the access to these through socially or institutionally constructed channels that together determine the living conditions of individuals.

2.5. THE CONCEPTUAL FRAMEWORK OF THE STUDY

The thesis adopts SLF as the main guiding framework of the study. SLF is selected as a conceptual tool for the following reasons:

1) SLF focuses on people and tries to identify the challenges and prospects that they face due to various shocks (such as climate change and adaptation) in pursuing their livelihoods based on their own personal or communal experiences of these challenges and prospects.

2) Climate change can affect various components (social, natural, financial, human and physical) of livelihood. In this regard, using SLF helps to make a comprehensive assessment of the effect of climate change and adaptation on livelihood and livelihood outcomes. Moreover, since the theoretical intentions of the thesis is to look into the transmission channels through which climate change affects livelihood outcomes, using SLF helps to understand the complex processes through which climate change and adaptation affect livelihood. The premise is that climate change not only worsens poverty and

food security conditions but it also poses challenges to rural development in general (Odufuwa & Fasina 2013:47-49).

3) SLF provides a better understanding of how climate change could be related to key livelihood outcomes such as poverty and food security (Odufuwa & Fasina 2013:47). The following explanation of the proposed conceptual framework is based on both theoretical and empirical literatures discussed in the above sections.

Climate change is a development issue that can negatively impact livelihood assets by reducing their quantitative and qualitative aspects which in turn affect the livelihood patterns of households (Andrew 2015:126). The complex interactions between livelihood components (natural, physical, human, financial and social) present an interesting research question: how does climate change cause livelihood pattern change? SLF can be used to answer this question.

In addition, one can link SLF with climate change adaptation. This helps to see how adaptation to climate change is affecting livelihoods and which component of livelihood is where adaptation is felt most. Climate change can influence the policies that governments make and the adaptation strategies that farmers adopt. As presented in figure 2.5, existing policies and institutions can influence households' susceptibility to climate change.

Against this background, the main argument of this thesis is that livelihood pattern could change because of climate change and adaptation strategies. And this change in livelihood pattern in turn can have implications for livelihood outcomes such as food security and poverty. However, a significant number of studies so far have dealt only with the direct impact of climate change on food security and poverty without first considering the impact of climate change and adaptation on livelihood pattern and its implication for livelihood outcomes such as food security and poverty. SLF helps to analyse this thoroughly.

2.6. CRITIQUES OF THE SUSTAINABLE LIVELIHOOD FRAMEWORK

Even though the Sustainable Livelihood Framework is extensively used among development experts and practitioners, there is also significant critique against it coming from both theoretical and empirical works. The critique has raised important theoretical, methodological and policy level issues that have helped to modify and reshape SLA. In this subsection, a discussion on the key critiques of SLA is presented.

SLA is a static framework that lacks or fails to capture dynamic conditions that would alter people's livelihoods. In other words, the framework fails to capture both internal and external factors that affect the living conditions of households (Toner & Anna 2002).

In this regard, this thesis also argues that SLF fails to capture the concept of changes in livelihood pattern (changes in asset and livelihood strategies). Climate change could affect livelihood pattern and this effect in turn can have implications for poverty and food security. The assumption is that livelihood pattern change could be one of the potential transmission channels through which climate change could impact the poverty and food security conditions of rural communities. Thus, the researcher has modified the standard SLF to include the concept of change in livelihood pattern in the framework (section 2.6.1).

SLA has also been critiqued with regard to the translation, measurement and operationalization of the five components of assets (social, natural, human, physical and financial). For example, Marzetti, (2001) (in Toner & Anna 2002) argues that 'social capital' could not be captured in the Portuguese language and as such the phrase 'ability to influence policy making' was used. This difference in translation, therefore, can affect the standardization of the measurements of asset components.

On top this, there is also an argument about the narrow definitions and conceptualizations of the components of assets. For example, Vermaak (2006) argues that development literatures and practitioners associate social capital with economic relevance or role more tightly than community members do. The author argues that social capital goes beyond the economic implications to encompass culture, norms and values of members of a community. In order to reduce measurement bias while selecting indicators for the five components of assets, the thesis selects indicators by prioritizing them using two criteria: 1) indicators widely and frequently used in the empirical literature, and 2) indicators that can be easily translated into a local language. Neefjes (2000) argues that since SLA just serve as a tool, it should be adapted to the specific context and situation (Neefjes 2000:59). Thus, the argument is that there is flexibility when it comes to the operationalization of the concepts and measurements of assets or capital indicators of SLA.

Another criticism of SLA is that it does not adequately capture the trade-offs between improvements in the livelihood of one group and the negative impacts on another group (Serrats 2017). For example, farmers might benefit from extensive and intensive agricultural practices using wetlands along riverbanks or lakes. However, fisher communities may be affected by these activities negatively. The same author also argues that SLA is weak when it comes to assumptions about assets. Because it assumes capitals can increase without limit, the concept of diminishing returns to factors of production is largely missing from the approach.

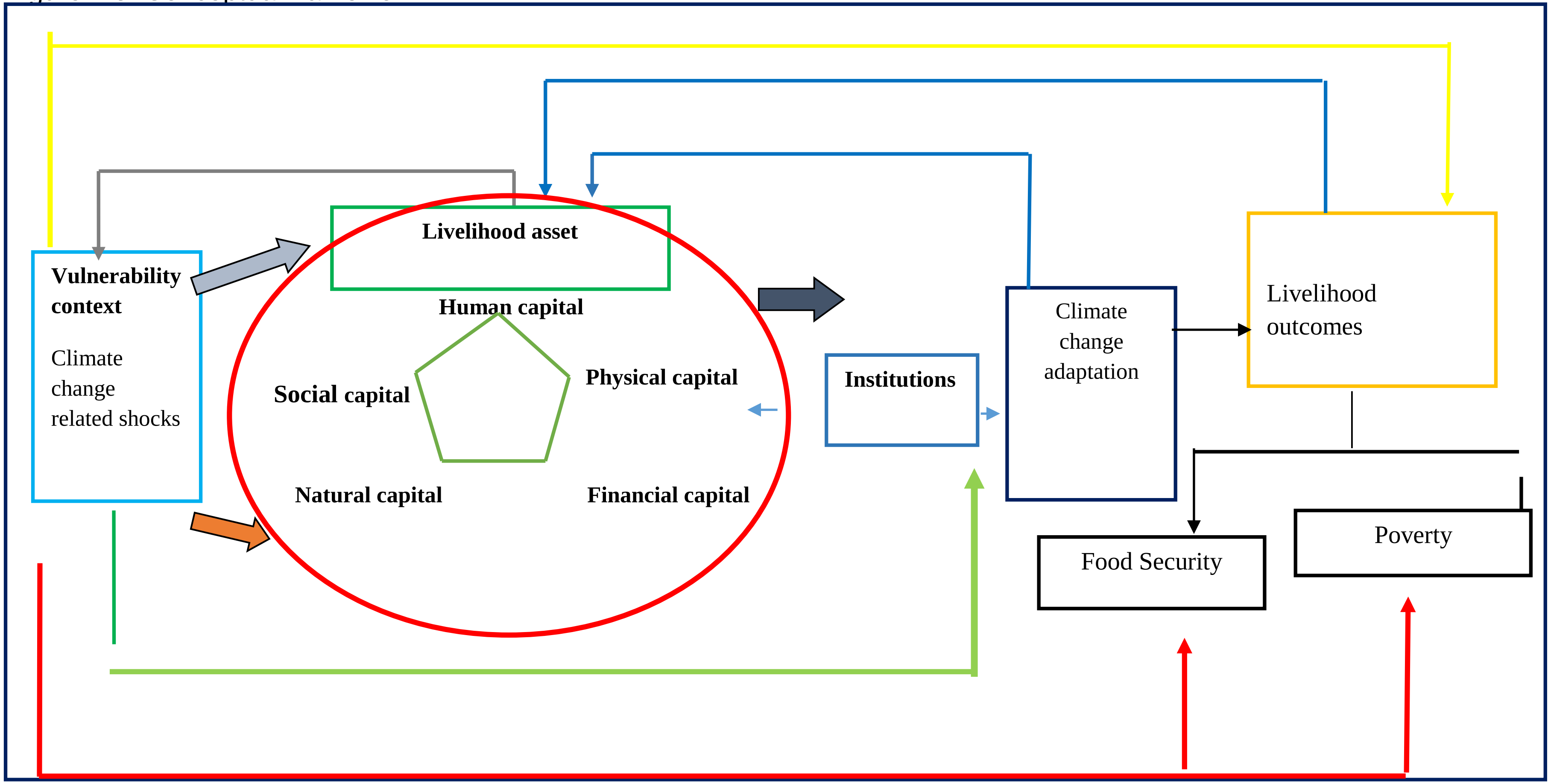
Another critique is related to the translation of the complex analysis done using SLA into relevant polices and interventions (Morce & McNamara :8). The authors provide an example where fishers had limited possibility of adjusting their livelihood conditions due to the restriction set by the government to maintain the sustainability of the stock.

Also, SLF does not show the link between macro and micro level vulnerability trends. Even though it provides ways of assessing vulnerability, the link between macro levels shocks (e.g. inflation) and micro level impacts (e.g. households) is not adequately captured. In this thesis, a time series analysis of climate change indictors is presented to link the higher level trend with that at the household level.

Figure 2.5 shows that in a livelihood context, climate change related shocks can affect all dimensions of livelihood assets (natural, social, physical, financial and human). In the same manner, climate change related shocks can affect the poverty and food security conditions of households or communities. These livelihoods are again affected by intermediaries such as structures (institutional arrangements) and processes (laws, polices, programs and projects). Thus, institutions and polices determine access to the various types of assets and options for livelihood strategies.

Intermediaries also serve to transmit the effects of climate change adaptation measures or strategies over to livelihood outcomes such as poverty and food security. Still, change in livelihood as a result of climate change is not captured by the standard Sustainable Livelihood Framework. This is important as this thesis aims to look at the change in livelihood pattern (caused by climate change) and the implications of this change for poverty and food security. As such, there is a need to modify the standard conceptual framework. The discussion on the modified Sustainable Livelihood Framework is presented in section 2.6.1.

Figure 2.5: Conceptual framework



Source: Own depiction using DFID framework

2.6.1 MODIFICATION TO THE STANDARD SUSTAINABLE LIVELIHOOD FRAMEWORK

The conventional livelihood framework does not capture the concept of livelihood pattern change or change in assets and livelihood strategies due to the impact of climate change (section 2.6). Moreover, the conventional livelihood framework does not capture the effect of livelihood pattern change on livelihood outcomes such as poverty and food security. Thus, modifications are made to incorporate the concept of change in livelihood pattern (change in assets and in livelihood strategies) as a basis to study the effect of climate change and adaptation on key livelihood outcomes (poverty and food security). The major argument here is climate change and adaptation can change the existing livelihoods pattern. Consequently, this will have an implication for poverty and food security.

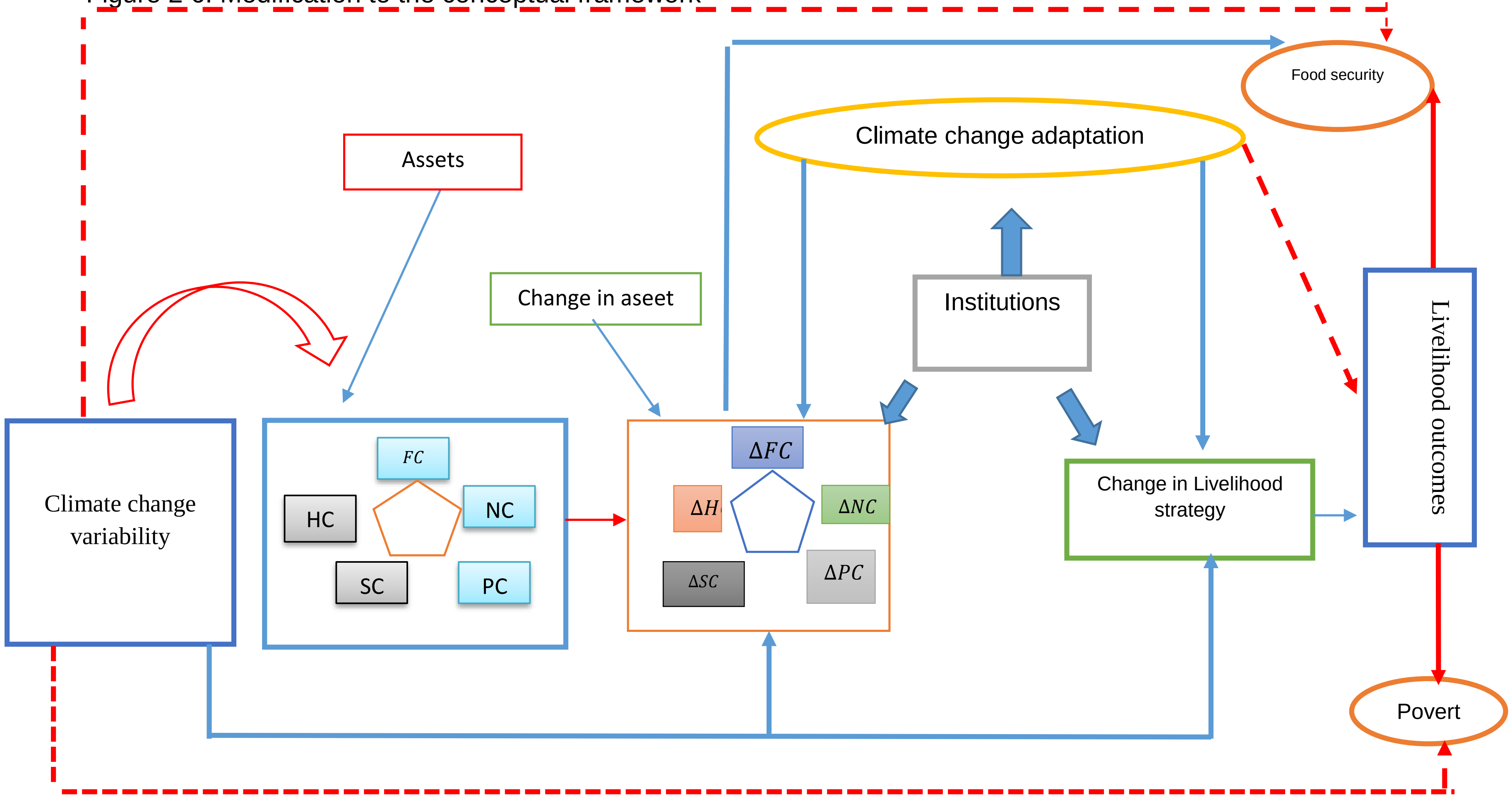
As presented in figure 2.6, the broken lines show the weak transmission channels of the effects of climate change and adaptation on livelihood outcomes. This means climate change and adaptation can affect livelihood outcomes (poverty and food security) even if livelihood pattern does not change. For example, climate change can affect food production and productivity (one component of food security) directly as climate change can bring statistical changes in rainfall, precipitation and temperature patterns. In this case, as most studies do, we can construct a statistical control method to estimate the effect of climate change adaptation on poverty and food security. However, such approach will not allow the analysis of climate change's impact from the perspective of livelihood pattern change. Thus, it is relevant to device a mechanism that lets us investigate the effect of the phenomenon through the livelihood pattern lens.

In the same manner, climate change adaptation can potentially bring change in livelihood pattern (change in assets and change in livelihood strategies) by affecting the conditions of various forms of assets and livelihood strategies. The interesting question here would be what will happen to the food security and poverty when livelihood pattern changes? Thus, the main argument here is there is a need to investigate the impact of climate change and adaptation from livelihood pattern change perspective. As presented in the modified conceptual framework, climate change and adaptation would bring change in livelihood pattern. In the same line of argument climate change adaptation can change livelihood pattern (asset and livelihood strategies) with a possible effect on food security and poverty.

Figure 2.6 depicts the modifications made to the standard SLA to accommodate the needs of this thesis in terms of analysing climate change through its effects on livelihood pattern. It shows that climate change related shocks can impact different components of assets (social, physical, natural, financial and human). Climate change can also cause changes in livelihood strategies. Both the changes in assets and livelihood strategies can in turn affect the poverty and food security conditions of households or community members (depicted using the solid lines).

The modification allowed to examine first the effect of climate change on livelihood pattern and then see the implication of the change in livelihood to poverty and food security. Thus, the link between climate change variables, livelihood, food security, and poverty investigated not in a direct way. Rather, the thesis investigated first the effect of climate change variables on livelihood (assets and strategies) and then examined the implication of change in livelihood pattern [due to climate change] on poverty and security.

Figure 2 6: Modification to the conceptual framework



ΔHC; *change in human capital*; ΔFC; *change in finaical capital* , ΔPC; *chane in phsical capital* , ΔSC ; Change in social capital

Source: Own depiction

2.7. THE LIVELIHOOD VULNERABILITY INDEX

The Sustainable Livelihoods Framework does not address the issues of livelihood sensitivity and adaptive capacity to climate change in rural livelihood (Sheikh & Akter 2017:42). In this regard, a new approach that integrates climate exposures and household adaptation practices has been developed to analyse livelihood pattern changes and risks from climate change. This new method is called Livelihood Vulnerability Index (LVI).

(Hahn, Riederer & Foster 2009:75) constructed hybrid indicators from SLA and Intergovernmental Panel on Climate Change (IPCC) framework to calculate a Livelihood Vulnerability Index (LVI) in two districts of Mozambique. The LVI uses indicators of exposure to climate change, and five capitals to measure adaptive capacity and their sensitivity to climate change impacts (Teshome 2016:19). Two approaches are presented: the first expresses the LVI as a composite index comprised of seven major components while the second aggregates the seven into IPCC's three contributing factors to vulnerability: exposure, sensitivity, and adaptive capacity (Teshome 2016: 18).

In this method, both primary and secondary data was used to construct the index and aggregate indicators at Woreda level. Therefore, this approach helps avoid the problems associated with relying on a single data source. In addition, it avoids dependence on climate models which need sophisticated skills and extensive secondary as well as primary data to provide accurate projections for community development planning (Hahn, Riederer & Foster 2009 :86).

In developing countries like Ethiopia that have diverse topography, regional climate projections are likely to show shadow differences in vulnerability among communities. (Hahn, Riederer & Foster 2009:75-76) argued that rather than structuring vulnerability assessment around climate projections, the LVI approach focuses on quantifying the current livelihood systems as well as the capacity of communities to alter these strategies in response to climate-related exposures. The LVI is designed to understand biophysical and socio-economic factors contributing to climate vulnerability at community level, It is also designed to be flexible so that researchers can readjust their analyses to suit the needs of a specific geographic area (Teshome 2016:19). In addition to the overall composite index, sectoral vulnerability scores can be segregated to identify potential intervention areas (Hahn, Riederer & Foster 2009:76). The detailed approach for the LVI is presented in the methodology sections (chapter 3).

2.8. OPERATIONALIZING THE CONCEPTUAL FRAMEWORK

In order to understand how livelihood is changing (because of climate change) and the impact of climate change adaptation on livelihood outcomes, the study analyses the five dimensions of assets (physical, social, human, financial and natural). This approach is used to examine how livelihood pattern is changing because of climate change and its implications for key rural livelihood outcomes (poverty and food security).

In addition, the Livelihood Vulnerability Index (LVI) approach is used to quantify the current livelihood systems as well as the capacity of members of the community to alter these strategies in response to climate-related exposures (section 7.3). Furthermore, the Leopold matrix is used to identify the impact of climate change on rural livelihood in the Lake Tana Basin (section 7.2.1.1).

Understanding the impact of climate change (how it is influencing the livelihood pattern of rural farmers) requires a deeper exploration to capture the experience of farmers and community members in the study area. To this end, these qualitative tools were applied: focus group discussions, in-depth interviews and participatory development scenarios with various stakeholders in the Lake Tana Basin.

2.9. CONCLUSION

The concept of climate change has evolved over time from being considered a scientific fact alone to the current understanding where its recognized as a development challenge.

The theoretical review section explained the development of the concept of food security from being initially viewed through the sole perspective of food supply availability to its present form where it is understood as comprising of the four dimensions of food security (access, availability, utilization and stability). In the same token, the theoretical review presented the development of the concept of poverty.

The chapter also covered the theoretical relationship between climate change and poverty. Climate change could influence poverty by reducing agricultural income and the quality and quantity of various resources and services. It could also diminish the value of assets or wealth through its effect on agricultural production and productivity. The theoretical foundations of the relationship between climate change and food security were discussed. Food security is one of the livelihood outcomes under investigation in this thesis. Paradigm shifts regarding food security in the context of development theories were presented. In the same manner, the position of food security during the shift in climate change paradigms was explored from a historical perspective.

The chapter also discussed how the various components of livelihood assets (human, physical, social, natural and financial) are related to climate change.

The empirical review section detailed how climate change has been observed to affect both poverty and food security conditions. The presentation in this section showed there are gaps in many of the listed studies as they lack explanation for the impact of climate change on various dimensions of poverty and food security. Moreover, it can be noted that there is only very limited literature on the effect of livelihood pattern change (due to climate change and adaptation) on poverty and security.

The empirical review section also presented evidence from previous studies for the effect of climate change adaptation on food security and poverty conditions of households. Two main gaps in the presented literature are noticeable: 1) the existing literature fails to explain the impact of climate change adaptation on all dimensions of food security and poverty. As such, the focus has been mainly on food production and income, and 2) the existing literatures does not show the effect of livelihood pattern change (due to climate change adaptation) on poverty and food security.

The Sustainable Livelihood Framework has been selected as the theoretical foundation of this thesis. This chapter listed the critiques on this framework such as the fact that the framework does not capture the concept of changes in livelihood pattern (changes in different forms of assets/capitals and in livelihood strategies). Moreover, it fails to link the implications of change in livelihood pattern for key livelihood outcomes (such as poverty and food security). Therefore, the argument in this regard is that livelihood pattern change (change in assets conditions and livelihood strategies) is one of the possible channels through which the effect of climate change can be transmitted to food security and poverty. Consequently, the conceptual framework has been modified to capture livelihood pattern change.

The conceptual framework guided the overall research in three ways: These are; 1) used to design the study tools including household survey, Focus Group Discussion (FGD), in-depth interview and Participatory Scenario Development (PSD), 2) to address the research objectives and research questions and 3) to guide overall data analysis.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

As presented in chapter two, this study focuses on the development aspects of climate change. These aspects of climate change are centred around people's experiences of natural or social phenomena. As such, this thesis goes beyond presenting climate change as only a scientific fact. This has shaped the research method and methodology adopted in the study which is the subject of this chapter. While the research method focuses on the types and sources of data as well as data collection mechanisms, the methodology covers the research approach and the overall philosophical perspective of the thesis.

In order to address the key research questions and objectives of the study, a mixed research approach has been chosen, which combines both qualitative and quantitative assessments. On the qualitative side, questions like how communities are experiencing climate change and livelihood pattern changes are posed. And on the quantitative side, concrete characteristics such as trends in climate variables and levels of household vulnerability are analysed.

Moreover, this chapter briefly presents the philosophical foundation of the thesis in light of the two approaches adopted in the study. As such, the study follows a pragmatic philosophical approach. The justification for the adoption of this approach comes from the objectives of the study. As mentioned in the objective section in chapter 1, the study wants to deeply understand the impact of climate change on livelihoods and at the same time tries to quantity the vulnerability of rural livelihood assets. This involves not only analysing the dimension of the impact of climate change on livelihoods as experienced by the study participants but also the quantification of the impact of the phenomenon on livelihood outcomes (poverty and food security).

3.2 RESEARCH APPROACH

3.2.1 Research approach

This thesis applies a mixed research approach comprised of qualitative and quantitative methods. These two methods have philosophical, methodological, analytical and epistemological differences (Creswell 2009: 6). Thus, a careful examination is needed when choosing and designing a given research approach consisting of both methods.

One reason for the selection of the mixed research approach for use by the study is the fact that the thesis explores the experiences and perceptions of the study community members regarding the climate in their area. This calls upon the respondents to provide information based on their subjective analysis of the reality around them. Almalki (2016) argues that since reality is socially constructed and complex in its very nature, there is a need to combine qualitative with quantitative research (Almalki 2016: 293).

Data triangulation is another reason for adopting the mixed research method. For example, climate change can be measured using different quantitative variables such as temperature and rainfall pattern. In this regard, the perceptions and experiences of community members towards climate change could substantiate the quantitative measurements of climate change variables.

Moreover, the thesis adopted the mixed method as it allows to use the interpretive or social constructivism paradigm whose objective is to explore the world including socio-economic phenomenon based on subjective measures or as they call it "personal experiences" (Rahi 2017: 1). In line with this, as the thesis aimed at exploring the opinion, experiences and perspectives of individuals and members of the community, it would be relevant to use the mixed method.

On the one hand, in quantitative research deign the focus of the research and or the researcher is mainly to undertake an analysis which involves mainly quantification (involves measuring of variables) of a phenomenon and assumes and consider social reality as objective fact (Nicholas 2006:36). In this thesis, the researcher applied the post positivist views for building knowledge and generating new knowledge by using quantitative mechanisms of inquiry including experiments and surveys with the objective of collecting and generating numerical data that help to measure and quantify some of climate change and livelihood variables(Creswell 2009:17).

Also, there is both methodological and conceptual limitations when using only one of the two approaches in a given study and there should be mechanisms to engage both so as to get the best of the two (Addae 2015:152). Even though the academic debate still continues regarding the strengths and weaknesses of qualitative and quantitative research approaches, a mixed method is considered to be strong with increasing popularity in social studies (Creswell 2009:204). This approach mostly bridges the limitations of quantitative and qualitative approaches and brings together both approaches in a single study (Addae 2015: 151).

Mixed method has a number of advantages as compared to using a single approach in a research. We can argue about the advantages of the mixed approach from theoretical, conceptual and data analysis perspectives. From conceptual perspective, the use of mixed method will provide a profound understanding of a given phenomenon as compared to researches that do not apply both a quantitative and qualitative approach (Mckim 2017: 202). The use of mixed approach will also provide strong theoretical foundation to the study subject as it combines elements from both approaches (Addae 2015:151).

In this thesis, given the nature of the research objectives and questions to be explored, examined and explained and attributes to be measured with regard to the impact of climate change and adaptation on key livelihood outcomes (poverty and food security), the appropriate research approach is the mixed method. In addition, given the conceptual complexity of the impact of climate change and adaptation on rural livelihood systems, the mixed research method is a best fit for the thesis.

3.2.2. Research design

As presented in section 3.4.1, the study uses the mixed research approach, there are various research designs that can be applied to implement this method in a single study. These include the embedded, explanatory sequential, parallel or concurrent**,** concurrent embedded strategy and exploratory sequential designs (Shorten & Smith 2017: 74).

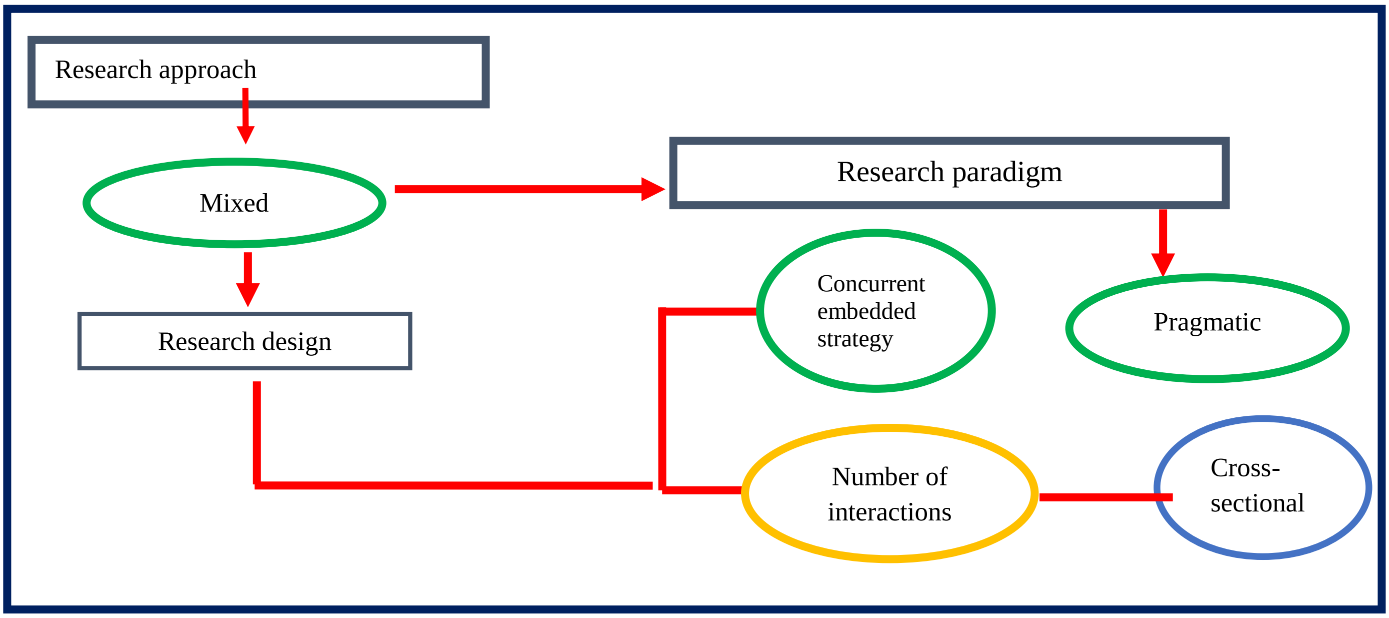
This study adopts the concurrent embedded strategy design where both qualitative and quantitative data is collected. This method is selected for the very reason that it helps to answer different research questions within the same study (Creswell 2009:214). In this thesis, there are two similar but somewhat different objectives. First, the study seeks to understand how livelihood pattern is changing because of climate change and adaptation. Second, the study seeks to explore the impact of climate change and adaptation on livelihood outcomes. Here the qualitative and quantitative data might be compared or it can be analysed side by side so as to answer two different objectives or research questions to provide an overall assessment of the issue under investigation (Creswell 2009:215). This makes the concurrent embedded strategy an appropriate design to address these key research questions and knowledge areas.

In addition, one can view the research design from the perspective of the number of interactions that the researcher makes with the study participants from whom data is collected. Based on this perspective, there are three research designs: 1) cross-sectional research design, 2) before after, time series, and 3) longitudinal design (Neuman 2014:43). In this respect, this study has adopted the cross-sectional research design which refers to a study at a single point in time (when one considers data collection at community level).

Last but not least, the study also used 30-year statistical data to examine the trend in climate change parameters like rainfall, temperature and precipitation. This help in explaining the nature of climate variability in the study area.

The overall research approach, paradigm and design of the thesis is summarized in figure 3.1. The study adopted the mixed research approach which consists of both qualitative and quantitative approaches. Moreover, the research paradigm serves as the philosophical foundation of the thesis. This is important as climate change impact on livelihood needs context specific analysis due to variations in livelihood and socio-economic context of communities.

Figure 3.1: The research approach, paradigms and research design of the



Source: Own depiction

3.2.3 Philosophical foundation of the thesis

In this thesis, the pragmatic research paradigm, which is the philosophical foundation of the mixed research approach, adopted to put the thesis into a theoretical perspective. The mixed method research approach uses the pragmatic philosophical approaches as well as combinations of philosophies when used in a single study (Shannon-baker 2016: 19). Thus, mixed method used to fill the gaps that occur when using only one of the research approaches. In this regard, the mixed method research would provide a more robust approach and allow comprehensive analysis of the research problem and or research objectives (Migiro & Magangi 2011: 3757).

Moreover, the justification for the adoption of this method comes from the objectives of the study. On one hand, the study explores the impact of climate change on livelihood pattern using subjective responses from residents, and on the other, it intends to quantify the level of vulnerability of households in the study area. Consequently, it involves analysing both qualitative and quantitative information, which requires a mixed research approach.

3.3. DATA TYPES AND SOURCES

3.3.1. Secondary data source

The study uses various types of data from different sources. Both primary and secondary data was collected to achieve the thesis objectives. The secondary data was collected from offices working on climate change, agriculture, food security and rural livelihoods in the study region. The following are key institutions that were contacted to obtain secondary data and access various documents including research reports, annual plans and compiled datasets:

- Blue Nile Water Institute (BWI),
- Ethiopian Meteorological Agency
- Meteorological Stations of Lake Tana Basin
- Amhara National Regional State Bureau of Finance and Economic Development (BoFED)
- Amhara National Regional State Bureau of Agriculture
- Kebele (smallest administrative units) Food Security Desk
- Kebele Water Desk
- Kebele Natural Resource Management Desk

The secondary data is used to understand the overall livelihood context and changes in weather related variables (temperature and rainfall pattern). Such key information was collected in relation to climate related variables, socio-economic conditions and agricultural production. In addition, secondary data was collected by reviewing food security strategy papers, poverty program documents, books, articles as well as published and unpublished reports.

3.3.2. Primary data source

Primary data was collected from sample households and community members using open and close-ended questions. The primary data has both quantitative and qualitative aspects. While the quantitative data was collected using household survey, the qualitative data was gathered using in-depth interviews, key informant interviews, focus group discussions and local level participatory scenario development workshops. The details on each of the data collection tools are presented in the next subsections.

3.4 RESEARCH METHOD

In this subsection, the data collection tools are presented. As mentioned in the above subsection (section 3.3), the study uses both primary and secondary data based on the objective of the study and nature of the research question at hand. In the following subsection a detail about the quantitative and quantities data collections tool is presented.

3.4.1 Qualitative data collection tools

Qualitative data was generated using various techniques including focus group discussions, in-depth interviews, key informant interviews, participatory scenario development workshops and document reviews. The collected qualitative data is used to capture, explore, and explain if and how climate change and adaptation impact livelihoods in Lake Tana Basin.

In addition, the qualitative data is used to explore the perception of community members about the pro-poorness of climate change adaptation strategies and to identify mechanisms to make these strategies work for the poor.

3.4.1.1 Focus Group Discussions (FGDs)

Focus Group Discussions (FGDs) are used to explore the experiences, perceptions and knowledge of community members with respect to the potential impact of climate change and adaptation on livelihood pattern. The FGD participants were selected using two sets of criteria: 1) community members should be above age 40, and 2) they should represent different livelihood paths. The selection was done in consultation with the local administration.

- **Above age 40**: This group of people were targeted because of the scientific proposition that climate change should be observed at least for 30 years by any respondent. This members of the community are assumed to observe or witness climate change and livelihood pattern changes overtime. Thus, the assumption is that they had a better chance to observe how environmental, social and economic activities were changing overtime because of climate related shocks.
- **Livelihood paths:** In order to examine the impact of climate change on different types of livelihood paths, community members from different life track history were included.

3.4.1.2. In-depth Interview

The in-depth interview was conducted in order to gain deeper insight and understanding of household member's experiences in relation to the impact of climate change and adaptation on rural livelihoods in the Lake Tana Basin. Moreover, the in-depth interviews were conducted with members of the community representing major livelihood pathways in the study area (i.e. crop and livestock producers as well as fishers).

3.4.1.3. Key Informant Interview (KII)

The KII was conducted with people who are knowledgeable about the Lake Tana Basin. These knowledgeable people are either those who have conducted research in the Tana basin or community members who have lived in the area for at least 40 years and whose source of livelihood is farming, livestock, mixed agriculture or fishing), these livelihoods are the top four sources income for the Lake Tana community (see chapter Four). The KII helped to understand how livelihood pattern is changing in the Lake Tana basin because of climate change and adaptation.

3.4.1.4 Local Level Participatory Scenario Development (PSD)

The PSD is a qualitative tool that involves the participation of key stakeholders to explore current and future conditions in order to assist study participants in identifying climate impact and adaptation options based on livelihood paths (World Bank 2010). Moreover, the PSD serves as a platform to understand how different groups of stakeholders view the range of possible adaptation options that are available to them (for example: from the perspective of pro-poorness).

In this thesis, three objectives are addressed using the PSD workshop: 1) evaluation (ranking) of climate change adaptation options in the Lake Tana Basin based on their beneficial value, 2) identification mechanisms to make climate change adaptation strategies work for the poor, and 3) identification of the impact of climate change on Tana basin livelihood system.

The PSD was conducted with key stakeholders including vulnerable farmers, community leaders, development agents, Kebele administration, Kebele water committee members, farmers, traders and fishers, ensuring diverse representation. The participant selection process was conducted in consultation with the Kebele administration. After the researcher briefed the Kebele administration on the objectives of the PSD, potential participants were solicited and listed for each target group.

In order to rank each adaptation option, the study used locally derived criteria and a simple matrix scoring system (table 3.1). (Low scores are indicated by a single dot and high scores by four dots).

Table 3.1: Matrix scoring to rank each adaptation option

Adaptation options	locally-derived criteria 1	locally-derived criteria 2	locally-derived criteria 3	locally-derived criteria 4	locally-derived criteria 5	Total score for each option
adaptation option 1						
adaptation option 2						
adaptation option 3						
adaptation option 3						
adaptation option 4						

Source: Own depiction

The PSD sessions lasted for about two hours and thirty minutes. The participants were engaged in a series of exercises and discussions to identify the effect of climate change and rank climate adaptation options using locally developed criteria (appendix G).

Since the PSD groups were composed of individuals from various livelihood paths, the dynamics in the group discussion made the climate change analysis relevant and contextual.

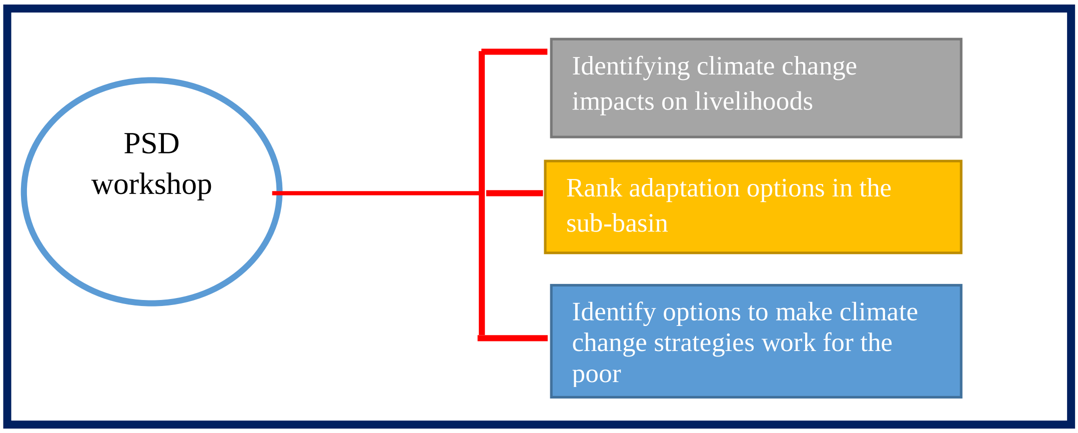
The participants discussed with one another about the effect of climate change and adaptation options in the Lake Tana Basin.

During a PSD session, a blank paper was provided to the group to identify the effect of climate change and rank adaptation options. Then they managed to produce three key outputs: 1) local criteria to evaluate climate adaptation options for the future in the Lake Tana Basin, 2) options to make climate change adaptation strategies work for the poor, and 3) effects of climate change on Lake Tana Basin livelihood. In this regard, the method allowed for the capture of the participants' perceptions, knowledge, experiences and practices that were shared in the course of interactions with different livelihood representatives.

As presented in Figure 3.2, at least three activities were carried out so as to guide the PSD workshop to attain the desired output from the workshops (figure 3.2). These are;

1. Identifying climate change effect on livelihoods: which allowed the participants to identify every possible impact of climate change in the basin.
2. Rank climate change adaptation options in the sub basin: after first identifying climate adaptation options in the sub-basin the study participants ranked climate adaptation strategies using local criterions.
3. Identify options to make climate change strategies work for the poor: the study participants identified different option to benefit the poor from adaptation strategies.

Figure 3.2 : PSD activities



Source: Own depiction using concepts from World Bank (2010)

3.4.2 Quantitative data collection tools

As presented in chapter two, the study used a mixed method approach comprising of both quantitative and qualitative data collection tools. Thus, quantitative data applied to address some of the objective of the study. For example, the study will seek to 1) examine the perception of households about the effect of climate change, 2) examine the perception of households toward the effect of climate change adaptation, 3) estimate how livelihood is vulnerable and which livelihood is vulnerable in the Lake Tana sub-basin, and 4) examine livelihood adaptation strategies followed by households. Moreover, aAs stated in the literature review section, climate change affects socio-economic conditions of households (chapter 2). In this context, quantitative socio-economic data was collected using a household survey.

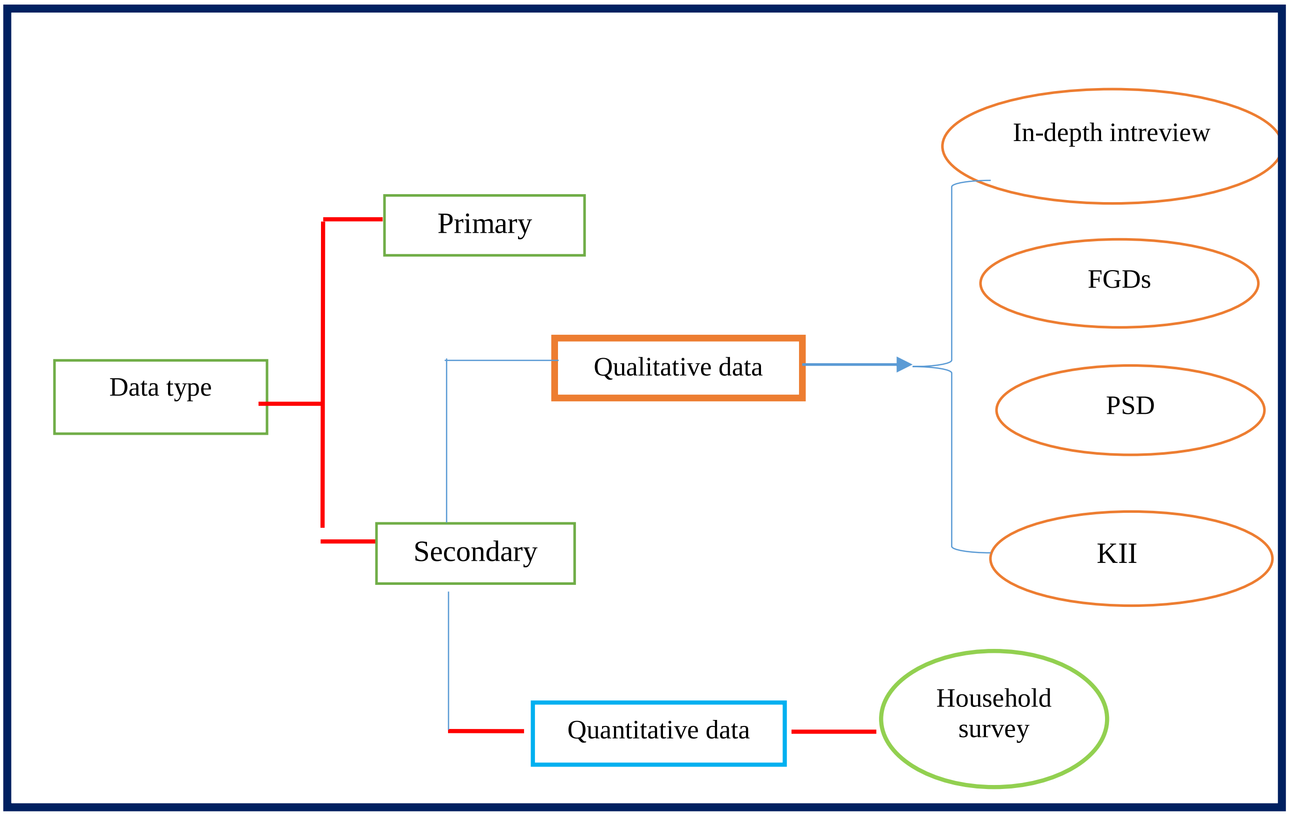
3.4.2.1 Household survey

To collect quantitative data using the household survey, a structured questionnaire was developed and administered to the study participants. The respondents were representative rural households in the study area. The household survey captured information from the participants in the areas of demographic characteristics, food security status and conditions, climate change adaptation strategies, crop and livestock production data, asset ownership, consumption data, perception about the effect of climate change and adaptation on livelihood pattern and the implications of livelihood pattern change on poverty and food security.

In addition, the household survey was used to explore if and how households changed or adapted their livelihood to minimize the effect of climate change through livelihood diversification, asset selling or ownership, change in farming practice, technology adoptions and other possible mechanisms available to them. Finally, data on ranking of various climate change adaptation strategies by households was collected.

The overall primary and secondary data used in the thesis is presented in figure 3.3. The Figure shows that both quantitative and qualitative data used in the thesis. While the qualitative data collected using FGD, KII, PSD and In-depth in review, the quantitative data collected using primary household survey.

Figure 3 3: Summary of type of data used in the study



Source: Own depiction

3.5 SECONDARY DATA COLLECTION

In addition to the primary data, secondary data was collected from various sources (table 3.2). Data on livelihoods (crop, fish and livestock production) was collected from the regional agriculture bureau. Climate related data including temperature, rainfall pattern was obtained from the National Meteorological Agency (NMA) and the meteorological stations at Lake Tana Basin. Moreover, data on population settlement, basin characteristics and agrology was collected from the Blue Nile Water Institute and the regional Bureau of Finance and Economic Development.

Table 3.2: Source for secondary data

Secondary data source	Data type
National Meteorological Agency and Meteorological Stations of Lake Tana sub-basin	Climate variable including temperature and rainfall
Regional Agriculture Bureaus	Agriculture fishing, and livestock production data
Amhara National Regional State Bureau of Finance and Economic Development	Socio economic data
Blue Nile Water Institute	Lake Tana sub-basin characteristics

Source: Own summary

3.6. SAMPLING DESIGN

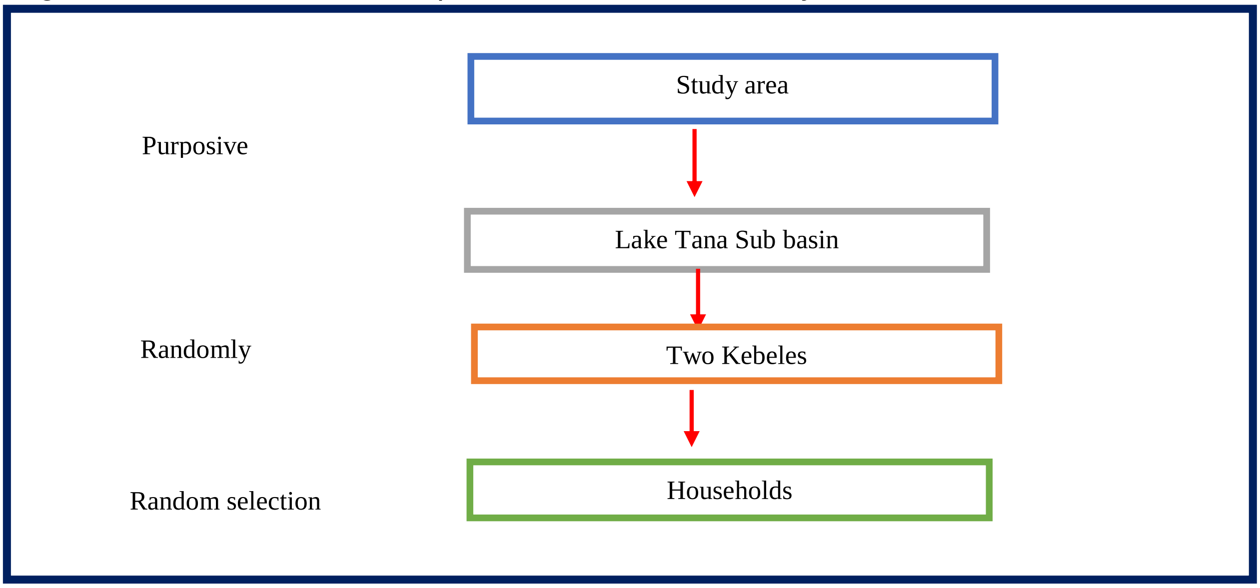
3.6.1 Sampling design for the quantitative data collection

As presented in figure 3.4, the study used a three-stage sampling procedure. In the first stage, the Lake Tana Basin was purposely selected for three reasons: 1) as presented in chapter 1, climate change has placed a serious challenge in the sub basin, 2) the sub-basin is a source of livelihood for millions of farmers, and 3) it plays a vital role in providing significant socio-economic values both for the Nile basin of Ethiopia as well as for downstream riparian countries.

In the second stage, the selection of study Kebeles (smallest administrative units in Ethiopia) was conducted. There are about a total of 16 Kebeles in the Lake Tana Basin (Table 3.3). At this stage, one Kebele from upper basin and one Kebele from the lower basin were randomly selected using a lottery method. Accordingly, Kuharmichael from the lower basin and Wagetera Kebele from the upper basin were selected randomly.

There are two key factor that determined the random nature of the Kebeles: 1) Kebeles in the upper and lower basins have the same agro-ecology within their respective geographical division, 2) the farming system tends to be similar in both upper and lower basins Kebeles (characterized by subsistence agriculture and traditional farming methods).

Figure 3 4: Flow chart for sample selection for the survey



Source: Own depiction

In the third stage, the study units or households were randomly selected to collect relevant data on agriculture, food security, income, livestock, climate adaptation practices, consumption, poverty, and demographic information.

Table 3.3: Districts and Kebeles in the Lake Tana Basin

District	**Lower basin Kebeles**	**District**	**Upper basin Kebeles**
Fogera	Shaga	Libokemkem	Michaeldebir
Fogera	Shina	Libokemkem	Libo
Fogera	Kuharmichael	Farta	Mokesh
Fogera	Bebekis	Farta	Amjaye
Libokemkem	Tezamba	Farta	Gentegna
Libokemkem	Bira	Farta	Sores
Libokemkem	Shinatsion	Farta	Darmo
Libokemkem	Kab	Libokemkem	Wagetera

Source: Own depiction using data from (Solomon, Adesola & Rao 2016).

The total number of households found in the immediate Kebeles of the upper and lower sub-basins is around 22792(chapter 4). The number of sample households to be selected from both the upper and lower sub-basins was calculated using sample size determination formula proposed by (Cochran (1997) in Solomon, Adesola & Rao 2016: 463). This formula is chosen in this thesis as it has already been applied and tested by another climate change study in a similar location (Solomon, Adesola & Rao 2016:464). Thus, the sample size calculation for selection of households from each sub-basin is as follows:

(i) the proportion (q) (q=0.5);
(ii) design effect (x) (2);
(iii) $\boldsymbol{\varepsilon}$ is the margin error (10percent margin of error at 95percent confidence);
(iv) 5percent non-response rate. The sample size determination formula is given as:

$$n_{nas} = \frac{x\left(z^{x}/_{2}\right)^{2} * q(1-q)}{\varepsilon^{2}} \qquad n_{as} = \frac{n_{nas}}{1(n_{nas}-1)\frac{1}{N_i}}$$

Where: Ni = the total number of households in each sub-basin n_{nas} = Non-adjusted sample size for each sub-basin and n_{as} = Adjusted sample size for each sub-basin. The final sample size (upper and lower basin), using the above formula, will be 282 respondents. The sampling distribution for each basin is presented in table 3.4.

Table 3.4: Sampling distribution between the upper and lower basin.

Sub-basins	Number of households in each sub-basin	Adjusted sample size	Sample size
Lower sub-basins	12098	136	142
Upper sub-basin	10694	134	141
Total	22,792	270	282

Source: Own summary

Every Kebele in Ethiopia has a households list. As such, the 282 respondents were selected from these lists. The selection of households was conducted using a systematic random technique. The following formula was used to determine the sample interval:

Sample interval for each basin = N/n

Where;

N = total population

n = sample size

The household head could be male or female. If the household head is not present, the sample was replaced by another household found in the Kebele list.

3.6.2 Sampling for the qualitative data collection

In the case of qualitative data, the non-probability sampling approach, particularly the purposive sampling technique was used to select respondents for the focus group discussions, in-depth interview, and key informant interviews and participatory scenario development. In the following subsection, a brief discussion is presented on how the purposive sampling technique was operationalised in each of the qualitative study methods.

3.6.2 .1 Sampling for in-depth interview

The in-depth interview was conducted with community members and other stakeholders found in the upper and lower basin Kebeles. These included men and women members from different economic status i.e. rich and poor. This was done because climate change affects the livelihood pattern and paths of the two groups in different ways.

The identification of rich and poor men and women members of the community (wealth ranking) of the community was conducted in consultation with the local administration in the two study Kebeles. The key criteria that were used for classification purposes include land holding, number of livestock owned, type of house that they lived in and ownership of forest (table 3.5). Using these criteria, the Kebele administration and researcher ranked and identified respondents for the in-depth interviews.

Table 3.5: Criteria used to classify poor and rich households

Criteria	Poor	Rich
Land size	Who do not own land if owned land size <1 hectare	who own land and land size is >1 hectare
Numbed of oxen owned	Who don't who own any and or <5	>=5
Ownerships of forest	Own forest	Do not own forest
Type of house	Mud	Corrugated

Source: Own summary of information from the Kebele

The Lake Tana Basin is also home for monasteries and churches which makes it an important site for tourist attraction. As such, monks or church leaders who have lived in the study area for more than 40 years were selected for the in-depth interview. As presented in section 3.4.1.3., this age group is considered knowledgeable about the livelihood changes and the effect of climate change on the basin.

The in-depth interviews were conducted with members of the community that differ in their livelihood paths. The major livelihood paths are crop production, livestock production, fishing, mixed farming, tourism, trading and small business and any combinations of these. Participants from these livelihood paths were identified in consultation with members of the community and Kebele administration. The inclusion of different livelihood paths in addition to the major livelihood path of agriculture allows for the capture of the full picture of the effect of climate change and adaptation in the livelihood system (table 3.6).

The in-depth interviews also included cooperative members, agricultural extension experts at regional, Woreda and Kebele level (Kebele level participants were drawn from the upper and lower basin), and livelihood experts found at Amhara Regional Agricultural Research Institute (ARARI), Bahir Dar University (BDU) and the Blue Nile Water Institute. The selection of these target groups or participants was based on three criteria: 1) sectoral representation, 2) knowledge of the study area, and) knowledge of the study subject.

Table 3.6: Sampling for in-depth interview

In-depth interview target groups	Representation	Number
Men and women members of the community based on their wealth status	Wealth status	4 (two from wealthy and two from non-wealthy members)
Church leader or monks	Monasteries surrounding the lake Tana	1
Peasants	Community members/ livelihood paths	1
Traders	Community members/ livelihood paths	1
Fisher	Community members/ livelihood paths	1
Tourist guides	Community members/ livelihood paths	1
Total		9

Source: Own depiction

3.6.2.2 Sampling for key informant interview

The KII samples were drawn purposely from community members and government, academic and research institutions found in the Amhara regional state (table 3.7). The selection of the KII subjects was conducted based on their knowledge of the study area. Thus, community members above 40 years of age were the primary target of the KII. This is important as they would have a better chance observing how their environment and livelihood have changed over time due to climate related factors. In addition, experts from various institutions were selected based on their research and work experience in the Lake Tana Basin.

Table 3.7Key informant interview

Target groups	Who they represent	Number
Community members	Community	2(one from upper basin and one lower basin)
Agricultural extension experts	Government	2 (at regional, Woredas and Kebele level)
District Food security	Government	1
Amhara Regional Agricultural Research Institute	Research institute	1 (Livelihood experts)
Bahir Dar University	Academic institute	1
Blue Nile Basin Institute	Research institute	2
Total KIIs		9

Source: Own depiction

3.6.2.3 Sampling for Focus Group Discussion (FGD)

The FGDs were conducted with people from different livelihood paths who live in the lower and upper basins (table 3.8). These participants were drawn from different livelihood paths (crop growers, livestock producers, traders, fishers and any combination of these four major livelihood paths). The list of Kebele members were taken from the Kebele administration and once the Kebele households list was secured, households were categorized into different livelihood paths, age ranges and wealth profiles. Concerning age, people who lived in the area for more than 40 years were the target of the FGDs. With the scientific proposition that climate change should be observed for at least 30 years, community members who were above 40 years of age were assumed knowledgeable about the climate and livelihood changes in the study area.

The diversity of the FGDs the participants indicated the views of a maximum number of livelihood groups. The participants for the FGD selected using convenient sampling technique.

The FGDs have helped in understanding the effect of climate change and adaptation on the various aspects of livelihoods in the Lake Tana Basin as perceived by members of the community. Moreover, the FGDs helped to answer the implications of livelihood pattern change (caused by climate change) for poverty and food security in the Lake Tana Basin system.

Table 3.8: Sampling for focus group discussion

Target groups for FGD	Number of FGDs
Different livelihood paths (crop producers, livestock producers, traders, fishers any combination of any of the four major livelihood paths).	1
Different livelihood paths (crop producers, livestock producers, traders, fishers any combination of any of the four major livelihood paths).	1
Total	2 FGDs

Source: Own depiction

3.6.2.4 Sampling for Participatory Scenario Development Group(s)

The PSD participants represented farmers (men and women as well as rich and poor), traders, fishers, Kebele administration, agricultural experts and development agents. Thus, participants for the PSD were drawn from community members representing various livelihood paths and conditions, making the PSD more robust in obtaining the required information.

The selection of participants for PSD was carried out using a purposive sampling technique in consultation with the local administration based on three factors: 1) long term residency in the study area, 2) long term participation in the respective livelihood pathways that include crop production, fishing, trade, livestock production, and 3) willingness to participate in the study subject.

3.7. THE DATA COLLECTION APPROACH

The study used Computer Assisted Personal Interviewing (CAPI) to collect the quantitative household survey data required to answer the key research questions by implementing fast, high quality and cost-effective methods of data collection. As such, tablet-based data collection techniques were applied. In this regard, the study used a freely available data management software called Census and Survey Processing System (CS-PRO) to design the questionnaire template. Once the design of the template was completed, the data manager uploaded the questionnaire to each tablet.

3.8 SURVEY PLAN

The number of field days depended on the sample size, the number of interviewers, and the number of respondents that an interviewer could engage with in a day. In this regard, one enumerator completed three interviews per day. This includes the time spent on finding the right study participant, break times, and working hours in a day. For the survey, four enumerators and two supervisors participated in the study. The number of days for the data collection is calculated as follows:

$$\boldsymbol{No.ofDays} = \frac{(SampleSize)}{(No.ofinterviewers\ X\ (InterviewQestionnairesperInterviewerperday\ )}$$

$$\boldsymbol{No.of\ Days} = \frac{281}{5\ X\ 3} = 18.7 \approx 19\ days$$

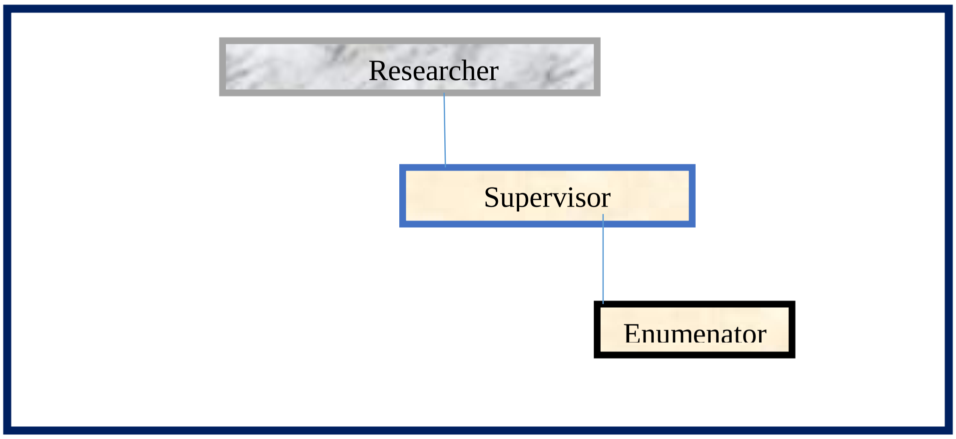
Interviewers' recruitment

Supervisors and enumerators were selected based on previous experiences in conducting similar types of surveys, language skills, familiarity and knowledge of the area and other qualifications. During the selection process, priority was given to those who had previous experiences in similar studies, particularity in climate change focused studies.

As presented in figure 3.5, the field team comprised of the researcher, supervisors and enumerators. The field team structure shows that the supervisors reported to the researcher and the enumerators reported to the supervisor. One supervisor and three enumerators were involved during the fieldwork. Moreover, specific tasks were given to each team. The main tasks of the researcher included controlling the overall data collection process, checking the data quality, and conducting FGD, KII interviews and participating in the PSD session.

The tasks of the supervisor included controlling the data quality, securing support letter from local administration, assigning enumerators to study site, collecting data from enumerators on a daily basis, providing feedback in collaboration with the researcher and conducting FGD, KII and PSD. The main tasks of the enumerators included collecting household data and conducting KII and in-depth interviews.

Figure 3 5: Field team structure



Source: Own depiction

3.9. DATA QUALITY CONTROL MECHANISM

Data quality is an important component of the research process. In this regard, the researcher has used various data quality control mechanisms. The data quality controls were implemented at different stages of the study i.e. pre-data collection, during field data collection and post data collection including data analysis. The details of technical quality assurance mechanisms at every step of the study are presented here.

Pre-data collection: The researcher considered training and pre-testing as parts of data quality assurance. Thus, intensive training of data collectors was conducted before the fieldwork. The overall purpose of the training was to: 1) ensure a uniform application of the interview materials, 2) explain the rationale of the study and study protocol, 3) motivate interviewers, 4) provide practical suggestions, and 5) improve the overall quality of the data. Mock interviews were prepared to check whether the interviewers had a consistent understanding of the concepts and ideas of the study.

As part of quality assurance mock interview conducted to identify minor linguistic and feasibility issues and enable better planning for the main phase. In addition, the researcher prepared a simple technical note for the study tam members to explain the purpose of the study, concepts of the study and sampling procedure.

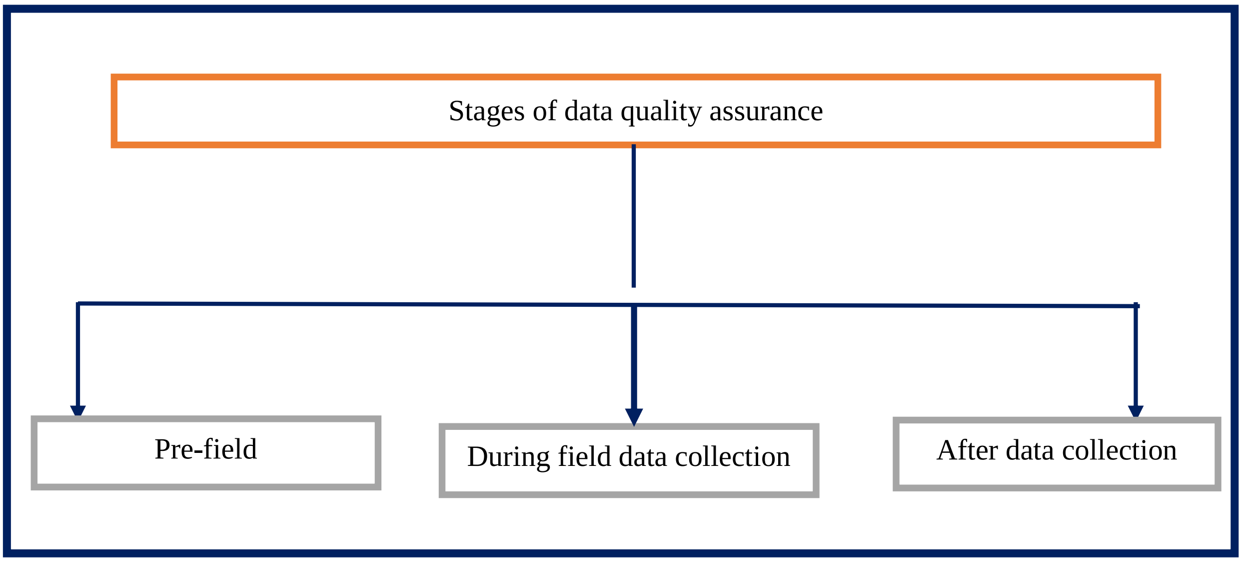
During data collection: During the field data collection, the researcher monitored the activities of the field staff at each stage of the field activity. In this regard, field supervisors were critical links between the researcher and the survey staff. They monitored production and performance and communicated any field issue that may have an effect on the quality and timely completion of the study. They were entrusted with ensuring that the data was collected according to protocol with the highest possible quality. The supervisors provided daily and continuous feedback to the researcher concerning data quality issues, both positive and negative. Moreover, the researcher visited the site regularly to monitor the overall activity.

Supervisors were instructed to lay out the daily work at the beginning of the workday with the interviewers and review results at the end of the day. In this review, interviewers would brief their supervisors about their interviews and results. Moreover, supervisors examined the completed interviews to make sure that the questionnaires were both complete and accurately coded. In addition, the researcher regularly connected with the field manager and the overall team leader through mobile phones, so questions could be resolved and clarifications shared with all teams in timely manner. The researcher also carried out the following activities: 1) made frequent unannounced spot checks on the teams in the field, 2) ensured that they followed the sampling methodology correctly, and 3) checked all forms to ensure that all sections were accurately completed.

<u>After data collection:</u> Real-time data synchronization of the field data was executed to the central data hub-computer /the one owned by the researcher/ using CAPI. The data manager, together with the study team, reviewed the synchronized data regularly for potential quality improvements.

To this end, as presented in the following figure, the study assured data quality at three stages namely pre data collection, during field data collections and after data collection.

Figure 3.6: Data quality assurance mechanisms



Source: Own depiction

3.10 DATA ANALYSIS PLAN OF THE STUDY

3.10.1 Qualitative data analysis

The qualitative data was analysed using thematic and dimensional analysis. First, the data was reduced into manageable portions for analysis (data reduction). The data from the in-depth interview, key informant interview and focus group discussion was coded and analysed according to the different emerging themes from the data. This has helped to identify the effect of climate change on different components of livelihood.

Moreover, thematic analysis helped to analyse how livelihood pattern changed because of the impact of climate change in the study area.

The themes were linked to the effect of climate change on livelihood assets (physical, social, natural, financial and human) and strategies. They were also organized in terms of implications of livelihood pattern change (due to climate change and adaptation) for poverty and food security (Chapter 7).

3.10.2 Quantitative data analysis plan

The quantitative data was analysed using statistical and econometric techniques. Moreover, qualitative data was used to substantiate the results of the quantitative analysis using triangulation techniques. The analysis of the quantitative outputs was done by using different descriptive and analytical statistical tools. When analysing frequencies, percentage changes and means of different continuous variables were derived and computed. Descriptive statistical methods such as means and confidence intervals of means were employed. In this regard, statistical tests like t-test were used to compare the perception of community members towards climate change in the upper and lower basins and estimate mean values of climate change indicators. Moreover, statistical estimation techniques were used to estimate the extent of vulnerability of livelihood components to climate change in the Lake Tana Basin.

Statistical analysis along with parametric and non-parametric tests for groups was conducted using STATA version 14.0 (chapter 7). And data management and cleaning was conducted using Statistical Package for Social Science (SPSS version 20).

3.10.2.1. Time series analysis of climate variables

In order to say there is climate change and variability in a certain country, region, zone or district, there is a need to examine the pattern in climate change variables over time (Birara, Pandey & Mishra 2018: 555). In this regard, studies have indicated that at least a 30-year data is required to follow the weather variability and change in climate related variables (Hayelom, Chen, Marsie &

Negash 2019:18). Accordingly, the thesis examined the trend in climate change variables in the past 30 years (Chapter 5).

In order to examine variability and long-term trends in climate change variables (rainfall and temperature), various statistical tools were used. These include the calculation of standard deviations (SD), mean, coefficient of variability (CV), Mann Kendall trend test and Precipitation Concentration Index (PCI). The calculation of the statistical measures followed the works of (Kumbuyo, Yasuda, Kitamura & Shimizu 2014:17-19 ; Zhang, Yao,QIan & Wang 2019: 4648). The formulas are presented below:

$$\bar{X} = \frac{\sum xi}{N} \tag{3.1}$$

Where; $\bar{X}$ =mean value

$xi =$ the i[th] variable

N= the number of observations

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{X})^2} \tag{3.2}$$

Where;σ standard deviation

N= number of observations

$\bar{X}$ = the mean value

x_i = i[th] variable or observation

$$CV= \frac{\sigma}{\bar{X}} \tag{3.3}$$

Where; CV is coefficient of variability

$\sigma =$ Standard deviation

$\bar{X}$ = mean

Finally, the precipitation index is given by the formula: (3.4)

$$PCI_{Annual} = \frac{\sum_i^{12} pi^2}{\left(\sum_i^{12} pi\right)^2}$$

Where;

PCI; Precipitation Concentration Index
pi = the rainfall amounts of ith month
Σ = Summation over 12 months

Additionally, the simple linear regression model was used to estimate temperature and rainfall trends. This method is widely applied in climate change related studies (Teshome 2016:19). The model was also helpful in examining long-term trends of climate change variables such as temperature, rainfall and precipitation. For this particular purpose, secondary climate data (rainfall, temperature and precipitation) was collected from the Blue Nile Basin Institute and Ethiopian Meteorological Agency. In this endeavour, the study used different statistical approaches to explain the trend in climate change related variables over time. This would substantiate the analysis of the perceptions of community members towards climate change in the area.

3.10.2.1.1. Weather data gathering, storage and analysis

The thesis used annual and monthly rainfall and temperature data collected by the meteorological stations at the Lake Tana Basin, which was later gathered by the Ethiopian National Meteorological Agency (ENMA). An official letter stating the nature and purpose of the study was provided to the ENMA to secure the data.

There are about ten gauge stations situated in the upper and lower basins of Lake Tana. However, two stations, one from upper basin and another from the lower basin, provided reliable and accurate data for the time series weather data analysis. These stations were the Bahir Dar station from the lower basin and the Debretabor station from the upper basin. These stations provided complete data at least for 30 years. In this regard, other studies have also indicated that data from these two stations are reliable and complete (Addisu et al 2015:5).

The data secured from ENMA was in an excel spreadsheet format. However, for the purpose of trend and other descriptive statistical analysis, the data was transformed to STATA data file format.

The data was analysed using simple descriptive statistics. This includes the calculation of standard deviations (SD), mean, coefficient of variability (CV), Mann Kendall trend test and Precipitation Concentration Index (PCI). The descriptions of these statistical measures are presented in section 3.10.2.1.

The interpretation of the descriptive statistics is based on the standard of similar studies. For example, for PCI, 1) if PCI <10, it shows uniform precipitation distribution (low precipitation concentration), 2) if PCI>11 and <15, it shows the existence of moderate precipitation concentration, 3) if PCI>16 and <20, it shows irregular distribution, and 4) if PCI>20, it shows strong irregularity (high precipitation concentration). The formula and the result of the analysis are provided in section 3.10.2.1 and 5.2 respectively.

The data was used by this thesis in two ways. First, it was used to provide scientific evidence for the change in weather conditions (temperature and rainfall) in the Lake Tana Basin. Second, the data was used to triangulate the data from the primary data (household and community level data). This helped to improve the validity and credibility of the findings. Moreover, it helped to reduce biases in the study.

3.10.2.2 Measuring Livelihood vulnerability in the Lake Tana Basin

The thesis applied Livelihood Vulnerability Index (LVI) to measure and calculate the vulnerability status of households in the Lake Tana Basin using a balanced weighted average approach. This formula helps to adjust the weighting scheme of livelihood sub-components as needed depending on the scale of analysis (Hahn, Riederer & Foster 2009:76). The sub-components were first measured and standardized as an index. The equation used for this conversion was adapted from (Hahn, Riederer & Foster 2009:76). This is the ratio of the difference of the actual values and a pre-selected minimum and the range of maximum and minimum values of indicators for each sub-component determined using data collected from households and secondary sources. On the bases of the analytical framework, vulnerability indicators and measurements were identified and operationalized.

As presented in following table, the livelihood vulnerability index has seven key components which includes socio-demographic profile, livelihood strategies, social networks, health, food, water, and natural disasters and climate variability.

Table 3.9: IPCC contributing factors to vulnerability and major components

Livelihood vulnerability index components	IPCC contributing factors to vulnerability
Socio-Demographic Profile	Adaptive capacity
Livelihood Strategies	
Social Networks	
Health	Sensitivity
Food	
Water	
Natural Disasters and Climate Variability	Exposure

Source: Sisay (2016:2)

Finally, the vulnerability can be estimated using a simple formula following the empirical work by Hahn, Riederer and Foster (2009:76) and and recently (Sisay 2016:2-3). Thus, the vulnerability index of the Lake Tana Basin is estimated using the following simple formula:

$$\text{Index} = \frac{S_D - S_{min}}{S_{max} - Smin} \quad (3.5)$$

Where SD is the original sub-component for the basin,

S-min and S-max are the minimum and maximum values, respectively, for each sub-component

After each was standardized, the sub-components are averaged using Equation (3.6) to calculate the value of each major component.

$$S_D = \frac{\sum_{n_i} Index_{\text{sDi}}}{n} \quad (3.6)$$

Where MD = one of the major components for the index

SDi = represents the sub-components, indexed by i, that make up each major component, n is the number of sub-components in each major component

3.10.2.3 Leopold matrix to identify the effect of climate change on livelihood pattern

In this thesis, one of the objectives of the study is to examine how livelihood pattern is changing (due to climate change in the Lake Tana Basin). In order to assess this change, this thesis used a simple descriptive statistics tool called the Leopold matrix.

The Leopold matrix was used to identify the effect of climate change on livelihood pattern based on people's experience of the phenomenon (Sheikh & Akter 2017:46). The construction of the Leopold matrix is simple and straightforward. Climate change's effect on livelihood pattern is ranked using an index matrix (which helps to prioritize livelihoods and identity impact on each of the key livelihood paths in the Lake Tana Basin). Following the work of (Sheikh & Akter 2017:46), the index matrix will rank livelihoods using Likert scales and thus livelihoods ranking can be defined as highly severe=5, severe=4, moderate=3, minor=2, low=1 or None=0.

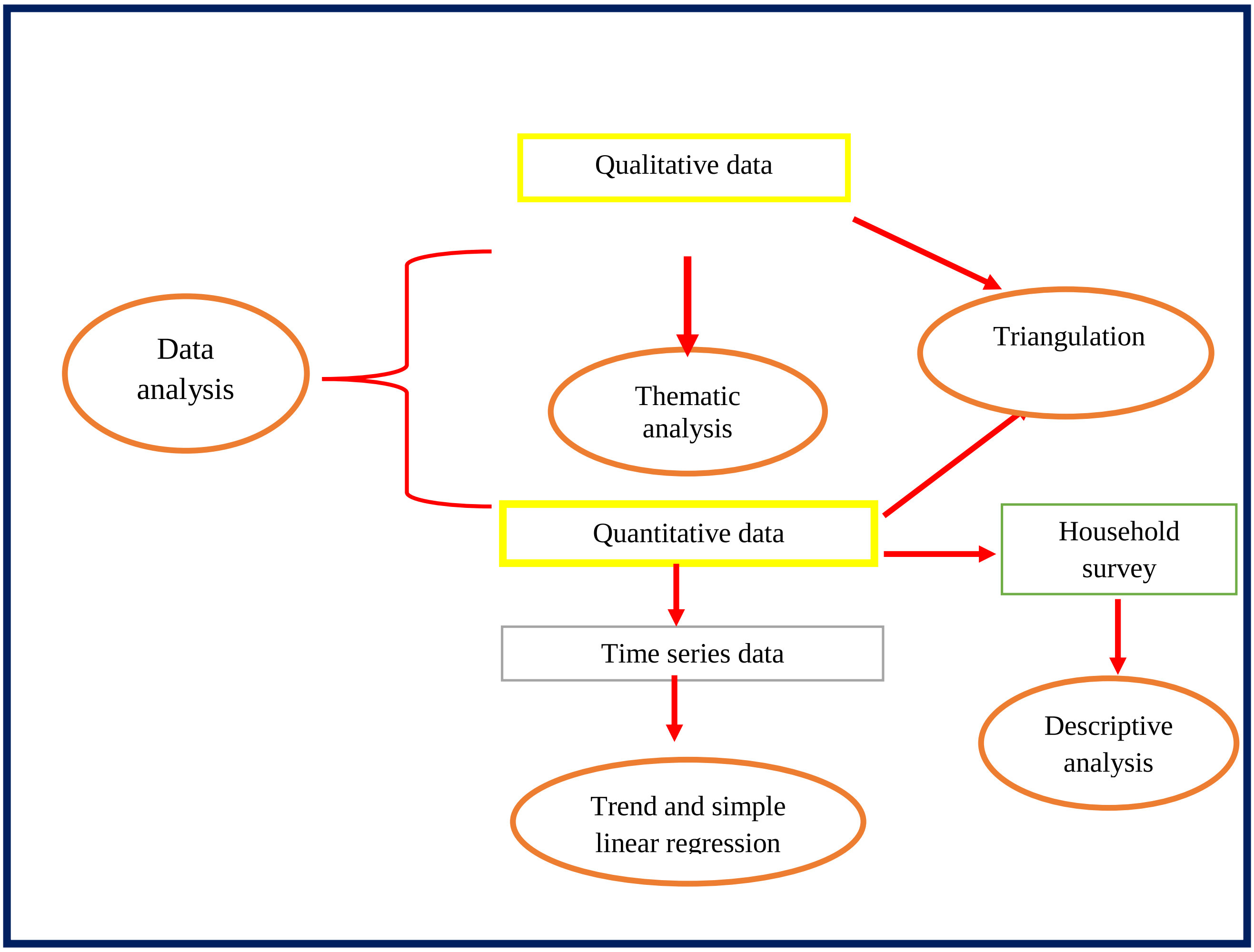
The livelihood ranking was completed using appendix H which was part of the household survey. After the ranking exercise is completed, then the frequencies are produced and the rankings are computed for each of the livelihood paths. Finally, a rank is assigned to each livelihood path according to the frequencies generated from the survey.

3.11. SUMMARY OF THE DATA ANALYSIS METHOD

The overall schema of the data analysis plan is presented in figure 3.7. The qualitative data was analysed using themes coming from the FGD, KII and in-depth interviews. Quantitative data (household survey and secondary climate data) was analysed using descriptive statistics, trend analysis and simple linear regression.

Moreover, data triangulation was used to substantiate the result of the qualitative and quantitative data. The triangulation facilitated validation of data through cross verification from two or more sources. In our case, data collected on the topic by quantitative approach (Survey) and qualitative methods (FGDs, in-depth interview and KII) were triangulated or analysed. This helped the researcher to check and establish the validity of the information in the thesis by analysing the research questions from multiple perspectives and arriving at consistency across data sources or approaches.

Figure 3 7: Schema of the data analysis plan



Source: own depiction

3.12. DATA SECURITY

The research followed various data security and safety measures throughout the entire data collection cycle. The data (quantitative and qualitative) was not shared in any form to a third party. In this regard, while the study implemented strict data security mechanisms on dozens of CAPI/tablets obtained for this study, the following are the key procedures followed by the researcher:

- All tablets and data collection devices were password or pass code protected.
- All tablets were encrypted.
- All tablets were securely stored during data collection
- All data was uploaded to the server, and a copy of the uploaded data remained in the Tablet for backup and recovery purposes
- Each day the enumerators or supervisors sent the data to the central computer
- For alternate use and as a data back-up, the field workers carried Flash drives

3.13. LINKING STUDY OBJECTIVES WITH DATA TYPES

The objectives and data types used in the thesis are summarized in table 3.10. Some of the objectives required quantification (i.e. measuring livelihood vulnerability to climate change, conducting trend analysis and measuring perceptions of the community towards climate change and adaptation) while other objectives required qualitative data (i.e. understanding of the effect of climate change on livelihood and the implications of livelihood changes for poverty and food security).

Table 3.10: Objectives and data types used

	Objective	Type of data
1	Analyse the trend and relationship between climate change variables (temperature and rainfall pattern) and crop production in the Lake Tana Basin	Secondary data
2	Investigate how climate change and adaptation are changing livelihood pattern in the Lake Tana Basin	Household survey+ FGDs + in depth interview + key informant interview
3	Assess the level of livelihood vulnerability in the Lake Tana sub-basin	Household survey+ FGDs + in depth interview + key informant interview
4	Examine the implications of livelihood pattern change (because of climate change and adaptation) for poverty and food security	Household survey+ FGDs + key informant interview
5	Investigate whether climate change adaptation strategies are pro-poor nor not.	PSD + household survey

Source: Own depiction

3.14 PRE TESTING OF DATA-GATHERING INSTRUMENTS

3.14.1 Pre-test of the study tools and data collection software

Prior to the actual data collection, the researcher prepared a pre-test using the tablets obtained for the actual data collection. In this regard, the researcher prepared a field manual for each team and distributed them to team leaders as references for key data collection activities (e.g. type of documents to review, type of institutions and individuals to contact for the KIIs, FGD and data quality measures, etc.). Then after recruiting and giving training for field personnel, the researcher conducted a pre-test in selected study areas using the developed study tools. As part of the training, a pre-testing of the audit tools was carried out after familiarizing the team with the tools.

The pre-test was used to evaluate the clarity and appropriateness of certain concepts of the survey tools. After the pre-test, modifications were made to the tools prior to their actual use in the field. The field-testing resembled the real implementation of the survey in order to test the full range of survey activities including questionnaire completion. An additional function of the pre-test was to provide more practical training to the survey team in administering the auditing of computer assisted data collection and management.

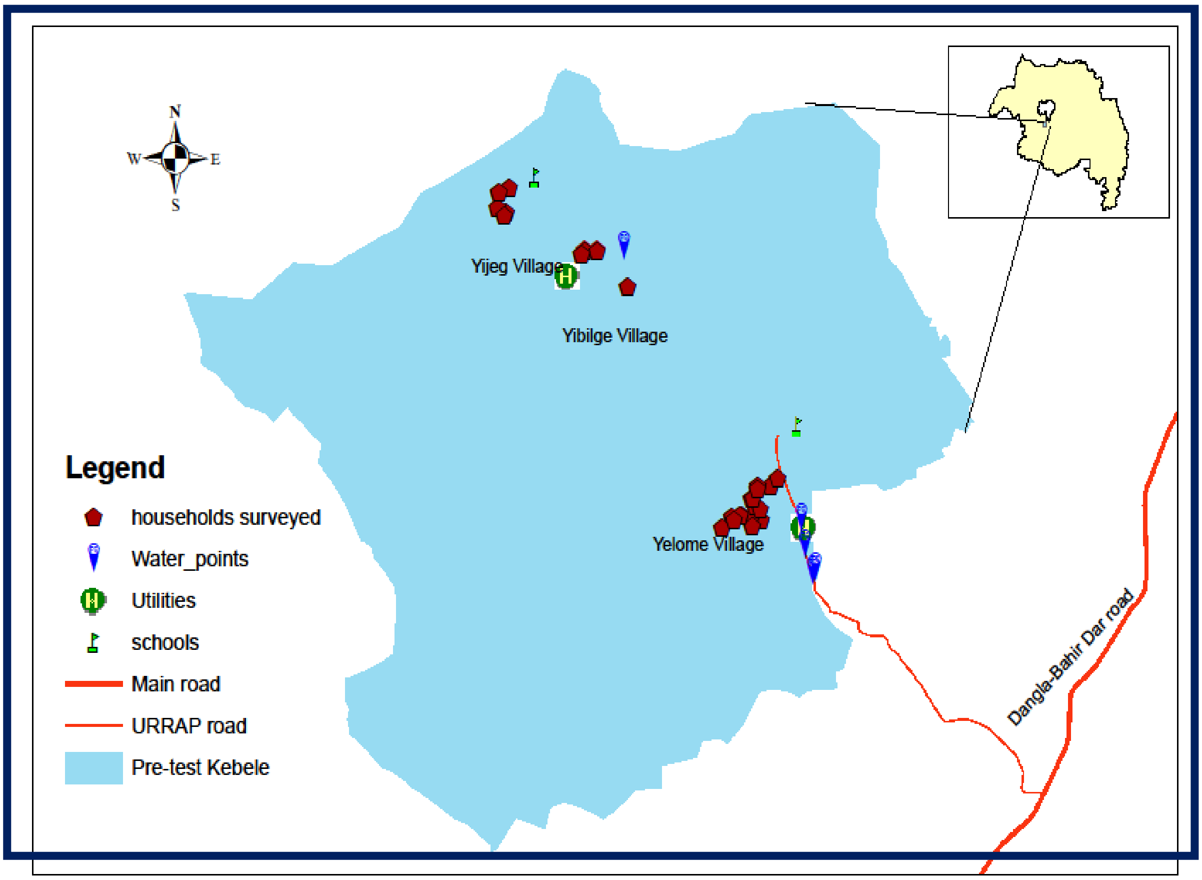
The researcher prepared a pre-test prior to the official data collection started. Thus, after recruiting and giving training for field personnel. There were two types of trainings while the first one focused on qualitative tool and the other focused on quantitative data. The training conducted face to face.

The researcher conducted the pre-test in selected areas (Kebeles) which have similar characteristics with the Kebeles and or households in the Lake Tana Basin. The pre-test had five objectives: 1) test whether the questionnaire can be completed on time, 2) test or check whether the study tools are clear enough, 3) check the flow of ideas and arrangements, 4) check if the translations are clear and up to standard and, 5) check the content and organization of the tools. The report from the pre-test is presented in the following subsection.

3.14.2 Pre-test report

Selection of area: The selection of Kebeles for the pre-test was based on three criteria: 1) the Kebele should not be far from the regional capital so as to save time and cost, 2) it should be in the Tana Sub basin, and 3) the Kebele should not be from the Kebeles to be covered in the main survey. In this regard, the researcher is very grateful to the regional agriculture bureau for their unlimited cooperation in selecting Kebeles for pre-test. Thus, as presented in figure 3.8, Yeloma Kebele was selected for the pre-test using the above three criteria.

Figure 3.8: Pre-test Keble map (Yeloma Kebele)



Source: Own construction using ARC-GIS 14

Table 3.11 shows the Woredas and Kebeles covered in the pre-test. The same table shows that the total population and the sample covered for the pre-test. The table shows that 1percent of the total population was assumed to be enough to conduct the pre-test.

Table 3.11: Kebele selected for the pre-test

Region	Woredas	Kebele	Kebele Population	Sample (1percent)
Amhara	Bahir Dar zuriya	Yeloma	5585	55

Source: Bahir Dar Zuriya city administration

Organization and management of the fieldwork for pre-testing: The fieldwork for pre-testing was organized in such a way to ease management and administration of the survey. It constituted the researcher, one supervisor and two enumerators. Prior to the data collection, training was given to the enumerators on the purposes and concepts of each survey instrument and its administration.

Types of instruments: As presented in this chapter, the study combines both quantitative and qualitative tools. Thus, there is a need to test both tools to validate and identify conceptual and technical issues that alter the quality of both types of data collection tools. In this regard, the pre-test included household questionnaire, key informant interviews and in-depth interviews.

Data entry and processing: As mentioned in the earlier section, the software that was applied for the data entry is Census and Survey Processing System (CS-PRO). In this regard, data entry training was given to all data encoders for two days. To ensure high quality of data entry, double entry of the encoded data was applied and any discrepancy was resolved by checking the administered questionnaire. The data cleaning was carried out using descriptive statistical tool and any erroneously entered data was re-entered and checked for reliability and consistency.

Pre-test schedule: The following tables summarize the work and time schedule for the pre-test that was carried out in the study region from January 2 to 6 /2021. Three types of tools were covered in the pre-test: 1) household questionnaire, 2) key informant interviews, and 3) in-depth interviews. A total of 5 field staff were involved in the pre-test. The work schedule is summarized in Table 3.12.

Table 3.12: Work schedule for the pre-test test

No	Tools	Data collectors	Days	Copies	Assigned individuals
1	Household questionnaire	3	3	40	Researcher and enumerators
2	Key informant	1	1	3	Researcher and enumerators
3	In depth interview	1	1	1	Researcher and enumerators

Source: Own depiction

3.14.3 Result of the pre-test

Survey instrument: One of the main purposes of the pre-test was to investigate the survey instrument and make the appropriate adjustment. In this regard, some questions that were found to be tricky and ambiguous were re-examined. For example, the term climate change could not easily be understood in its scientific form by some of the respondents. Thus, during the actual data collection period (using the local language), farmers' knowledge was used (based on their experience and perception and long-time observation).

During the pilot test farmers did not easily recognized some of concepts in their scientific terms. For example, the term climate change could not easily be understood in its scientific form by some of the respondents. Thus, during the actual data collection period (using the local language), farmers' detection knowledge was used (based on their experience and perception and long-time observation).

In some parts of the questionnaire, the order of the questions had to be corrected because it was out of place. And some questions were found to be leading. These and other issues were well addressed after the pre-test. Moreover, the household questionnaire was redesigned (in terms of structure) so as to save time and make the concept easily understandable for participants. However, no major modification was needed in the qualitative tools except for editing the local language.

3.15. TRANSLATION OF STUDY INSTRUMENT

During the translation of the study tools from English to the local language (Amharic), the researcher, in collaboration with a professional translator, produced a translated version of the tools that matched the English versions as much as possible. As literature indicates, a well translated survey instrument has consistent meaning across major local languages in the study area in order to maintain conceptual (when the concept being measured is the same across groups) and semantic equivalence (words and sentence structure in the translated text having the same meaning as the source language) across cultures (Beaton & Guillemin 2000: 225).

To this end, the thesis adopted the method of survey translation that is provided by (Beaton & Guillemin 2000). Their approach consists of a six-stage process: translation, synthesis, back translation, expert review, pretesting, and submission and appraisal. Thus, at first, the English version was given to the main translator and then the translated version returned for the researcher for synthesis. Then other experts provided their feedback on the questionnaire. Based on the feedback, the questionnaire was returned to the language translator for editing. A pre-test was then conducted for all the translated tools. Finally, feedback was provided based on the results from the pre-test.

3.16. CONCLUSION

In this thesis, the pragmatic philosophical approach has been adopted as the theoretical basis of the study. As mentioned in the objectives section, this thesis explores the effect of climate change on livelihood pattern. As such, the thesis adopts the mixed research method that is comprised of both qualitative and quantitative data to address the research questions and objectives. Qualitative data was collected using focus group discussions, participatory scenario development, key informant interviews and in-depth interviews. And the quantitative data was collected using a household survey. The selection of households was carried out using a simple random sampling technique and the final sample size was determined using a sample size formula.

The study used both primary and secondary data sources. The secondary data was used to describe the social, economic, cultural, demographic, agro-ecological and climatic characteristics of the study area while primary data was used to explain and evaluate the interaction between climate change and livelihood in the Lake Tana Basin.

The thesis applied both descriptive and inferential statistics to analyse the data. Descriptive and inferential statistics was used to analyse the quantitative data and thematic analysis was used for the qualitative data. The qualitative data was used to substantiate the results from the quantitative data analysis.

In order to keep the research protocol, the study secured an ethical clearance certificate from the University of South Africa. In addition, the study secured study permit and a government clearance letter from the Amhara Regional State Bureau of agriculture. Moreover, the consent of the study participants was obtained by providing all the necessary information.

One of the mechanisms of maintaining research data quality is testing the study tools before the actual data is collected. In this regard, a pre-test of all study tools was conducted before the actual data collection and before survey implementation. The pre-test was conducted in one of the Kebeles of the Lake Tana Basin.

CHAPTER 4: ADMINISTRATIVE, SOCIO- ECONOMIC, SCIO-CULTURAL AND CLIMATE PROFILES

4.1 INTRODUCTION

The objective of this chapter is to explain the administrative, socio-cultural, socio-economic, climate and natural profiles of the Lake Tana Basin system in general and Lake Tana in particular. In this endeavour, the study uses various secondary sources including published and unpublished documents (Chapter 3).

The first subsection discusses the administrative and geographic profile of Lake Tana basin. This subsection focusses on the political boundaries and geographic characteristics of the Lake Tana sub basin. The second sub-section discusses the socio-cultural conditions of the Lake Tana basin. In this regard, the subsection presented the key cultural assets of the study area deals with the demographic and major economic activities (agriculture, livestock, fishing and other economic activities) in the Lake Tana sub basin. The third subsection presented the socio-cultural profile of the Lake Tana sub basin. The fourth section presents the demographic profile of the Lake Tana basin. The fifth section presented the livelihood Profile of the Lake Tana basin, which is important to identify key sources of livelihood in the basin. The sixth subsection presented, the natural and climate profile subsection of presents the natural and climate characteristics of the sub-basin and finally the seventh subsection presented the Climate of Lake Tana Sub basin.

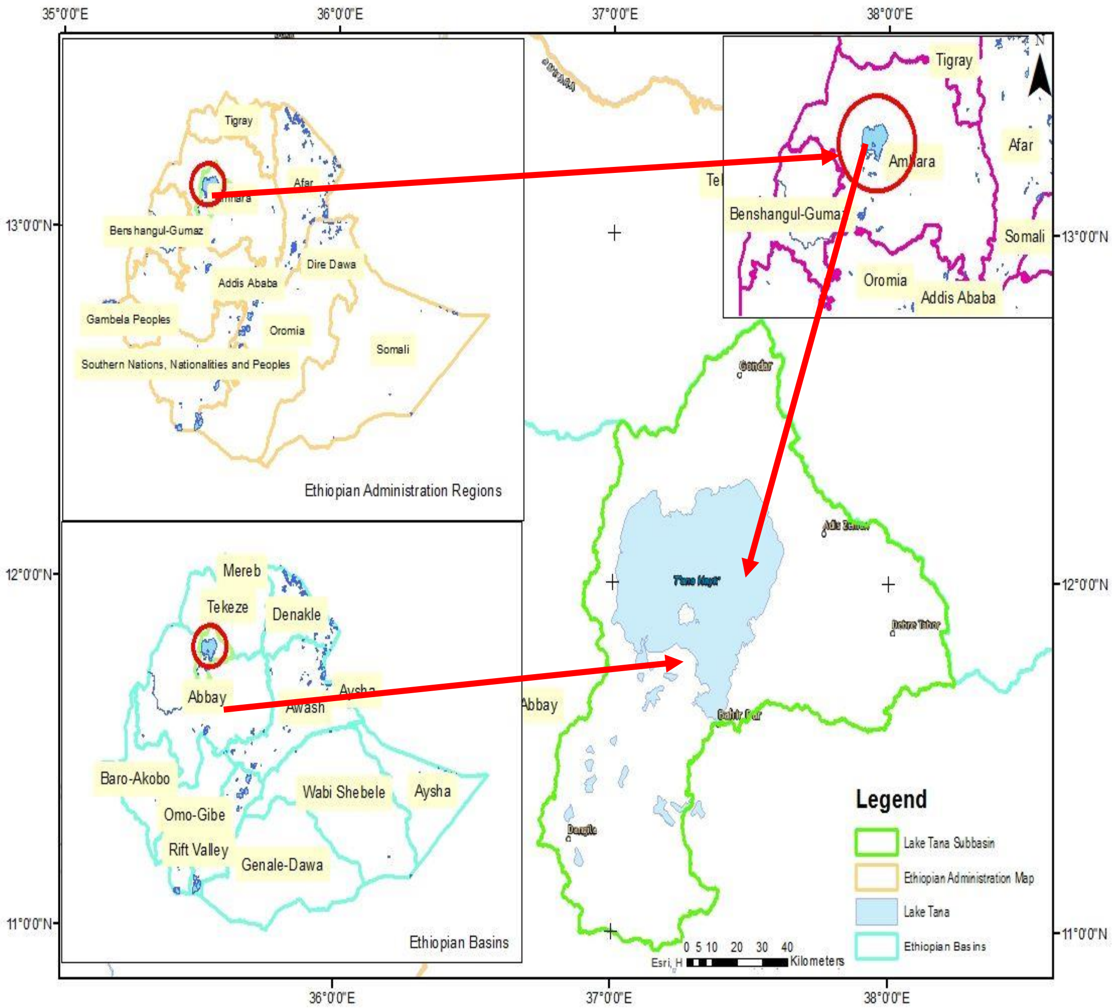
4.2 ADMINISTRATIVE AND GEOGRAPHIC PROFILE

There are about 12 regional states in Ethiopia. These regional states have their own parliament with defined legislative and executive bodies. The regional states are organized based on language and ethnic composition.

At the highest level, each regional state has its own president. Administratively, each regional state is further divided in zones which are further divided into Woredas (districts). The smallest administrate unit is called Kebele and in the administrative chain, a Kebele reports to its Woreda which in turn reports to its zone and the zone reports to the regional state/government.

The Lake Tana Basin is located in the Amhara regional state of Ethiopia (12° latitudes 10.95° and 12.78°N, and longitude 36.89° and 38.25°E), stretching to around 15,096 km^2 and contributing about 85percent of the annual flow of Nile River (Addisu et al 2019:3) . Moreover, Lake Tana, which is part of one of the 12 major river basins systems in Ethiopia, is the largest lake in the country and the third largest in the Nile Basin river system (Dile, Berndtsson & Setegn 2013:18). Interestingly, Lake Tana is the major water source for the Blue Nile river which accounts for 85 percent of the water in the Nile river. This makes Lake Tana Basin an important political and economic centre both for the country and the Nile basin system. A detailed socio-economic profile is presented in subsequent chapters.

Figure 4.1: Location map of Lake Tana Basin



Source: Own depiction using data from Ethiopian Institute of Water Resources (EIWR).

As presented in table 4.1, Lake Tana is around 84 km long and 64 km wide with an estimated mean and maximum depth of 7.2 and 14 meters respectively. It has an estimated total surface area in the range of 3060 km^2 to 3150 km^2 with a volume of 28km^2 at 1785 meters above mean sea level (Wale 2008).

Table 4 1: General descriptions of Lake Tana

Descriptions	**Measurements**
GIS location	12^0 00' N, 37015'E
Altitude	1785m above mean sea level
Surface area	3150 km^2
Catchment area	15000km^2
Maximum length	84 kilometres
Maximum width	64 kilometres
Volume	28km^3
Evapotranspiration	1160 mm and 1900 mm per year

Source: Compiled from (Wale, 2008)

Administratively, the Lake Tana Basin is divided into four major zones referred to as Agew Awi, North Gondar, South Gondar, and West Gojjam. There are also three major administrative Woredas (districts) and 14 Kebeles that make up the upper and lower basins (Solomon, Adesola & Rao 2016: 466). The largest and densely populated city in the Lake Tana Basin is Bahir Dar which in fact serves as the seat of the Amhara regional state.

Table 4.2: Zones of the Lake Tana Basin

Zone Names	**Location**
Agew Awi	Upper basin
West Gojjam	Upper basin
North Gondar	Lower basin
South Gondar	Lower basin
Total	4

Source :Compiled from Solomon, Adesola and Sulaiman, Rao (2018)

The Lake Tana Basin region covers a total area of 1,589,654.98 hectares with a huge potential for agriculture and fish production, irrigation and hydropower generation. In fact, as presented and discussed in chapter 1, the Growth and Transformation Plan of Ethiopia has identified the Lake Tana Basin as one of the major development corridors of the country (Yitbarek, Belay and Bazezew 2019). A more detailed description of the socio-economic conditions in the Lake Tana Basin is discussed in subsequent subsections.

4.3 SOCIO- CULTURAL PROFILE

The Lake Tana Basin in general and the Lake Tana region in particular has many unique and important cultural and natural assets and sites. There are about 20 monasteries on the lake islands which were constructed during the sixteenth and seventeenth century (McCartney, Alemayehu & Awulachew 2010). These monasteries serve as an important spiritual and tourist sites for orthodox Christians and international visitors.

In addition, as part of the Blue Nile basin, the Late Tana Basin shapes the culture of several distinctive peoples. For example, the ethnographic landscape include Christian highland farmers, Cushitic-speaking Agaw farmers and Muslim traders (who speak Amharic) and the Omotic-speaking Shinasha (McCann & Blanc 2016:113-116). Therefore, the Lake Tana Basin does not only function as economic or livelihood source for the inhabitants of the basin but also provides cultural and spiritual values. The social, economic and cultural epicentre of the Lake Tana Basin is Bahir Dar city that currently serves as the capital of the Amhara regional state (McCann & Blanc 2016:114).

4.4 DEMOGRAPHIC PROFILE

According to a recent estimate, the total population in the Lake Tana Basin is estimated to be above four million with a density of 228 people/km^2 (Assefa & Abebe, 2018:3) . The population has grown from 2 million as estimated by the Central Statistical Authority of Ethiopia (CSA) in 2007 (McCartney, Alemayehu and Awulachew 2010) to its current size of 4 million (Amhara National Regional State Bureau of Finance and Economic Development 2020). The increase could mainly be attributed to migration into the city of Bahir Dar and the relatively long elapsed time since the specified initial estimate (Assefa & Abebe 2018:3). Moreover, the population of Ethiopia reached 110 million in 2020 starting from just 80 million in 2007 (Central Statistics Authority 2021).

A recent study on demographic characteristics of Lake Tana basin shows that while the age structure between 0-18 years old is the largest age category, women in the productive age also account significant proportion (Anteneh 2017:283) and (Am, BoFED 2020). This implies the existence of high dependency and potential for population explosion in the years to come (Table 4.3). The same table shows the gender division of sample thus while 49 percent of the population are male the result 51 percent are female. The same table also shows the age and gender structure compared to the national figure. The result shows that while the gender structure at the basin directly reflects the national figure the age stricture also nearly shows a similar pattern both at levels.

The total number of farmers found in the immediate Kebeles of the upper and lower sub-basins is around 22792 (Solomon, Adesola & Rao 2016: 463). This population is used as basis to estimate the number of sample households to be included in the household survey.

Table 4.3: Age and gender structure of the Lake Tana Basin

Regional figure				National figure	
	Age Category	Number	Percent	Number	Percent
Age	0-18	1,600,000	40	45 million	31
	18-40	1,300,000	33	35 million	30
	40-60	1,000,000	27	30 million	27
	Above 60	100,000	3	4 million	3
Gender	Male	1,920,000	48	53 million	48
	Female	2,080,000	52	57 million	52
	Total	4,000,000	100	110 million	100

Source: Amhara Regional Bureau of finance and economic development (2020) and CSA (2020)

4.5 LIVELIHOOD PROFILE

The Lake Tana Basin has critical national and regional significance as it can be used for agriculture related activities, fishing, transportation, energy generation and tourism services (Setegn 2010:9). It has also far reaching socio-economic implications for the region as well as downstream eastern Nile basin riparian countries (Addisu 2019:7). In fact, the Lake Tana Basin has rich biodiversity and it is listed among the top 250 lake regions that should be preserved for their global biodiversity importance (McCartney, Alemayehu & Awulachew 2010).

Furthermore, the Lake Tana Basin supports various livelihoods and economic activities, the major ones being crop, livestock and fish productions (Yitbarek, Belay and Bazezew 2019:3-4). The government of Ethiopia considers the Lake Tana Basin an important area for development given its water resource potential that can support various economic activities for both the region and country (Goshu & Aynalem 2017:5). In fact, as presented in the problem statement of this study, the government of Ethiopia has identified the Lake Tana Basin as one of the growth corridors of the country. For example, since 2015, various mega hydropower and irrigation projects are being constructed in almost all tributary rivers of the basin (Dejen, Anteneh & Vijverberg 2017:1848).

The Lake Tana Basin has a rich livestock production capacity with an estimated 10 million livestock population that can support at least 10 million people (Assefa & Abebe 2018:3). However, this livestock sector is heavily traditional and much more work remains to be done in order to improve and modernize the sector in general and the marketing systems in particular to harness its economic potential.

Lake Tana Basin also serves as a rich source of fish which is an important means of livelihood. This is evident as Lake Tana is home to 21 fish species that are endemic to Ethiopia (Dejen, Anteneh & Vijverberg 2017:1845). Studies indicate that the fish production in Lake Tana can reach up to 13,000 tonnes per annum but the current production is only 1,000 tonnes per year (McCartney, Alemayehu & Awulachew 2010:4). Thus, there is a huge potential to exploit in terms of fish production which could lead to large-scale exports to the international market (Misganaw & Getu 2016:1). The same authors argue that illegal fishing activities, dam construction, traditional system of production, lack of fish market polices and absence of strong institutions to support the development of the fishing industry have caused the development of the sector to remain low. In addition, the fish production in Lake Tana is being affected by climate change (fluctuation of rainfall, temperature, and humidity) and anthropogenic activities (overgrazing, deterioration of wetlands, recession agriculture and agricultural influents) in the area, resulting in declining fish variety and production rate (Asmare, Demissie, Tewabe & Endalew 2016:).

Agricultural crop production is the other important economic sector and source of livelihood in the Lake Tana Basin system. There is high crop diversity in the basin consisting of major crop categories that include cereals, legumes, root crops, oil crops, vegetables, fruit crops and other cash crops (Abera 2017:375). The major crops that are grown in the basin generally cover at least half a million hectares of land (Assefa & Abebe 2018:2). Moreover, there are large arable land and water resources that can be used for expansion of the current irrigated agriculture. However, despite the existence of these resources, the development of irrigated agriculture remains low and production is still subsistence and rain-fed. In fact, about 80 percent of the cultivated land in the basin is under rain-fed system, only the rest being cultivated using irrigation and residual moisture (Abera 2017:376). As presented in the literature review section of this study, this makes farmers in the Lake Tana Basin more vulnerable to the possible impacts of climate change.

4.6 NATURAL PROFILE

Lake Tana and the surrounding areas support high biodiversity including at least 217 bird species, as a result, the location is included in the global list of top 250 lake regions with the highest importance for biodiversity (McCartney, Alemayehu & Awulachew 2010:3). This makes the area one of the most important natural sites that need protection in order to maintain the balance of natural biodiversity at the global level in general and within the region in particular.

The altitude of the Lake Tana Basin ranges from 1788 to 3712 meters above mean sea level and the lake alone is found at 1786 meters above mean sea level (Yilma & Awulachew 2009:47). Thus, the basin enjoys a varied agro-ecology that ranges from Woyna-Dega (sub temperate area) to Alpine (land above 3700 mean sea level), making it very suitable for growing various types of agricultural crops (Solomon, Adesola & Rao 2016:2). Furthermore, the same authors reported that while Basalt and Marsh soils were dominant in the geology of the basin, lacustrine deposits are prominent in the east and north east of the lake.

Table 4.4: Summary of natural characteristics of the Lake Tana sub-basin

Characteristics	Descriptions
Topography	1788 meters and 3712 meters above sea level (mean sea level)
Hydrology (Mean annual runoff)	3576.3 MCM
Land Cover	Moderately cultivated, with partly covered by shrub lands and grasslands
Soil	The dominant soil type is Haplic Luvisols and Chromic Luvisols.
Geology	Basalt and Marash

Source: Compiled from (Yilma and Awulachew, 2009).

4.7. THE CLIMATE PROFILE

The Lake Tana Basin contains different agro-climatic zones within the temperate zone based on altitude and as such, it includes Woyna-Dega, Dega, Wurch and Alphine Wurch (Solomon, Adesola & Rao 2016:2). The following table provides information on percentage and altitude of each agro-ecology. The table shows that while the major agro-ecology of the Lake Tana Basin is Woyna-Dega which accounts for 79.5 percent of the area, Dega, Wurch and Alpine-Wurch cover 20 percent, 0.43 percent and 0.07 percent of the basin respectively. Here it should be noted that the Lake Tana Basin has a dominant temperate climate because of its high altitude (Solomon, Adesola & Rao 2016:2) .

Table 4.5: Agro-ecological zones of Lake Tana sub-basin

Agro-ecology	Altitude	Proportion or share
Woyna-Dega	below 2300 m.a.s.l	79.5 percent
Dega	2300 to 3200 m.a.s	20 percent
Wurch	3200 to 3700 m.a.s.l.)	0.43 percent
Alphine Wurch	above 3700 m.a.s.l.	0.07percent

Source: Summarized from Solomon, Adesola and Rao (2016:2).

Data on the region's rainfall distribution shows that the Lake Tana Basin receives an average annual rainfall of 1329 mm (Assefa & Abebe 2018:3). Moreover, the same authors state that during a single rainy season, the annual rainfall can range from 900 to 2346 mm. However, it should also be noted that time series analysis of rainfall data reveals that there is a declining trend in the amount of mean annual rainfall in the region that can largely be attributed to climate change related factors (Addisu, Selassie, Fissha & Gedif 2015:5). This is clearly expected to affect those people in the basin whose livelihoods depends on rain-fed agriculture which is the most sensitive economic activity when it comes to climate change impact.

And according to (Assefa & Abebe 2018:3), the average air temperature of the Lake Tana Basin ranges from 18 to 21 °C. However, time series trend analysis of temperatures in the Lake Tana Basin shows that there is a generally increasing trend in the average temperature (Addisu et al 2015:5).

4.8. CONCLUSION

Administratively, the Lake Tana Basin is located in the Amhara National Regional State of Ethiopia. According to a recent estimate, the total population in the Lake Tana Basin is above four million with a density of 228 people/km^2.

The Lake Tana Bain in general and the Lake Tana region in particular has many unique and important cultural and natural assets and sites.

In this regard, there are about 20 monasteries on the lake islands. These monasteries serve as an important spiritual attraction and recreational sites for Ethiopia Orthodox Christians and international tourists respectively. The Lake Tana Basin contains different agro-climatic zones within the temperate zone based on altitude and as such, it includes Woyna-Dega, Dega, Wurch and Alphine Wurch.

The livelihood profile of the area shows that agricultural crop and livestock production as well as fishing are the main sources of livelihoods for the residents in the Lake Tana Basin. Moreover, there is high crop diversity in the basin and the major crop categories include cereals, legumes, root crops, oil crops, vegetables, fruit crops and other cash crops.

CHAPTER 5: TIME SERIES ANALYSIS OF CLIMATE CHANGE VARIABLES

5.1 INTRODUCTION

Livelihood in the Lake Tana Basin is heavily dependent on rainfall pattern because of the reliance of millions of farmers on rain-fed agriculture. Thus, there is a need to examine the trend in key weather variables in the Lake Tana Basin. The time series analysis helps in understanding how weather variables are changing over time. Moreover, the trend analysis helps to triangulate the nature of weather variables with the perceptions of community members (Chapter 6).

This chapter has three important components. First, it establishes a benchmark for the perceptions of community members. In essence, it provides evidence for the claim that the climate of the Lake Tana Basin is changing over time. Second, it helps to triangulate change in climate variables with the household survey (chapter 6). Third, it helps to understand the relationship between crop production and climate change variables over time.

Accordingly, the focus of this chapter is to examine the long-term nature of rainfall and temperature trends as well as their relationship with crop production in the Lake Tana Basin.

5.2 TIME SERIES ANALYSIS OF WEATHER VARIABLES

In this subsection, the nature and trend in weather variables (mainly rainfall and temperature) is presented. The analysis shows that in the past 30 years, rainfall was erratic while temperature was rising. The details about the data, formula and interpretation are provided in section 3.10.2.1.and 3.10.2.1.1.

5.2.1 Time series analysis of rainfall pattern

Before looking into the trend in the rainfall data, there is a need to examine the descriptive statistics of the data. In the following table, the descriptive statistics for the mean monthly aggregated rainfall data for the lower Lake Tana Basin is presented. The descriptive statistics for the monthly aggregated rainfall data is calculated for the period between 1989 and 2019. The result of the descriptive statistics summary shows that the top 4 maximum rainfall levels as well as the top 4 highest mean rainfall levels were recorded for the months of June, July, August, and September (table 5.1). The same table also shows that the highest mean monthly rainfall is 489.72mm and the highest maximum rainfall is 765 mm, both recorded in the same month of July. Moreover, from this table it can concluded that the lower basin of Lake Tana Basin gets most of its rain during the summer season (June, July, August and September). In fact, summer is the main rainy season in Ethiopia.

Table 5.1: Mean monthly aggregated rainfall data in the lower basin

Months	Min	Max	Mean	Standard Deviation	Coefficient of variation
Jan	0.0	13.3	1.71	3.81	2.23
Feb	0.00	59.40	2.56	10.83	4.23
Mar	0.00	111.30	16.08	28.15	1.75
Apr	0.00	91.00	25.51	28.59	1.12
May	5.40	230.90	80.89	61.65	0.76
Jun	59.50	442.70	227.18	95.89	0.42
Jul	356.60	765.00	489.72	108.36	0.22
Aug	0.00	606.30	382.43	107.93	0.28
Sep	77.50	334.40	202.85	54.77	0.27
Oct	4.00	191.60	83.72	57.64	0.69
Nov	0.00	35.30	9.25	10.01	1.08
Dec	0.00	34.00	4.56	8.40	1.84

Source: Own depiction using data from Ethiopian National Meteorological Agency.

In the same manner, the descriptive statistics for the upper Lake Tana Basin is presented in table 5.2 below. The analysis summarizes the mean monthly aggregated rainfall data for the period between 1989 and 2019. The result in table 5.2 shows that the top 4 maximum rainfall levels for the upper basin were recorded for June, July, August, and September with amounts of 345mm, 592.1mm, 628.5mm and 321mm respectively. The table also shows that the top 4 highest mean annual rainfall data is recorded for the same months of June, July, August and September with amounts of 151.7mm, 396.59mm, 375.94mm and 188.5 mm respectively. The table also shows the driest months in the basin are January, February and March. The result confirms that there is a similarity between the two stations (upper and lower basin) in terms of months with highest rainfall.

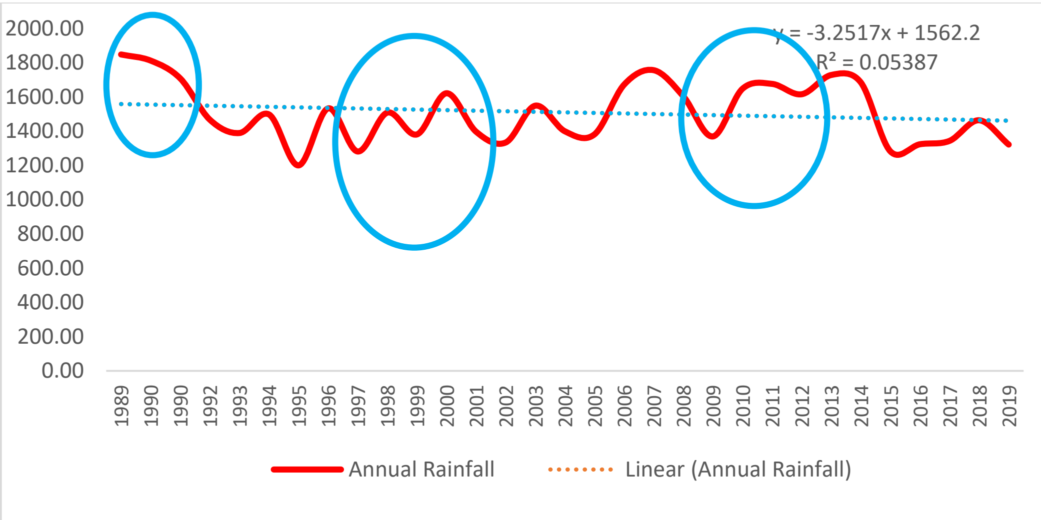
Table 5.2: Mean monthly aggregated rainfall data in the upper basin

Months	Min.	Max.	Mean	SD	CV
Jan	0	81.4	5.46	14	2.56
Feb	0	81.1	7.99	18.3	2.29
Mar	0	98	34.65	33.42	0.96
Apr	5.5	118.3	49.94	33.51	0.67
May	10.3	211.5	92.49	67.25	0.73
Jun	73	345	151.7	59.43	0.39
Jul	234	592.1	396.59	83.57	0.21
Aug	190.2	628.5	375.94	92.09	0.24
Sep	80.1	321	188.53	55.53	0.29
Oct	2.9	305	74.9	65.51	0.87
Nov	0.5	76.2	22.78	17.3	0.76
Dec	0	82.5	11.86	15.96	1.35

Source: Own depiction using data from the Ethiopian National Meteorological Agency

The trend in the annual rainfall data for the lower Lake Tana Basin is presented in figure 5.1. The trend analysis shows how the annual rainfall data behaved for the 30-year period between 1989 and 2019. The result in figure 5.1 shows a decreasing trend in annual rainfall with a strong annual rainfall variability that can also be seen in the trend line equation given by the equation. $y = -3.2517x + 1562.2$. This equation has at least two important implications: 1) it shows the existence of a decrease in rainfall that is indicated by the negative slope (-3.25) of the equation, and 2) the R^2 shows the variation due to the independent variable in the model is 5percent .

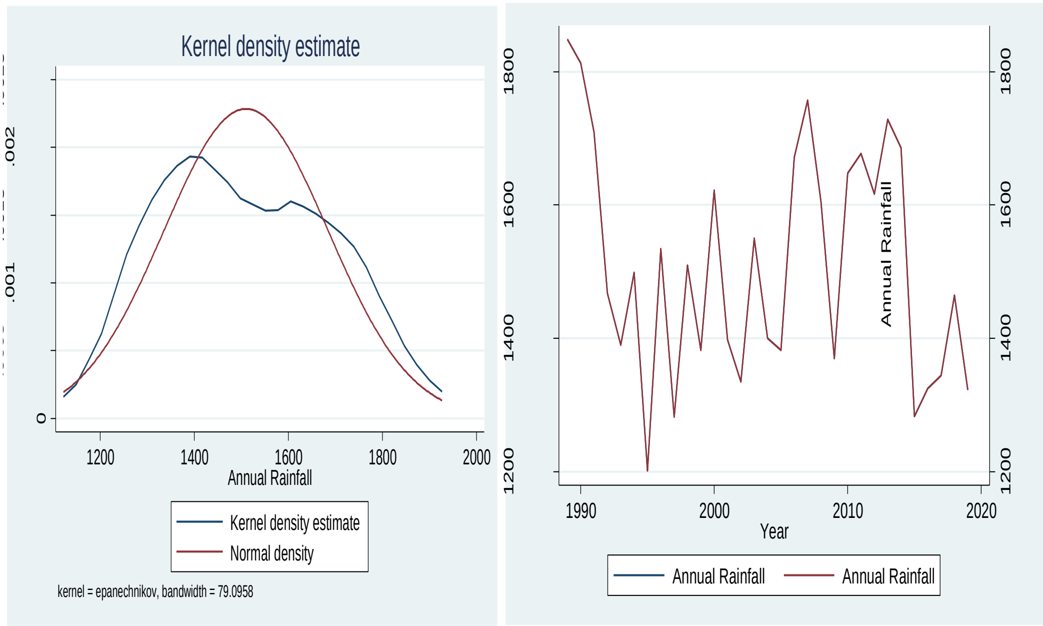
Figure 5.1: The trend in annual rainfall data in the lower basin



Source: Own depiction using data from the Ethiopian National Meteorological Agency

In addition, the Kernel density distribution is presented in figure 5.2. The Kernel density function helps to smooth each data point into small density bumps that are summed together to obtain the final density estimate. When compared to the use of a traditional histogram, the Kernel method gives a better understanding of the probability distribution of the variable. In figure 5.2, the curve obtained for the annual rainfall trend using the kernel density function (distribution of rainfall data) is shown juxtaposed against the normal density distribution. The analysis indicates that the distribution of rainfall pattern has not been smooth throughout the period considered.

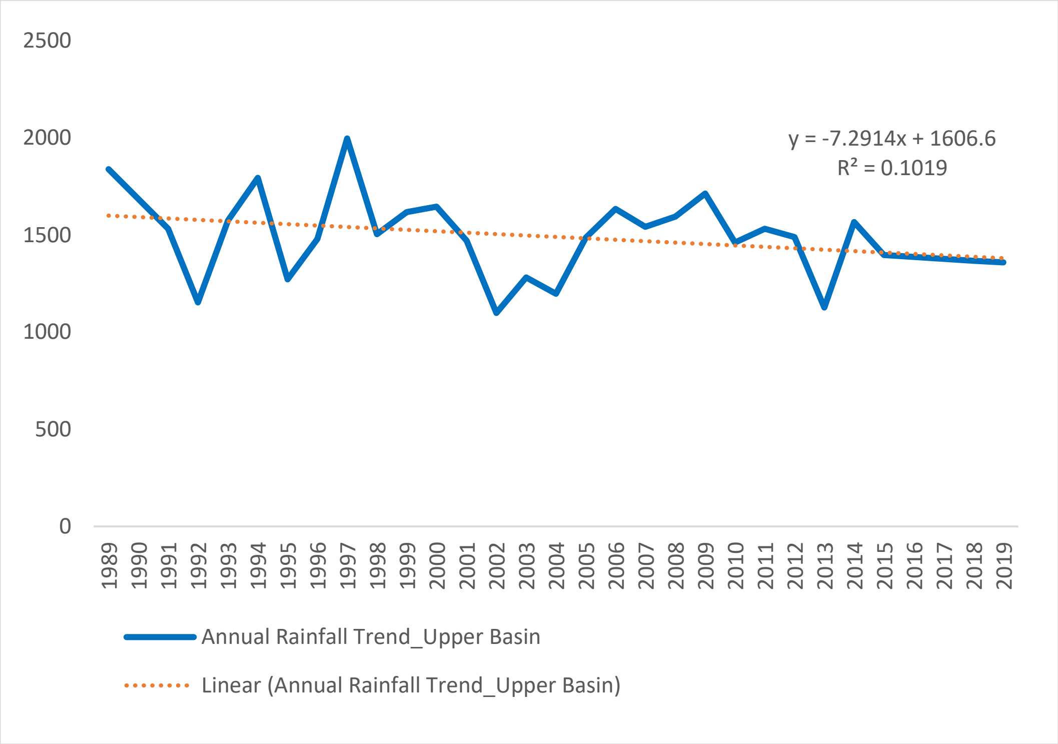
Figure 5.2: Time series trend, Kernel density estimate and normal density



Source: Own depiction using data from the Ethiopian National Meteorological Agency

The trend in rainfall data obtained from station in the upper basin of Lake Tana Basin is presented in figure 5.3. As is the case for the lower basin, the result in figure 5.3 shows a decreasing trend in annual rainfall for the upper basin. This can be seen from the trend line equation given by the formula $y = -7.2914x + 16062.2$. The equation's slope (-7.29) indicates a decreasing trend and the value for R^2 shows that the variation in the dependent variable is 10percent .

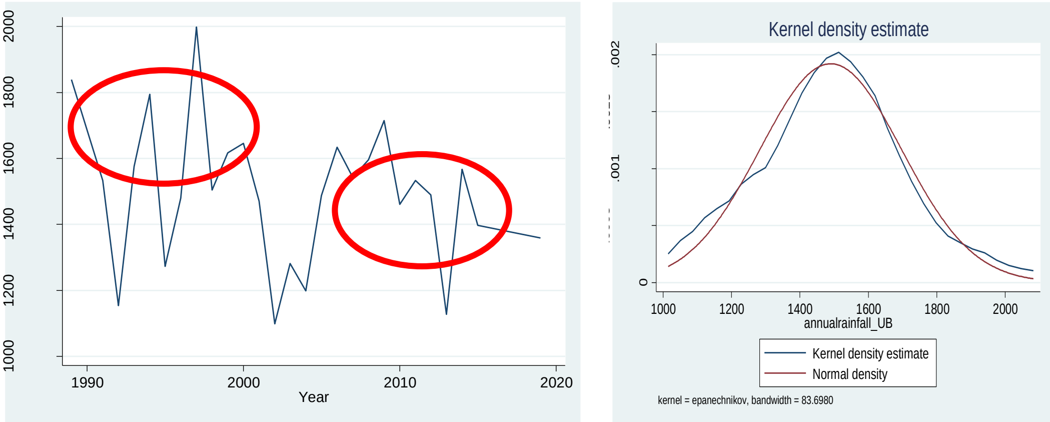
Figure 5.3: Trend in annual rainfall in the upper basin



Source: Own depiction using data from the Ethiopian National Meteorological Agency

The nature of rainfall variability in the upper basin is presented using Kernel density distribution in figure 5.4. The result shows that even though there exists variability in the trend curve, the Kernel density estimate indicates that the kernel density curve more or less matches the normal density curve unlike the rainfall pattern in the lower Lake Tana Basin. In Ethiopia, there is variation in climate and weather variables even within the same Kebele. Therefore, this difference in the nature of rainfall variability between the lower and upper basins is expected.

Figure 5.4: Kern density estimate (left) and normal density (right)

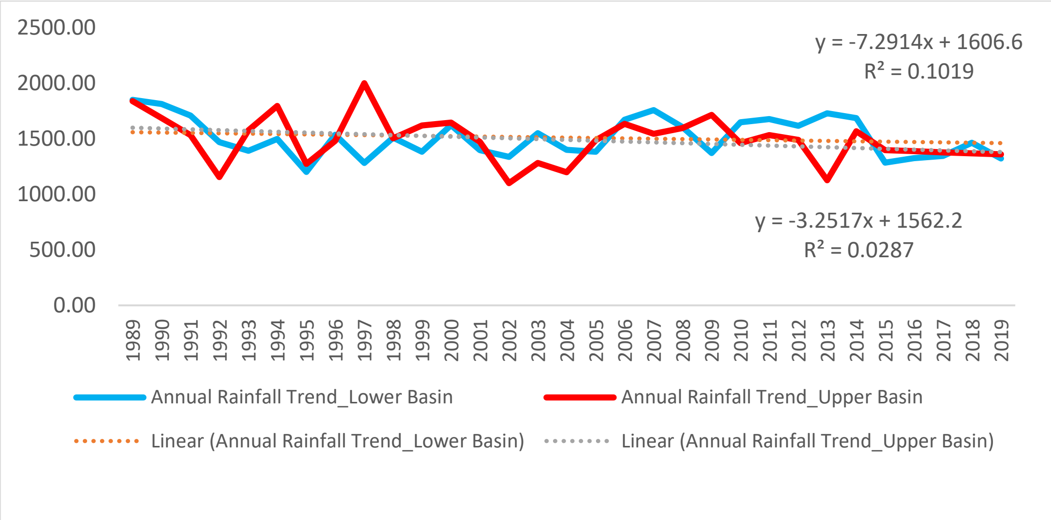


Source: Own depiction using data from the Ethiopian National Meteorological Agency

The trend in annual rainfall for the lower and upper basin are presented together in figure 5.5. As the slope of the coefficients of the linear trend estimation indicates, there is a decline in the volume of rainfall both in the lower and upper basins of the Lake Tana Basin.

From figure 5.5, it can be said, the trend in annual rainfall was erratic for both basins. Moreover, from the regression coefficient, annual rainfall has declined by an average of 7.2mm and 3.2mm for the lower basin (-7.2914x + 1606.6) and the upper basin (-3.2517x + 1562.2) respectively. Thus, for every additional year we can expect rainfall to decline by an average of 7.2mm and 3.22mm for the lower basin and the upper basin respectively.

Figure 5.5: Trend in annual rainfall in the lower and upper basin



Source: Own depiction using data from the Ethiopian National Meteorological Agency

Table 5.3, shown further down, summarizes the mean, standard deviation and coefficient of variation and Precipitation Concentration Index (PCI) for both the lower and upper basins of the Lake Tana Basin system.

The result shows that the mean rainfall is 1510mm and 1489.9mm in the lower and upper basins respectively. And the coefficient of variability (CV), which is obtained by dividing standard deviation by mean value and multiplying by 100, is 11.56mm and 13.93mm in the lower and upper basins respectively (table 5.3). According to (Hundera, Mpandeli and Bantider, 2019:4), there are three possible interpretation for the values of CV: 1) if CV is less than 20, the implication is that there is low rainfall variability, 2) if it lies between 20 and 30 then one can interpret it as moderate rainfall variability, 3) if it is greater than 30, one can interpret it as high rainfall variability. Accordingly, the result in table 5.3 shows that there is low rainfall variability both in the lower and upper basins. However, other studies have indicated that there is high rainfall variability (inter-annual variability of rainfall distribution) when one considers the different seasons separately (Samy, Ibrahim, Mahmod, Fujii, Eltawil & Daoud 2019:2). The implication is that there is a need to consider multiple aspects of rainfall variability measurements.

Table 5.3 also shows Precipitation Concentration Index (PCI) values. According to Hundera, Mpandeli & Bantider (2019:3), this value can be interpreted in four ways: 1) if the value of PCI is less than 10, it shows the existence of uniform distribution of precipitation, 2) if it lies between 11 and 15, it shows moderate precipitation concentration, 3) if it lies between 16 and 20, it shows irregular distribution of precipitation, and 4) if it is greater than 20, it can be interpreted as strong irregularity of precipitation (high concentration). The PCI is greater than 20 for the lower basin which indicates irregular precipitation and it is between 16 and 20 for the upper basin which indicates strongly irregular precipitation (Table 5.3). The implication is that both the upper and lower basins are experiencing changes in rainfall pattern which is a key indicator of climate change in the area. This has an implication for the community as most depend on agriculture which as noted earlier is the most sensitive sector when it comes to climate change.

Table 5.3: Comparison between the two basins

Measurements	**Lower basin**	**Upper basin**
Mean (mm)	1510.205	1489.968
Standard deviation (SD)	174.655	207.6495
Coefficient of variability (CV)	11.56505	13.93651
Precipitation Concentration Index (PCI)	21.6657	17.676

Source: Own depiction using data from meteorological station

5.3. TIME SERIES ANALYSIS OF TEMPERATURE PATTERN (ANNUAL AND MONTHLY)

The descriptive statistics (mean, standard deviation, maximum, and minimum and coefficient variation) for the monthly temperature data of the lower and upper basins of the Lake Tana Basin system is presented in tables 5.5 and 5.6 respectively. The result for the lower basin in table 5.4 shows that the top 3 highest maximum temperatures are recorded for the months of April, May and June with values of 24 ^{0}C, 27 ^{0}C and 25 ^{0}C. The same table shows that the highest mean temperature was recorded in the month of May. Moreover, the highest variations of mean monthly temperature were recorded for the months of December and March.

Table 5.4: Descriptive statistics for mean monthly aggregated temperature for the lower basin

Months	Mean	SD	Min	Max	CV
January	17.55	0.77	16.45	19.01	0.04
February	15.53	7.50	15.94	21.32	0.48
March	20.7	5.87	15.43	20.00	0.67
April	21.6	7.68	16.92	24.12	0.49
May	21.6	7.32	14.41	27.00	0.50
June	20.12	1.49	19.37	25.50	0.07
July	19.52	0.57	18.59	21.50	0.03
August	19.28	0.44	18.55	20.30	0.02
September	19.51	0.49	18.00	20.70	0.03
October	19.88	0.71	17.79	21.55	0.04
November	18.76	0.95	17.50	20.90	0.05
December	15.78	7.97	17.20	19.60	0.51

Source: Own depiction using data from the Ethiopian National Meteorological Agency

Similarly, for the upper basin, table 5.5 reveals that the top 3 highest mean temperatures were recorded for the months of March, April and May with values of 17.5^{0}C, 17.3 ^{0}C and 17.2^{0}C respectively and the top 3 maximum temperatures were recorded for the same months of March, April and May with values of 24.4^{0}C, 19.7 0C and 19.1^{0}C respectively. The same table shows that the highest coefficient of variation was recorded for the month of December.

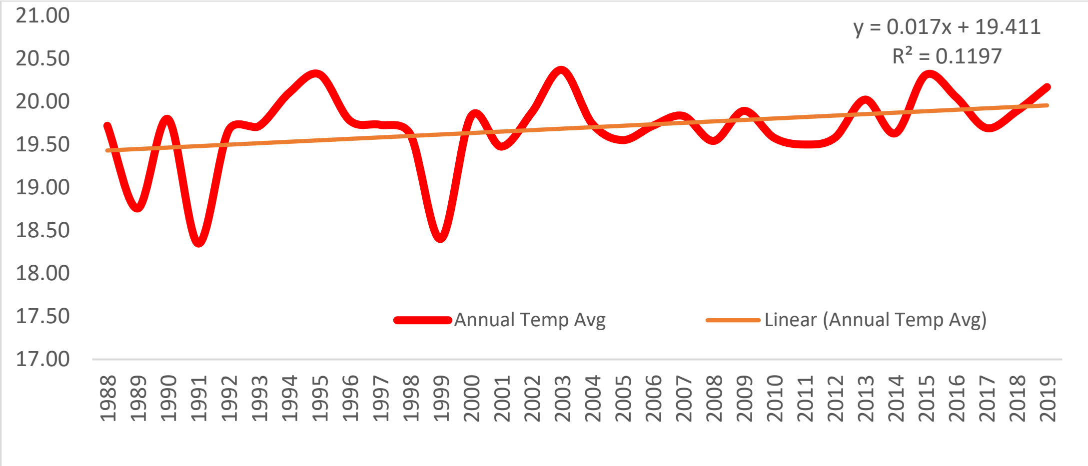
Table 5.5: Descriptive statistics for mean monthly aggregated temperature for the upper basin

Months	Mean	SD	Min	Max.	CV
January	15.5	0.8	13.4	17.6	0.05
February	16.4	1.8	8.1	18.0	0.11
March	17.5	3.0	10.0	24.4	0.17
April	17.3	1.5	11.4	19.7	0.09
May	17.2	1.3	13.4	19.1	0.07
June	16.0	0.6	14.6	17.3	0.04
July	14.7	0.8	13.6	16.5	0.06
August	14.4	0.3	13.6	14.9	0.02
September	14.5	0.4	13.7	15.6	0.03
October	13.4	7.7	13.7	27.0	0.58
November	14.9	0.9	13.0	17.8	0.06
December	14.9	1.0	12.7	18.1	0.06

Source: Own depiction using data from the Ethiopian National Meteorological Agency

The time series mean monthly temperature was analysed for the period of 30 years ranging from 1989 to 2019. The data for the analysis came from two stations, one from the upper basin (Debretabor station) and the other from lower basin (Bahir Dar station). According to the results in figures 5.6 (a) and 5.6 (b), the fitted linear trend line for the lower basin shows the existence of an increasing trend in temperature in the basin and this is reflected by the positive coefficient of the slope of the linear equation. Likewise, the result for the upper basin also reveals the existence of an increasing trend in the mean temperature in the period considered. The positive coefficient of the slope of the fitted linear equation indicates this rising trend.

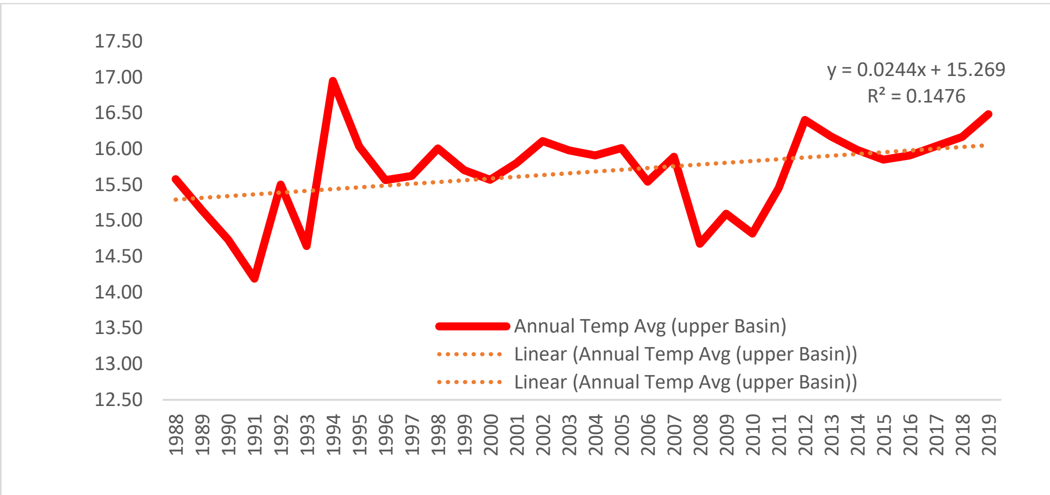
Figure 5.6 (a): Trend in temperature in the lower basin



Source: Own depiction using data from the Ethiopian National Meteorological Agency.

From figures 5.6 (a) and 5.6 (b), it can be observed that the relative increase in temperature was gradual. Moreover, from the regression coefficient, annual temperature has increased by an average of 0.01 ^{0}c and 0.02 ^{O}C for the lower basin (y = 0.017x + 19.411) and the upper basin (0.0244x + 15.269) respectively. Thus, for every additional year we can expect temperature to increase by an average value of 0.01 ^{0}c and 0.02 ^{o}c for the lower basin and upper basins respectively.

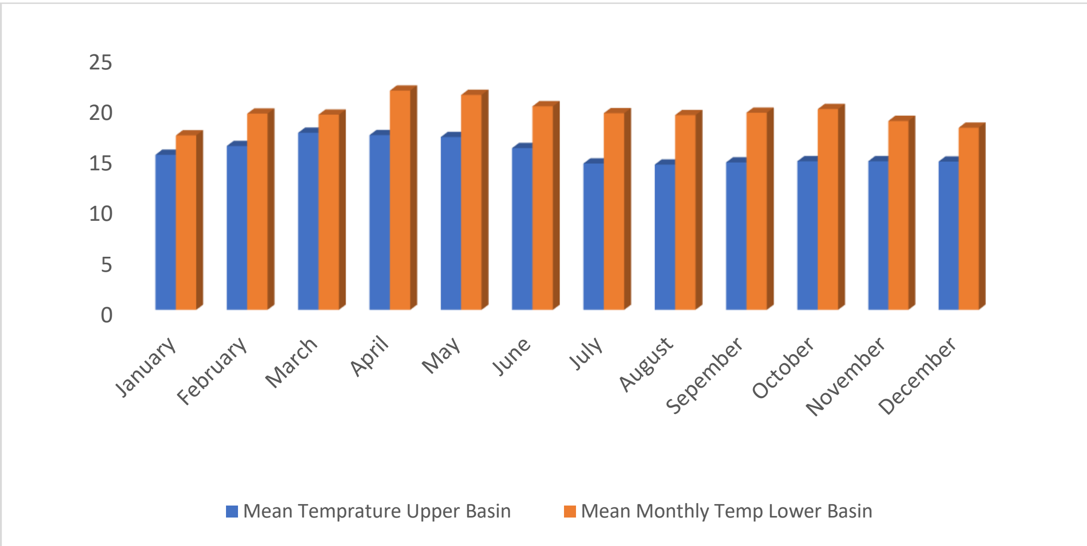
Figure 5.6(b): Trend in temperature in the upper basin



Source: Own depiction using data from the Ethiopian National Meteorological Agency.

The next figure (5.7) shows the aggregate mean monthly temperature data for lower and upper basin stations of the Lake Tana Basin. The chart generally indicates that the values of aggregated mean monthly temperature data in the lower basin tend to be greater than the values in the upper basin. The result in Figure 5.7 also shows that the top 2 highest mean monthly temperatures were recorded for the months of April and May both for the lower and upper basins.

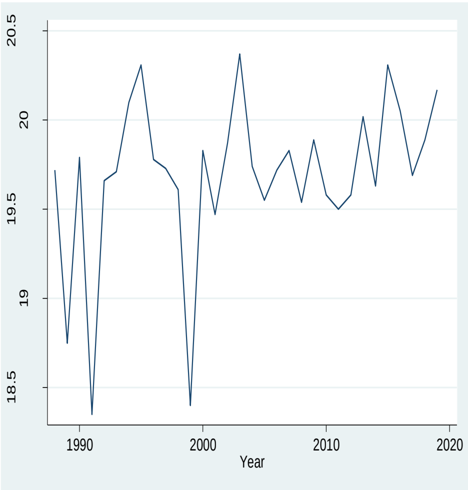
Figure 5.7: Aggregated mean monthly temperature

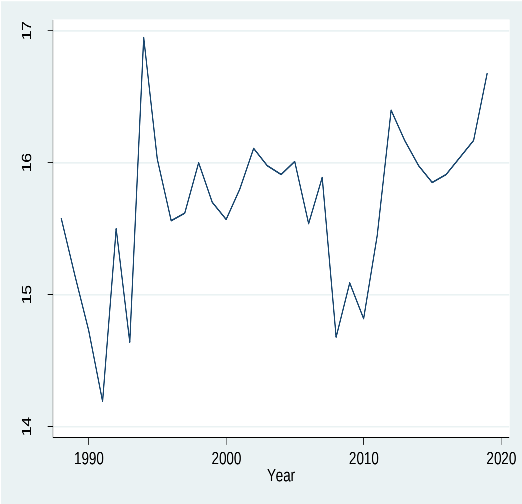


Source: Own depiction using data from the Ethiopian National Meteorological Agency

The next figures (5.8 and 5.9) compare the nature of the trend in annual temperature series between the lower and upper basins of the Lake Tana Basin system. The result in figures 5.8 and 5.9 indicate the existence of temperature variability both in the lower and upper basins. This is somewhat consistent with the results of the descriptive statistics presented in table 5.4 and 5.5.

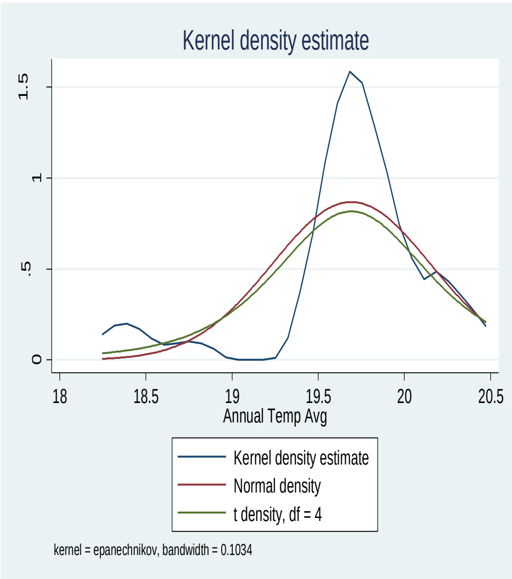
Figure 5.8: Trend in annual temperature in the Lower Basin (left) and upper (right)

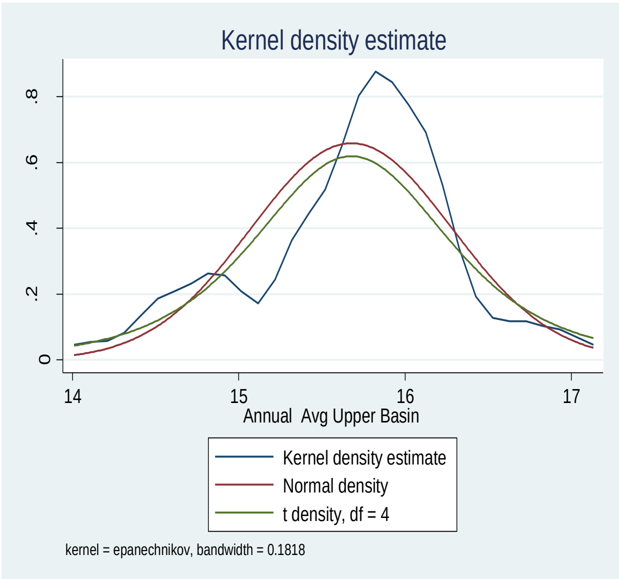




Source: Own depiction using data the Ethiopian National Meteorological Agency

Figure 5.9: Annual average temperature Lower Basin and upper basin





Source: Own depiction using data the Ethiopian National Meteorological Agency

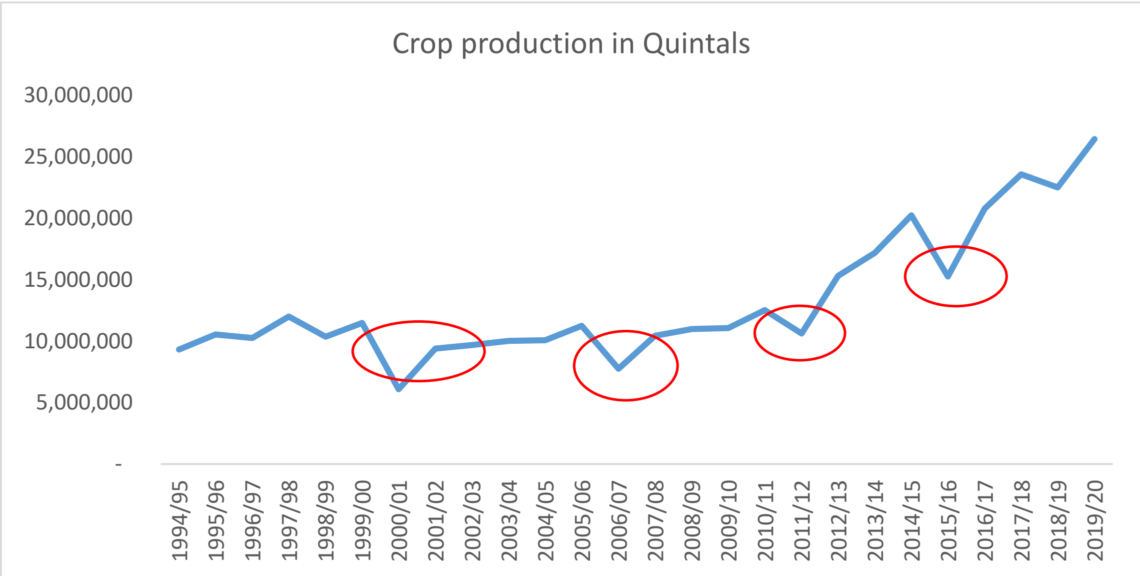
5.4. TIME SERIES ANALYSIS OF CROP PRODUCTION AND CLIMATE CHANGE

5.4.1. Trends in crop production

Agriculture is an important source of livelihood for community members in both the lower and upper basins. In this regard, crop production remains an important agricultural activity in the basins (chapter 6). Thus, there is a need to examine the relationship between climate change variables and crop production.

The trend in the following figure (5.10) shows that there is variability in crop production over the period considered. This has been especially observed for the periods 2000/2001, 2006/07, 2011/12 and 2015/2016. Other studies have also indicated that these periods were characterized by severe droughts (Gebregeorgis,2020:750).

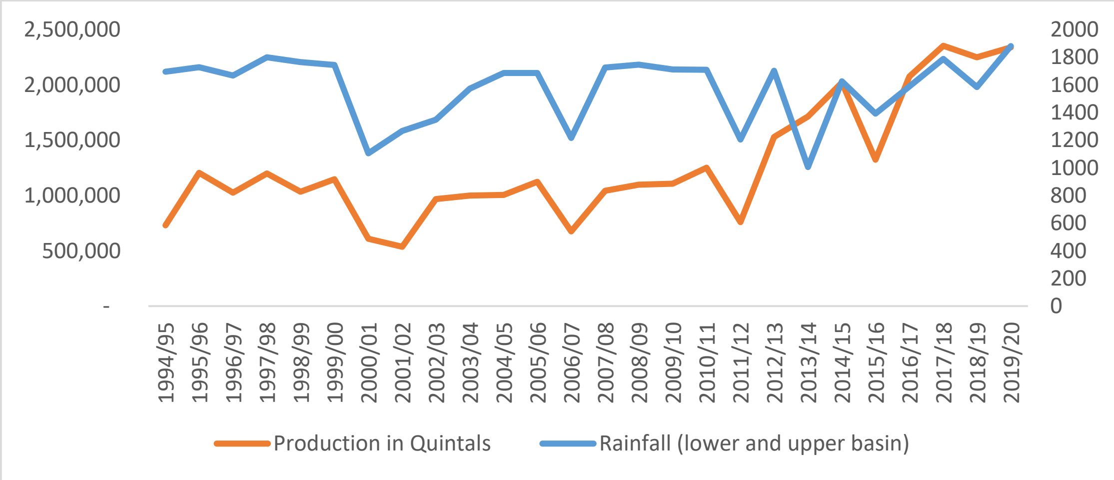
Figure 5.10: Trend in crop production in the Lake Tana basin



Source: Own computation using STATA

The following figure (5.11) depicts the very close association of crop production and rainfall in Lake Tana Basin indicating the climate sensitivity of crop production in the basin is very high (combined data for upper and lower basin data) in Lake Tana Basin. Other previous studies have also shown that the basin is very sensitive to changes in rainfall which affects agricultural crop production and productivity, Habtamu et al (2015:34).

Figure 5.11: Trend in crop production and rainfall



Source: Own computation using STATA

5.4.2. Modelling cereal crop production and climate variability in the Lake Tana Basin

In order to understand the interaction between crop production and rainfall pattern in the Lake Tana Basin, a dynamic ordinary least square (OLS) regression model is used. The basis for the theoretical framework is the traditional Ramsey growth model adjusted for the Ethiopian context by incorporating rainfall variability and temperature data within crop production as a major determinant. The effect of other factors such as quantity of fertilizer and land etc. has been controlled in the model. The Cob Douglas production function for cereal crop production has been adjusted for the Ethiopian case and transformed into log form in Equation (5.3).

5.4.2.1 Data sources

The major data sources are Ministry of Finance and Economic Development (MoFED), Ethiopian National Meteorological Agency, Central Statistical Agency (CSA) and Ethiopian Economics Association database. The sample size of the dataset runs from 1994-2019. The dynamic OLS estimation technique has been used. This technique has three advantages relative to other time series models: 1) it is robust in the context of a small sample size, 2) corrects simultaneous bias, and 3) corrects small sample bias (Kassahun,2019:14).

5.4.2.2. Selection of variables

The selection of variables is based on empirical works that used a time series crop production model with climate change variables.

Kassahun (2019:15) estimated the impact of rainfall variability on crop production using time series data. The estimation result shows that climate change induced rainfall variability is an inevitable threat to crop production in Ethiopia. Moreover, the study indicates that the cultivated area, fertilizer used and labour also affect crop production. However, the analysis fails to show the impact of temperature on crop production.

Ketema (2020:5) applied the ARDL approach to co-integration to investigate the long-run and short-run determinants of agricultural output in Ethiopia. The result reported that rainfall, and fertilizer affected the output positively and significantly, while drought has negatively affected agricultural output in the long run.

A study by Chandio et al (2018:35) examined the effect of climate change factors on cereal yield in Turkey during 1968–2014 by employing ARDL co-integration model. The results showed that there is a long-term relationship between climate change variables and cereal yield. Thus, average temperature has diverse effects on cereal yield, whereas average rainfall has a positive effect on the yield in both the long-run and short-run periods. The main missing element from this study is that it fails to consider the effect of rainfall divergence.

A study conducted by Abbas Ali et al. (2021:34) shows that in the long run, rainfall positively affects both cereal production and yield, while temperature has an adverse negative effect. Their finding further reveals that the cereal crop area positively and significantly impacts the long-run cereal production and yield.

The above empirical studies show that a time series crop production model specification that considers climate change can incorporate variables such as rainfall, temperature, land size and cultivated area etc.

5.4.2.3. ***Model specification***

The following time series model is created to capture the relationship between climate variables and crop production based on the work of Kassahun (2019:15).

$$Q_{it} = B_0 * (Rainde_t)^{B1} Temp_t^{B2} \coprod_{I=2}^{K} Z_t^{Bi} \varepsilon_t \qquad 5.1$$

$$ln(Q_{it}) = B_0 + B_1 \ln(Raindev_{it}) + B_2 \ln(Temp_t) + \sum_{i=1}^{k} B_i \ln(Z_t) + \varepsilon_t \qquad 5.2$$

By adding additional regressors and the logarithmic form of regressors, Equation (5.2) further transforms into the following equation:

$$LnQ_t = B_0 + B_1 LnRaindev_t + B_2 LnTemp_t + B_4 LnAreaculti_t + B_5 LnFerti_t + e_{it}$$
(5.3)

Where:

LnQ =log of crop production,

$LRainde_{it}$ =log of rainfall,

$LTemp_{it}$ =log of temperature,

$LLand_{it}$ =log of land cultivated,

$Lferti_{it}$ =log of quantity of fertilizer used

5.4.3 Result

In many instances, multivariate time-series data is non-stationary. Thus, descriptive analysis is important to understand the properties and the behaviour of the study variables before estimating the time series model. In this regard, the result in Table 5.6 shows that all variables included in the model have less standard deviation than the mean values; this indicates the normality of the variables. Moreover, to avoid the variation of the variables as well as homogeneity, variables are changed to their logarithmic form.

Table 5.13:Descriptive summary of variables

Variables	*Mean*	*Standard deviation*	*Skewness*	*Kurtosis*
Quantity of crop production (tonnes)	*1275124*	*765*	*0.9420*	*2.530*
Fertilizer used kilograms per hectare	*18.72*	*12*	*0.915*	*2.181*
Rainfall (mm)	*1576*	*238*	*0.899*	*2.435*
Land cultivated	*6000*	*1785.4*	*1.476*	*3.803*

Source: Own computation using STATA

In a multivariate time-series model, one should check the stationarity of the variables using the Dickey –fuller (DF) unit root test. This test can be used both at level and first difference form. If variables are non-stationary at level but stationary at first difference, we will use vector error correction model. As the result of table 5.7 below shows, all the variables are none stationary at level.

However, they are all stationary at 1 percent level of significance in their first difference form.

Table 14: Stationarity test of the variables

Variables at level	*Computed DF at lag*		*Variables in difference*	*Computed DF at lag*	
	0	*1*		*0*	*1*
LQ	*1.762*	*0588*	*DLQ*	*-4.220**	*-4.976**
LRaindev	*-2.317*	*-2.532*	*DRrain*	*-3.934**	*-3.226***
LFertilizer	*-1.835*	*-2.441*	*DFertilizer*	*-4.423**	*-2.437*
LLand	*-2.000*	*-2.386*	*DLand*	*-5.243**	*-2.578*
Critical value at 1 percent; 5 percent and; 10percent					

Source: own computation using STATA

After controlling the impacts of cultivated area, land size and fertilizer, the impact of rainfall and temperature has an expected sign in the crop equation. The result of the estimated model is given in table 5.8. The result shows that a 1 percent increase in temperature will lead to a decrease in cereal crops production by 2.2 percent. In the case of rainfall, a 1percent increase in rainfall divergence from its optimal level will lead to a decrease in cereal crops production by 0.23 percent. When the annual rainfall diverges from its mean (both upward and downward), the level of production of crop diminishes significantly. Thus, it is not the amount of rainfall per se that matters but how that rainfall diverges from its optimal level. However, other empirical studies that used actual amount of rainfall (than the mean deviation) found a positive and significant impact of rainfall on farming in Ethiopia, Kassahun (2019:15).

The result in the same table shows that a 1percent increase in fertilizer consumption per arable land increases crops production by about 0.35 percent in the long run. This result is consistent with the empirical findings of Ketema (2020:34) who reported a positive and significant effect of fertilizers on agricultural crop production in the long run.

In the long run, the coefficient of arable land indicated a positive and significant effect on cereal crops production, as a 1 percent increase in the area of arable land increases cereal crops production by 1.82percent in the long run. This implies that cereal crops production is highly responsive to changes in the area cultivated which is consistent with the empirical research findings of Block (2008 :34).

The coefficient of temperature shows that a 1 percent increase in temperature decreases crop production by 2.2 percent. Thus, temperature has a significant negative effect on cereal crops production. This result is consistent with conclusions made by Abbas (2021:65).

Table 5.15: The dynamic OLS model result

Beta	***Coefficient.***	***Std. Err.***	***Z***	***p>|z|***
LRaindiv	*-0.235*	*0.0688*	*2.40*	*0.031*
LLand	*1.7187*	*0.3449*	*4.69*	*0.000*
LFerti	*0.359*	*0.0872*	*3.89*	*0.002*
LTemp	*−2.234*	*0.5644*	*−1.99*	*0.066*
Cons	*239.31*	*0.011*	*12.35*	*0.002*

Source: Own computation using STATA

5.4.3.1 Post estimations tests for the time series model

Post estimation for the Dynamic OLS is presented in Table 5.9. Based on the heteroscedasticity test (White's Heteroskedasticity) output, the prob>chi2 value is 0.643. Based on the hypothesis that has been created (Ho: constant variance), the results of the hypothesis testing indicate that the null hypothesis is accepted (p-value is greater than 0.05). Thus, it can be concluded that the residual variance is constant (homoscedasticity).

Also, the Breusch-Godfrey serial correlation test shows based on the hypothesis that has been created (Ho: there is no serial autocorrelation in the model), the null hypothesis is accepted (p-value is greater than 0.05). Thus, there is no serial autocorrelation in the model. The same table indicates that the error term in the model is normally distributed (Jarque- Bera test).

Table 5.16: Post estimation results

Tests	Values	Probability
White’s Heteroskedasticity Test Result	0.771	0.643
Breusch-Godfrey Serial Correlation LM Test	1.226	0.27
Jarque-Bera normality Test	4.672	0.47

Source: Own computation using STATA

5.5. CONCLUSION

The analysis of climate change variables involved different statistical measurements including descriptive statistics (mean, standard deviation, maximum, minimum and coefficient variation) and simple regression equations that are used to show the trend in climate related variables such as temperature and rainfall pattern. The time series mean monthly temperature was analysed for the period of 30 years ranging from 1989 to 2019. The time series mean monthly rainfall was also analysed for the same time period. The result shows the existence of an increasing upward trend in mean temperature in the Lake Tana Basin. In addition, the separate results for the upper and lower basin also reveal the existence of an increasing upward trend in the mean temperature in the period considered. In addition, the rainfall data obtained from both the lower and upper basin satiations of the Lake Tana Basin shows a decreasing trend in annual rainfall.

Also, the relationship between crop production and climate change was examined using time series data spanning from 1994 to 2019/20. The study used the dynamic OLS model. The result shows the existence of links between cereal crop production and rainfall, temperature, fertilizer use and cultivated land. The result of the model shows rainfall and temperature have significant negative effects on cereal crops production while fertilizer consumption and land cultivated have the exact opposite effects on the same activity.

CHAPTER 6: DEMOGRAPHIC AND SOCIO-ECONOMIC ATTRIBUTES OF THE RESPONDENTS

6.1 INTRODUCTION

This section discusses the demographic and socio-economic characteristics of the respondents from the study area. An examination of these characteristics of the study participants is important to understand their food security and poverty conditions. For example, in addition to other factors, the amount of food required at household level depends on the family size (Harris-Fry Harris-Fry, Shrestha, Costello & Saville 2017:17; Sisha 2020:7). Moreover, human capital or labour at household level is also an important factor in determining production activities at this level. Thus, it is relevant to look at these characteristics in order to understand the livelihood context of the study population.

The first two sections discuss the geographic characteristics of the respondents. The geographic characteristics presented the sample distribution across the upper and lower basin of the study areas. The demographic characteristics section presented information on sex, age, level of education, family size and marital status of the households' head in sample. The typology of livelihood section presented the type of livelihood strategies and conditions of the respondent's in terms of accessibility to social and economic infrastructures.

6.2 DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

The data in table 6.1 shows that 58 percent of the respondent households are headed by males and 42 percent by females. In the study area, males and females have clear and defined roles when it comes to social, religious and economic activities. For example, the male members of the community are responsible for livelihood related activity such as farming and fishing. In fact, these economic activities are considered as the major role of male members of the community because the activities are assumed to require physical strength. On the other hand, female members of the community work at home and they are involved in household activities such as cooking, fetching water and cleaning.

There are different monasteries and religious institutions in the study area. Male members of the community have easy access to the education given in these religious institutions and can assume spiritual leadership positions there. The religious education includes literature, writings (Ethiopian alphabets), Ethiopian poetry, church history, etc. This seems to have translated into male members of the community also assuming community leadership posts more than females. Thus, the inclusion of females in the study helps to look at some of the results disaggregated by gender.

The same table also shows that 67 percent are married. Even though it has now slightly declined, early marriage was a common practice in the study area. Thus, female members of the community have less access to education and are more likely to be illiterate than their male counterparts for two reasons: 1) they cannot easily access religious education (as religious education is only allowed for male members of the community), and 2) the practice of early marriage prevents females from attending to school more so than males.

Table 6.1: Demographic characteristics of respondents

Variables	Category	Frequency	Percent
Sex	Male	163	58
	Female	118	42
	Total	281	100.0
Marital Status	Married	187	67
	Divorced	1	0.7
	Single	93	33
	Total	281	100.0
Age	25<=	4	1.4
	26-34	28	10
	35-43	69	24.6
	44-52	78	27.8
	53-61	76	27
	Above 62	26	9.3
Education level	Can’t write and read	205	73
	Write and read	76	27

Source: Own summary using household survey

As presented in table 6.2, the average age of the respondents is 48 years old. This implies that most of them are in their productive age and this means most of the participants can increase their agricultural productivity, allowing them to improve their income. In fact, in Ethiopia, recent studies have shown that younger farmers tend to buy and use more agricultural technologies (improved seeds and fertilizer) than older farmers (Yigezu 2021:58).

Education

The result in table 6.1 shows that while 73 percent of the research participants cannot read and write, the remaining 27 percent can read and write. Studies show that education and household livelihood status seem to correlate in many ways (Adeoye et al 2019: 153-154; Iqbal et al 2021:9-10). In this regarded, the literature identifies that households with education have some advantages over those without one, for example: 1) educated households can easily understand the role of new agricultural technologies and their applications, 2) educated households are better in terms of management and utilization of resources, 3) educated households can better diversify and earn income from non-agricultural activities (Iqbal et al 2021:9-10). However, this argument does not refute the role of indigenous knowledge that famers accumulate thorough experience. Furthermore, as human capital is an important component of assets, which is associated with the level of education, and since the majority of the respondents in this study reported that they cannot read or write, it can be argued that the community is under threat from lack of adequate human capital.

Moreover, the same table also shows the number of family size in terms of number of children, number of male and female members and total family size. The result shows that while the mean value of family size is 6, the mean number of male and female children is 3 in both cases. The result generally shows large family size. The same table shows comparisons between household and regional level figures for some of the variables. For example, the average family size is 6 and 7 for the surveyed households and the region respectively. Also, the average age is equal for both the region and the surveyed households.

Large family size has an implication for poverty and food security. In fact, many studies indicate that family size has an effect on poverty and food security conditions of rural communities. For example, as family size increases, the poverty and food insecurity conditions of rural communities worsens due to lower amount of resource per capita and higher dependency ratios (Agidew & Singh 2018:21; Sileshi, Kadigi, Mutabazi & Sieber 2019:15).

Table 6.2: Descriptive statistics for variables

Variables	N	Minimum	Maximum	Mean	Regional averages
Average Age of the household head	281	25	70	48	48
Number of Adult Males (18 - 64)	281	0	4	2	2
Number of Adult Females (18- 64)	281	0	3	2	No data
Adult Males (Age greater than 64)	281	0	1	0.13	No data
Adult Females (Age greater than 64)	281	0	1	0.03	No data
Number of Children Males (Age<18)	281	0	7	3	No data
Number of Children Females (Age<18)	281	0	8	3	No data
Family Size	281	2	9	6	7

Source: Own estimation from Survey data and Amhara National Regional State Bureau of Finance and Economic Development (ANRS and BoFED).

6.3 SOCIO-ECONOMIC ATTRIBUTES OF THE RESPONDENTS

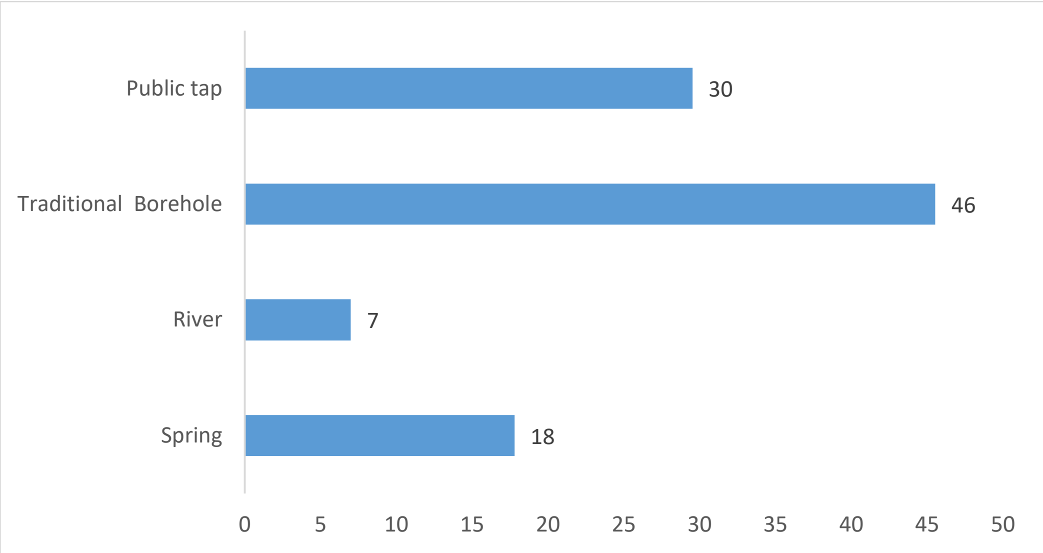
6.3.1 Access to economic and social infrastructure

Social and economic status of communities is important when it comes to livelihood improvements for rural communities. This subsection discusses the conditions of the study households in terms of key social and economic infrastructure indicators. These include access to clean water, energy, market, health facility and education. In the livelihood framework, access to socio-economic infrastructures and institutional arrangements determine the response capability of households to different kinds of shocks like climate change.

6.3.1.1 Access to water

Access to water is an important indicator for decent livelihood as it is key for agricultural production and food preparation as well as healthy life style. In this regard, it is important to discuss the conditions of water resources in the study area in terms of both natural conditions and water management or use perspectives. As presented in the following figure, borehole, public tap and spring are the three dominant sources of water for drinking and other household activities. As presented in figure 6.1, of the total 281 respondents, while 46 percent uses traditional borehole, the remaining 30 percent and 18 percent uses public tap and spring water respectively.

Figure 6.1 : Source of water for household activities (percent)



Source: Own depiction using household survey

The result is important in that even though the area is endowed with a huge water resource potential, the availability of clean and safe water is limited. According to local tradition, there a is saying that says *"የአባይን ልጅ ውሃ ጠማው"* which translates into English as "*the son of Abay/Nile thirsts for water*", an irony used to express how those living along the river Abay/Nile and the basins of Lake Tana still lack access to clean water.

Figure 6.2: A farmer fetching water from a traditional well

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Source: Field picture taken during data collection

Nonetheless, the study area has a huge water resource potential that can be used both for irrigation and energy generation/hydropower dams. Moreover, there are many rivers that are tributaries to the Blue Nile in general and Lake Tana in particular. However, the development of this resources in terms of agricultural water management and the provision of clean drinking water is at an early stage of development. Given the immense water resource potential of the Lake Tana Basin, the development of the water resources for agricultural purposes and electricity is still at low stage of development. This is evident as the result shows low-level electricity use and access. Indeed, low energy access is one of the main challenges in rural Ethiopia.

Figure 6.3: Wetland around the Lake Tana

Source: Field picture taken during data collation

Regardless, there are efforts being made at national and regional levels to harness the basin's potential for hydropower and irrigation purposes. For example, in recent years, the government of Ethiopia has implemented eight agricultural development projects in the basin (Elahi, 2006:89 ; Elhamid, Monem & Aly 2019:131). And without a doubt, the Great Ethiopian Renaissance Dam (GERD) is an important development project in the basin due to its political, economic and regional implications.

It is important that this mega project is used to benefit and improve the livelihoods of communities in the Lake Tana Basin as a top priority. According to the capability approach, access to resources is crucial in securing a sustainable livelihood for the poor. Presently, the study area has a huge water resource potential for irrigation and electricity but there is still low level of electric power usage and clean water coverage.

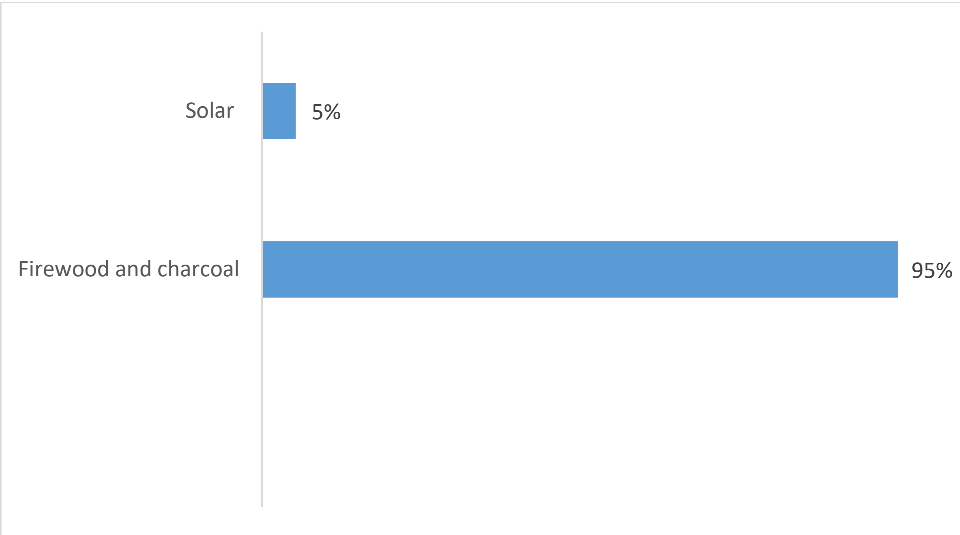
6.3.1.2 Access to energy

Access to energy can play an important role in fostering rural livelihood outcomes such as improved food security and reduced poverty. Many rural communities in developing countries are trapped in what is termed as “energy poverty” which affects the productivity, income and health of rural communities (Nguyen & Su 2021:51).

The result presented in figure 6.6 shows that almost all respondents, 95 percent (N=281), use traditional sources of energy (firewood and charcoal) for cooking. The national figures indicate similar results. For example, (Tiruye et al 2021:32) stated that almost nearly 90percent of remote rural areas of Ethiopia use primary sources of energy that include charcoal, animal residue, fuel wood and dung. This unmet demand for energy has many important implications for rural livelihood in general and households in the Lake Tana Basin in particular. In this regard, one the female participants of the in-depth interview reported the following:

“We used to rely on the nearby forest to meet our energy demand for our day to day activities like cooking. However, in recent years the forest coverage is declining and we need to travel longer distances to get firewood”.

Figure 6.4: Source of energy for cooking



Source: Own depiction using household survey

Because of the dependency on forest resources for energy consumption, the forest coverage in the Amhara region has significantly dwindled (Marie et al. 2021). The same is true for the Lake Tana Basin. According to the FGD participants, they have witnessed a significant decline in forest coverage in the past 10 years. Moreover, they reported that they used to see many types of varieties of forest trees in the past but this is not the case now. This situation was reported by one of the FGD participants as follows:

“In the past, the forest cover used to be like a young man’s hair and it used to support our livelihood but now it looks like a man with a bald hair”.

Figure 6.5: Deforestation in the Lake Tana Basin

Source: Field picture taken during data collection

There is a noticeable reduction in forest coverage although the forest has been an important source of livelihood in both the upper and lower basins. In addition to deforestation for energy purposes, the forest cover decline is caused by high population growth. According to the report from the Woreda agriculture bureau, there has been significant forest clearing for agricultural purposes. The current forest cover is limited to monasteries and churches due to their spiritual significance.

Figure 6.6: Forest coverage preserved inside and around the church compound

Source: Field picture taken during data collection

6.3.1.3 Access to market

Table 3.4 shows that economic infrastructures are relatively inaccessible in the study area. In this respect, the result shows that while the mean travel time to nearest market is six hours, mean travel to the nearest all weather road is 8 walking hours. This has an important implication for agricultural market participation. Studies indicate that distance to market will affect the level of households' market participation which plays a key role in improving livelihood conditions for rural communities by enhancing income (Mekonnen & Alamirew 2018:9). Besides, communities with poor access to market are more vulnerable to climate change related shocks (Asfaw, Maggio & Palma 2020).

Figure 6.7: Farmers carrying their product to the nearby market

Source: field picture taken during data collection

6.3.1.4. Access to health and education

The result shows that while the average travel time to the nearest primary school is 13 minutes, the mean average travel time (walking distance) to nearest secondary school is 57 minutes (Table 6.3). The same table also shows that while the average travel time to the nearest health extension service is 26 minutes and the average travel time to the nearest farmers training is 12 minutes (Table 6.3). Thus, it seems social infrastructures are relatively easily accessible compared to economic infrastructures like markets.

Table 6.3: Accessibility indicators

Variables	N	Minimum	Maximum	Mean	S.D
Travel time to the nearest primary school (minutes)	281	5	60	13	7
Travel time to the nearest secondary school (minutes)	281	5	220	53	27
Distance to the nearest market (km)	281	0.5	12	6	2
Travel time to health extension service(minutes)	281	3	90	26	17
Travel time to farmers training centre (in minutes)	281	2	60	12	6
Distance to all whether road (kms)	281	0.02	16	8	5
Travel time to major water source (minutes)	281	0	60	21	13

Source: Own depiction using household survey

6.4. TYPOLOGIES OF LIVELIHOOD STRATEGIES IN THE LAKE TANA

In a Sustainable Livelihood Framework, identification of livelihood strategies is important as it helps to understand the context in which communities experience shocks such as climate change. In this regard, livelihood strategies that households in the Lake Tana Basin adopted is presented in the following table. The result obtained from the survey shows that crop and livestock production and fishing are the top three livelihood strategies in the basin (table 6.4). This implies that community members in the basin are engaged in economic activities that are more susceptible to climate related shocks.

Table 6.4: Typologies of livelihood strategies

Livelihoods strategies	Frequency	percent
Crop production	275	98
Livestock production	263	94
Fishing	80	28
Tourism	70	25
Forest production	40	14
Trade activities	26	9
Employee in Public sector	8	2
Employee in Private sector	10	3
Casual labour	30	10

Source: Own depiction using household survey

In addition to the three common livelihood strategies (crop production, livestock production and fishing), farmers or households are also engaged in other types of activities including tourism, forest production, trade, casual labour etc.

Figure 6.8: Maize farm (left) and cattle production (right) in Lake Tana Basin

Source: Field picture

The result shows that while crop and livestock production were the dominant sources of livelihoods in the past five years, the remaining livelihood strategies (fishing, tourism, and forest production) were not consistently used as sources of livelihood for communities in the Lake Tana Basin. From this, one could claim that livelihood activities are less diversified and farmers are more dependent on crop production.

Table 6.5: Livelihood strategy and income

Livelihood strategy	Yes	No	Total
Crop production	275	0	275
	100.0percent	0.0percent	100.0percent
Livestock production	263	0	263
	100percent	0.0percent	100.0percent
Fishing	30	50	80
	37percent	63percent	100.0percent
Tourism	10	60	70
	14percent	86percent	100.0percent
Forest production	40	0	40
	100percent	0.0percent	100.0percent
Trade activities	0	26	26
	0.0percent	100percent	100.0percent
Employee in Public Inst.	0	91	8
	0.0percent	100.0percent	100.0percent
Employee in Private Inst.	0	10	10
	0.0percent	100percent	100.0percent
Casual labour	0	30	30
	0.0percent	100percent	100.0percent

Source: Own estimation from survey data (Row percentage reported).

The fact that farmers are more dependent one agricultural based activities (mainly crop and livestock production) implies that they are more susceptible to the possible impacts of climate related shocks as agriculture is the most vulnerable sector to the impacts of climate change.

6.4.1 Livestock production

In the study area, it is common to integrate livestock raising with crop production for three important reasons. First, like many other highland agricultural areas of Ethiopia, crop production in the Lake Tana Basin relies on oxen-dragged plough. In fact, mixed farming system or crop-livestock systems accounts for about 90percent of the farming system in Ethiopia (Amejo, Gebere, Kassa & Tana 2019:3). Second, farmers integrate crop and livestock production as a risk minimization strategy when it comes to livelihood security.

Third, community members in the study area consider livestock as an important form of asset and wealth indicator. In this regard, the FGD reveals that while households who own more than ten oxen are considered as wealthy, those who do not have any or those who own less than ten oxen are considered as poor. Moreover, in the household survey and FGD, farmers reported that they sometimes use selling of livestock as a last resort when they face serious shocks.

Figure 6.9 : Ownership of oxen is an indicator of wealth

Source: Field picture.

6.4.2 Crop production

Agricultural crop production is an important source of livelihood in the Lake Tana Basin. The result presented in table 6.6 (allowing for multiple response options) shows that rice, maize and teff are the most common crops grown in the basin (N=281). The basin is suitable for growing a variety of crops including but not limited to teff, maize, rice, millet and sorghum. This helps to improve food security conditions at the household level and further enhance livelihood conditions.

Farmers in the upper and lower basin produce crop twice a year during the seasons of Meher (main) and Belg (minor). Crop production during both seasons takes place under rain-fed system. The application of irrigation systems for farming is not common in the area. However, some rich farmers use irrigation (motor pump technology).

Another interesting issue in the crop sub-system is that the changing cropping pattern around the wet lands areas of the Lake Tana Basin. Few years back, maize and teff were the main cereal crops but have since given way to rice. According the key informant interview with the Woreda agriculture expert, the main reason for this is the relative high price (economic incentive) and productivity of rice as compared to traditional crops such as teff.

Table 6.6: Types of crop grown in the Lake Tana Basin

Crop type	Percent
Rice	80percent
Maize	92percent
Teff	66percent
Millet	14percent
Onion	9percent
Sorghum	5percent
Vetch	5percent
Tomatoes	5percent
Lentils	2percent

Source: Own depiction using household survey

As presented in Table 6.6 above, the common crop types grown in the basin include rice, maize, teff and millet. According to the regional agriculture bureau, cereal production accounts for more than 90 percent of total crop production (Ministry of Agriculture and Rural Development 2020:35).

Rice is not a traditional food in the study region and Ethiopia. However, thorough agricultural expansion programs, it has been introduced to the wetland areas of the Lake Tana Basin. It has now become a strategic crop for food security and most farmers are producing it for both domestic and commercial purposes. Indeed, there are many contributing factors that led to the success of rice in the region. These includes the agro-ecological potential and economic incentives of rice as well as its compatibility with local farming systems (Alemu & Thompson 2020:8-10). In fact, some famers have even shifted from producing local crops like Teff to producing rice.

6.4.3 Fishing activity

Fishing mentioned as another an important source of livelihood for members of communities in the Lake Tana basin. The fishing activity is conduct at the Lake Tana , which is important source of livelihood for the Blue Nile basin in general and lake Tana basin in particular (Taye 2021). In fact, fishing in the Lake Tana region supports at least more than half million people (Asmare et al 2016:549). Thus, the role of fishing in sustaining and supporting livelihood cannot be undermined. Up until recently, fishers used traditional mode of fishing harvesting. However, in recent years some cooperatives union have introduced motor boats that facilitate to fishing production. Nevertheless, the dominant form of fish harvesting is still using traditional boats. According to an interview with fish cooperative members around Bahir Dar city (a catchment near Lake Tana), the traditional fish harvesting technique is not efficient in terms of both productivity and production.

On the other hand, this important livelihood is under a serious threat due to human activity and large-scale development projects in the area. The FGD participants responded that development projects such as the construction of large dams are threatening their livelihoods. One of the FGD participants reported the following:

“Development projects such as the construction of dams is threatening our lives. For example, recently, the government completed the Beles I and Bels II hydropower plants. Even though the construction provided temporary employment for members of the community, it has negatively affected our main source of livelihood, fishing. Now, both the water level of Lake Tana and the quantity of fish we used to catch have declined”.

These concerns of fishers and member of the community coincides with the result of a study conducted by (Goshu & Aynalem:2019:11). According to these authors, since the study area is identified as a development corridor by the regional and federal governments, there is massive development intervention projects such as the construction of commercial irrigation and hydropower dams which are threatening both the ecosystem in general and fish production in particular. A key informant from the Blue Nile Basin Institute said the following:

“*The level of Lake Tana significantly drops during the dry season due to the hydropower dams constructed along the Lake Tana tributaries. This has undermined the vegetation coverage which serves as a source of food for fishes”*.

Another important challenge is the conditions of the Negde Woito community**.** The Negde Woito are minority members of the community who are experienced in traditional boat construction from a papyrus plant found in the surrounding area. In addition to fishing, this community relies on the papyrus resource as a livelihood base. However, the papyrus vegetation is declining day to day because of the fluctuation in the water level of Lake Tana, which they attribute to hydropower projects in the area.

6.5. CONCLUSION

The chapter presented the conditions of social and economic infrastructures in the study area. The result shows that social infrastructures are relatively easily accessible compared to economic infrastructures like markets. There is low level of coverage in terms of access to market, energy and water. In addition, the chapter revealed that crop, livestock, fishing and tourism activities are the major livelihood strategies in the region. This implies that community members are engaged in economic activities that are more sensitive to climate related shocks.

The data shows that while crop and livestock productions have been the dominant sources of livelihoods in the past five years, the remaining livelihood strategies (fishing, tourism, and forest production) have not been consistent sources of livelihood for communities in the Lake Tana Basin.

CHAPTER 7: CLIMATE CHANGE, ADAPTATION AND LIVELIHOOD

7.1 INTRODUCTION

In this chapter, the effect of climate change and adaptation on the livelihoods of the Lake Tana Basin is discussed. The Lake Tana Basin has many livelihood options that could support and sustain life (Chapter 6). In fact, the basin serves as an important source if livelihood for millions of people. These livelihood options include but are not limited to crop production, livestock raising, fishing and tourism (Chapter 6). In this chapter, we will assess whether climate change and adaptation have affected the key livelihood strategies and assets in the basin. Thus, the perception of climate change’s influence on key livelihood indicators and variables is discussed. In the Sustainable Livelihood Framework approach, any shock in the livelihood will affect the livelihood strategies and assets of people. In this regard, considering climate change as the main shock in the livelihood of the Lake Tana basin, this chapter mainly discusses how the key livelihood strategies and assets affected by climate change and which livelihood systems affected the most as experienced by members of the community. The chapter also provides perception of the community on change in climate variables. The trends in climate variables from the secondary data show changes in the variables such as decline in rainfall and increase in temperature (chapter 5). Consequently, this chapter will cross-match the results of the secondary data analysis with the perceptions of the community.

7.2. CLIMATE CHANGE AND LIVELIHOOD

In this subsection, the study assesses the perceptions of members of the community towards climate change. The perception analysis provides information about the understanding of community members with regard to climate change related variables such as temperature and rainfall. As presented in chapter 5, the statistical trend analysis shows that while there is a general decline in the amount of rainfall, there is an increase in mean annual average temperature. In this subsection, the study seeks to examine whether community members feel the same way.

7.2.1. Perception of climate change

Different indicators are used to assess the climate change conditions in the Lake Tana Basin. Among these indicators are the perceptions of the respondents towards changes in the levels of temperature and rainfall. In order to see how much the respondents are well aware of the Lake Tana Basin and its surroundings, an important question was asked about the number of years that the respondents lived in the area. The descriptive statistics presented in table 7.1 shows that on average, the respondents have lived in the area for 40 years. This means the respondents are knowledgeable enough to observe and report the possible changes in climate variables such as temperature and rainfall.

Moreover, key informant interviews and FGDs were conducted with select members of the community. The argument here is that rural communities can understand and observe the change in their environment. In fact, rural communities are dependent on the natural environment to sustain their livelihoods and as such, they do have a good understanding and knowledge of their surroundings. Thus, we can rely on their perceptions and judgments of the changes in their environment and ecology.

Table 7.1: Number of years respondents lived in the area

Question	N	Minimum	Maximum	Mean
Number of years lived	281	20	70	40

Source: Own summary from the household survey

The result presented in figure 7.2 shows that 92 percent (N=281) of them have perceived changes in the conditions of temperature. According to the in-depth interviews, FGDs and KIIs, the change in temperature is mainly expressed as an increase in the variable. The following statements express the participants' views concerning the rise in temperature:

"I compare the increase in temperature to a fire incidence that starts at small scale but later invades everything". (FGD participant).

"Thinking of the rise in temperature, I would say God is angry and turned his face against us". (In-depth interview with a peasant).

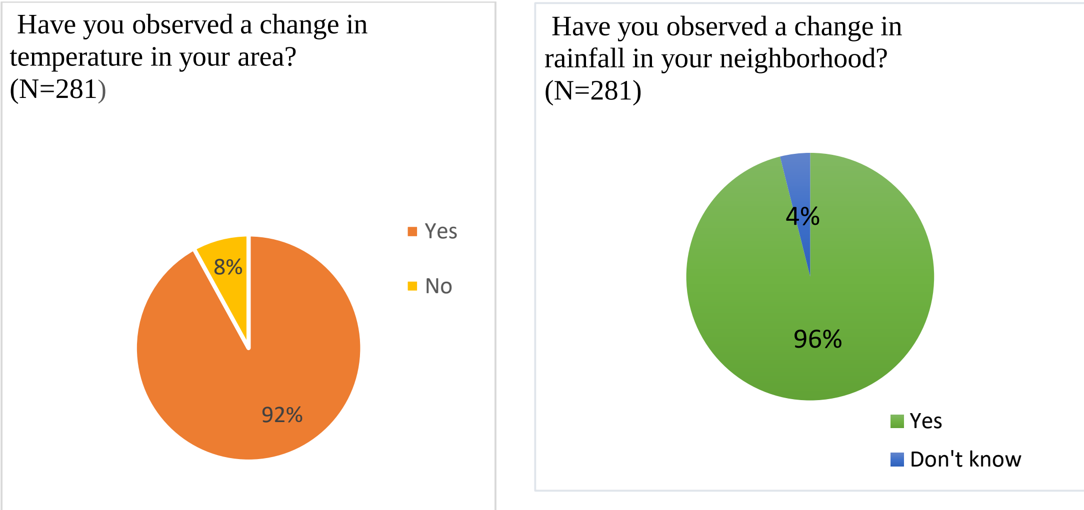
"This area used to be cold and suitable for living and conducting agriculture but in recent years the temperature is so harsh that it is like living in hell". (KII with the Woreda agriculture expert).

"I have noticed that the land is getting hotter and hotter making it difficult to hold moisture, which is important for our main economic activity of agriculture. In fact, we have noticed that during times when the temperature is cold, the land receives moisture and we are able to produce much agricultural output without any worry and even sell some proportion to the nearby market. However, after the change in temperature [increase], we have started to worry whether we could be able to produce enough food four ourselves let alone sell to the market". (In-depth interview with a peasant).

The implication from the above statements is that the farmers have long experienced and well observed the rise in temperature in the Lake Tana Basin. Moreover, from the statements they made, it can be said that the increase in temperature is serious and unprecedented to members of the community in the area. Due to its altitude, the study area is still classified as having a temperate or highland climate (Abeje et al 2019:2). But the finding here indicates that farmers are experiencing a rise in temperature which seems to have altered the climate make-up of the region.

In addition, the result presented in figure 7.1 shows that 96 percent of them perceived changes in the amount of rainfall. This result is consistent with what is reported in chapter 5 as the data there indicates a general increase in temperature and a decline in rainfall. Moreover, the result is consistent with what is reported by other climate change impact studies. For example, a study conducted in Bahir Dar Zuria Woreda found out that about 92 percent of the study participants perceived changes in the pattern of rainfall distribution during the main rainy season and that about 84.5 percent of the respondents in the district believe that climate change is the main cause of rainfall variability (Kefyalew, Alemayehu and Addis Getu, 2016:115). Thus, climate change is well understood and noticed by the community and recognised as a real problem.

Figure 7.1: Perception of change in temperature (left) and in rainfall (right)



Source: Own summary from the household survey

In addition, the descriptive result presented in table 7.2 shows the difference in perception about changes in rainfall between the upper and lower basins is statistically significant ($\chi 2$ = 11 with P<0.001). Moreover, the descriptive result presented that the difference in perception about change in temperature between the upper and lower basin of the Lake Tana basin is statistically significant ($\chi 2$ =11 with P<0.001) (see table 7.3). However, the main argument here would be farmers have perceived change in rainfall pattern. In fact, since the majority of them have are crop producers they can easily detect the change in rainfall pattern.

In the same token, the descriptive result in table 7.3 indicates that the difference in perception about changes in temperature between the upper and lower basins is statistically significant ($\chi 2$ = 15 with P<0.001). This is expected as climate and agro-ecology varies even within the same Kebele in Ethiopia due to the altitude (Chala, Simane & Alamirew 2016:231).

Table 7.2: Perception of climate change (rainfall) in the study area

Rainfall	Lower basin	Upper basin	Total	χ2 value	P value
Yes	138	132	270	11***	0.000
No	0	11	11		
Total	138	143	281		

***Values are significant at $P<0.001$

Source: Own summary from the household survey

In the same token, the descriptive result presented that the difference in perception about change in temperature between the upper and lower basin of the Lake Tana basin is statistically significant ($\chi2 = 15$ with $P<0.001$). This is evident as climate and agro-ecology varies even with the same Kebele in Ethiopia due to the altitude (Chala, Simane & Alamirew 2016:231). Thus, farmers might have different perception towards temperature.

Table 7.3: Perception of climate change (temperature) in the study area

Temperature	Lower basin	Upper basin	Total	χ2 value	P value
Yes	134	125	259	15***	0.001
No	4	18	22		
Total	138	143	281		

***Values are significant at $P<0.001$

Source: Own summary from the household survey

The other indicator of climate change related shocks in the area is the number of droughts, floods and frosts. The descriptive result in table 7.4 shows that droughts and floods are becoming frequent phenomena. However, frost seems to be a less important shock in the area as its frequency is low. In the Sustainable Livelihood Framework, any change or shock in a given livelihood could potentially threaten livelihood assets (Thakur & Bajangain 2019:174). In line with this, frequent droughts and floods reported by the study participants pose threats to the livelihood of communities along the Lake Tana Basin.

Table 7.4: Number of climate related shocks reported

Indicators	Minimum	Maximum	Mean
Number of droughts in the last 5 years	1	4	3
Number of floods in the last 5 years	1	4	3
Number of frosts in the last 5 years	1	2	0.14

Source: Own summary from the household survey

The household survey also reveals the perceptions of community members towards different measurements of climate change variables and indicators. The result shows that almost all the survey participants reported that while temperature is getting hotter, precipitation and rainfall is becoming unpredictable. The frequency result in table 7.5 shows that a significant number of them reported that they lost more crops and livestock during the years because of bad weather. Moreover, the same table shows that most reported that their income has declined which can be explained by crop and livestock loss.

Table 7.5: Frequency on the perception of climate change related variables

Statements	Strongly Disagree	Dis agree	Neutral	Agree	Strongly Agree	Total
The temperature got hotter over the years	2	1	1	90	187	281
Rain became lesser and unprecedented over the years	1	1	0	112	167	281
Precipitation became more unpredictable over the years	2	0	0	135	144	281
There are a long-term shifts in precipitation	2	4	2	144	129	281
Rainfall became more unpredictable from year to year	2	1	2	148	129	281
There are long-term shifts in temperature	2	1	2	146	130	281
I have lost more corps during the last years because of bad weather conditions	2	7	4	142	126	281
I have lost more livestock during the last years because of bad weather conditions	2	15	28	138	98	281
The quality of the harvest has become worse in the last years	2	1	2	144	128	281
The quality of the harvest has affected sales of the product	2	7	4	141	125	281
My income decreased due to the loss of crops/livestock because of bad weather	2	15	28	138	98	281

Source: Own depiction using survey data

In order to substantiate the frequency distribution table shown above, the mean score result is presented in the table 7.6. The mean score summarizes each of the statements provided in the list. Accordingly, using a five-point Likert scale, the mean score result shows that for nearly all the items, the mean score is more than 3 points. Thus, the respondents in general agree with each of the provided statements that measure the perception of climate change and its impact. For example, there is an agreement on statements such as, the temperature is getting hotter, rain is becoming lesser and precipitation is becoming more unpredictable.

Table 7.6: Mean scores of the items

Statements/Items	N	Minimum	Maximum	Mean
The temperature got hotter over the years	281	1	5	4.65
Rain became lesser and unexpected over the years	281	1	5	4.57
Precipitation became more unpredictable over the years	281	1	5	4.49
Rainfall became more unpredictable from year to year	281	1	5	4.43
There are long-term shifts in precipitation in your area or farm	281	1	5	4.43
There are long-term shifts in temperature in your area or farm	281	1	5	4.44
I have lost more corps during the last years because of bad weather conditions	281	1	5	4.36
I have lost more livestock during the last years because of bad weather conditions	281	1	5	4.12
The quality of the harvest has become worse in the last years	281	1	5	4.38
The quality of the harvest has affected sales of the product	281	1	5	4.29
My income decreased due to the loss of crops/livestock because of bad weather	281	1	5	4.29

1=Strongly Disagree; 2=Disagree; 3=Neutral; 4=Agree; 5=Strongly Agree
Source: Own depiction household from survey

7.2.1.1. Perception of the effect of climate change on livelihood strategies

Climate change affects livelihood conditions of rural communities in many ways and the literature has identified agriculture based livelihood as the main channel through which the effects of climate change is transmitted to rural communities (Ubisi et al 2017:27; Thakur & Bajangain 2019: 173). In this regard, the survey shows that until recently, most members of the community in the Lake Tana Basin relied on crop and livestock production and fishing (Chapter 6). By implication, this would mean communities in the basin are more susceptible to the possible impacts of climate change duet to the sensitivity of agriculture to climate-induced shocks.

The perception of the severity of the effect of climate change on identified livelihood strategies in presented in table 7.7. The result shows that community members perceived that crop and livestock production, fishing and tourism as being severely affected by climate change.

Table 7.7: Perception of severity of the effect of climate change on different livelihoods

Livelihoods	Very Minor	Minor	Medium	Severe	Very Severe	Total
Crop production	0	18	14	148	95	275
	0	6.5 %	5.1%	53.8%	34.5 %	100 %
Livestock production	0	16	69	79	99	263
	0	6%	26%	30%	39%	100%
Fishing	0	0	0	0	80	80
	0	0.0	0	0	100%	100%
Tourism	0	0	0	0	70	70
	0	0.0	0%	0	100%	100%
Forest production	0	0	0	0	40	40
	0	0	0	0	100%	100%
Trade activities	0	0	20	6	0	26
	0.%	0	77 %	23%	0.0%	100%
Casual labour	30	0	0	0	0	30
	100 %	0	0	0.0	100%	100%

Source: Own summary from the household survey

Climate change affects crop production since it impacts both temporal and spatial distribution of rainfall and precipitation. As indicated in the literature review, agriculture is the most sensitive sector to climate change, making farmers the most vulnerable group to the phenomenon. This is the case in the Lake Tana Basin as a peasant who participated in an in an in-depth interview reported:

"Previously we used to know and be able to predict when to sow and collect our harvests, however in recent years, we could not easily predict when the rain would come; in fact, we are under the mercy of nature than ever before".

Thus, according to the perception of members of the community, climate affects crop production through its effects on rainfall. In this respect, other studies have also proven that rainfall variability is one of the main factors that affect crop production and productivity in the northern part of Ethiopia where Lake Tana Basin is found. These studies indicate that erratic rainfall has a significant negative effect on crop production. According to their result, when rainfall diverges from its mean, the level of production of all crop types diminishes significantly (Ginbo 2022:13; Wubie 2015:103). However, the effect of climate is heterogeneous when altitude (the criterion for agro-ecology classification in the country) is considered. For example, results show that climate change will induce an increase in coffee and teff yields by 31 percent and 8.3 percent respectively at high altitudes by the years 2041–2060 compared to 1988–2018 under a medium emissions scenario. Conversely, it will reduce coffee yield by 3 percent at low altitudes, and barley, maize, and wheat yield by 22.7 percent , 48 percent , and 10 percent , respectively, at high altitudes (Ginbo 2022:12-13).

The main rainy seasons in the Lake Tana Basin covers the months of June, July and August. However, in recent years, farmers have observed that either rainfall has declined in quantity or has been delayed by few months than usual, making it difficult to practice crop production. Given the fact that agricultural production in the basin is mainly rain-fed, the spatial and temporal variation in rainfall pattern has important implications for crop production and productivity.

The study used the Leopold matrix to identify the effect of climate change on key livelihood strategies by ranking the effect of climate change on different livelihood strategies (section 3.10.2.3). However, in order to capture accurate information, this question was forwarded only to those whose livelihood entirely depends on the five key livelihood strategies. As a result, the sample size was reduced to only 70 respondents as those households who rely on less than four livelihood strategies were excluded from the analysis. The result of the Leopold matrix is summarized and presented in the table 7.8. The Leopold matrix is interpreted based on a defined scale (Sheikh & Akter 2017:47).

The scales are:
0– No observable effect;
1– Low effect;
2– Tolerable effect;
3 – Medium high effect;
4 – Sever effect;
5 – Highly serve effect.

As presented in the ranking matrix, crop production ranked to be the most severely affected livelihood strategy as nearly all respondents ranked it either in the server or highly server category (table 7.8). Similar results are found in other studies, most probably due to the sensitivity of agriculture (Lemi & Hailu 2019: 14;Wubie 2015:106). The same table shows that livestock production ranked second in terms of the most severely affected livelihood strategy by climate change. Tourism and fishing ranked 3rd and 4th in the ranking matrix. Tourism ranked last possibly due to the indirect effect of climate change on it compared to the agriculture sector.

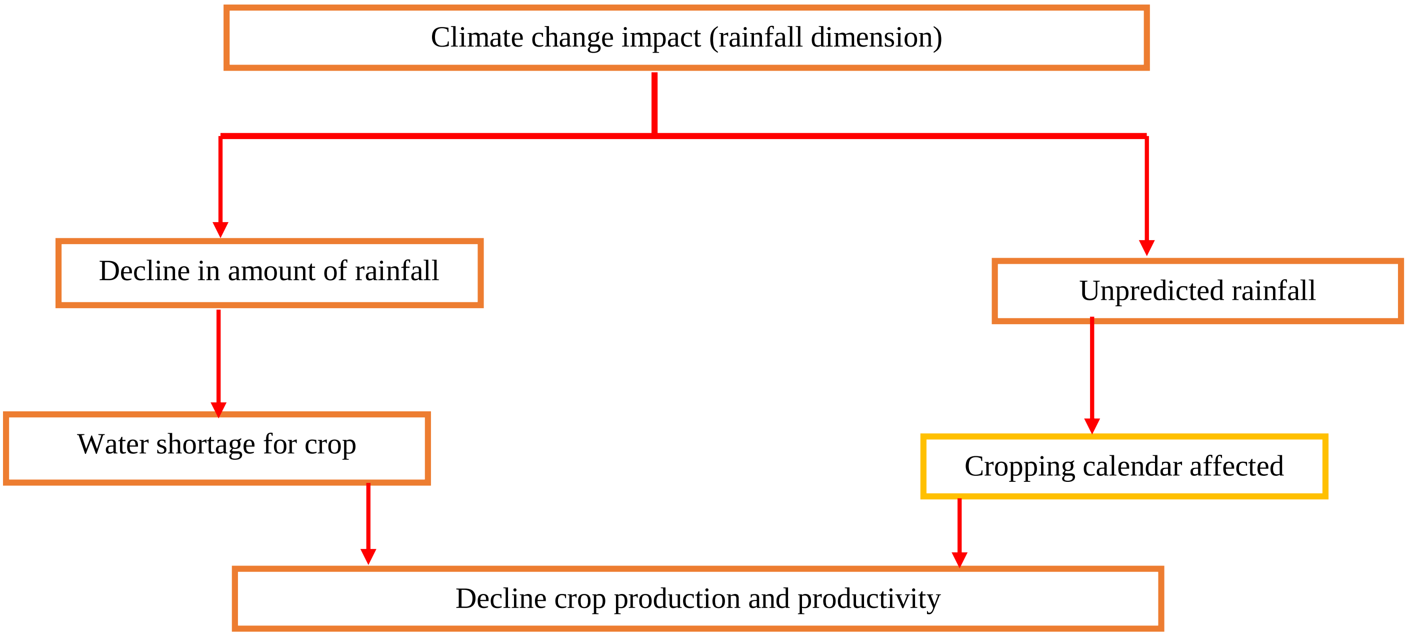
Table 7.8: Livelihood ranking using Leopold matrix

Livelihoods	Priority							
	Highly Severe (5)	Severe (4)	Medium (3)	Minor (2)	Low (1)	No (0)	Total frequency	Rank
Crop	55	15	0	0	0	0	70	1
Livestock	32	25	13	0	0	0	70	2
Fishing	32	15	23	0	0	0	70	3
Tourism	22	29	19	0	0	0	70	4

Source: own computation using Household survey data

Figure 7.2 summarises the above discussion on farmers' perceptions about the effect of climate change (mainly due to change in rainfall distribution) in Lake Tana Basin. Climate change manifests in the study area in terms of decline in the amount and predictability of rainfall and increase in temperature. The decline in the amount of rainfall has caused water shortage for crop production while the unpredictability of rainfall has affected the cropping calendar.

Figure 7.2: Farmer's perception of the effect of climate change



Source: Own description based on the discussion

Livestock production is also an important source of livelihood in the Lake Tana Basin (chapter 6). As most farmers practice mixed farming systems, livestock production plays an important role in their livelihoods. As presented in table 7.9, most of the respondents perceived the existence of the effect of climate change on livestock production. In fact, the research participants have reported that water and feed shortage and increase in livestock mortality as the top three effects of climate change on livestock. Moreover, the research participants perceived the frequent occurrence of droughts due to climate change.

Similarly, climate change also affects livelihood components (crop and livestock) in the Lake Tana Basin through its influence on temperature. Thus, increases in temperature have affected crop and livestock production and fishing activity. During the FGDs, participants indicated that high temperature affects the amount of required water for crop and livestock production.

Table 7.9: Major effects of climate on livestock production ranked by farmers

Major effects	**Rank**
Water shortage	1st
Feed shortage	2nd
Decline in livestock productivity	3rd
Increased livestock mortality	4th
More conflict	5th
Increased disease prevalence	6th
Longer time to reach mature weight	7th

Source: Own summary from the household survey

In fact, water shortage ranked as one of the top climate effects on livestock production in the basin. Members of the community have reported decline in water level in rivers, ponds as well as water storage facilities. This is especially evident during the dry season. One of the FGD members in the lower basin reported:

"During the rainy season, all our water storage facilities will be filled with water for some time and every one would be excited, however due to the immediate rise in temperature, all that has been stored will be lost and our smiles will go away and then we will start to worry about the harvest".

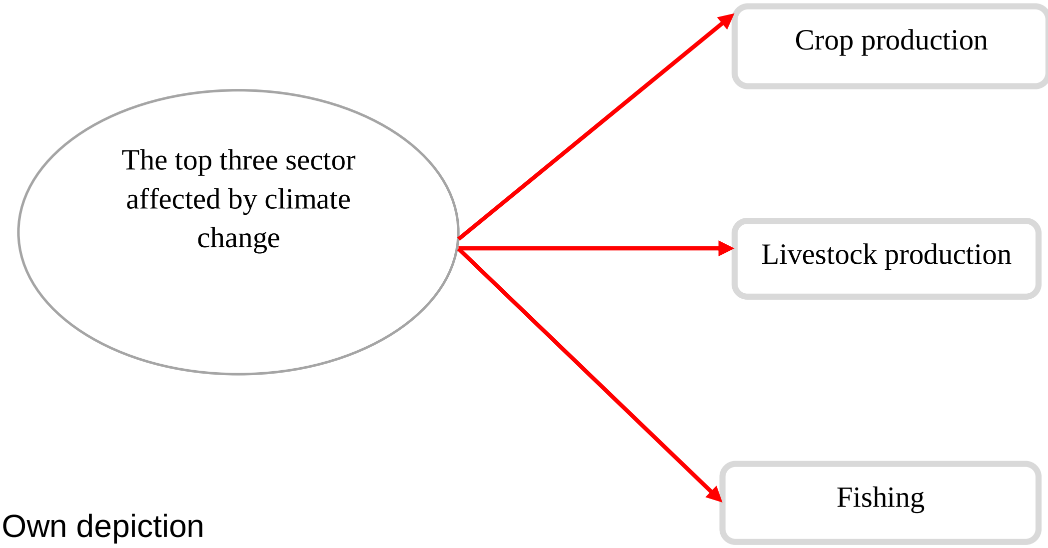
Feed shortage ranked as the second most important climate effect on livestock in the Lake Tana Basin. As indicated by other research reports, the spatial and temporal variability of rainfall and temperature pattern affects the quantity and availability pastureland and water for livestock production (Rojas-Downing et al 2017: 145). This is especially the case when one considers the comparatively longer dry season. However, in recent years, the characteristics of the dry and rainy seasons are becoming similar in many ways. For example, one of the FGD respondents reported:

“Previously we used to make a distinction between the rainy season and the dry season, however now since the rain in the rainy is either unpredictable or the amount is small, we do not see much difference between the two seasons”.

The Lake Tana Basin is an important source for fishing and tourism activities and members of the community use the two options as alternative sources of livelihood. However, these sectors are under threat due to climate change related shocks (Table 7.7). The effect of climate change on fishing activities seems indirect. According to a key informant interview, due to the effect of climate change on agriculture (which brought decline in agricultural production and reduced income), people have abandoned agriculture and started fishing, causing the overexploitation of some of the fish species, which has been confirmed by other research findings. For example, according to (Asmare et al 2016: 548), the stock of aquatic animals declined in the basin due to climate change and other anthropogenic activities.

Figure 7.3 summarises the discussion presented in this subsection. The top three sectors affected by climate change in the Lake Tana Basin are crop and livestock production and fishing activity. Thus, the more community members depend on these livelihoods, the more they are likely to experience the negative impacts of climate change.

Figure 7.3: The top three impacts of climate change on sources of livelihood



Source: Own depiction

7.2.1.2. Climate change’s effect on assets

Assets are important components that make up the Sustainable Livelihood Framework (SLF). In SLF, the key assets include physical, social, natural and human capital. The argument here is that climate change could affect one or more of these components and further impact livelihood outcomes such as food security and poverty. In this regard, the first task is to identify the key livelihoods and the different asset indicators that help to examine the exposure of members of the community and their assets to climate change.

The key indicators of livelihood assets used for this purpose by the thesis are identified based on the literature review and the local context (Abeje Tsunekawa, Haregeweyn, Nigussie, Adgo, Ayalew, Tsubo, Elias, Berihun, Quandt, Berihun & Masunaga2019:5; Mekonen & Berlie 2021:6; Sujakhu Sailesh, Jun, Dietrich, Yufang & Jianchu 2019:7; Tiruye, Besha, Mekonnen, Benti, Gebreslase & Tufa 2021:7). However, in addition to the key asset indicators identified from the literature, open-ended options are also allowed to capture other asset concepts.

There are at least two objectives here. The first is to identify which assets were changing overtime as a result of climate change and the second is to identify which assets were severely affected by the possible effect of climate change related shocks. Analysis of climate change effects on asset indicators helps to understand how livelihood pattern is changing around the study area. Based on the sustainable livelihood framework, asset and livelihood strategies define the conditions and response capacity of households to any sort of shocks including climate change induced ones.

Allowing for multiple response, the result presented in table 7.10 summarizes household’s response on the perceived changes in assets due to climate change. The table shows that the top three changes observed are water for agriculture, grazing land and income from livestock. The same table shows that the least perceived change is access to health with a percentage score of

7percent. This indicates that the most important changes observed are for agriculture-related asset indicators. This is expected at least for two reasons: first, agriculture is the most important and dominant sector for the area and second, the literature has identified agriculture as the most sensitive sector to climate change.

Table 7.10: Perceived effect of climate change on asset indicators

Indicator	Yes	No	Don't know
Water for agriculture	95percent	3percent	2percent
Grazing land	95percent	5percent	0
Agriculture land use	95percent	3percent	1percent
Income from livestock	92percent	7percent	1percent
Farm income	87percent	13percent	0
Forest cover	87percent	12percent	1percent
Group cooperation during Challenges	78percent	20percent	2percent
Access to credit	78percent	22percent	0
Frequency of extension	75percent	25percent	0
Credit from financial institutions	68percent	32percent	0
Income from fishing	62percent	23percent	14percent
Housing: traditional	57percent	43percent	0
Borrow from a neighbour	54percent	43percent	3percent
Remittance	48percent	42percent	10percent
Education (any interruption)	32percent	66percent	1percent
Members migration	13percent	87percent	0
Access to health care	7percent	93percent	0

Source: Own summary from the household survey

In addition, the severity of the effect of climate change on assets was examined using a Likert scale based indicator. The result of this analysis is presented in table 7.11. The data shows that grazing land, agricultural water, agriculture land use, forest cover, farm income, income from livestock and group cooperation are the most severely affected livelihood assets or capitals.

Table 7.11: Severity of the negative effect of climate change on livelihood assets

Indicator	Very Minor	Minor	Medium	Severe	Very Severe	Total
Grazing land	0	0	11	193	61	265
Water for agriculture	0	6	29	180	51	266
Agricultural land use	0	6	64	156	45	271
Forest cover	0	2	22	160	58	242
Remittance	10	4	12	51	17	94
Borrow from a neighbour	4	3	11	58	13	89
Farm income	0	0	12	135	73	220
Income from livestock	0	10	58	129	31	228
Income from fishing a	32	0	0	70	10	80
Credit from financial	0	4	32	98	25	159
Group cooperation	0	0	21	139	25	185
Education (any interruption)	3	15	14	38	2	72
Members migration	1	4	3	5	0	13
Access to health care	0	3	32	56	9	100
Housing	0	4	11	93	25	133
Access to credit	0	8	21	84	17	130
Frequency of extension	0	19	34	49	14	116
Total	50	99	412	1,712	496	2,769

Source: Own summary from the household survey

Natural Assets

The natural asset dimension has been captured using indicators such as grazing land, water for agriculture, agricultural land use and forest cover. Climate change related shocks can have both direct and indirect implication for these key assets identified in table 7.11. The result presented in this table indicates that farmers have perceived changes in all indicators of natural assets. One of the FGD participants reported, "*The grazing land is becoming* *empty and dryer and as such, we could not get adequate fodder for our livestock population"*. And one of the KII said, *"previously the grass regenerated quickly, however in recent years, the regeneration rate of grass has been reduced significantly due to decline in soil moisture"*. This shows that climate change can bring change in land use in general and agricultural land use in particular. The same result has been observed by other similar studies in Ethiopia. For example, Brychkova, Kekae, McKeown, Hanson, Jones, Thornton, & Spillane (2022:11) find that by 2050, Buffel grass is likely to be negatively affected by climate change in regions such as Tigray.

One of the key observed changes is the availability of water for agriculture. According to FGD participants, they have lost harvest many times in the past ten years due to the decline in the amount rainfall during the two production seasons (Belg and Meher). They have also reported that due to increase in temperature during the dry season, the soil usually loses its moisture, which affects crop productivity. One of the FGD participants reported the following, "*Sometimes I feel that I am being played by nature; during the wet season, extension workers advise us to store water but during the dry season, all the stored water will be lost before we use any of it on our farm"*. This has an important implication for farm income. As reported by the KII and FGD participants, farm income has declined due to the reduction in crop production and productivity (as a result of decrease in rainfall in the past five years). The following are some of the reflections from in-depth interview participants:

"I used to rely on my farm and I never expected the sky will turn its face against us but nowadays the rain has become so unpredictable and so too our farm income" (In-depth interview with a peasant in the upper basin).

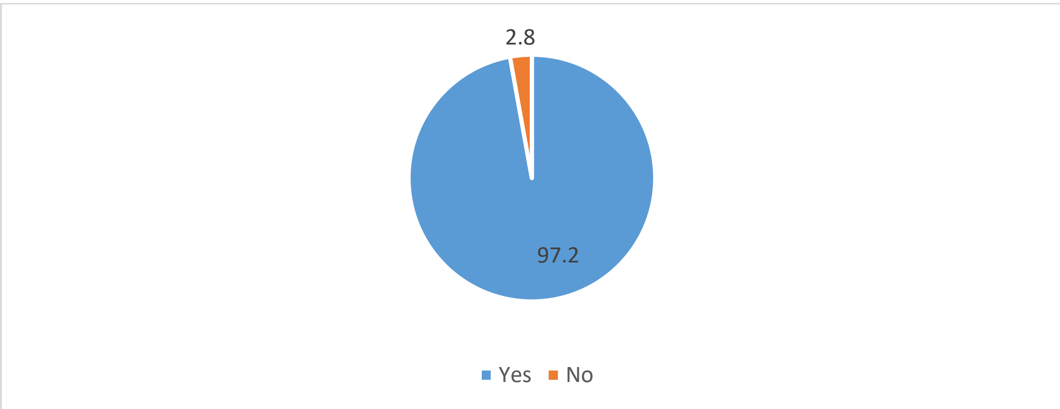
"I have lived here for more than 55 years and I never used to see people praying for rain as it was natural for it to come during the production seasons. However, now we always pray for rain and such prayer has become an important part of our life as we frequently lose our harvest" (In-depth interview with a peasant in the lower basin).

Thus, from these statements, it is clear that members of the community perceive changes in water for agriculture.

Financial assets

Financial asset/capital is measured using proxy indicators such as remittance, borrowing from neighbours, income (from farm, livestock and fishing) and credit from financial institutions. As presented in table 7.11, among the listed indicators, the effect of climate change on income from livestock and crop ranks at the top. This is due to the direct effect of climate change on crop and livestock production since more than 80 percent of the respondents rely on these activities to support their livelihoods. In fact, the household survey shows that nearly 97 percent (N=281) reported that climate change has affected their income (figure 7.4).

Figure 7.4: Perception of the effect of climate change on Income



Source: Own depiction using household survey

The household survey also shows that farmers have perceived the negative effect of climate change in different sources of income. The frequency result presented in table 7.12 below shows that most households reported and ranked the level of perceived severity (negative effects) from “severe” to “very severely.” Thus, climate change has posed a serious threat for one of the key components of livelihood outcome (income).

Table 7.12: Perception of severity of the effects of climate change on various sources of income

Source	Very low	Low	Medium	Severe	Very Severe	Total
Farm income	2	28	64	110	76	280
Non-farm income	6	25	108	82	59	280
Assistance [aid]	8	55	77	75	65	280
Remittance	4	34	111	62	60	281
credit	6	20	67	108	80	280
Saving	6	30	96	85	63	280

Source: Own depiction using household survey

In the same token, the discussion during the FGD and KII indicted that climate change affected crop production and productivity, which in turn affected income from crop sales or farm income. In this regard, one of the FGD participants reported the following:

"In the past, we used to borrow money from one another but now since everyone is affected by the bad conditions of the rainfall, there is no one to borrow from".

"We are not getting enough fodder for our livestock due to the longer dry seasons and decline in the amount of rainfall and our income from livestock related activities has declined in the past few years".

Thus, climate change affects financial asset/capital through its effect on natural capitals such as crop production, agricultural water and livestock production.

Social Asset

In Ethiopia, many important indigenous associations have existed in different forms (cultural, religious and socio-economic contexts) for thousands of years. Among such indigenous voluntary associations, Edir and Equb are the prominent ones.

Households have also perceived that climate change could affect social capital through its effect on indigenous labour sharing system. As reported by members of the community, they have a social group or association called "Debo". Debo refers to a local social association where community members contribute and exchange labour mainly for agricultural purposes (Kebede & Butterfield 2009:258). However, due to crop failure and decline in farm income (caused by lack of rainfall) some household members have migrated to neighbouring cities to look for better jobs. This has created labour shortage for some members of the community during agricultural peak seasons. Here it would be relevant to look at the following report from a KII participant:

"During the good times I used to supply labour for the Debo. However, now I could not do that anymore because my sons have already left me to look for a better life. While they were here, they used to participate in the Debo representing my family but now, no one will contribute labour to me as I cannot do the same for others".

The implication here is that climate change seems to affect social capitals through its effect on indigenous social systems. Labour sharing has an important social and economic value for the community. The effects of climate change on indigenous support institutions could even lead to food insecurity in some cases (Negera, Bekele, & Wondimagegnehu,2019:127).

Equb is a major local self-supporting system that has been affected by climate change. The main function and purpose of Equb is to provide a savings mechanism or platform for the community, which is key for the economic sustainability of households (Sudhakar2019:70). However, due to the decline in crop production and income from farming caused by erratic rainfall, some members are not able save money for Equb. As such, only a small number of community members are participating in this social activity. In this respect, it is important to mention the view of a study participant:

“Due the decline in the amount of rainfall and seasonality, my income from crop sales has been declining over the past five years. As such, I could not afford to pay for Equb. I used to pay Equb on a monthly basis but now I am no longer a member. I have stopped paying my contribution for six months, as a result, I do not have the right to benefit from the association”.

Thus, indigenous institutions such as Equb and Debo which can serve as a mechanism to cope with stresses and to support livelihoods during unexpected crises have been disrupted because of the effects of climate change.

Human capital

The effect on this asset component has been captured using education, members’ migration and access to health care. The result presented in the above table shows that famers perceived changes in human capital indicators in the past years. However, compared to other asset indicators, human capital indicators scored the least percentage. The figures show that only 32 percent, 13 percent and 7 percent perceived change for education (interruption), members’ migration and access to health respectively. Farmers in the upper basin reported that they experienced education interruption due to unpredictable rainfall. In one incident, the rains broke the bridge at the village preventing students from going to school. Moreover, due the crop failures (associated with rainfall variability) in different production reasons, some members of the community have migrated to the nearby city to look for better income and improve their livelihoods. This has created labour shortage for some households. One of the community members who participated in the FGD reported the following;

“Our young ones left to look for a better life in the city of Bahir Dar and as a result we were not able to plough our land as we used to do in previous years.

As you can see I am not strong enough to work the farm. I have tried many times to hire labour during the peak season but it is expensive and I could not afford it".

7.2.2. Climate change and livelihood pattern change in the Lake Tana Basin

In the previous subsection, we have seen that climate change has affected major livelihood strategies and assets or capitals. It has affected crop and livestock production and fishing. In the same manner, even though the degree of the negative effects vary, climate change has also affected, human, social, natural and financial capital of communities in the Lake Tana Basin. This subsection presents the findings related to the effects of climate change in the context of livelihood pattern change. As presented in chapter 2, the main argument of the thesis is that climate change affects livelihood pattern. As such, there is a need to assess the relationship between climate change and new livelihoods.

As discussed in chapter 3, during the pilot test farmers did not easily recognized climate change in its scientific terms. Thus, during the actual data collection period (using the local language), farmers' detection knowledge was used (based on their experience, perception and long-time observation). Accordingly, during the FGD and in-depth interview, farmers marked out different characteristics of climate variables (rainfall and temperature). As such, farmers marked out the following characteristics of rainfall and temperature.

- Fluctuation on the timing of rainfall/ affects local calendar
- Shortness of rainfall at time is the reference terms that farmers used to describe the duration and pattern of rainfall.
- Diminishing tendency of rainfall amount over time
- Food is more frequent and strong in recent years.
- The days tend to be very hot

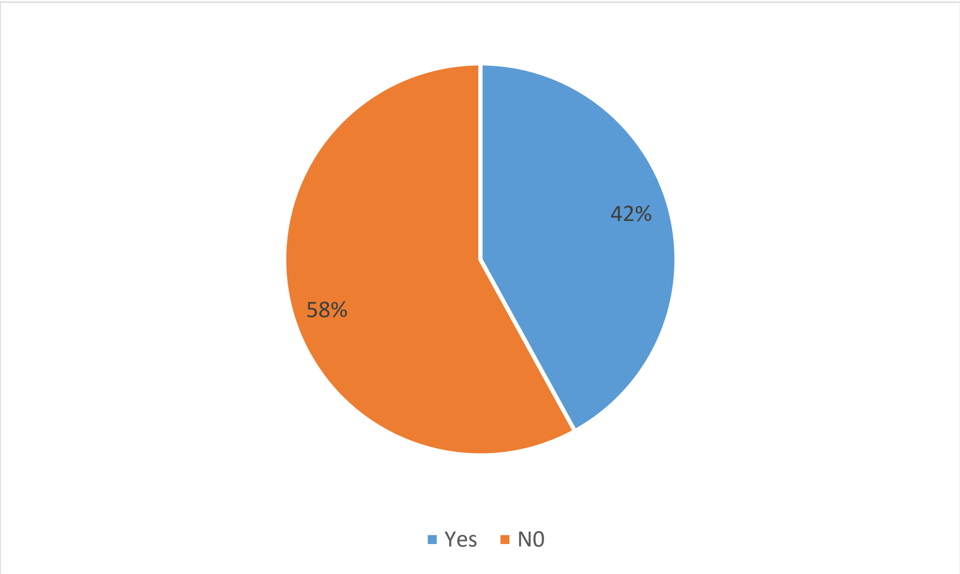
- The sun feels harsh (compared to childhood time).
- Land is getting and could not hold moisture

7.2.2.1. The effect of climate change and new livelihood strategies

Due to the negative effects of climate, there are many new livelihood strategies applied by households in the study areas. As presented in the previous section, climate change has affected the main and dominant forms of livelihood in the Lake Tana Basin including crop production, livestock and fishing which are the main means of sustenance in the basin. The study also outlined that these livelihoods are directly or indirectly under severe threats because of climate change. Moreover, even though the severity varies, the various forms of capital or assets are under threat for the same reason. Thus, the interesting questions to ask are: 1) does climate change cause any change in livelihood strategies? and 2) are there new livelihood strategies in the basin?

In this regard, as presented in the following figure, while 42 percent (N=281) of the respondents reported that they have adopted new livelihood paths because of the effects of climate change, the reaming 58 percent did not (figure 7.5).

Figure 7.5: The pursuit of new livelihood in the Lak Tana sub-basin



Source: Own depiction

Member of the community reported that they no longer could sit and wait for the rain to come as they used to do during the good old days. One of the in-depth interview participant reported the following:

“It is not wise for us to sit down and wait for the rain because we fooled ourselves many times by doing that. Challenges have thought us wisdom so the effects of climate change have forced us to look for other means of livelihood strategies to support our families”.

Thus, because of the negative impacts of climate change, households and community members in the Lake Tana Basin are adjusting their livelihood paths by entering into new livelihood strategies.

7.2.2.2. New livelihood strategies adopted by study households

The Lake Tana Basin is endowed with rich natural fauna and flora as well as historical heritages that have the potential to become important tourist destinations. The natural fauna and of the area has been well documented and studied in previous papers (Dile, Berndtsson & Setegn 2013:42; Solomon, Adesola & Rao 2016:463). However, the area is still underdeveloped in terms exploiting the natural ecology for economic purposes. The government of Ethiopia and the regional administration have identified the basin as an important growth corridor that can bring enormous economic benefits. However, other stakeholders too should consider the sustainable use of these natural resources. The national and regional governments point out that the Lake Tana Basin is ideal for large-scale fishing, tourism, hydropower generation and irrigation. However, they do not indicate how it could be used in a sustainable manner. Moreover, given the ever-increasing pressure from climate, sustainable resource usage and planning should be a top policy priority.

In addition to the already existing livelihood strategies, households were requested to list new livelihood strategies that they are applying because of the negative effects of climate change. The quantitative survey was used to identify and quantity new livelihoods adopted by households. The result from the survey indicates that the majority of them followed migration, tourism, petty trade, daily labour and handicrafts as a new livelihood options or strategies (table 7.13).

Table 7.13: New livelihoods adopted by Household

New livelihoods	Frequency
Tourism	60
Petty trade	26
Daily labours	25
Handicraft	70
Migration	120
Fishing	50

Source: Own summery from the survey data

Tourism and handicrafts as new livelihood pattern: Since the Lake Tana Basin is an important tourist site both for its natural and cultural sites, some community members have engaged in tourism related activities, mostly as tourist guides. The survey data shows that nearly 60 households have engaged in tourism related activities as a new livelihood strategy. However, working as a tourist guide is not an easy task for some members of the community due to the langue requirements. As such only young members of the households/community are engaged in this livelihood activity. One of the FGD participants reported:

> "Our *young people are working as tourist guides because they do have a better education preparation, however the work is seasonal and the income is not consistent*".

This has become attractive for young members of the community because of land scarcity as well. A peasant who participated in the key informant interview reported the following:

"W*e do not have additional land for the new generation or our grandchildren; we have shared all what we have long ago".*

Other members of the community are engaged in producing handicrafts so that they can earn additional income by selling their products to tourists coming to the area. The FGD participants reported that older male and women members of the community carry out this activity. One of the FGD participants mentioned:

“Since we cannot travel longer distances for economic opportunity, we work on handicrafts to support our livelihoods”.

Migration and daily labour as new livelihood pattern: As crop production declines, households have begun sending their family members to Bahir Dar (the regional capital city) to make a living. The household survey shows that nearly 120 households have considered migration as a new livelihood strategy. This is especially common among youth members of the community. The youth aspire to go to Bahir Dar as it is the industrial centre and capital of the Amhara regional state. In recent years, the city and its surroundings experienced a construction boom, making it more attractive for the youth. Moreover, the completion of the Bahir Dar industrial park has attracted many youths to the city. One of the FGD participants reported the following:

“Many of the youth in our village migrated to the city of Bahir Dar looking for new economic opportunities and they are no more interested in agriculture as the sky stopped giving her blessings”.

One of the many causes of youth migration is decline in agricultural production, which again is the consequence of rainfall variability.

A recent report from the city of Bahir Dar indicates that the city has been flooded with many migrants. Some of them even use the city of Bahir Dar as transit to go to border cities like Metema that allow them to further access the Sudanese border. However, in this thesis the participants only reported the first destination of migrants. However, if further probes were made about the final destinations of migrants, destinations outside the country could have been reported. Thus, this would require additional investigation. One of the key informants from Bahir Dar reported:

“We came here [Bahir Dar] for economic reasons but we could not secure a decent job as the wage rate at the industrial park is very small and this will not allow us to form a decent life so I am planning to cross the borders”.

Household members also use working as daily labourers as an alternative livelihood strategy during crop failure. This is especially common among adult members of the family who did not migrate. As the basin is a growth corridor, there are many development projects including construction of roads, hydropower and irrigation dams. These have allowed community members to work as daily labourers on various undertakings.

Petty trade as a new livelihood strategy: Petty trade is another important economic activity that households mentioned as a new livelihood strategy. In fact, 26 households indicated that they have engaged in petty trade as a new livelihood strategy. According to a key informant interview with a Woreda agricultural expert, in the recent past, trade and trade related activities used to be carried out mainly by the Gurage community. In fact, the Gurage community used trade as their main source of livelihood throughout Ethiopia (Seware, Dullo & Fanta 2021:43). However, in recent years, non-Gurages including the Amharas (90 percent of the community in the study area are Amharas) have started to engage in petty trade as a source of livelihood. The Amharas used to be predominately agrarian. In recent years however, this has changed as some members of the community have started to engage in petty trade as an additional livelihood strategy.

Fishing as a new livelihood strategy: Even though fishing has been a conventional livelihood strategy in the area after crop and livestock production, some community members only joined this activity as a new livelihood strategy due to the effects of climate change. The major reason for joining this livelihood strategy is to diversify and improve living conditions. In this regard, the household survey shows that at least 50 households have joined fishing activity as a new livelihood strategy. In the FGD discussion, community members indicated that the main reason for joining fishing activity is crop failure and decline in agricultural productivity, which shows agriculture has become a risky business for most farmers who are normally resource constrained to begin with. In this regard, it will be relevant to mention the following views of the study participants:

"I never thought of starting fishing until I learned that we could no more rely only on crop production to sustain life".

"I love farming and I grew up doing it but I started fishing due to the unfavourable rainfall that resulted in frequent crop failure".

"I started fishing because it is less risky unlike agriculture and can provide a quicker source of cash than farming".

Thus, farmers have intentionally started fishing as a livelihood strategy in response to the decline in agriculture.

Figure 7.6: A farmer trying to catch a fish in Lake Tana

Source: Field picture taken during data collection

7.3. ASSESSING LIVELIHOOD VULNERABILITY

An assessment of household level livelihood vulnerability was carried out based on social, natural, institutional, financial and human capital aspects of livelihood. The measurement of the different forms of assets followed the works of (Bhandari 2013:126;Hahn, Riederer & Foster 2009:81;Rahaman, Sajib & Alam 2019; Teshome 2016:21). The measurement for each LVI sub component is presented in table 7.16. The assessment of livelihood vulnerability was done for the different components of capital using various indicators for each one. For example, an assessment of households' levels of natural assets vulnerability to climate change was estimated using access to forest, land size and number of oxen owned based on results from the household survey.

The indices of livelihood vulnerability for each of the assets is constructed using simple weighed average approach. The vulnerability indicators are stated and normalized as the ration of the differences of the actual values and pre-selected minimum values, and the range of maximum and minimum values of indicators obtained from the household survey (Teshome 2016:21). The formula for Vulnerability Index (VI) is:

$$VI=\frac{Observed\ values-Minimum\ values}{Maximum\ values-Minimum\ values} \tag{7.1}$$

The above vulnerability index formula takes some form of functional relationship between the dependent variable and vulnerability (Hahn, Riederer & Foster 2009:81;Teshome 2016:21). In this regard, according to Teshome 2016:21), the literature indicates two types of functional relationships: 1) a scenario where vulnerability increases with the increase in the value of the indicator which entails a positive relationship between vulnerability and the predicators (for example as distance to nearest agricultural market increases vulnerability increases and the larger the change in rainfall and temperature, the greater the vulnerability of the community to climate change related risks). In this case, the normalization is estimated using equation 7.2, and 2) the case where vulnerability decreases with the increase in the value of the adaptive capacity indicator (inverse relationship between adaptive capacity indicator with vulnerability).

Let's look at an example where normalization is calculated. Table 7.14 show that the maximum distance to market is 12 kms and the minimum is 0.5 kms for households in the study Kebele while the observed (average) value is 6 kms.

Table 7.14: Descriptive statistics for access to market

Variable	Mean	Minimum	Maximum
Distance to market	6 km	0.5km	12 kms

Source: Own summary using household survey data

Now, the normalization of indicator for the study Kebele is calculated as follows:

$$\frac{6-0.5}{12-0.5} = 0.47 \quad (7.2)$$

For the second scenario where vulnerability decreases with the increase in the value of the adaptive capacity indicator (inverse relationship between adaptive capacity indicators and vulnerability), the normalization value for each indicator is given by equation 7.3:

$$\text{Inverse index} = \frac{Maximun\ values\ - Observed\ values}{Maximum\ values - Minimum\ values} \quad (7.3)$$

To illustrate this, we can consider farm size. As farm size increases, household vulnerability to climate change related shocks decreases. This is because increase in farm size (which is a wealth indicator in rural communities) will help farmers to develop and increase their adaptive capacity. For example, the observed value (represented by average farm size) is 0.25 hectares (table 7.15).

Table 7.15: Descriptive statistics for land size

Variable	Mean	Minimum	Maximum
Total land owned	1.75 ha	0.25 ha	6 ha

Source: own summary using household survey

Thus, the normalized score for the households is calculated as:

$$\frac{0.25\ -1.75}{6-0.25} = -0.26 \quad (7.4)$$

The vulnerability score that is calculated for each indicator using data from the household survey is then averaged using Eq. 7.5 to calculate the value of for each major component. In this study, following the works of (Teshome 2016:21), the VI scales from 0 to 1; 0 denotes least vulnerability or no vulnerability and 1 denotes maximum vulnerability:

$$\frac{\sum_{i=1}^{n} Index}{n} \qquad (7.5)$$

Where n is the number of indicators in each component and Index is the calculated vulnerability index for each indicator. The functional relationship between vulnerability and each indicator is presented in table 7.16. The relationship of the indicators with vulnerability, the method of their selection and their definitions are based on previous empirical papers (Hahn, Riederer & Foster 2009:81; Teshome 2016:21).

Table 7.16: Functional relationship between venerability and each sub component

Asset	Subcomponents	Measurement	Units	Relationship with Vulnerability
Natural asset	Access to water?	1. yes 2.no	percent	As population with access to water increase, vulnerability decrease
	Access to forest	1. yes 2.no	percent	As population with access to forest increase, vulnerability decrease
	Land size	Ha	Ha	As land size increases vulnerability decreases
	Number of oxen owned	Number	Number	As number of oxen owned increases vulnerability decreases
Physical capital	Access to electricity	1.yes 2.no	percent	As population with access to electivity increase, vulnerability decrease
	Distance to the nearest market	Km	Km	As distance to market increases vulnerability increases
	Access to health facility	Km	Km	As health facility increases vulnerability decreases
Social capital	Membership in associations	1.yes 2.no	percent	As population membership in associations increase, vulnerability decrease
	Have you received support from the community?	1.yes 2.no	percent	As social support increases vulnerability decreases
Human capital	Household size	Number	Number	As dependency increases vulnerability increases
	Have you attended school of any sort?	1.yes 2.no	percent	As education level increases vulnerability decreases
Institutional capital	Regular extension services	1.yes 2.no	percent	As access to extension increases vulnerability decreases
	trainings received on climate change	1.yes 2.no	percent	As training increases vulnerability decreases
	Safety net beneficiary	1.yes 2.no	percent	As population with access to safety net beneficiary increases , vulnerability decrease
Financial capital	household annual income	ETB		As income increases vulnerability decreases
	Can you easily access credit	1. yes no	percent	As access to credit increases vulnerability decreases

The summary of indexed livelihood indictors for each capital presented in the in Table 7.17. The values are indexed numbers calculate using equation 7 and 9. As presented in table 7.17, the indexed is scaled from 0 to 1; 0 denotes least vulnerable or no vulnerability and 1 denotes most vulnerable livelihood component in the basin.

The result shows that access to water resource (0.42), access to forest (0.67), land size (0.5) and number of oxen owned (0.89) contribute greatly to the vulnerability levels of natural asset. The result show that relatively land size (0.5), access to forest (0.67) and number of oxen owned (0.89) contribute greatly to the vulnerability levels of natural asset. The vulnerability score for farm size is very high which explained by the fact that the per capita farmland found to be 0.57. On the other hand, the vulnerability score of access to forest was also vary high which can be explained the status of access to forest that is only 33 percent (N=281) have access to forest resources. The same table shows only 20 percent (N=281) have more than five number of oxen.

The same table shows that as compared to other indicators, the vulnerability score of access to electricity (0.97) and distance to the nearest market (0.47) found to very high and as such greatly contribute to the vulnerability levels of physical asset. This is because while only 3 percent have access to electricity the other rely on traditional source of energy. In the same token while some would travel only 0.5 kms to get to the nearly market other are expected to take up to 12 kms to get to the market.

On the other hand, support from the community (0.6) and access to education (0.65) found to contribute greatly to the vulnerability levels of social and human capital respectively. The vulnerability score for support from the community found to be very high which can be explained by the fact that only 40 percent (N=281) provided community support. In the same manner, the vulnerability score for access to education was found to be very high, which could be explained by the fact that only 35 (N=281) percent have attended school. Furthermore, the result also shows that training (0.85) and access to credit (0.7) contribute greatly to the vulnerability levels of institutional and financial capitals respectively. This can be explained by low level training provision (only 15 percent have received training) and low access to credit (only 30percent have access to credit).

Table 7.177: Normalized vulnerability indices for selected indicators

Asset	Subcomponents	Measurement	Mean	Maximum	Minimum	VI
Natural asset	Access to water resource	1. yes 2.no	58	100	0	0.42
	Access to forest	1. yes 2.no	33	100	0	0.67
	Land size	Ha	1.75	6	0.25	0.50
	Number of oxen owned	No.	5	30	2	0.89
Physical capital	Access to electricity	1.yes 2.no	3	100	0	0.97
	Distance to the nearest market	Km	6 kms	12 kms	0.5 kms	0.47
	Access to health facility	minutes	26	90	3	0.26
Social capital	Membership in local associations	1.yes 2.no	82	100	0	0.18
	Have you received support from the community?	1.yes 2.no	40	100	0	0.6
Human capital	Household size	Number	5	9	2	0.42
	Have you attended school of any sort?	1.yes 2.no	35	100	0	0.65
Institutional capital	Regular extension services	1.yes 2.no	60	100	0	0.4
	Trainings received	1.yes 2.no	15	100	0	0.85
	Safety net beneficiary	1.yes 2.no	50	100	0	0.5
Financial capital	household annual income	ETB	24798	130,000	11,000	0.1
	Can you easily get credit access	yes no	30	100	0	0.7

Source: Own summary using the household survey

The result in table 7.17 shows that access to water resource (VI=0.42), access to forest (VI=0.67), land size (VI=0.5) and number of oxen owned (VI=0.89) contribute greatly to the vulnerability levels of natural asset and that relatively, land size (VI=0.5), access to forest (VI=0.67) and number of oxen owned (VI=0.89) contribute greatly to the vulnerability levels of natural asset. The vulnerability score for farm size is very high which is explained by the fact that the per capita farmland is 0.57. The vulnerability score of access to forest is also very high which can be explained with the status of access to forest which is only 33 percent. The same table shows only 20 percent have more than five oxen.

In the same table, compared to other indicators, the vulnerability scores of access to electricity (VI=0.97) and distance to the nearest market (VI=0.47) are very high. As such, these indicators greatly contribute to the vulnerability levels of physical asset. This is because 97 percent of the respondents don't have electricity access and rely on traditional sources of energy and some of them travel up to 12 kms to get to the nearest market.

Support from the community (VI=0.6) and access to education (VI=0.65) also contribute greatly to the vulnerability levels of social and human capital respectively. The vulnerability score for support from the community is very high which can be explained by the fact that only 40 percent received community support. In the same manner, the high vulnerability level of education be explained by the fact that only 35 percent have attended school. Furthermore, the result also shows that training (VI=0.85) and access to credit (VI=0.7) have large effects on the vulnerability levels of institutional and financial capitals respectively. This can be explained by low level training provision (only 15 percent have received training) and low access to credit (only 30 percent have access to credit).

The average for each livelihood component is presented in table 7.18. The result shows that nearly all livelihood components tend to be highly vulnerable. Thus, the main agreement here is that livelihood vulnerability indices (LVI) have placed the study households at the most vulnerable position.

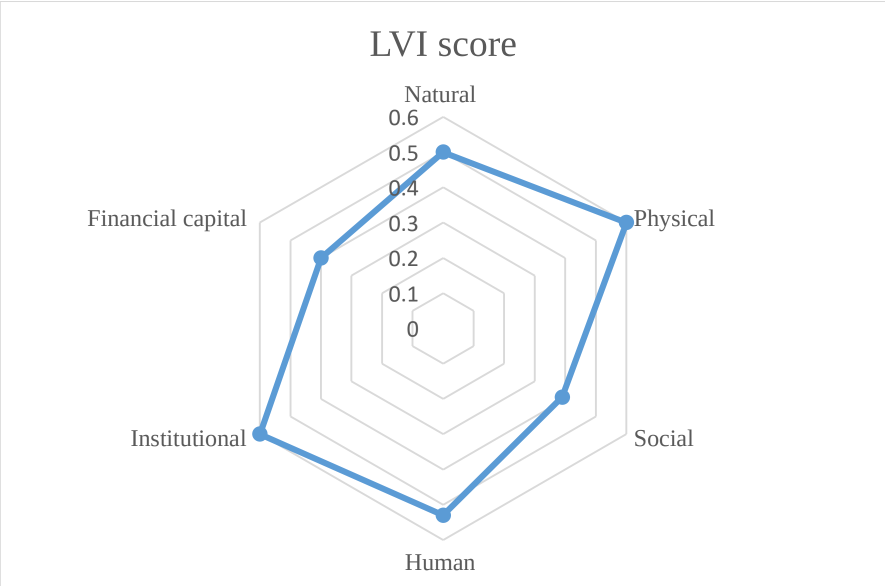
Table 7.18 : Average LVI by category

Capitals	LVI score
Natural	0.5
Physical	0.6
Social	0.39
Human	0.53
Institutional	0.6
Financial	0.4
Average score	0.5

Source**:** Own depiction using data from household survey

The same result is presented using the vulnerability radar diagram (Figure 7.7) where the Index value of 0 means no or very low vulnerability and vulnerability increases as LVI values increase outwards from the centre. Both results in table 7.18 and the vulnerability radar show that physical and institutional capitals rank top in terms of their vulnerability positions.

Figure 7.7: Vulnerability radar diagram



Source: Own depiction using data from household survey

7.4. CLIMATE CHANGE ADAPTATION AND LIVELIHOOD PATTERN CHANGE

In this subsection, the perceptions of community members towards the effect of climate change adaptation on livelihood pattern change is presented and an attempt is made to understand which livelihood pattern is most affected by climate change adaptation.

As perceived by members of the community, climate change adaptation has altered livelihoods in the Lake Tana Basin (only those who have adopted climate change adaptation strategies were requested their opinion). However, one should also take into account that since most adaptation strategies are linked to crop production or farm-based livelihood, the relationship between climate change adaptation and livelihood pattern change is mostly perceived from the perspective of agriculture or crop production livelihood. This is evident as most adaptation strategies are meant to fight the possible negative effects of climate change on crop or farm-based livelihood. Allowing for multiple response questions, the result shows that the four major livelihood strategies that are affected by adaptation are crop and livestock production, fishing and tourism (table 7.20).

7.4.1 Crop-based livelihood and climate change adaptation

The study participants have perceived that climate change adaptation has brought about change in crop-based livelihood strategy. The result presented in table 7.19 shows that 85 percent of those who adopted climate change strategies have perceived this change. The focus of this section is to understand the process of how crop-based livelihood changes due to adaptation measures.

Table 7.19: Perception of climate change adaptation's effect on change in livelihood strategy

Livelihood strategies	This livelihood is affected by climate change adaptation measures (A/B)	Number of Who said "Yes" to the effect on livelihood (A)	Number of Who adapted to climate change (B)	Number of Households in this livelihood (C)
Crop production	85percent	163	192	275
Livestock production	75percent	98	131	263
Fishing	100percent	80	80	80
Tourism	100percent	70	70	70
Forest production	100percent	40	40	40
Trade activities	0percent			26
Private sector employee	0			10
Casual labour	0			30

Source**:** Own depictions using survey data

The participants reported that the effect of an adaptation strategy on crop production could be either positive or negative. For example, one of the adaptation measures taken by the community members is rainwater harvesting to compensate for water shortage (Figure 7.8). However, the problem with this is that water storage facilities require additional plots of land. One of the FGD participants reported:

“Extension agents through continuous campaign advised us to construct water storage facilities to save water; as a result, most of us built the water storage facility but given our small plots of land, we are no longer interested to adopt this technology”.

Figure 7.8: Rainwater harvesting practice

Source: Field picture taken during data collection

Another key informant participant reported the following:

“I *have built three water storage facilities and I even received an appreciation letter (model farmer) from the local administration but my crop production dwindled when compared to the previous year because I used less hectare of land”*

In Ethiopia, the average land holding is less than 0.5 hectare and farmers would be tempted to allocate this small plot of land among competing interests. Thus, technologies such as rainwater harvesting that require additional plots of land could have unintended negative results.

The empirical literature on climate change adaptation shows that farmers do not respond to modern forms of adaptation measures because they are less educated in general or don't have modern education (Ali et al 2021:1). However, farmers have their own good reasons when they up take a farm technology or when they decide not to adopt one as they have lived with the environment for thousands of years both in bad and good times, which has allowed them to develop the skills and knowledge necessary to respond to environmental adversities.

Another effect of climate change adaptation on community members involves crop varieties where local seeds are mixed with other breeds that are assumed to be drought resistant and high yielding. One of the in-depth interview participants reported, "*There were different indigenous or local seeds in our area but now we have lost them somehow*". Another FGD participant reported, "*The local seeds are less productive (in terms of output per hectare) but are suitable for the soil types and are very organic"*. Thus, climate change adaptation strategies can bring about change in crop-based livelihood by transforming the local or indigenous seed varieties. Moreover, farmers further reported that even though improved seeds could boost production, local seed varieties still have comparative advantages in some areas. For example, peasants who participated in the FGDs reported the following:

"Local seeds varieties are better than the new or improved breeds due to their suitability for the soil type in our area. The new breeds are far less suitable".

Thus, even though mixed breed seeds can have short-term positive effects on production and productivity, they could have negative consequences in the long-term due to mismatch with the local soil type. This indicates that soil suitability analysis should be performed before implementing such technologies.

Figure 7.9: Farmers applying improved seed

Source: Field picture taken during data collection

7.4.2. Livestock-based livelihood and climate change adaptation

The result presented in table 7.19 (section 7.4.1) shows that 75percent of respondents whose major livelihood strategy is livestock production and who have adopted adaptation strategies perceived that climate change adaptation has impacted livestock-based livelihood. The following discussion describes how climate change adaptation strategies affect livestock-based livelihood.

In the study area, mixing local oxen varieties with foreign breeds has been introduced as a climate change adaptation measure to increase productivity as well as improve the quality of oxen products. However, the local communities have started to observe the difference between the local and mixed breeds. According to one of the FGD participants:

“It is clear that the mixed breeds have high productivity when it comes to oxen products but they are not good at resisting diseases and can easily die after being attacked by some of the prevalent diseases in the area”.

Thus, climate change adaptation has changed the type of local livestock breeds in the study area. The empirical literature has little to say about the effects of climate change adaptation on local livestock breeds but Hoving, Stienezen, Hiemstra & van Dooren (2014) argue that even though mixed breeds can increase productivity, they cannot keep their expected productivity in more extreme climatic situations and as such, quick replacement of local breeds by mixed ones should be avoided.

Another adaptation has to do with the sale of livestock by some members of the community during drought periods. However, during these periods, the price of livestock is much lower and one of the respondents in the FGD discussion reported, “*We usually sell our livestock during drought periods but we cannot negotiate for better price because of our immediate needs”.* Thus, even though the sale of livestock is one of the adaptation strategies for households, it affects natural asset negatively.

7.4.3. Fishing and climate change adaptation

The result presented in table 7.19 (section 7.4.1) shows that 100 percent of the respondents whose livelihood is based on fishing and who have adopted adaptation strategies reported that climate change adaptation has altered their livelihood. However, the effect of climate change on this livelihood seems to be indirect. According the interviews conducted with members of the fish association in Lake Tana area, the effects of climate change adaptation on fishing occurs indirectly through the effect of the phenomenon on resource competition. One of the FGD participants reported:

“Due to the negative effects of climate change on crop production, some farmers are shifting from farming to fishing and because of this, the fishing community has increased significantly, affecting our share from fish harvesting and hence our income”.

Thus, climate change adaptation affected fishing-based livelihoods by creating resource competition between those who are predominantly farmers and those have always been fishers. A key informant from the agricultural bureau reported:

“Resource competition was created when those who used to be farmers started fish production (due to crop production failure) as an alternative means of livelihood, however, this diversification has not been welcomed by most fishing communities in the Lake Tana Basin”.

In fact, some even argue that fish production has dwindled because of the new comers to this livelihood sector. One of the FGD participants reported, “*The new comers would catch even small fishes and because of this, our production has significantly declined”.*

7.4.4. Tourism and climate change adaptation

The study participants have perceived that climate change adaptation has impacted tourism-based livelihood strategy. The result presented in table 7.19 (section 7.4.1) shows that a significant number of those who have been using tourism as a major livelihood strategy perceived that climate change adaptation has altered tourism-based livelihood.

Many years back, there were only few tourist guides and interpreters but in recent years, there are many young people joining the sector due the poor performance of the agricultural sector. During an in-depth interview, tourist guides working around Lake Tana and monasteries reported the following:

"I have worked as a tourist guide for more than 15 years. I managed to establish a family and buy a small house with the decent income that I used to get by working as a guide. However, in recent years, we see many tourist guides in our area coming from other areas or the nearby rural Kebeles and their major reason is the poor performance in agriculture. I am afraid that if this continues, we might lose our jobs eventually".

7.5 CLIMATE CHANGE ADAPTATION AND LIVELIHOOD

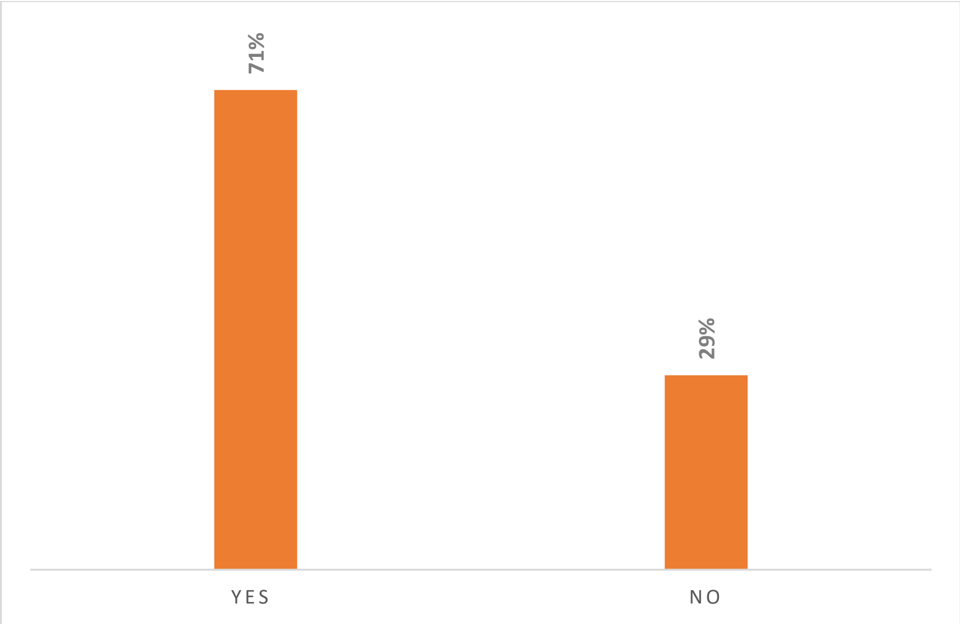
The analysis done earlier has revealed that farmers have perceived changes in climate related indicators such as temperature, rainfall, and precipitation (section 7.2.1 and 7.4). Moreover, the secondary data analysis from nearby meteorological stations in the Lake Tana Basin have also indicted that there is variability in terms of temperature and rainfall pattern in the basin (chapter 5). Consequently, climate change has brought changes to natural, social, physical, financial and human assets (section 7.2.3). In addition, climate change has forced community members in the Lake Tana Basin to follow other livelihood strategies some of which are non-farm activities (section 7.2.4.1 and 7.2.5). In this subsection, farmers' adaptive responses to climate change is presented.

7.5.1. Climate change adaptation strategies

Farmers experiencing climate change could respond to the impacts of climate change using either self-initiated or program-based adaptation. In this study, we focus on self-initiated adaptation strategies as there is no notable program-based adaptation activity in the study area. As such, farmers were requested to report the adaptation strategies that they used in their community and farms.

In this regard, one of the respondents from the FGD reported, "*Farmers select climate change adaptation options using their practical skill and knowledge from the past many centuries".* The data from the household survey shows that farmers use various types of self-initiated traditional and modern adaptation strategies to curb the possible impacts of climate change. The survey data shows that nearly 71percent (N=281) have adopted one or more climate adaptation strategies (figure 7.10). These strategies can be categorized as farm and non-farm activities.

Figure 7.10: Climate adaptation decision



Source: Own summary using household survey

The household survey result shows that community' members uses a range of adaptation strategies to minimize the possible negative impacts on their sources of livelihoods. These adaptation strategies categorized in to two major components. These are strategies linked to farm activities and adaptation strategies linked to non-farm activities. The following subsection discusses each types of adaptation strategy.

7.5.1.1. Adaptation strategies related to farm activities

These adaptation strategies are directly linked to agricultural production and farm activities. Thus, farmers use them to curb the possible negative impacts of climate change on agricultural production caused by the decrease in the amount rainfall and increase in temperatures. As presented in table 7.20, the top adaptation strategies include traditional irrigation, improved agronomic practices, improved seeds, selling of assets and tree planting with reported percentage of 93percent, 85 percent, 80 percent, 78 percent and 68percent respectively.

Table 7.20 : Types of adaptation strategies: Multiple response allowed

Types of adaptation strategies	Frequency	Percent
Traditional irrigation	186	93
Improved agronomic practices	170	85
Improved seeds	160	80
Selling of assets	157	78
Tree planting	121	68.7
Migration	121	43
Crop switching	98	49
Off farm activities	100	50
Crop rotation	67	33
Fallowing	63	31
Shifting Cultivation	50	25

Source: Own Summary from Household survey data

Traditional irrigation

Households reported that, in the past, rainfall pattern and distribution used to be regular and predictable. One of the elderly members of the community in the FGD reported, "*In the past, we never worried about the rainfall, however since the past fifteen years, things have started to change and the rain has become so unpredictable".* This statement indicates that rainfall variability can be considered as a new phenomenon that did not exist some years back.

The temporal and spatial variability of rainfall has forced them to apply traditional irrigation system in order to save water for the dry season as a response to rainfall variability during the two-production seasons. The common forms of traditional irrigation practices are river diversion and rainwater harvesting. These irrigation systems are widely applied among crop producers because they are cost effective and easy to use compared to modern irrigation systems. The major cost associated with these two types of traditional irrigation technologies mainly has to do with labour cost.

Improved agronomic practices and improved seeds

In order to reduce the risks related to climate change, farmers also use agronomic practices and improved seeds. The Lake Tana Basin is an agro-based region where climate change has become a crucial factor in explaining crop failures and declines in livestock production in recent years. In this regard, households in the Lake Tana Basin use various agronomic practices such as organic and inorganic fertilizer, changing the date of plantation and a variety of early maturing crops. This shows that farmers tend to use agronomic practices that are easy and less costly to adopt.

7.5.1.1.2. Adaptation strategies linked to non-farm activities

These adaptation strategies are not directly applied to crop and livestock production activities but operate indirectly as coping mechanisms. These strategies include selling assets, off-farm activities and migration. As summarized in table 7.20, the percentage of households that followed these adaptation strategies are 78 percent, 50 percent and 43 percent respectively. The off-farm activities include daily labour, handicrafts, petty trade and working as security guard. These activities are associated with the development projects in the area. As the Lake Tana Basin is identified as an important growth corridor by the regional government, there are many mega development activities like construction of dams, commercial irrigation and road projects. Some members of the community (male or female) work as daily labourers on these projects. These undertakings have also allowed some male members of the community to work as security guards while some female members are able to earn income by providing food and coffee for the labourers working on these projects. These adaptation strategies have allowed members of the community to support their families during crop failure and extended drought periods.

The adaptation strategies linked to non-farm activities indicates that there is a shift from natural based livelihood activity (mainly crop and livestock production) to a non-natural resource based activities here termed as non-farm activities such as petty trade, daily labourers and handicrafts and working as security guard in the nearby development projects.

Selling of assets

Selling of assets is considered as the last option for household members who face climate related hazards such as droughts or famines. Sometimes the droughts will linger for two or more production seasons, creating food shortage both for home consumption and the market. During this period, some households and members of the community sell some or all of their assets to fill inter-temporal consumption gaps.

Migration

Another important adaptation strategy is migration. As the result in table 9.1 shows, at least 43 percent of the households have used migration as adaptation strategy. However, migration is common only among young members of the community. Young people travel either to the city of Bahir Dar or nearby Woredas. Bahir Dar is the ideal destination for young people as it is growing in terms of both economic opportunities and social services. One of the respondents reported, *"When there is crop failure, young people usually migrate to the city of Bahir Dar for better economic opportunity*". Another respondent in the FGD reported:

"I distributed land among my children so that they can plough. However, they are no longer interested in farming due to the frequent droughts; thus, they went to the nearby city to look for better job opportunities".

Therefore, climate change causes migration in the community through its influence on agriculture. But according to a key informant interview conducted with a researcher at Bahir Dar University, climate change is not the only factor that causes migration. Population pressure and land scarcity also contribute to people's movement. According to this key informant interviewee:

“The challenges in the Lake Tana Basin are multifaceted and some of these are climate change, population growth and land scarcity, which are the main reasons for the increasing number of migrants in the regional capital”.

7.6 PRO-POORNESS OF CLIMATE CHANGE ADAPTATION STRATEGY

As presented in section 7.2.3, climate change brings change in asset and livelihood pattern, which in turn affect key livelihood outcomes such as poverty and food security. Thus, there is a need to design effective adaptation strategies at national, regional and local level. However, this would be meaningless unless climate adaptation strategies are local and pro-poor. Thus, there is a need to examine the pro-poorness of climate adaptation strategies.

As presented in chapter 2, the poor are hardest hit by the negative impacts of climate change due to their dependency on agriculture, the most sensitive sector to the phenomenon. Moreover, the empirical review in that chapter shows that the poor are the least likely to adapt to climate change due to their limited capacity to respond to climate change. In this chapter, the pro-poorness of climate adaptation strategies, the perceptions of members of the community in that respect and the mechanism to make adaptation work for the poor are discussed. In order to achieve this objective, rather than following the top-down approach in which adaptation strategies are simply prescribed by experts to the local people, the study uses a bottom up approach (Crescenzi 2013: 773) that puts local people at the centre both in identifying problems and in suggesting solutions.

7.6.1. Perception of pro-poorness of climate adaptation strategies

As presented in chapter 2, there are various dimensions and measurements of poverty that use different approaches such as those based on income, consumption or expenditure and asset. However, in this subsection, the study participants’ definition and understanding of poverty is presented. The argument is that community members have their own understanding of what is meant by poor and rich, which may or may not be aligned to the standard definitions and measurements of poverty (section 2.2.1.4.)

In order to understand how members of the community differentiate between the poor and rich, the researcher allowed participants to use their own criteria. This was captured during the in-depth interviews with community members and PSD participants. The PSD revealed that land ownership, land size, ownership of household assets and number of oxen owned are considered the major criteria by members of the community for classifying a household as poor or rich (table 7.21).

Table 7.21 : Community member's classification of poor and non-poor

Category	No of oxen owned	Land worship	Land size	House type
Poor	<5	Don't own	<1 ha (if land owned)	Mud
Rich	>=5	Own land	>1 ha	Corrugated

Source: Own depiction

Moreover, the participants of the key informant interviews also provided wide ranging definitions to the concept of poverty. Here I cite a few of the definitions given by the participants:

"Poverty means lack of land, which is vital to retain wealth and secure the future". (An in-depth interview with a peasant in the lower basin).

"When someone is poor, there will be many commanders over his life". (An in-depth interview with a fisherman in the upper basin).

"Poverty means when you do not have land and oxen, which gives you social status in our area". (An in-depth interview with a peasant in the lower basin).

"If you do not secure your future, then you are poor". (An in-depth interview with a young man working as tourist guide).

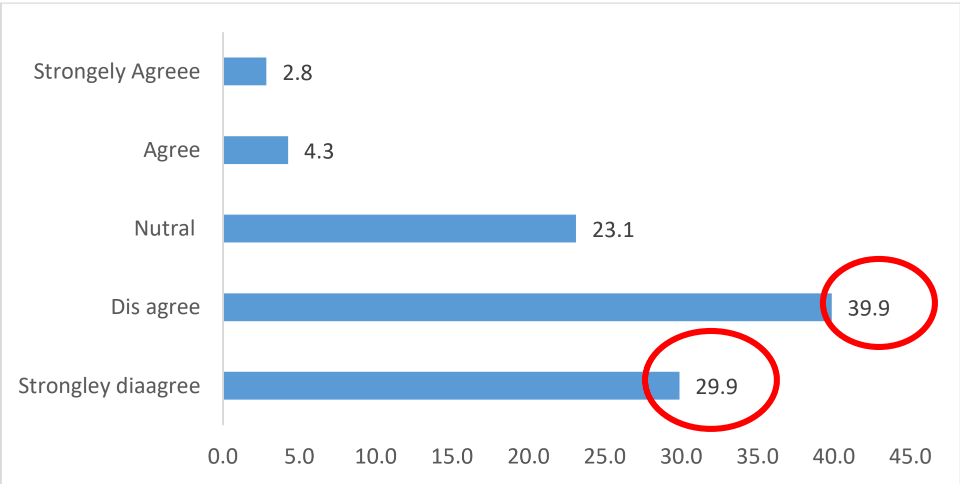
"Poverty means when you do not have access to natural resources of any sort". *(*An in-depth interview with a peasant in the upper basin).

"Poverty means when there is nothing to share with your children and grandchildren". (An in-depth interview with a priest in the community).

It is apparent from these responses of members of the community that the local knowledge on poverty is wide and deep. They view poverty from the perspectives of access to resources and securing one's future. It is important to note that the definitions of poverty vary according to the livelihood paths that these members of the community follow. For example, for peasants, poverty appears to be an issue of securing land while for the tourist guides, poverty has to do with power dynamics and determining one's future.

The perceptions of study participants towards the pro-poorness of climate adaptation strategies is captured using the household survey (figure 7.11). In this regard, the result presented in the following figure shows that nearly 70 percent (N=281) are in disagreement with the statement 'the poor are benefiting from climate adaptation strategies.

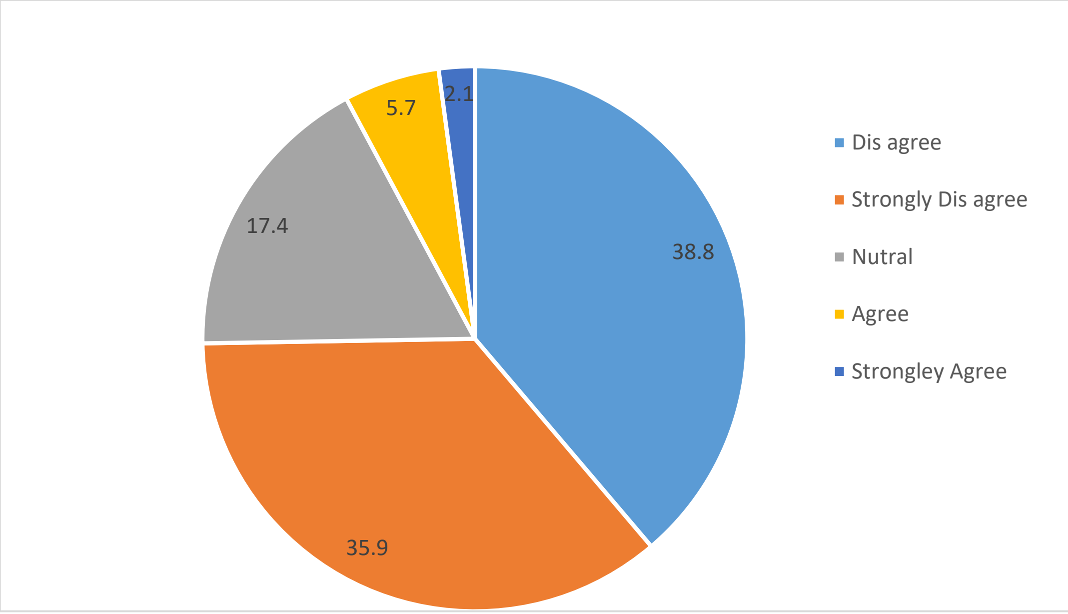
Figure 7.11: Perceptions of the benefit of climate adaptation to the poor



Source: Own depiction using survey data

In addition, the household survey shows that many of the respondents did not agree with the pro-poorness of climate adaptation strategies. In this regard, the result in the following figure shows that more than 70 percent (N=281) perceived that climate change adaptation strategies are not pro poor. This result includes both the perceptions of those who are using one or more climate adaptation strategies and those who did not use any of the climate adaptation strategies.

Figure 7.12: Perception of the pro-poorness of climate adaptation strategies



Source: Own depiction using survey

During the FGD, study participants mentioned some of the reasons why climate adaptation strategies are not pro-poor. According to the FGD participants, cost of technology, accessibility and nature of the technology rank top (table 7.22). Cost of climate adaptation is the dominant factor in other studies as well. For example, Osei (2017:31) sites the high cost of adaptation and the low level of households income as important factors in preventing climate adaptation by the poor and (Ige, Akinnagbe, Odefadehan & Ogunbusuyi 2021:609) have found out that the cost of labour, inadequate technical know-how and the cost of equipment are the main constraints.

Table 7.22: Reasons why climate adaptations are not pro-poor.

Reason	Rank
High cost	1st
Difficulty to access	2nd
Not friendly to apply	3rd
Requires high technical skill	4th
Not linked to local credit schemes	5th

Source: Own depiction using survey

During the PSD, community members were also allowed to mention criteria to make climate adaptation strategies work for the poor. As summarized and presented in table 7.23, community members identified six key measures that are needed to make climate adaptation strategies work for the poor. These include suitability to local context, link to credit scheme, low cost, ease of use, use of local materials, accessibility of farming training centres. The same table shows that the list of criteria somewhat differs between the upper and lower basins. PSD participants in that the lower basin did not identify link to credit scheme and accessibility of farming training centres as required measures. This appears to be due to the complete lack of these services in the lower basin, resulting in the participants not being aware of the concepts to start with.

Table 7.233: Measures needed to make adaptation work for the poor.

Measures	Upper basin	Lower basin
Suitability to the local context (for example soil and land)	X	x
Link to credit scheme	X	
Low cost	X	x
Ease of use	X	x
Use local materials	X	x
Uses local knowledge	X	x
Accessibility of farmers training centres	X	

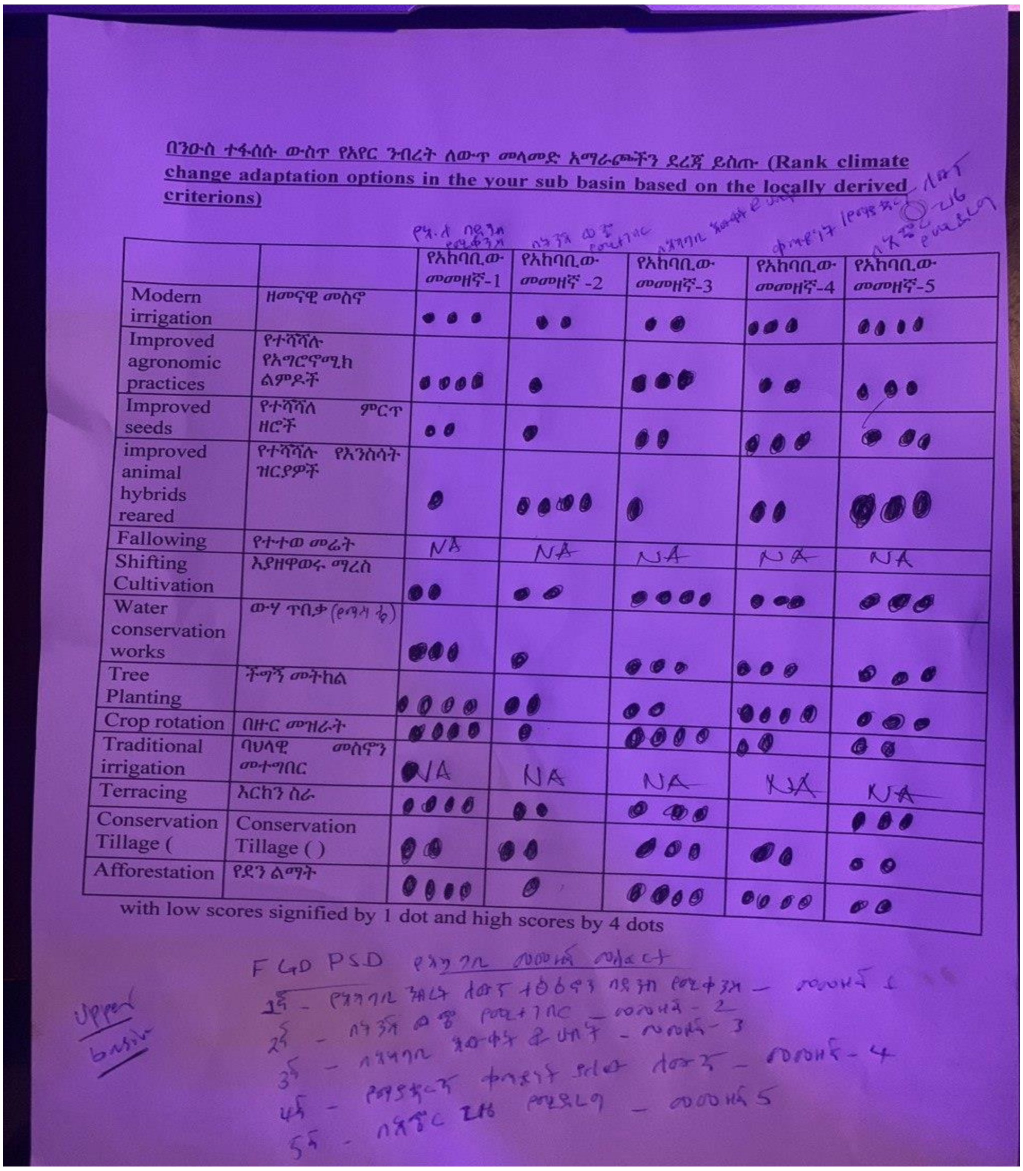
Source: PSD conducted by the author

7.6.2. Farmers' choice of climate adaptation strategies

Even though the net effect still needs further study, climate change adaption can enhance livelihood outcomes and benefit rural communities in many ways. However, the important question is: what local criteria will farmers use to rank climate adaptation strategies? To answer this question, a Participatory Scenario Development (PSD) was conducted for community members from lower and upper basins. The PSD brought together various participants including fishers, crop and livestock producers, traders and church leaders. This identification process of local criteria for effective strategies through the participation of the community is important in selecting strategies that are locally suitable in terms environmental, social and economic dimensions.

In the first stage of the PSD, community members allowed to list down and identify local criterions that would help to rank various climate adaptation strategies. During this exercise, every participant allowed to list down the all-possible criterions independently. Once they list down the criterions, they allowed so that they can work as a group to identify the top criterions. These local criterions then used to rank the various adaptation strategies. The five local criterion identified these five criteria: 1) the strategy should significantly reduce the effects of climate change, 2) it must be low cost, 3) it must be implemented using local knowledge and resources, 4) it must be long lasting (sustainability), and 5) it must be easy to implement within a short period of time. Once this list was prepared, the next step was to rank the different climate adaptation strategies according to the identified local criteria. As presented in figure 7.13, the dots indicate the ranking level: a single dot signifies lowest rank and four dots signify highest rank.

Figure 7.83: Ranking of climate change adaptation strategies using local criteria



በንዑስ ተፋሰሱ ውስጥ የአየር ንብረት ለውጥ መላመድ አማራጮችን ደረጃ ይስጡ (Rank climate change adaptation options in the your sub basin based on the locally derived criterions)

		የአከባቢው መመዘኛ-1	የአከባቢው መመዘኛ -2	የአከባቢው መመዘኛ-3	የአከባቢው መመዘኛ-4	የአከባቢው መመዘኛ-5
Modern irrigation	ዘመናዊ መስኖ	●●●	●●	●●	●●●	●●●●
Improved agronomic practices	የተሻሻሉ የአግሮኖሚክ ልምዶች	●●●●	●	●●●	●●	●●●
Improved seeds	የተሻሻለ ምርጥ ዘሮች	●●	●	●●	●●●	●●●
improved animal hybrids reared	የተሻሻሉ የእንስሳት ዝርያዎች	●	●●●●	●	●●	●●●
Fallowing	የተተወ መሬት	NA	NA	NA	NA	NA
Shifting Cultivation	እያዘዋወሩ ማረስ	●●	●●	●●●●	●●●	●●●
Water conservation works	ውሃ ጥበቃ	●●●	●	●●●	●●●	●●●
Tree Planting	ችግኝ መትከል	●●●●	●●	●●	●●●●	●●●
Crop rotation	በዙር መዝራት	●●●●	●	●●●●	●●	●●
Traditional irrigation	ባህላዊ መስኖን መተግበር	●NA	NA	NA	NA	NA
Terracing	እርከን ስራ	●●●●	●●	●●●		●●●
Conservation Tillage (	Conservation Tillage ( )	●●	●●	●●●	●●	●●
Afforestation	የደን ልማት	●●●●	●	●●●●	●●●●	●●

with low scores signified by 1 dot and high scores by 4 dots

FGD PSD

Upper basin

Source: Own depictions from PSD

NA = Community members did not agree on the rank to be assigned to this adaptation strategy

The result of the analysis shows how the community members ranked the various climate adaptation strategies being practiced in the basin. As shown in table 7.24, while afforestation, tree planting, shifting cultivation and modern irrigation ranked relatively at the top (summation of the dots in figure 7.14), improved seeds and animal hybrids ranked least.

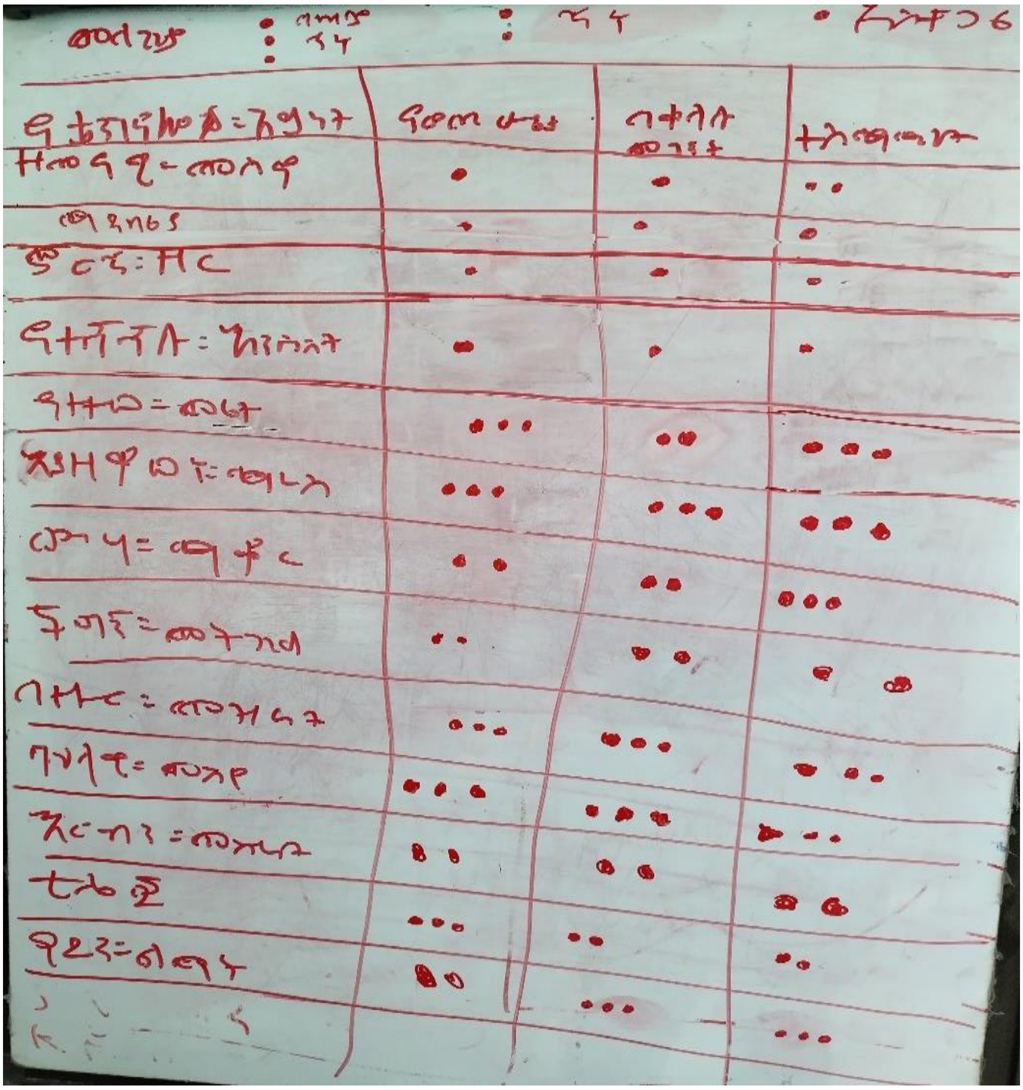
Table 7.24 25: Ranking climate adaptation strategies using local criteria

Adaptation strategies	Rank
Modern irrigation	14
Agronomic practices	13
Improved seeds	11
improved animal hybrids	11
Shifting cultivation	14
Water conservation works	13
Tree planning	15
Crop rotation /switching	13
Terracing	12
conservation tillage	12
Afforestation	15

Source: Own depiction using PSD

In addition, the PSD participants evaluated each climate adaptation strategy in terms of its pro-poorness using agreed criteria and definitions. According to the participants, in order to say climate adaptation strategies are pro-poor, three conditions are required: 1) cost of implementing the strategy must be low, 2) it must be easily accessible, and 3) it must be locally available. Figure 7.14 shows the result of the PSD exercise by the participants in the national language (Amharic).

Figure 7:14. Ranking adaptation strategies based on their pro-poorness



N.B: One dot denotes low score, two dots medium score and three dots high score (local language is used)

Source: Own depiction using PSD

The result presented in table 7.24 is the translated version of figure 7.14. It shows that except for fertilizer, modern irrigation, improved seeds and improved livestock breeds, almost all strategies have high pro-poor scores. Through further discussion with PSD participants, it was concluded that even though the strategies with low pro-poor score have positive effects on poverty and food security, their expensiveness, lack of accessibility and availability make these technologies difficult to be utilized by the poor.

Table 7.26 : Ranking of pro-poorness of climate adaptation strategies

Adaptation strategies	Implemented at low cost	Accessibility	Availability	Total
Modern irrigation	1	1	2	4
Modern fertilizer	1	1	1	3
Improved seeds	1	1	1	3
Improved animal hybrids	1	1	1	3
Fallowing	3	3	3	9
Shifting cultivation	3	3	3	9
Rain water harvesting	2	2	3	7
Tree planning	2	2	2	6
Crop rotation /switching	3	3	3	9
Traditional irrigation	3	3	3	9
Terracing	2	2	2	6
Tillage	3	2	2	7
Afforestation	3	3	3	9

1= low score, 2= dots medium score and 3= dots high score
Source: Own depiction using PSD

7.7. CONCLUSION

Households revealed that there is a declining trend in rainfall and an increasing trend in temperature. In this regard, the household survey shows that rainfall is changing both in terms of amount and timing. The analysis also indicates that climate change related shocks such as droughts and floods are becoming more frequent in the Lake Tana Basin.

Climate change has affected both livelihood strategies and assets in the Lake Tana Basin. These strategies are crop, livestock and fishery activities and the affected forms of assets are financial, natural, social and human capital. Moreover, the perceptions of community members regarding the severity of the negative effects of climate change in relation to livelihood asset indicators is presented in table 7.11. It shows that asset indicators such as grazing land, agricultural water, agriculture land use, forest cover, farm income, income from livestock and group cooperation are the most severely affected livelihood assets or capitals.

The study has used LVI to identify the most vulnerable livelihoods to climate change in the Lake Tana Basin. The result of the vulnerability analysis shows that all livelihood components tend to be highly vulnerable. Thus, the main argument here is that livelihood vulnerability indices (LVI) have placed the study households at the most vulnerable position. In this regard, both the average indices table and vulnerability radar show that physical and institutional capitals ranked top in terms of their vulnerability positions.

In order to respond to the negative effects of climate change, the study community adopted various adaptation strategies. These include farm and non-farm strategies. The top farm related adaptation strategies include traditional irrigation, improved agronomic practices, improved seeds and tree planting. The top non-farm related adaptation strategies include sale of assets, off-farm activities and migration. These climate change adaptations have brought about changes in livelihood pattern in the Lake Tana Basin. The result shows that that the four major livelihood strategies affected by adaptation measures are those that depend on crop and livestock production, fishing and tourism.

The PSD approach was used to identify farmers' choices of climate adaptation strategies and their pro-poorness. The five local criteria identified by the participants for a most effective adaptation strategy are: 1) the strategy should significantly reduce the negative effects of climate change, 2) it must be low cost, 3) it must be implemented using local knowledge and resource, 4) it must be long lasting (sustainability), and 5) it must be easily implemented within a short period of time. The result of the strategy ranking exercise by community members using local criteria shows that while afforestation, tree planning, shifting cultivation and modern irrigation rank relatively at the top, improved seeds and improved animal hybrids rank least. In addition, climate adaptation strategies are also ranked based on their pro-poorness. The pro-poorness criteria are cost, accessibility and local availability. The result shows that fertilizer, modern irrigation, improved seeds and improved livestock breeds have low pro-poorness scores related to their highest cost of implementation, inaccessibility and difficulty to obtain them locally.

CHAPTER 8: IMPLICATIONS OF CLIMATE CHANGE AND ADAPTATION FOR POVERTY AND FOOD SECURITY

8.1. INTRODUCTION

In chapter 7, we saw that climate change and adaptation affected livelihood strategies and assets in the Lake Tana Basin. These livelihood bases include but are not limited to crop and livestock production, fishing and tourism. Moreover, climate change has also brought about livelihood pattern changes in the Lake Tana Basin (section 7.2.4.1). In fact, because of climate change, new livelihood options or strategies have been adopted by members of the community. In this chapter, we will see the implications of the change in livelihood pattern (caused by climate change) for key livelihood outcome indicators such poverty and food security. This chapter, therefore, captures the implications of the changes in asset (natural capital, social, human, and financial capital) and livelihood strategies for food security and poverty in the Lake Tana Basin.

In this thesis, the discussion on the interrelationship between climate change and livelihood as well as the effect of climate change and adaptation on poverty and food security follows a different approach from other works on the topic. That is to say, statistical control methods are widely used to show the effect of climate change on poverty and food security indicators in previous studies. However, these methods do not show the process of change or effect on poverty and food security. Thus, we currently do not have much knowledge about the transmission mechanisms of the effect of climate change and adaptation towards livelihood outcomes (poverty and food security). In this chapter, first the effect of climate change and adaptation on livelihood pattern is examined. Then the impact of livelihood pattern change (due to climate change and adaptation) on poverty and food security is explored. The argument is that climate change affects poverty and food security by changing livelihood pattern (changes in livelihood strategies and activities). Thus, climate change and adaptation can potentially change asset conditions, livelihood activities and strategies of rural communities that could bring about change in poverty and food security conditions of the same. In this regard, this chapter discusses the implication of change livelihood pattern (due the climate change adaptation) for poverty and food security discussed.

8.2 IMPLICATIONS OF CLIMATE CHANGE FOR POVERTY AND FOOD SECURITY

In this subsection, the analysis focuses on the implications of climate change for the livelihood outcomes of poverty and food security among the community members of the Lake Tana Basin. The result is presented using different dimensions of poverty and food security. As presented in chapter 2, one of the gaps in the literature is lack of evidence for the effect of climate change on different dimensions of poverty and food security.

8.2.1 Perception of severity of effect of climate change on food security

As presented in chapter 5, climate change variables such as temperature and mean rainfall are found to have a significant negative effect on agricultural production in the Lake Tana Basin (which is the direct effect of climate change on one of the components of food security).

On the other hand, the household survey captured the perception of households towards the severity of the effect of climate change on different components of food security (because of effect of climate change on livelihood strategies). Here it should be noted that this is the effect of climate change on components of food security through its effect on livelihood strategies.

The frequency result on table 8.1 shows that the majority number of households (frequency) rated the negative effect from medium to very severe to almost all components of food security. Thus, households have perceived the impact of climate change on different components of climate change. The frequency table shows that nearly all ranked from medium to very severe.

Table 8.1: Severity of the effect of climate change on food security

Food security dimension	Very low	Low	Medium	Severe	Very Severe	Total
Crop productivity	0	28	106	107	30	272
Food access	0	18	113	113	28	272
Number of food items on the plate	2	38	105	101	26	272
Food production	2	51	75	113	30	271

Source: Own summary using household survey data

Other similar studies have also found out that community members have already perceived the impact of climate change on food security in Ethiopian (Ayinu, Ayal, Zeleke & Beketie 2022:9 ; Debela, Caroline, Kerry, Ross, Corkrey & David 2015:12;Weldearegay & Tedla 2018:9). These studies reveal the existence of a spatial and temporal rainfall variability with various degrees and widespread household food insecurity due to climate change related shocks. However, they mainly focus on crop production and food calorie intake to the neglect of the other dimensions of food security.

8.2.2. Climate Change, livelihood pattern change (change in asset) and food security

Climate change related shocks can have negative effect on the various forms of assets or capitals (Thakur & Bajagain 2019:175) . Moreover, households with limited livelihood assets are more vulnerable to the impacts of climate change and food insecurity (Kangalawe & Lyimo 2013:271).

The discussion in this thesis reveals that climate change brought about change in some of the livelihood assets (See section 7.2.2). In this subsection, we are going to see the implications of livelihood pattern change (change in assets also referred to as natural, social, physical, human and financial capitals) caused by climate change on different components of food security in the Lake Tana Basin.

Natural capital and food security

Households that are heavily dependent on natural capital are more likely to be affected by climate shocks such as droughts than those that are less dependent on the natural environment (Gary 2006: 386). Thus, changes in natural capital could directly affect food security.

More and more areas of Lake Tana and its surroundings have now become agricultural land (one of the natural capitals) due to the effect of climate change and other related factors. One of the KII reported, "*In last two decades, with decline in amount of rainfall, increasing population pressure and limitation of land and water, farming moved to the shorelines of Lake Tana basin".* In addition, according to some of the key informant participants, this has threatened fish production as the chemicals used for agricultural purposes (pesticides for example) are affecting the food and water consumed by the fish population. One of the KII participants reported, "*Agricultural pesticides, water hyacinth infestation and dam construction have become serious threats to fish production".* An in-depth interview participant reported, "*We now catch less fish as compared to what we used to catch ten years ago".* Other studies have also indicated that the catch per unit of effort for all types of fish taxa have declined during the last two decades (Dejen, Anteneh & Vijverberg 2017: 1847). This has an important implication for food security as it affects the food dietary diversity at household level. One of the members of the fish association near Lake Tana reported the following:

"Previously, we used to catch fish both for the local market and for home consumption, however, as the fish population dwindled, we no longer consume fish at home but only supply the market".

Thus, changes in asset such as fish stock could reduce food dietary diversity at household level which could further exacerbate the food security conditions of the household.

Another important observed change is the decline in availability of water for agriculture (due to rainfall variability) and loss of land moisture (due to high temperatures). Household members reported that this has affected the productivity of land which in turn has affected both income and food consumption at the household level. One household member reported, "*In recent years,* we *have not been able to produce more food due to the unpredictable nature of the rainfall, making things difficult for us as our family size is growing each year".* Another household member reported, "*Our income has significantly declined due to the reduction in the amount of rainfall and as such we could not buy additional food items for our children*". This shows that the effect of climate change transmitted into nutritional security (dietary diversity) through its effect on farm income.

Social capital and food security

Social capital plays an important role in food security at community and household level. A review of the literature on this topic reveals that social capital improves food security through knowledge and product sharing (i.e., sharing food products which facilitates food availability and access to food) (Nosratabadi, Khazami, Abdallah, Lackner, Band, Mosavi & Mako 2020:9).

Change in social capital (caused by climate change) affects food security conditions of the study households in two ways. First, due to unsuitable conditions for farming (increasing temperatures and changing rainfall patterns), some members of the household have already migrated in search of better livelihood to the nearby cities like Bahir Dar. As such, some members of the community do not have adequate labour supply during the peak agricultural seasons. Second, lack of labour supply has prevented some members from using the traditional labour pulling mechanism called "Debo" because those who can't contribute enough people to this mechanism are excluded from using the system. One of the household survey participants reported:

"I have sent my boys to Bahir Dar and as such, I could not contribute the required labour to the "Debo". Because of this, no one is interested to work on

my farm during harvesting time. This has affected my efficiency during harvesting and I have lost my crops many times".

Another FGD participant reported:

"We used to borrow food from one another in time of drought and crop failure. However, since climate change affected everyone, everyone is in need of food".

Thus, climate change can have a negative effect on social capital through its effect both on food access and availability at the household level.

An empirical study by Sseguya, Robert & Flora (2018:128), shows that at the household level, social capital is positively associated with food success. They used 'Food Insecurity Access' scale and 'Cognitive and structural indicators' to measure food access conditions and social capital respectively. However, their analysis failed to capture the channel through which social capital affects food access. The lack of this information makes it difficult for policymakers to come up with effective interventions.

Human capital and food security

The resultant effect in change in human capital (due to climate change) is transmitted through its effect on availability of labour at the household level. Climate change has forced some community members to send their children to the nearly urban areas and the regional capital. One of the FGD participants reported the following:

"I have sent my children to the nearby city because they are not happy about how the farming is going. Because of this, there is no one to take care of the farm related activities. We are too old to work on the farm so we rented it out at a very low price".

Therefore, because of labour shortage, some community members could not produce enough food. Another study found a similar result but with a different measure of human capital (level of education) (Obayelu, Adepoju & Omirin

2019:91). They argue that low level education leads to low-income jobs and this hampers households' ability to acquire resources to purchase food, thereby increasing the level of food insecurity in the households.

A key informant interview conducted with an agriculture extension worker also indicated the same. The extension worker reported:

"Since farming is no longer an attractive sector for the young generation, some older members of the community sent their children to the nearby cities hoping to get better income. However, this created labour shortage for the same households and they were not able to plough and produce adequate food. According to my observation, these members of the community now changed from being producers of food to net buyers of food".

The effect of human capital (labour availability) on food security seems to have a similar pattern as that of social capital when one looks at them from migration perspective.

Financial capital and food security

Financial asset is measured using proxy indicators such as remittance, borrowing from a neighbour, income (from farm, livestock and fishing) and credit from financial institutions. As presented in chapter 7, the effect of climate change on financial capital indicators is well noticed by the study participants.

The effect of climate change on financial capital (change in financial asset) has an important direct implication for food security. The study participants reported that the effect of climate change on financial capital has deteriorated their food security conditions. One of the FGD participants reported the following:

"Previously we used to save some money by selling crop and livestock to buy additional food and non-food items from the nearby market but now we cannot do that due to the decline in crop production. As such, we do not buy additional

food items rather we only produce for self-consumption and we can no longer afford to buy additional food items for our children as we used to do before".

A female participant in the FGD reported, *"We used to borrow enjera (which is made from an indigenous grain called teff) from our neighbours in those good times but now no one is in a position to lend food in fact food is becoming like gold".* Thus, climate change's effect on financial asset is impacting physical access to food. Another key informant interviewee reported, "*We used to reinvest in our farm buy buying improved seed and fertilizer but now since our income has significantly declined, we could not reinvest on crop production".* The implication here is that the effect of climate change on financial capital has become a constraint for agricultural production, which in turn hampers food availability both for market and for self-consumption.

A recent empirical study by Mthethwa & Edilegnaw (2021:16), shows that financial capital plays a critical role in rural South Africa, allowing rural households to be resilient in the face of food insecurity during shocks. However, their analysis did not capture the process through which financial capital affects the food security conditions of rural communities.

The discussion here in section 8.2.2 (the implications of change in asset due to the negative effect of climate change) is summarized in the Table 8.2. The summary indicates that while change in natural asset (due to the negative effect of climate change) affects food access, utilization and availability, change in social capital influences food access and availability only. The same table shows that while the effect of climate change on financial capital/asset affects food access, utilization and availability, change in human capital impacts only the food access and availability components of food security. The overall implication here is that the effect of climate change on asset/capital has a disaggregated impact on the dimensions of food security, therefore, the transmission channels could vary.

Table 8.2: Asset change and food security dimensions

	Food security dimensions			
Assets /capitals	Food access (physical)	Food access (economic)	Food utilization (dietary diversity)	Food availability (food production)
Natural capital	●		●	●
Social capital	●			●
Financial capital	●	●	●	●
Human capital	●			●

Source**:** Own summary

8.2.3. Climate Change, livelihood pattern change (livelihood strategy) and food security

Because of climate change, members of the community have been practicing new livelihood strategies. So the question here is: what are the implications of this change in livelihood pattern for food security in the area? The result from the household survey indicates that the majority of the respondents adopted new livelihood options or strategies such as tourism, petty trade, daily labour and handicraft.

Tourism and food security: The study participants have reported that having their family members work in the tourism sector has allowed them to secure additional income that has helped them purchase food during drought periods. In this regard, study participants have reported that even though the sector is seasonal, it has contributed to consumption smoothing during drought periods. One of the household interviewees reported:

"Tourists will come to our area during the months of January, February and March. During this months, we will send out young and educated boys to Bahir Dar, Lake Tana, the nearby monasteries and ancient churches for them to work as tourist guides and interpreters and this has allowed us to get additional income to buy goods when the need arises".

Thus, this livelihood has helped to improve food security to some members of the community through its effect on food or economic access.

Fish production and food security: The study participants have reported that entering the fish sector helped them to secure dietary diversity**.** A participant in FGD reported, "*We primarily catch fish for commercial purpose but sometimes since we do not sell all that we caught, we will take it home to consume it with our families*". This has an implication for two important dimensions of food security. First, even though it was not intentional, this additional livelihood strategy is contributing to dietary diversity at household level (more food on the plate) and second, it has allowed physical access to food. Moreover, they are also able to save money by selling fish through fisheries' associations and this is helping them to buy food when crop fails. It is important to mention the perspective of one of the household interviewees here:

"In the past, I used to wait for the crop production season to buy food and non-food items, however, since I started fishing, I am able to save some money and this additional income has allowed me to buy food and non-food items anytime".

Another FGD participant indicated, "*Since I started working as a fisherman, I have managed to secure additional income and I have used this additional income to buy food during drought seasons"*. Thus, fishing has improved the physical and economic conditions around food as well as its utilization and availability. However, since those who recently started fishing as a new livelihood strategy are considered as a threat by those who are predominately fishers, the sustainability of this livelihood is in question.

Interestingly, as summarized in table 8.3, only fishery, as a new livelihood strategy, contributes to all the aspects of food security. Even though this would require additional investigation, one of the possible reasons is probably due to the high utilization the product (fish) as consumable food. Thus, those in fishery have better chances of physically accessing food compared to those who take up other new livelihood strategies such as petty trade, daily labour, handicrafts, tourism and migration. The other livelihood strategies are not necessarily used directly to obtain food items but indirectly thorough the income they provide. On the other hand, an additional income might not necessarily be used to purchase food.

Petty trade and food security: The study participants have reported that working in petty trade has helped them to secure additional income. They are able to buy food from the nearby market with this income, thereby increasing food availability at the household level. One of the FGD participants reported:

"Since I started working as petty trader, I have been able to secure additional income on a daily basis and this has allowed me to buy food at any time. I never had the chance to earn or secure daily income from crop sales or from farming activities".

Thus, petty trade has increased the purchasing power of households and allowed them economic access to food. Moreover, some households reported that petty trade has let them buy fertilizer and improved seeds that can increase crop production. In this regard, here is a perspective from one the of household interviewees:

"With the additional income, I have managed to buy agricultural inputs that can improve crop production".

Another in-depth interview participant reported:

"Since I started working as a petty trader, I am able to buy fertilizer thorough credit scheme".

Thus, the implication is that petty trade as a new livelihood strategy has the potential to improve food availability for commercial and home consumption by enhancing food production.

Daily labour, handicrafts, migration and food security: These livelihood activities are carried out by various members of the community. While older male members of the community work as daily labourers, female members work in handicrafts and young members use migration as a livelihood strategy. The FGDs with members of the community have revealed that these new livelihood strategies have allowed them to buy additional food, which is an instance of economic access to food. It is interesting to note here that the decision to work as daily labourer or in handicrafts or migrate is motivated by droughts that are caused by extreme climate events having to do with rainfall variability and rise in temperatures. The following are some of the points raised during FGD with members of the community:

"I decided to work in the nearby hydropower construction site because I am convinced that I can no longer wait for the rain as the rain is unpredictable and farm income is no more sustainable. Because of this, our food security condition has been under threat for so long. By working as daily labourer, I have somehow managed to secure some additional money to buy both food and non-food items".

"Our young people are looking for better livelihood and opportunities at the regional capital since farming is no longer attractive. They have decided to go to Bahir Dar and sometimes they send us money and we use that to buy food when we face drought".

The implications of livelihood pattern change (livelihood strategy) due to climate change on food security is summarized in the table 8.3. The result shows that while all new livelihood strategies improve food access (economic), only fish production improves all the components of food security conditions (physical access, economic access, utilization and availability). There are two possible reasons for this. First, fishing activity is directly linked to both consumption and production. Second, sometimes households engage in both crop and fish production and this brings food diversity when fish is consumed at home. The other new livelihood strategies do not directly affect both food production and consumption. Rather they affect food security through the income impact.

The same table shows that petty trade improves food availability by further enhancing food production. The implication here that livelihood pattern change (caused by climate change related shocks) has a disaggregated effect on the dimensions of food security.

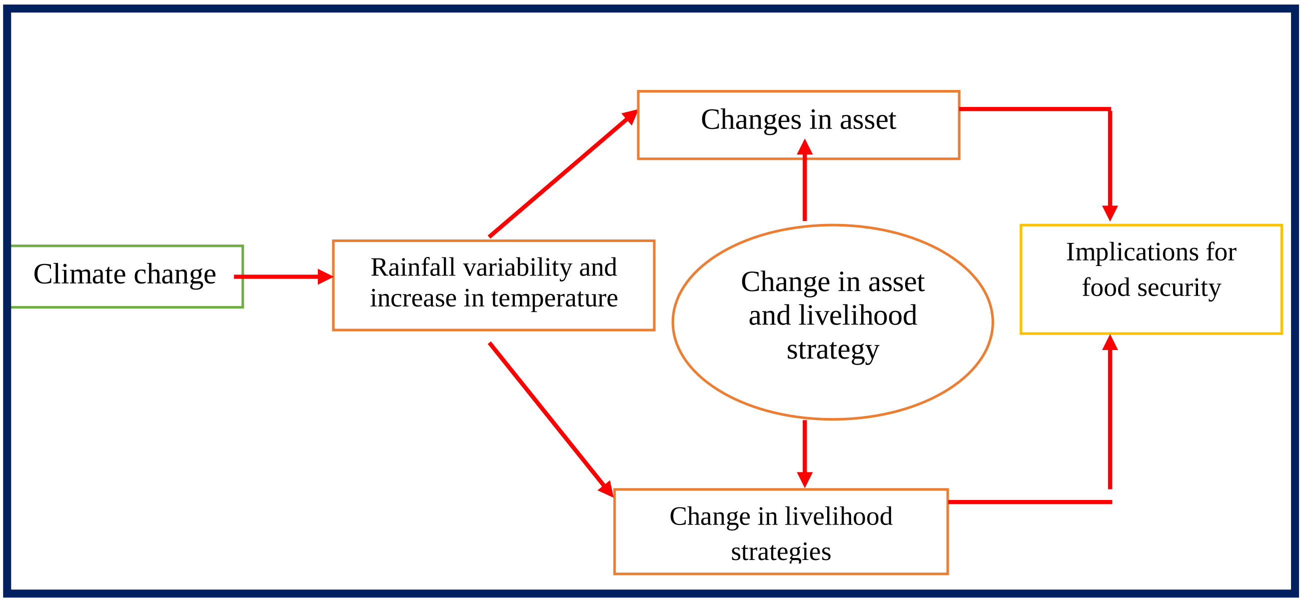
Table 8.3: New livelihoods strategies and food security dimensions

	Food security dimensions			
New livelihoods	Food access (physical)	Food access (economic)	Food utilization (dietary diversity)	Food availability (food production)
Tourism		●		
Fishery	●	●	●	●
Petty trade	●	●		●
Daily labourers		●		
Handicrafts		●		
Migration		●		

Source: Own summary using household survey

The discussion in this subsection is summarised in figure 8.1. As presented in chapter 7, climate change (rainfall variability and increase in temperature) bring about change in asset and livelihood strategy. The discussion in this chapter shows that these changes in livelihood pattern (change in asset and livelihood strategy) have implications for different components of food security.

Figure 8.3: Conceptualizing climate change, livelihood pattern change and food security

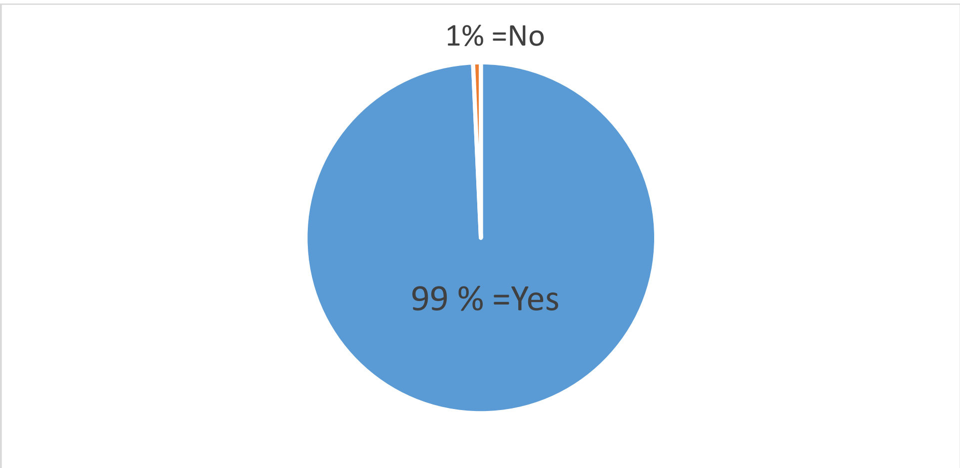


Source: Own depiction

8.2.4 Change in asset (due to climate change) and poverty

Household members have reported that climate change's effect on asset has an impact on the poverty conditions of the household. The result in the following figure shows that nearly 99 percent (N=281) have perceived that change in asset (due to climate change) has an effect on poverty conditions of the household.

Figure 8.4: Perception of the effect of change in asset on poverty



Source: Household survey

In the same token, the perception of the severity of the effect from change in asset (due to climate change) on different components of poverty is presented in table 8.4. The result shows that nearly all components are affected with severities ranging from severe to very severe. This indicates that households have noticed the relationship between changes in various forms of capital (natural, social, human and financial) and dimensions of poverty.

Table 8.4 : Severity of the effect of change in asset on dimensions of poverty

Poverty dimension	Very low	Low	Medium	Severe	Very Severe	Total
Income	4	4	6	175	90	279
Food expenditure	2	4	19	192	62	279
Non-food expenditure	2	21	57	155	44	279
Asset	2	49	73	108	47	279

Source: Own summary using Household survey

The direct effect of change in natural capital on dimensions of poverty can be understood from is effect on income. Climate change's effect on natural capital could reduce income since it impacts crop and livestock production directly as observed by study participants in chapter 7. One of the household interviewees reported, "*The decline in rainfall amount has affected our income and what do you think this has led to? We are even becoming poorer than ever".* Another FGD participant reported the following:

"*Seven years ago, I used to be one of the model farmers in our village but in the past three years, drought came and I lost my decent income from crop and livestock production. In fact, I have also sold some of my properties and now I am on the list of poor and food insecure households".*

In line with this, an empirical study also shows that climate related shocks erode smallholder farmers' livelihood potential through the reduction of productive assets, leading to a poverty trap (Hansen, Hellin, Rosenstock, Fisher, Cairns, Stirling, Lamanna, van Etten, Rose, & Campbell 2019:29)

Thus, change in natural asset could have a double effect on poverty: one through directly reducing income and the other through depleting the physical asset base of a household.

Change in financial capital (caused by climate change) also has an implication for poverty. The analysis in chapter 7 shows that climate change is mostly associated with financial capital in terms of income gained by borrowing from neighbours as well as through crop and livestock production. Thus, change in financial capital has an implication for poverty because it affects one of the poverty dimensions (income).

Besides, since financial capital depends on elements of natural capital (mainly livestock and crop), the effect of change in natural capital on poverty dimensions can potentially be transmitted to the impact of financial capital on poverty.

And although few households depend on forest products sales (one form of natural capital), climate change has also affected this sector. According to key informant interviews and FGDs with community members, sales of forest products provide additional financial capital that is used for various activities such as buying medicine, sending their children to school and purchasing food from the local market. However, the forest coverage has been declining over time due to reduced rainfall. One of the key informants reported the following:

"Ten years ago, nearly every household in this area used to have some form of forest in their garden including indigenous trees. However, this has changed in recent years and it is no longer common to see forests in backyards; only few households are generating income this way".

Thus, climate change's effect on natural or financial asset (forest and sales of forest products) has an impact on food and non-food expenditures.

The effect of climate change on social capital has also implication for poverty. Climate change has forced some members to migrate to urban areas and this has affected the farm labour needs of some households. Moreover, since labour is expensive, they cannot hire labourers, resulting in crop losses during harvest time, which is their main source of income. One of the FGD participants reported the following:

"Five years ago, I distributed land to my three boys. However, they could not continue to produce due to frequent droughts in the area. Therefore, they left everything and went to Bahir Dar to look for better livelihoods. As for me, you can see that I am old so I cannot go anywhere. I tried to plough the land in the past two production seasons but during harvesting period, I could not collect my harvest at the right time".

The discussion on the implications of change in asset (due to climate change) for poverty is summarized and presented in table 8.5. The result shows that while natural capital affects all three dimensions of poverty, financial capital affects only the income and expenditure components and social capital affects only the income dimension.

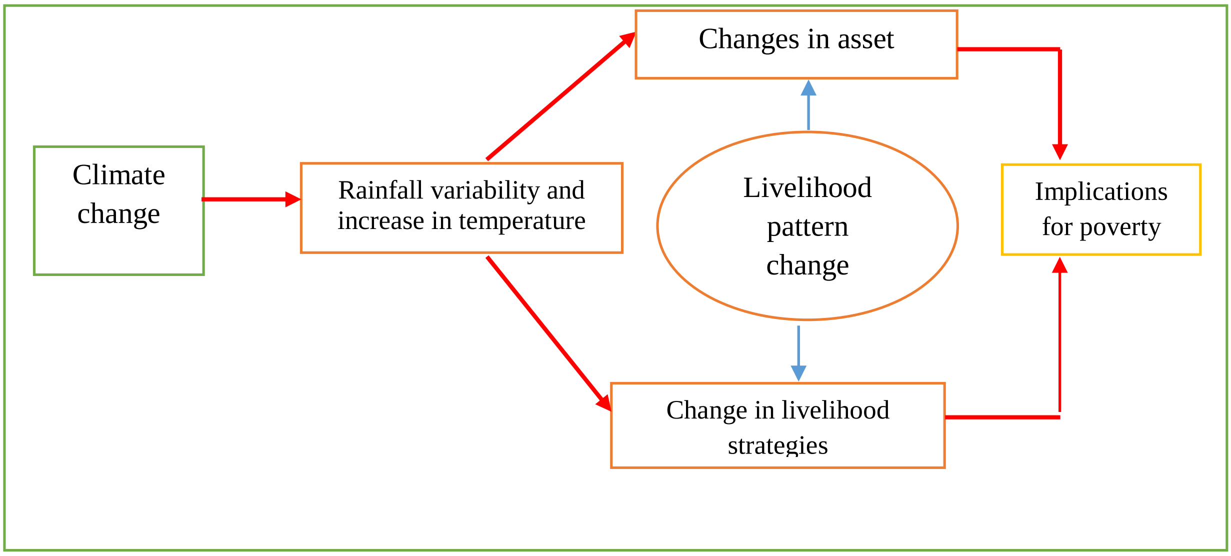
Table 8.5: Change in asset and its effect on dimension poverty

Capital indicators	Poverty dimension		
	Income	Asset (physical)	Expenditure
Natural capital	●	●	●
Social capital	●		
Financial capital	●		●

Source**:** Own summary

Figure 8.3 summarises the implications of climate change for household assets, income and consumption. As presented in chapter 7, climate change in the form of rainfall variability and increases in temperatures has brought about change in livelihood pattern by altering assets (social, natural, financial, physical and human) and livelihood strategies (both natural or farm based and non-natural or non-farm based). As presented in the current chapter, these changes in livelihood patterns have affected the different dimensions of poverty expressed as income, asset and expenditure.

Figure 8.5: Conceptualizing climate change, livelihood pattern and food security



Source: Own depiction

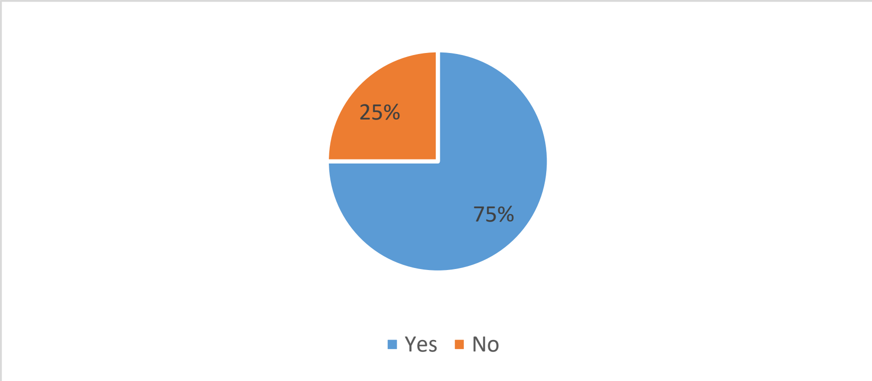
8.3. IMPLICATIONS OF CLIMATE CHANGE ADAPTATION FOR POVERTY AND FOOD SECURITY

In chapters 5 and 6, both the time series analysis and household survey have shown that the Lake Tana Basin has experienced climate change in form of decline in rainfall and an increase in temperature. The resultant effect is that farmers have started to take farm and non-farm related measures or adaptation strategies to respond to the negative impacts of climate change. Moreover, climate change adaptation has also brought about change in livelihood pattern (section 7.5). In this regard, this subsection discusses the implication of climate change adaptation for poverty and food security.

8.3.1. Implication of climate change adaptation for poverty and food security

As presented in chapter 2, one of the proxy measures of poverty is expenditure. The household survey captures the perceptions of households on the effect of climate change adaptation on annual expenditure. The result depicted in figure 8.4 shows that 75 percent of households have perceived the effect of climate change on annual expenditure which is one of the dimensions of poverty. This has occurred as households incur adaptation expenses when they apply some adaptation strategies such as improved seeds.

Figure 8.6: Perception of the effect of climate adaptation on annual expenditure



Source: Own depiction using household survey data

According to the household survey and FGDs, community members have used the sale of physical asset as one of the major adaptation strategies to curb the impacts of climate change on their livelihoods. In fact, asset is important for rural communities as it is a means of maintaining wealth, providing them with security during natural crises such as droughts (Ali et al. 2021:2). However, according to the FGDs, climate change in the form of unpredictable rainfall and floods have forced them to sell their assets at a lower market prices. For example, one of the FGD participants reported the following:

"I sold my TV due to crop failures and the sale has made me even poorer because I sold my asset at lower a price than the actual market price and I only used the income to buy food".

Though households can get an immediate cash or income using this strategy, they put themselves under greater threat when one considers the long-term consequences of asset sales. The fact that households sell assets at lower price than the normal market price can force farmers to fall into a poverty trap. In the household survey, one of the interviewees reported the following:

"I sold my asset for an emergency when I encountered crop failure in 2018. Now, I notice that I could have sold it for a higher price if I had the time to respond to the situation". Once households sell their assets, the effect could

last for many years to come. During normal seasons, assets are much more expensive and as such, it might take years for households to regain or acquire the same types of assets.

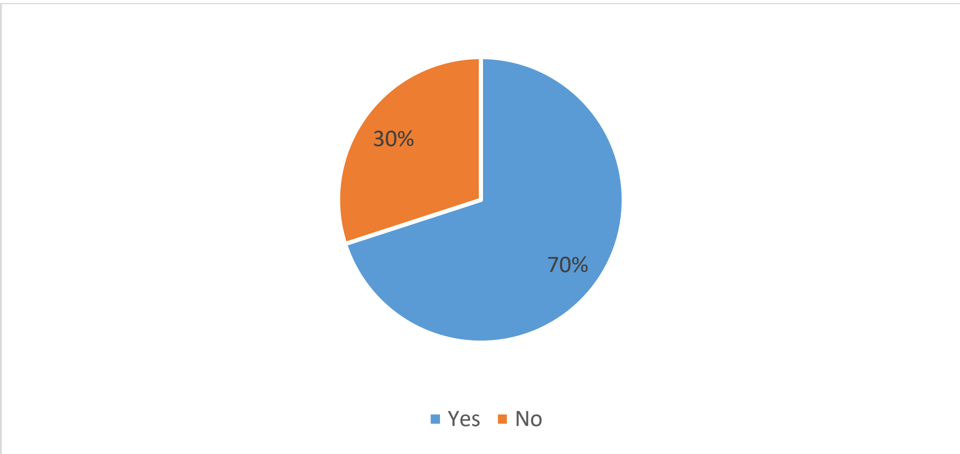
Households also sell assets such as livestock to respond to the possible negative effects of climate change, facing similar price disadvantages. One of the key informant interviewees reported the following:

"The price of livestock would increase three of four times during Ethiopian holidays but during crop failure, we would sell them for much lower price".

The above interviewee's report indicates that if famers had enough time to adjust to crop failure, they could have sold their livestock for a better price, thus, households are price inelastic during drought seasons. This is because when crops fail, farmers need to take an immediate action (for example sell livestock) to curb the effect of crop failure. Therefore, this particular measure of adaptation lowers the income dimension of poverty.

The household survey also captures the perceptions of households regarding the effect of climate change adaptation on income. The result in figure 8.5shows that 70 percent (N=281) of the respondents have perceived the effect of climate change on income. This may be due to the fact that households can secure additional income by pursuing some adaptation strategies such as improved seeds, tourism and irrigation.

Figure 8.7: Perception of the effect of climate change adaptation on income



Source: Own depiction using the household survey

For example, farmers have started to use traditional irrigation (river diversion and rainwater harvesting) as an adaptation strategy to mitigate the effects of climate change. According to the FGDs with community members, irrigation enhances households' income as it increases the number of production periods. Since these are traditional irrigation practices (river diversion and rainwater harvesting), there is no significant cost of adaptation except labour (most use family members). In relation to the effect of irrigation on income, one of the in-depth interview participants reported the following:

"Since we started using irrigation, our income has increased because we are able to produce two or more times within a year".

On the other hand, according the FGDs, farmers with small plots of land were not able to use rainwater harvesting. One of the FGD participants reported the following:

"I could not harvest rainwater because I do not have enough land to allocate for it so I could not tell you how it can be associated with income".

Improved seeds are another measure of climate change adaptation adopted by households in the study area. According to information from KII, improved seeds have increased income from crop production compared to the past when this option was not in use. One of the participants of the key informant interview reported the following;

"I used improved seeds in the last four production seasons and I have managed to secure additional income because I produced more crops per hectare than before but now I am not using improved seeds anymore because it is much more expensive now than it used to be three or four years ago".

The implication is that improved seeds can enhance income at the household level but its use might not necessarily be sustainable due to its increasing cost.

Due to the effect of climate change on major livelihood strategies such as crop and livestock production, community members in and around Lake Tana Basin have also started fishery and tourism as additional livelihood strategies. The inclusion of these strategies into household activities has improved income for members of the community. In this regard, household interviewees reported the following;

"I have now started to use fishing as an adaptation strategy and this helped me to secure some additional income but the problem is we are new comers to these livelihood activity and early settlers in the Lake Tana are not happy about us so we do not see its sustainability".

"When we are lucky enough, we would get income from fishing activity on weekly basis if not on daily basis".

In the same token, tourism has also improved income for some members of the community. A peasant who participated an in-depth interview reported:

"In the past three production seasons, I could not secure a decent income from farming. As such, I started sending my children who are attending secondary school to work as guides in the nearby monasteries (during the peak tourist seasons) and though it is seasonal, it helped me to secure additional income to buy food and even sometimes non-food items such as durable assets".

However, except for tourism, there is no clear indication how these additional strategies enhance and build assets that can indicate long-term benefit. Thus, households did not say anything about the possible effect of these adaptation strategies in improving assets and expenditure on non-food items. But those who started fishery as a new livelihood strategy reported that it has improved their food security conditions by providing an additional food item to the household. One of the FGD participants reported:

"In addition to generating additional income for the family, you can now see fish on our table but we worry about its continuity in the future because there seems to be a decline in the stock of fish in Lake Tana".

Moreover, some members of the community have shifted from producing traditional crops to those that have high economic value with drought resistant nature. In this regard, the notable one is the production of khat. Khat is a natural stimulant cultivated in most of the countries of Eastern Africa and the Middle

East particularly in Yemen (Binalfew, 2017:16). One of the key informant interviewees reported the following;

> *"Planting chat was not common in our area and no one used to chew khat for any social or cultural reasons. However, in recent years both planting and chewing khat has become a common practice in our area".*

The study participants reported the economic value of the crop and the unpredictability rainfalls as the two major reasons for shifting to khat production. In this regard, it is important to report the view of one of the FGD participants:

"I used to grow maize in my farm but I found out that khat has more returns in terms of income and it also grows quickly compared to any other crop".

This shows that producing khat affects income which is a dimension of poverty. Another FGD participant reported, *"I started khat planting because of the unpredictable nature of the rainfall in recent years and in fact compared to other crops khat is more drought tolerant*". The FGD participants indicate that this adaptation measure has made them net buyers of food. In this regard, one of the FGD participants reported, "*Previously we used to produce food for ourselves but since I allocated all the land for the production of khat, I have now started to buy food".* Thus, in this regard, this climate change adaptation could affect food production at household level but its effect on the other dimensions of food security is not clear and needs further investigation.

The FGD and key informant discussions on the implication of climate change adaptation for dimensions of poverty and food security is summarized in table 8.6. As presented in the table, different adaptation strategies have different effects on the dimensions of poverty and food security. If the box is spotted using a red circle, then it shows that the study participants have identified the effect as present and if not, the effect is not observed or its presence is not clearly determined at least in this research.

As shown in table 8.6, the sale of livestock has affected the income dimension of poverty as well as the access (economic) dimension of food security. By selling their livestock, community members can get an immediate disposable cash and with this additional income they can buy food. Nevertheless, this adaptation strategy does not have a long-term effect on food security. The reason is that famers only use the additional income to buy food without investing on productivity activity (buying fertilizer or seeds) that would bring long-term effects on food security and poverty.

Improved seeds are indicated as having an effects on the income and expenditure dimensions of poverty. The table also shows that this adaptation strategy also affects the access and availability dimensions of food security. The impact on the dimensions of poverty is observed in two ways: 1) when farmers buy seeds from a local cooperative union (considered an expenditure with a short-term effect), and 2) when the seeds are used to enhance farm production and productivity (which increases farm income as a long-term effect). Since improved seeds are directly used in the production of crop, it affects the food production and access dimension of food security. A peasant participant of an in-depth interview reported the following:

“Even though it is not easy to get improved seeds in our area (on time and at low cost), it has greatly helped me to improve my production and productivity”.

On the other hand, even though the sale of assets as an adaptation measure has an immediate effect on income (more disposable income), it can also push the same households into the poverty trap by depriving them of assets they usually use to secure their livelihoods from unprecedented long-term shocks. The sale of properties affects the income and asset (decline in the number of physical asset) dimensions of poverty.

Fishery as an adaptation strategy affects the income dimension of poverty. As presented in the above discussion, those who join fishery due to crop failures can secure additional income by selling fish products to the local restaurants and food shops. In addition, fishery also allows direct physical access to food and brings dietary diversity when consumed at home. However, fish consumption at home occurs only during those periods when the product is not sold at the market. The following statement is reported by a fisherman who participated in an in-depth interview:

"If we get the chance to sell our catch at the nearby market or restaurant, we will secure additional income but if not, we will use it for home consumption".

In the same token, tourism as an adaptation strategy affects the income and asset dimensions of poverty as well as the economic access dimension of food security. In addition, switching of crops affects the income dimension of poverty, thus, farmers can get better income by selling a new crop (khat). However, since they now shifted from producing traditional crops to the new plant of khat, farmers have to buy food from the market.

Table 8.6 summarises the above discussion on the implications of climate change adaptation for poverty and food security. The following are key findings:

- The sale of livestock as an adaptation measure affects the income dimension of poverty
- The sale of livestock as an adaptation strategy affects the access dimension of food security
- The application of improved seeds as an adaptation strategy affects the expenditure dimension of poverty
- The application of improved seeds as an adaptation strategy affects the expenditure, access and food availability dimensions of food security.
- The sale of properties as an adaptation strategy affects the asset (physical) dimension of poverty
- The sale of properties as an adaptation strategy affects the access dimension of food security

- The application of irrigation as an adaptation strategy affects the income dimension of poverty
- The application of irrigation as an adaptation strategy affects the food access and availably dimensions of food security
- The use of fishery as an adaptation strategy affects the income dimension of poverty
- The use of fishery as an adaptation strategy affects the food access, utilization and availability dimensions of food security
- The use of tourism as an adaptation strategy affects the income and asset dimensions of poverty
- The use of tourism as an adaptation strategy affects the food access dimension of food security
- Crop shifting as an adaptation strategy affects the income dimension of poverty
- Crop shifting as an adaptation strategy affects the food availability dimension of food security

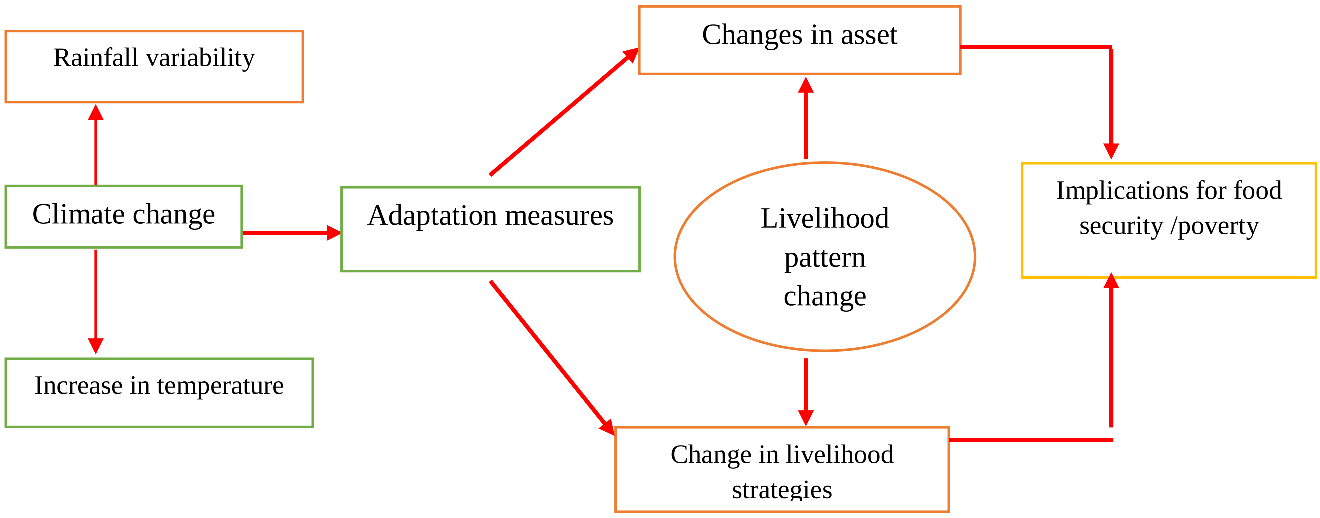
Table 8.6: Climate change adaptation, poverty and food security

Indicators	Poverty dimension			Food security			
Adaptation strategies	Income	Asset	Expenditur e	Access (physical)	Access (economic)	Utilization (diversity)	Food availability (production)
Sale of livestock	●	●			●		
Improved seeds	●		●	●			●
Selling of assets	●	●		●	●		
Irrigation	●						●
Fishing	●			●		●	●
Tourism	●	●			●		
Crop shifting	●						●

Source: Own summary

The relationships between climate change, adaptation and livelihood outcomes are summarized in the flowchart shown in figure 8.6. Climate change in form of rainfall variability and temperature rise has forced community members to take various adaptation measures. These adaptation measures in turn have brought change in livelihood pattern expressed in terms of changes in asset which have implications for food security and poverty conditions of households.

Figure 8.8: Conceptualizing climate change adaptation, livelihood pattern



Climate change and food security

Source: Own depiction

8.4. CONCLUSION

In this chapter, the effect and implications of climate change and adaptation for poverty and food security is presented. This chapter, therefore, captures the implications of the changes in asset (natural and physical capital) and livelihood strategies for food security and poverty in the Lake Tana Basin. There are four findings in the chapter: 1) climate change adaptation has an effect on different components of poverty and food security, 2) adaptation has brought livelihood changes that affect dimensions of food security and poverty, and 3) the effect of livelihood changes (due to climate change adaptation) is still not clear for some dimensions of poverty and food security.

CHAPTER 9: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

9.1. SUMMARY

The main objective of this thesis is to evaluate the effect of climate change and adaptation on livelihood pattern (as expressed in changes in asset and livelihood strategies) and to explain the implications of these changes in livelihood pattern for livelihood outcomes mainly poverty and food security. Thus, the main premise is that climate change brings change in livelihood pattern and this change has implications for poverty and food security. In order to answer the research questions and objectives, the study uses a mixed method approach that constitutes of both qualitative and quantitative dimensions. As such, both qualitative and quantitative data was collected. While the quantitative data was gathered using a household survey, the qualitative data was collected using FGDs, PSDs, in-depth interviews and key informant interviews (chapter 3). Moreover, the study examines the trend in climate change variables using secondary data from the National Meteorological Agency (chapter 5). In this section, conclusions and recommendations are provided in line with the objectives of the study.

9.2. CONCLUSIONS

Objective 1: Analyse the trend and relationship between climate change variables (temperature and rainfall pattern) and crop production in the Lake Tana Basin

Rural livelihood in the Lake Tana Basin depends on crop production, livestock raising and fishing (chapter 6). Thus, most community members depend on agriculture which is one of the most sensitive sectors to climate change. The study examines the trend and relationship between climate change variables (temperature and rainfall pattern) and crop production over time in the Lake Tana Basin. The data used for the time series analysis was obtained from the Ethiopian Meteorological Agency and was originally collected by the nearby stations in the Lake Tana Basin. These stations have provided complete and reliable data that spans at least 30 years. The result of the analysis shows that the Lake Tana Basin region experienced increase in mean monthly temperature and decline in mean monthly rainfall (chapter 5). This provides the scientific evidence for the existence of climate change in the study area. Moreover, the result from the survey data shows that climate change is accompanied by frequent droughts, crop failures and floods (chapter 7, section 7.2.1). Thus, climate change has become a real threat for millions of farmers in the Lake Tana Basin.

The relationship between crop production and climate change is examined using time series data spanning from 1994 to 2019/20. The study uses the dynamic OLS model for analysis. The result shows the existence of a relationship between cereal crop production and rainfall, temperature, fertilizer use and cultivated land. Temperature has a significant negative effect on cereal crops production while fertilizer consumption and land cultivated have significant positive effects on cereal crops production.

In addition to the scientific assessment of climate change variables using statistical methods in chapter 5, the study assessed the perceptions of community members. The data for this was gathered using a household survey and focus group discussions with community members in the lower and upper basins. The result of the data analysis shows that community members have perceived changes in all climate change indicators, namely temperature and rainfall (chapter 7, section 7.2.1). The members have perceived a decline in rainfall and an increase in temperature. This result is consistent with the secondary data analysis of climate change trend in the Lake Tana Basin (chapter 5).

Objective 2: Investigate how climate change and adaptation are changing livelihood pattern in the Lake Tana Basin

The study reveals that climate change poses a great challenge to the livelihood conditions of communities in the Lake Tana Basin. The result shows that both assets (social, human, natural, physical capitals) and livelihood strategies are affected by climate change (sections 7.2.1.1 and 7.2.1.2 and 7.2.3). According to the study, crop and livestock production and fishing are severely affected by climate change (section 7.2.1). Moreover, climate change impacts different components of assets (section 7.2.1). The main observed changes are in grazing land, agricultural water, agriculture land use, forest cover, farm income, income from livestock and group cooperation (section 7.2.2). In fact, these assets are the most severely affected by livelihood components of assets or capitals. In this regard, the main finding of the study is that climate change has brought about changes in livelihood pattern expressed in forms of changes in assets and changes in livelihood strategies (sections 7.2.2 and 7.2.2.1).

The negative impacts of climate change have forced farmers to follow new livelihood strategies thus there is a perceived livelihood pattern change expressed in the form of change in or introduction of new livelihoods and asset. Because of the negative impacts of climate change, household and community members in the Lake Tana are adjusting their livelihood paths and strategies by entering into new livelihood strategies in addition to the traditional ones (crop and livestock production). These new livelihood strategies include tourism, petty trade, daily labour, handicrafts, migration and fishing (section 7.2.2.1).

The analysis shows that households use a wide range of climate adaptation strategies to respond to the negative effect of climate change on asset and livelihood strategies. The adaptation strategies are categorized into two major components which are strategies linked to farm activities and those linked to non-farm activities. The top farm adaptation strategies include traditional irrigation, improved agronomic practices, crop rotation, shifting cultivation, crop switching, improved seeds and tree planting (section 7.4.1.1). Strategies linked to non-farm activities include sale of assets, off-farm activities and migration (section 7.4.1.2).

The study also investigated whether climate adaptation strategies are changing livelihood pattern in the Lake Tana Basin system. The result from the analysis shows that climate adaptation has in fact brought about changes in livelihood pattern (section 7.5). The four major livelihood strategies affected by climate change are crop and livestock production, fishing and tourism (Section 7.5.1-7.5.4). Climate change adaptation measures changed the local crop varieties (local crop breeds were mixed with foreign ones considered to be drought-resistant). Also, these measures altered local livestock breeds as well in the study area. Moreover, the measures created resource and livelihood competition in case of tourism and fishing based livelihood activity (sections 7.5.1 - 7.5.4).

Objective 3: Assess the livelihood vulnerability in the Lake Tana Basin

In order to identify the livelihood component most affected by climate change, the thesis uses the livelihood vulnerability approach. The result indicates that nearly all components of assets (social, psychical, financial, human, institutional and natural) tend to be vulnerable to climate change. However, the top vulnerable assets are physical and institutional capitals/assets (section 7.3).

Objective 4: Examine the implications of livelihood pattern change (caused by climate change and adaptation) for poverty and food security

The study assesses the effects of changes in livelihood pattern (changes in asset due to climate change) on the different dimensions of food security, namely: food access, availability, production and utilization (section 8.2.1). Particularly, the result shows that changes in natural assets have affected food access, utilization and availability and the effect on social capital has impacted food access and food availability (section 8.2.1). Moreover, while the effect of climate change on financial capital/asset has affected food access, utilization and availability, the effect on human capital has influenced the food access and availability components of food security (section 8.2.1). Another key finding also indicates that climate change has a negative effect on social capital (existing traditional and social systems). As such, climate change found to be have a negative effect both on food access and food availability at household level (section 8.2.2).

The overall implication is that climate change has a disaggregated effect on asset/capital and dimensions of food security. Moreover, the transmission channels of the effect of climate change vary.

In the same token, the study presented the implications of livelihood pattern change (change in livelihood strategy due to climate change) on dimensions of food security (section 8.2.2). The result shows that while all the new livelihood strategies improve food access (economic), only fish production has improved all the components of food security (physical access, economic access, utilization and availability) (section 8.2.2.) The result also reveals that petty trade improves food availability by further enhancing food production. The implication here is that livelihood pattern change (due to climate change related shocks) brought about disaggregated effects on the dimensions of food security.

The thesis also examines the implications of climate change adaptation for poverty and food security (Section 8.3.1). As such, the thesis assesses the implication of key climate change adaptation strategies, namely: sale of livestock (natural capital), the application of improved seeds, sale of physical assets (physical capital), application of irrigation, engaging in fishery activity, engaging in tourism activity and change in crop type. The finding shows that climate change adaptation has a disaggregated effect on the dimensions of poverty and food security (section 8.3.1).

Objective 5: Investigate whether climate change adaptation strategies are pro-poor nor not

Another finding of the study covers the pro-poorness of climate change adaptations. In this respect, the analysis shows that the poor are not benefiting much from adaptation strategies (section 7.5.1). The study evaluated climate adaptation strategies with respect to the poor using local criteria (section 7.5.2). In this regard, the PSD approach is used to identify farmers' choices of climate adaptation strategies. The five local criteria identified by the participants are: 1) a strategy should significantly reduce the negative effects of climate change, 2) it must be low cost, 3) it must be implemented using local knowledge and resources, 4) it must be long lasting (sustainability), and 5) it must easily be implemented within a short period of time. The result of the ranking exercise (using local criteria) shows that while afforestation, tree planting, shifting cultivation and modern irrigation relatively rank at the top, improved seeds and animal hybrids rank least (section 7.5.2).

9.4. RECOMMENDATIONS

This subsection discusses recommendations based on the key findings from the thesis:

- Rural communities whose livelihood depends on agriculture and on related economic activities are the most susceptible group of society with respect to climate change due to their reliance on a sector that is the most sensitive to the phenomenon. As such, there is a need to work towards rural industrialisation that would allow these communities to engage in agro-processing as well as non-agricultural sectors that can strengthen their resilience in the face of the negative consequences of climate change. This will reduce their dependency on vulnerable economic activities such as subsistence agriculture.

- Climate change affects all components of livelihood, therefore, there is a need to design strategies and measures tailored to each type of livelihood. Most adaptation strategies and programs focus on the agriculture sector but even though agriculture is the dominant economic activity in many rural areas, rural livelihood is actually multifaceted.

- Climate change affects traditional social capital systems that have implications for food security. Thus, there is a need to strengthen these systems to better protect the food security conditions of rural communities.

- Farmers are well-aware of the types of climate adaptation strategies that best fit their local context and conditions. Thus, climate change programs and policies that aim to develop climate adaptation strategies need to follow a bottom-up approach, rather than a top-down one. The bottom-up approach would allow farmers and community members to get involved in the planning and identifying of climate adaptation strategies suitable to their locality.

- Designing climate adaptation strategies need to consider the poor in society to protect them from the negative impacts of climate change. In any situation, the poor are always hardest hit. Thus, climate policymakers need to design inclusive polices that benefit vulnerable people. In order to be pro-poor, climate adaptation strategies and technologies need to consider cost, availability, ease of use and local fitness.

- Climate change and adaptation studies need to consider livelihood pattern change (change in asset and livelihood strategies) as an important analysis approach or concept to understand the complex pathways and transmission channels of the effect of climate change on poverty and food security.

- Climate change adaptation strategies directly or indirectly affect dimensions of poverty and food security components of rural communities. Thus, climate adaptation strategies and policies need to consider the implication of adaptation options for the different dimensions of poverty and food security because some strategies could worsen poverty and food security conditions of households. In addition, climate adaptation strategies have a disaggregated effect on poverty and food security. Thus, adaptation policymakers and program managers should always carefully consider the implications of the selected coping mechanisms for poverty and food security. In the same manner, climate adaptation strategies have a disaggregated effect on food security. Thus, the designing of climate adaptation strategies and programs need to consider the implication of climate change and adaptation for food security before the implementation of such the strategies.

9.5. SUGGESTIONS FOR FURTHER RESEARCH

The thesis has not been able to clearly identify the implications of changes in livelihood pattern (due to climate change and adaptation) for some of the dimensions of poverty and food security. This might be due the complex nature of the interaction between climate change, poverty and food security. As such, there is a need to conduct further analysis on how climate change and adaptation induce livelihood pattern changes which in turn impact poverty and food security conditions.

Moreover, the thesis has used cross-sectional study design to investigate how livelihood pattern is changing due to climate change and adaptation. Consequently, further research is needed to understand the dynamic change in rural livelihood over time (due to climate change and adaptation) which the selected type of study design has not been able to identify.

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APPENDICES

APPENDIX A: CONSENT FORM

CONSENT TO PARTICIPATE IN THIS STUDY

I, __________________ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.
I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.
I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).
I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.
I agree to the recording of the <insert specific data collection method>.
I have received a signed copy of the informed consent agreement.
Participant Name & Surname………………………………………… (please print)
Participant
Signature…………………………………………Date…………………
Researcher's Name & Surname: Naod Mekonnen Anega

Researcher's signature ………………… .Date…………………

APPENDIX B: PARTICIPANT INFORMATION SHEET

PARTICIPANT INFORMATION SHEET

Date: ________________________________

Title: Impact of Climate Change and Adaptation in the Lake Tana Basin Livelihood System: Implication for Food Security and Poverty

Dear Prospective Participant,

My name is Naod Mekonnen. I am now doing my PhD thesis with professor Frank de beer in the Department of Development at the University of South Africa. We are inviting you to participate in a study entitled Evaluation of the Impact of Climate Change and Adaptation in the Lake Tana Basin Livelihood System: Implication for Food Security and Poverty. I am conducting this research to find out how livelihood pattern is changing in the Lake Tana Basin as result of climate change and adaptations as well as its implications for poverty and food security in the basin.

You name and contacted details obtained from the Kebele administration and the section of the participants including you was random. Thus, your selection is random and chosen from the household list to participate in this study. The total number of participants is around 281. You are selected to take in this study to participate as a respondent and your role crucial in the completion of the research. The study involves questionnaires. The questionnaire will have sought to collect information related to demographic, socio economic, agricultural production, consummation, food security perception on climate change and livelihood related information. The expected duration of participation in the survey is 30 minutes.

Please note that participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason. Please also note that it will not be possible to withdraw once they have submitted the questionnaire and there are no any financial benefits that you get by being a participant in this study. There are no also negative consequences or inconvenience and/or discomfort that can be created to you as result of participating in this research.

You have the right to insist that your name will not be recorder anywhere and that no one, apart from the researcher and identified members of the research team, will know about your involvement in this research. In addition, your name will not be recorded anywhere and no one will be able to connect you to the answers you give. Your answers will be given a code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings.

Only data transcriber and data entry personnel and the researcher will have access to the data. Individuals will maintain confidentiality by signing a confidentiality agreement. Please note that confidentiality agreements should be submitted to the Research Ethics Review Committee for consideration. Your answers may be reviewed by people responsible for making sure that research is done properly, including the transcriber, external coder, and members of the Research Ethics Review Committee. Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records.

In another note, the data will also be used for other purposes, such as a research report, journal articles and/or conference proceedings. A report of the study may be submitted for publication, but still individual participants will not be identifiable in such a report. Please keep in mind that it is sometimes impossible to make an absolute guarantee of confidentiality or anonymity, e.g. when focus groups are used as a data collection method. A focus group is a kind of interview where 7-10 respondents selected from the community will participate a group to discuss on key issues related to the research focus.

While every effort will be made by the researcher to ensure that you will not be connected to the information that you share during the focus group, I cannot guarantee that other participants in the focus group will treat information confidentially. I shall, however, encourage all participants to do so. For this reason, I advise you not to disclose personally sensitive information in the focus group.

The research will make every effort to protect the security of the data. Thus, the researcher will store hard copies of your answers for a minimum period of five years in a locked cupboard/ in Addis Ababa and for future research or academic purposes; electronic information will be stored on a password-protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. Furthermore, the information will be destroyed at the end of the 5th year. In this regard, hard copies will be shredded and electronic copies will be permanently deleted from the hard drive of the computer using a relevant software programme.

There is no payment and reward for associated with participants of the study. Please also note that there are no costs incurred by you for being a participant in the study.

This study has received written approval from the Research Ethics Review Committee of the c*ollage of development studies,* UNISA.

If you would like to be informed of the final research findings, please contact Naod Mekonnen on +2510911347118. The findings are accessible for 2022. Should you require any further information or want to contact the researcher about any aspect of this study, please contact naodmekonnenn@gmail.com.

Thank you for taking time to read this information sheet and for participating in this study.

Thank you.

APPENDIX C: STUDY TOOLS

UNIVERSITY OF PREOTRA AND SOUTH AFRICA

THE IMPACT OF CLIMATE CHANGE AND ADAPTATION IN THE LAKE TANA BASIN LIVELIHOOD SYSTEM: IMPLICATION FOR FOOD SECURITY AND POVERTY

Household Questionnaire

INTRODUCTION: This questionnaire developed to collect data to assess and evaluate the impacts of climate change and adaptation in the lake Tan Basin Livelihood in Amhara region, Ethiopia. The expected implications from this PhD thesis would be to provide insights for informed decisions towards building climate resilient sustainable livelihood that help to reduce poverty and improve food security in a changing climate. Thus, I kindly request your valuable response based on the following questions.

1. **Location**

S.no	Location information	
1.1	Zone	
1.2	Woreda	
1.3	Kebele	
1.4	Village	
1.5	Basin Location	1.Lower basin 2.Upper basin
1.6	Climatic zone	1.Dega 2.Woyina Dega 3. Kolla

2. Demographic

S.no	2. Demographic	
2.1	Sex	1. Male 2. Female
2.2	Age in years	
2.3	Marital Status	1. Married 2. Divorced 3. Singe 4.Widowed
2.4	Family size	1.Male adult -------- 2.Female adult ------- 3.Male Children ------ 4. Female children __ 5.Total--------
2.5	Year of schooling	

3. Accessibility

3.1	Travel time to the nearest primary school (in minute	
3.2	Travel time to the nearest secondary school (in minutes)	
3.3	Distance to the nearest market (in km)	
3.4	Travel time to health extension service(in minutes)	
3.5	Travel time to farmers training centre (in minutes)	
3.6	Distance to all whether road (in kms)	
3.7	Distance to major water source (minutes)	

4. Household asset

S.no	Asset	Options	Response
4.1	House ownership	1.Own 2.Rented 3.Other ,	
4.2	Main Source of drinking water	1.Spring 2.River 3.Rainwater 4.Retail shops 5.Pipe water 6. Bore hole 7.Other	
4.3	Main Energy source for cooking	1.Fire wood, 2.Charcoal 3.Crop residue 4.Manure 5.Electricity 6. other	
4.4	Do you have consistent water supply	1.yes 2.no	
4.5	Do you have solar plate for power supply?	Yes 2. No	

5. Livelihoods (assets) conditions

Asset			
Natural asset	**5.1**	Do you have land registration certificate?	1. Yes 2.No
	5.2	Access to forest	1. Yes 2.No
	5.3	Access to grazing land	1. Yes 2.No
Physical capital	**5.4**	Access to drinking water	1.Yes 2.No
	5.5	Access to electricity	1.Yes 2.No
	5.6	Access to irrigation	1.Yes 2.No
	5.7	Road quality to market place	1.Bad 2.Not good 3.Good 4.Very good, 5.Excellent
Social capital	**5.8**	Membership in local associations	1.yes 2.no
	5.9	Held coffee ritual	1.yes 2.no
	5.10	Settled disputes in the past 12 month	1.yes 2.no
	5.11	Have you been the head of the community in the past 24 month	1.yes 2.no
	5.12	Have you received any kind of support from the community/ neighbour	
human capital	**5.13**	Household size	
	5.14	Age of the household head	
	6.15	Have you attended school of any sort?	
Institutional dimensions	**6.16**	Do you have land certificate?	1.Yes 2.No
	6.17	Regular extension services	1.Yes 2.No
	6.18	trainings received on climate change	1.yes 2.No
	6.19	credit access	1.yes 2.No
	6.20	Safety net beneficiary	1.Yes 2.No
	6.21	Forest use policy (rule)	1.Yes 2.No
	6.22	water use policy(rule)	1.Yes 2.No
	6.23	Information source about agriculture?	Extension Farmer to farmer Neighbourhood Radio Other
	6.24	Number of contacts with extension agents this year	
Financial capital	**6.25**	household annual income	
	6.26	Can you easily access credit	Yes No Don’t know

6. Climate system

	System	Reponses
6.1	Climatic zone	1.Lowland, 2.Middeland 3. Highland
6.2	Major crop production seasons	1.Belg 2.Meher 3.Both
6.3	Number of droughts in the last 5 years	
6.4	Number of flood in the last 5 years	
6.5	Number of frost in the last 5 years	
6.6	What is the effect of the climate related shocks (flood, drought and frost) your livelihood?	

7. Did your household produce any crops in the last 12 months?

1. Yes 2. No

8. Perception of the impact of climate variability

	Impacts Dimensions	1.Very low 2.Low 3.Medium 4.High 5.Very high 6.None 7.Don't know
8.1	Decrease in precipitation (rainfall)	
8.2	Decrease in fish production	
8.3	Ecosystem damage	
8.4	Decrease in biological productivity and plant cover	
8.5	Increasing of surface temperature	
8.6	High rainfall variability	
8.7	Decrease in livestock productivity	
8.8	Increased risk of livestock mortality	
8.9	Increased frequency of drought	
8.10	Food insecurity and loss of livelihood	
12.11	Depressed crop yields and shortened growing season	
8.12	Increase in climate related health effect	
8.13	Increased likelihood of forced sale of productive assets and indebtedness	
8.14	Migration of able bodied adults in search of off-farm employment	
8.15	Dependency on food relief and remittances	
8.16	Unsustainable exploitation of natural resources	
8.17	Decreases in total income	
8.19	Decrease in crop sales	
8.20	Decrease in food availability	
8.21	Decrease in food consumption	
8.22	Decrease in food storage	
8.23	Decrease in food per capita	
8.24	Low calorie intake	
8.25	Resource conflict	
8.26	High mobility	
8.27	Increase in incidence of flood	
8.28	Increase in the occurrence of unseasonal rain	

9. Climate Change, livelihood Strategies and Livelihood Pattern Change

Livelihoods strategies		Climate change impact		Climate Change Adaptation and Livelihood Pattern Changes	
	9.1 Has this [livelihood strategy] been your source of income for your household in the past 5 years?	9.2 Does climate change brought about change in this [livelihood strategy]? (in the past 5 years?)	9.3 If yes, please state the severity of the impact on the following livelihood strategies	9.4 Does climate change adaption brought about change in any of the livelihood strategies?	9.5 If yes, please state the severity of the impact on the following livelihood strategies
	1.Yes 2.No (if No, skip to next Livelihood strategy)	1.Yes 2.No (if No, skip to Q13.4)	1.Very minor 2.Minor 3.Medium 4.Severe 5.Highly Severe	1.Yes 2.No (if No, skip to next Livelihood strategy)	1.Very minor 2.Minor 3.Medium 4.Severe 5.Highly Severe
Crop production					
Livestock production					
Fishing					
Tourism					
Forest production					
Trade activities					
Employee in Public Inst.					
Employee in Private Inst.					
Self-employment					
Casual labour					
Other					

9.5. How does climate change affect your key livelihood strategies?
9.6. What changes have you observed in your livelihoods because of climate change?
9.10. What new livelihood did you peruse because of climate change?

10. Climate Change, Assets and Livelihood Pattern Change

			Climate change impact		Climate Change Adaptation and Livelihood	
Asset type	S.no.	10.1 Indicator	10.2 Have you observed any change in the following assets because of climate change in the past 5 years?	10.3 If yes, Severity of the impact	10.4 Does climate change adaptation brought about change in one or more of the following assets in the past five year?	10.5 If yes, Severity of the impact
			1.Yes 2.No 3.Don't know **If 2 or 3, skip to next indicator?**	1.Very minor 2.Minor 3.Medium 4.Severe 5.Very Severe	1.Yes 2.No 3.Don't know	1.Very minor 2.Minor 3.Medium 4.Severe 5.Very Severe
Natural asset	1	Grazing land				
	2	Water for agriculture				
	3	Agricultural land use				
	4	Forest cover				
Financial asset	5	Remittance				
	6	Borrow from a neighbour				
	7	Farm income				
	8	Income from livestock				
	9	Income from fishing activity				
	10	Credit from financial institutions				
Social asset	11	Group cooperation during challenge				
Human asset	12	Education (any interruption in family members)?		Number		Number
	13	Members migration (number)		Number		Number
	14	Access to health care when sick				
Physical asset	15	Housing: traditional (non-flood resistant) house				
Institutions	16	Access to credit				
	17	Frequency of extension contact				

10.6 How does climate change affected the different component of assets at your household? You can discuss in relation to social, financial, human, natural and physical assets.

10.7. What are the major effects of climate change on your assets because of climate change?

11. **Climate change and resource use**

	11. **Climate change and resource use**		
11.1	Does climate change affect resources use?	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q17
11.2	If yes, How		
11.3	Does the effect of climate change on assets and livelihood strategies brought change in resource access and uses changes?	1.Yes 2.No 3.Don't know	
11.4	If yes, How and what changes occurred?		
12. Climate change and food security			
12.1	Does climate change effect on asset affected food security?	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q21
12.2	If "Yes", indicate the severity of the impact on the following food security dimensions		
12.2.1	Crop production	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
12.2.2	Crop productivity	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
12.2.3	Food access	0.None 1.Very low 2.low 3.Medium	

		4.Severe 5.Very Severe	
12.2.4	The number of food type at the plate	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
12.2.5	Is there a change on household food security due to the change in livelihood strategies?	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q23
	How do your food security conditions affect by the impact of climate change on asset? You can tell me your experience in relation to any of the components of food society (number of food items, food access, food production and productivity)		
13	**Which part of food security conditions affected most because of the effect of climate change on livelihood strategies?**		
13.1	Crop production	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
13.2	Crop productivity	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
13.3	Food access	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
13.4	Number of food type on the plate	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
	How do your food security conditions affect by the impact of climate change on livelihood strategy? You can tell me your experience in		

	relation to any of the components of food society (number of food items, food access, food production and productivity)		
14. Climate Change, Livelihood Pattern Changes and Poverty			
14.1	Does climate change effect on asset-affected poverty?	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q25
14.2	If "Yes", indicate the severity of the impact on the following dimensions of poverty		
14.2.1	Income	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
14.2.2	Expenditure	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
14.2.3	Assets	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
	How does the impact of climate change on asset affected you? You can tell me your experience in relation to any of the components of poverty (income , expenditure and asset)		
14.3	Is there change on household poverty conditions due to the changes in livelihood strategies? (caused by climate change)	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q27
14.4	If yes, indicate the severity of the impact on the following poverty measures strategies		
14.4.1	Income	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	

14.4.2	Expenditure	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
14.4.3	Assets	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
14.4.4	How does the impact of climate change on livelihood strategies affected you? You can tell me your experience in relation to any of the components of poverty (income , expenditure and asset)		
15	Does the effect of climate change adaptation on asset affected food security conditions of the household?	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q29
15.1	If "Yes", indicate the severity of the impact on the following food security dimensions		
15.1.1	Crop production	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
15.1.2	Crop productivity	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
15.1.3	Food access	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
15.1.4	Number of food items on the plate	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
15.1.5	How the impact of climate change adaptation on asset affected you? You can tell me your experience in relation to any of the components		

	food security (crop production, crop productivity , food access and number of food items on the plate)		
16	Is there a change on household food security due to the change in livelihood strategies because of climate change adaptation?	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q18
17	If yes, which part of food security conditions affected most because of the effect of **climate change adaptation** on livelihood strategies?		
17.1	Crop production	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
17.2	Crop productivity	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
17.3	Food access	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
17.4	The number of food type at the plate	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
17.5	How the impact of climate change adaptation on livelihood strategies affected you? You can tell me your experience in relation to any of the components food security (crop production, crop productivity , food access and number of food items on the plate)		
18	Does the effect of **climate change adaptation** on asset-affected poverty conditions of the households?	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q33
18.1	If "Yes", indicate the severity of the impact on the following dimensions of poverty		

18.1.2	Income	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
18.1.2	Food expenditure	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
18.1.4	Assets	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
	How the impact of climate change adaptation on asset affected you? You can tell me your experience in relation to any of the components of poverty (income , expenditure and asset)		
19	Is there a change on household poverty conditions due to the change in livelihood strategies? (caused by climate change adaptation)	1.Yes 2.No 3.Don't know	If 2 or 3, skip to Q35
	If yes, indicate the severity of the impact on the following dimension of poverty		
19.1	Income	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
19.2	Expenditure	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
19.3	Assets	0.None 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	

19.4	How the impact of climate change adaptation on livelihood strategy affected you? You can tell me your experience in relation to any of the components of poverty (income , expenditure and asset)		
20. Climate Adaptation Practices			
20.1	For how many years did you live in this village?	[in number of years]	
20.2	Have you observed a change in the level of temperature in your neighbourhood?	1.Yes 2.No 3.Don't know	
20.3	Have you observed a change in the level of rainfall in your neighbourhood?	1.Yes 2.No 3.Don't know	
21	**Rank the challenges of climate change adaptation in the Lake Tana Basin**		
21.1	Unreliable water source	[Rank from 1 to 12]	
22.2	Agro-ecology	[Rank from 1 to 12]	
22.3	Distance and access to a market	[Rank from 1 to 12]	
22.4	Lack of information on climate change adaptation	[Rank from 1 to 12]	
22.5	Limited Income	[Rank from 1 to 12]	
22.6	High cost of farm inputs (i.e. fertilizer, Pesticides, improved seeds)	[Rank from 1 to 12]	
21.7	Poor agricultural extension service Delivery	[Rank from 1 to 12]	
21.8	High cost of irrigation facilities	[Rank from 1 to 12]	
21.9	Lack of support from government	[Rank from 1 to 12]	
21.10	Credit constraints	[Rank from 1 to 12]	
21.11	Shortage of labour	[Rank from 1 to 12]	
21.12	Land constraint	[Rank from 1 to 12]	
22	If you observe changes in temperature, precipitation and rainfall, what measures (most often) have you taken in the past three years. (If Q20.3 or Q20.2 is yes)		

	Climate adaptation practices	Options	Repons es
22.1	Modern Irrigation	1=Yes,0=No	
22.2	Improved agronomic practices	1=Yes,0=No	
22.3	Improved seeds	1=Yes,0=No	
22.4	improved animal hybrids reared	1=Yes,0=No	
22.5	Fallowing	1=Yes,0=No	
22.	Shifting Cultivation	1=Yes,0=No	
22.7	Crop production diversification	1=Yes,0=No	
22.8	Soil and Water Conservation	1=Yes,0=No	
22.9	Tree Planting	1=Yes,0=No	
22.1 0	Crop rotation	1=Yes,0=No	
22.1 1	Off-farm activities	1=Yes,0=No	
22.1 2	Sale of labour	1=Yes,0=No	
22.1 3	Selling of honey, clothes, or home made products like mattresses, hot food, beverages, whips and ropes	1=Yes,0=No	
22.1 4	Selling of assets	1=Yes,0=No	
22.1 5	Migration	1=Yes,0=No	
22.1 6	Traditional irrigation	1=Yes,0=No	
22.1 7	Frequency of Irrigation farming practice	1. Increased 2. Decreased 3. No change	
22.1 8	Frequency of Improved Agronomic practices	1. Increased 2. Decreased 3. No change	

22.19	Number of improved seeds has been	1. Increased 2. Decreased 3. No change	
22.20	Animal hybrids	1. Increased 2. Decreased 3. No change	
22.21	Frequency of Fallowing	1. Increased 2. Decreased 3. No change	
22.22	Rate of shifting cultivation	1.Increased 2. Decreased 3. No change	
22.23	Frequency of crop rotation	1.Increased 2. Decreased 3. No change	
22.24	Frequency and cycle of land ploughing	1.Increased 2. Decreased 3. No change	

23. Household expenditure and climate change			
23.1	Does climate **change** affected your annual expenditure in the past 3 years?	1.Yes 2.No	If No, skip to Q52
23.2	If yes, indicate the severity of the impact of clime change on expenditure	1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
23.3	Does climate **adaptation** affected your annual expenditure in the past 3 years?	1.Yes 2.No	If No, skip

			to Q53
23.4	If yes, indicate the severity of the impact of clime adaptation on expenditure on food expenditure items	1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
23.5	If yes, indicate the severity of the impact of clime adaptation on expenditure on non-food expenditure items	1.Very low 2.low 3.Medium 4.Severe 5.Very Severe	
24	**Household income**		
24.1	Does **climate change affected** your level of income	1.Yes 2.No	If No, skip to Q25
If yes, indicate the severity of the impact on each source of income (Not Applicable=if income source is not applicable to your household)		0.No impact 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe 6.Not Applicable	
24.1	Farm income		
24.2	Non-farm income		
24.3	Assistance (aid)		
24.4	Remittance		
24.5	Credit (borrowings)		
24.6	Saving		
24.7	Explain how climate change affected your income		
25	**Does climate adaptation affected your level of income**	1.Yes 2.No	If No,

			skip to Q26
If yes, indicate the severity of the impact on each source of income (Not Applicable=if income source is not applicable to your household)		0.No impact 1.Very low 2.low 3.Medium 4.Severe 5.Very Severe 6.Not Applicable	
25.1	Farm income		
25.2	Non-farm income		
25.3	Assistance (aid)		
25.4	Remittance		
25.5	Credit (borrowings)		
25.6	Saving		
25.7	Others		
25.8	Explain how climate adaptation affected your income		
26.Perception about climate change variable in the Lake Tana Basin			
26.1	What is your opinion on the following statements in the past 5 years in the basin	1.Strongly Disagree 2. Disagree 3.Neutral 4.Agree 5.Strongly Agree 6.Don’t know	
26.2	The temperature got hotter over the years		
26.3	Rain becomes lesser and unexpected over the years		
26.3	Precipitation becomes more unpredictable over the years		
26.4	Rainfall becomes more unpredictable from year to year		
26.5	There is long term shifts in precipitation on your		

26.6	There are long-term shifts in temperature in your area or farm?		
26.7	I have experienced rainfall to be steady over the last 5 years		
26.8	I have lost more corps during the last years because of bad weather conditions		
26.9	I have lost more livestock during the last years because of bad weather conditions		
26.10	The quality of the harvest has become worse in the last years		
26.11	The quality of the harvest has affected sales of the product		
26.12	My income decreased due to loss the loss of crops /livestock resulting from bas weather		
27 Farmers' perception of increasing temperature and decreasing precipitation past 5 years			
	Indicators of temperature change		
27.1	Longest months with high day time temperature	1.Yes 2.No	
27.2	Frequent occurrence of heat-induced crop disease	1.Yes 2.No	
27.3	Switch to heat tolerant crop types/varieties (not previously adapted to the area	1.Yes 2.No	
27.4	Frequent occurrence of heat-induced livestock disease	1.Yes 2.No	
27.5	Frequent occurrence of heat-induced human disease	1.Yes 2.No	
27.6	Emergence of new plant species/invasive species in the form of weed	1.Yes 2.No	
27.7	Quick disappearance of water sources/points due to high evaporation	1.Yes 2.No	
28	**Indicators of precipitation change**		
28.1	Shortened length of rainy season	1.Yes 2.No	
28.2	Change in planting time/date to adjust to onset of rainfall	1.Yes 2.No	
28.3	Early onset and early exit of rainy season	1.Yes 2.No	

28.4	Erratic nature of rainfall/Increased volume of rainfall at a time	1.Yes 2.No	
28.5	Late onset of rainy season	1.Yes 2.No	
28.6	Crop failure due to water shortage	1.Yes 2.No	
28.7	Switch to drought tolerant crop types/varieties (not previously adapted to the area)	1.Yes 2.No	
29. Climate change adaption and its pro poorness			
29.1	Are the poor benefiting from adaptation measures?	1.Yes 2.No	
29.2	Are adaption measures helping the poor in the fight against the negative impacts of climate change	1. Yes 2.No	
29.3	What measures are need to be taken so that the poor could be benefited from adaptation measures?		

30. Rank impact of climate change on the following livelihoods

30.1 Livelihoods						
	Highly Severe (5)	Severe(4)	Medium(3)	Minor (2)	Low (1)	No (0)
Crop production						
Livestock production						
Mixed farming						
Fishing						
Tourism						
Other to be identified						

In-depth interview

- How do you express the change in the climate (rainfall and temperature) in your area?
- What is your major sources of livelihood?
- What is the impact of climate change on these sources of livelihood?
- What changed in your livelihood because of the impact of climate change?
- What is the impact of climate change on assets? You can tell me your observation and experience in relation to social, financial, physical, human, and natural assets.
- What is the impact of climate change on livelihood strategies?
- How does the impact of climate change on livelihood strategies affected you? You can tell me your experience in relation to any of the components of poverty (income, expenditure and asset)
- How does the impact of climate change on assets affected you? You can tell me your experience in relation to any of the components of poverty (income, expenditure and asset)
- How does the impact of climate change on livelihood strategies affected you? You can tell me your experience in relation to any of the components of food security (food production, productivity, food access and number of food items on the plate)
- What adaptation measures have you taken to respond to the negative impacts of climate change?
- What is the impact climate adaptation on livelihood strategies and assets?
- How the impact of **climate adaptation strategies** on assets and livelihood strategies affected you? You can tell me your experience in relation to any of the components of poverty (income, expenditure and asset)
- How the impact of **climate adaptation strategies** on livelihood strategies affected you? You can tell me your experience in relation to

any of the components of food security (food production, productivity, food access)

Key informant interview

- How do you express climate change in your area?
- What is the impact of climate change on the Lake Tana Bain livelihoods?
- How livelihood is changing because of climate change?
- What are the implications of livelihood change for dimensions of poverty (income, asset and expenditure)?
- What is the implication of livelihood change for dimension of food security (crop production, crop productivity, food access, number of food items on the plate)?
- What are the key adaptation strategies in the basin?
- Do you think climate adaptation strategies changed livelihood pattern? If yes, how?
- What are the implications of livelihood change for poverty (in relation to income, asset and expenditure)?
- What is the implication of livelihood changes for food security (crop production, crop productivity, and food access, number of food items on the plate)?

FGD Questionnaires

- What is the impacts of climate change on livelihoods in your area?
- Which livelihood is changing because of climate change?
- What is the implication of livelihood pattern change for poverty and goof security?
- What the impact of climate change adaptation on livelihood?
- Which livelihood is changing as because of climate change adaptation?
- Are climate adaptation strategies pro poor? If not what are the reasons?

- List five major reasons why climate adaptation strategies are nor pro-poor and rank them.

Reason	Rank

Participatory Scenario Development (PSD)

- What is the impact of climate change on livelihood in your area?
- Are climate adaption measures helping the poor in the fight against the negative impact of climate change? If not what are the reasons?
- List five criteria to rank climate adaptation strategies based on their usefulness using locally derived criteria
- Rank climate change adaptation options in your basin using the locally derived criteria

Technology	Local criterion 1	Local criterion 2	Local criterion 3	Local criterion 4	Local criterion 5
Modern irrigation					
Improved agronomic practices					
Improved seeds					
improved animal hybrids reared					
Fallowing					
Shifting Cultivation					
Water conservation works					
Crop rotation					
Traditional irrigation					
Terracing					
Conservation Tillage					
Afforestation					

With low scores signified by 1 dot and high scores by 4 dots

- What measures are needed to make climate adaptation work for the poor?

- List three criteria to make climate change adaptation work for the poor

- Rank climate change adaptation strategies based on the above listed three criteria

Adaptation strategies	**Criterion 1**	**Criterion 2**	**Criterion 3**
Modern irrigation			
Modern fertilizer			
Improved seeds			
Improved animal hybrids			
Fallowing			
Shifting cultivation			
Rain water harvesting			
Tree planning			
Crop rotation /switching			
Traditional irrigation			
Terracing			
Tillage			
Afforestation			

1=dots low score, 2= dots medium score and 3= dots high score

APPENDIC D: ETHICAL CLEARANCE CERTIFICATE

UNISA university of south africa

COLLEGE OF HUMAN SCIENCES RESEARCH ETHICS REVIEW COMMITTEE

11 February 2020

NHREC Registration # : Rec-240816-052

CREC Reference # : 2020-CHS-Depart-64078558

Dear Naod Mekonnen Anega

Decision:
Ethics Approval from 11 February 2020 to 11 February 2023

Researcher(s): Naod Mekonnen Anega

Supervisor(s): Prof FC De Beer

develo@telkomsa.net

Evaluation of the Impact of Climate Change and Adaptation in the Lake Tana Basin Livelihood System: Implication for Food Security and Poverty

A
G

Qualifications Applied: PhD in Development Studies

APPENDIX E: TECHNICAL NOTES FOR THE DATA COLLECTORS

The main objective of the thesis is to examine how climate change and adaptation are changing livelihood pattern (change in assets and livelihood strategies) in the Lake Tana Basin and the implications of this change in livelihood pattern on key livelihood outcomes (poverty and food security.)

Sampling design for the quantitative data collection: The study will make use of the three stage sampling procedure. In the first stage, the Lake Tana sub basin, found in the Amhara regional state of Ethiopia purposely selected for two reasons. In the second stage one Keble from upper basin and one Keble from the lower basin will be randomly selected which add up to two Kebeles. In the third stage, the study units or households randomly selected to collect relevant data on agriculture, food security, income, livestock, climate adaptation practices, consumption, poverty, demographic information etc.

Sampling size: The Households survey at the two immediate Kebeles found in upper and lower sub-basins. According to (Solomon, Adesola and Rao, 2016:3) the total number of farmers found in the immediate Kebeles of the upper and lower sub-basin is around 19,500. The sample households selected from both the upper and lower sub-basins using sample size determination formula proposed by Cochran (1997). Using this formula, the total number of sample of household to be covered in the study is 281.

Appendix E: CERTIFICATE OF TRANSLATION

Haced Consultancy

CERTIFICATEOF TRANSLATION

This is to certify the translation of informed consent and questionnaires for the project entitled "EVALUATION *OF THE IMPACT OF CLIMATE CHANGE AND ADAPTATION IN THE LAKE TANA BASIN LIVELIHOOD SYSTEM: IMPLICATION FOR FOOD SECURITY AND POVERTY" by our firm to Mr. Naod Mekonnen Anega.*

The service was performed to translate the following documents from English to Amharic:

1) *Informed consent*
2) *Structured questionnaires tool*
3) *in-depth interview guide*
4) *Key informant interview*
5) *Focus group discussion*

ዶ/ር ሀብታሙ አዳነ
ዋና ስራ አስኪያጅ
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General Manager

Mob.
0924134123

Date: 02/08/2019

Email: habtamuadane@yahoo.com

hacedconsultancy@gmail.com

Appendix F: INFORMED CONSENT FORM

በደቡብ አፍረካ ዩኒቨርስቲ

የ ኢኮኖሚ ልማት ጥናት ትምህርት ክፍል

መረጃ መስጫ ቅፅ፡

በቅድሚያ ጤና ይስጥልኝ! እኔ …………………. የተባልኩ የመጣሁት ከደቡብ አፍሪካ ዩኒቨርስቲ ነው። እየሰራን፡ ያለነው፡ ጥናት፡ በአየር ንብረት ለውጥ ምክንያት እና የአየር ንብረት ለውጥጡን ለመቋቋም በማህበረሰቡ በተወሰዱ አና በሚወሰዱ ሰራዎች እንዴት የጣና ሃይቅ አከባቢ እና የማህብረሰቡን የኑሮ መሰረት እና ዘይቤ እየተቀየረ እንዳለ ለመረዳት ነው። ይህም ለወደፊት ጥናቶች እንደመነሻ መረጃ እና የአየር ፀባይ ለውጥን በተገቢው መንገድ ለመቋቋም የሚረዱ የፖሊሲ አማራጮችን ለመቅረጽ ይረዳል፡ ለጥናቱ የሚያስፈልጉ መረጃዎች ከእርሶ፡ እና ከተለያዩ ባለሞያዎች የሚሰበሰብ ይሆናል።ስለዚህም የእርስዎ በዚህ ጥናት ላይ መሳተፍ እጅግ በጣም ወሳኝ ነው።እርስዎ በዚህ ጥናት ላይ ለመሳተፍ የተመረጡት፡ በእድል፡ ሲሆን በዚህም፡ ጥናት፡ ላይ እንዲሳተፉ፡በትህትና፡ እንጠይቆታለን። በዚህ፡ ጥናት፡ ላለመሳተፍ፡ መሉ፡ መብት፡ ያሎት ሲሆን ፡ ለመሳተፍ፡ ከመረጡ፡ ደግሞ፡ ቃለመጠየቁን፡ በፈለጉት፡ ጊዜ፡ የማቋረጥ፡ መብት፡ አሎት። በዚህ ጥናት ላይ በመሳተፍዎ ወይም፡ ባለመሳተፎ ወይም፡ በማቋረጦ፡ ምንም አይነት ተጽኖ፡ አይመጣበትም ።

ማንኛውም እርስዎ የሚሰጡት መረጃ ሚስጥራዊነቱ የተጠበቀ ይሆናል። ከዚህ ጥናት የተሰበሰበው መረጃ ሙሉ፡ ሚስጥራዊ፡ ቁጥርን፡ በመጠቀም፡ እና፡ መረጃው፡ እንዲቆለፍ፡ በማድረግ፡ ሚስጥራዊነቱ የተጠበቀ እንዲሆን፡እናደርጋልን። ከጥናት፡ ቡድን፡ ውጪ፡ ማንም፡ የተሰበሰበውን፡ መረጃ፡ ማግኘት፡ አይችልም። እንዲሁም መረጃዎቹ ከተገለፁት ዓላማዎች ውጪ ለሌላ ዓላማ የማይውል መሆኑን ልናረጋግጥልዎ እንወዳለን። ይህ፡ ጥናት፡ እንዲሳካ፡ የርሶ፡ ፍቃደኝነት፡ እና፡ የነቃ፡ ተሳትፎ፡ በጣም አስፈላጊ፡ ነው። በዚህ፡ ጥናት፡ ለመሳተፍ፡ ከተስማሙ፡ ጥያቄዎችን፡ እንጠይቆታለን። ቃለመጠይቁ፡ 90 ደቂቃ፡ ይወስዳል።

ስለጥናቱ ይበልጥ ማወቅ ከፈለጉ የጥናቱን መሪ ናእድ መኮንንን ማግኘት ይችላሉ። +2510911347118

ስለዚህ ጥናት መጠየቅ የሚፈልጉት ነገር አለን?

በዚህ ጥናት ለመሳተፍ መስማማቶን፡ የሚገልፁበት፡ ቅጽ

እኔ፡ ከዚህ፡ በታች፡ የፈረምኩት፡የዚህን፡ ጥናት፡ አላማ፡ በመገንዘብ፡ እንዲሁም፡ ሀሳቤን፡ ከቀየርኩ፡የመውጣት፡ መብት፡ እንዳለኝ፡ በማወቅ፡ በዚህ፡ ጥናት፡ ለመሳተፍ፡ መስማማቴን፡ አረጋግጣለሁ።

የተጠያቂው ፊርማ፡ ---ቀን፡---------------/-------------/-----

ቃለመጠየቁን፡ የሚያደርገው፡ ሰው፡ ስም፡ አቶ/ ወ/ሮ/ወ/ሪት --------------------------------ቀን-----------/--------/--------

Appendix G: TIME SHEET USED DURING THE PSD

Activity	Time allocated	Outcome
Introduction • Introducing of the participants to each other • Objective of the PSD	20 minutes	Participants understood the objective of the research and PSD exercise
Discussion issues • perception about the effect of climate change • the different effects of climate change • Climate change adaptation options • Developing local criteria for climate change adaptation	1 hour	Climate change impacts identified Local adaptation criteria developed
Rank climate change adaptation options	1 hour	Adaptation options ranked using local criteria
Closing remarks	10 minutes	

Appendix H: LEOPOLD MATRIX

Livelihoods	Priority							
	Highly Severe (5)	Severe(4)	Medium(3)	Minor (2)	Low (1)	No (0)	Total frequency	Ranking
Crop production								
Livestock production								
Mixed farming								
Fishing								
Tourism								
Other to be identified								

Source: Sheikh & Akter(2017)

Appendix I: ENGLISH LANGUAGE CERTIFICATE

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CERTIFICATE of ENGLISH EDITING

This certificate confirms that the manuscript listed below was edited by expert English editor.
The following issues were corrected. grammar, spelling, punctuation, sentence structure, and phrasing.
The respective institution can contact *us for a copy of the edited document that was submitted to the authors.*

Manuscript Title:

Climate Change, Adaptation and Livelihood Changes in the Lake Tana Basin: Implication for Food Security and Poverty.

Author:

Naod Mekonnen Anega

Date issued:

July 05, 2023

Certificate number:

ET.123686.

General Manager