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þÿ S m a l l h o l d e r   F a r m e r   s   P e r c e p t their Adaptation Strategies to Climate Change and Variability in the Dangila District of Awi Zo Ne, Ethiopia

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SMALLHOLDER FARMER'S PERCEPTION AND THEIR ADAPTATION STRATEGIES TO CLIMATE CHANGE AND VARIABILITY IN THE DANGILA DISTRICT OF AWI ZO NE, ETHIOPIA

MSc Thesis

BY

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Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (MSc.) in “Environment and Climate Change.”

Advisor: - Solomon Addisu (PhD)

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THESIS APPROVAL SHEET

As a member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Abaynew Mulat Yimenu entitled **"Smallholder Farmer's Perception and their Adaptation Strategies to Climate Change and Variability in Dangila District of Awi Zone, Ethiopia."** We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (MSc) in Environment and Climate Change.

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DECLARATION

This is to certify that the thesis entitled **"Smallholder Farmer's Perception andtheir AdaptationStrategies to Climate Change and Variability in Dangila District of Awi Zone, Ethiopia."** Submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in **"Environment and Climate Change"** to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. Abaynew Mulat is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for an award of any degree or diploma to the best of our knowledge and belief.

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ABSTRACT

Climate change is a global phenomenon. Its impact on agricultural activities and the livelihood of the population in developing countries has increased dramatically. Understanding how farmers perceive climate change and how they adapt to it is very important to the implementation of adequate and relevant adaptation strategies. This study was conducted in the Dangila district to investigate farmers' perception and the trend of rainfall and temperature, the adaption strategies, and the factors that impact their choice to adapt by sampling 138 farm households. Both primary and secondary data sources were used in the study. The survey questionnaire, FGD, and KII were used to gather the data. The Mann-Kendall trend test and Sen's Slope estimator were used to analyze the trend and magnitude of climate change. Furthermore, descriptive statistics and a multinomial logit model were used to identify adaptation strategies and determine factors that influence the choice of adaptation strategies, respectively. The rainfall showed a non-significant increasing trend in winter (Bega), summer (June – September), and annually. However, there is a non-significant decreasing trend of rainfall in the spring (Belg) season. From 1991-2022, the annual maximum and minimum temperatures have shown a statistically significant increasing trend, with recorded increments of 0.3 ^{O}C decadal with a 0.03 ^{O}C yearly increasing rate. Farmers perceived an increase in annual temperature and a decrease in rainfall trend with low variability. Among the interviewed farmers chi-square test showed a significant variation in the perception of temperature and rainfall over Agroecology and Sex. The descriptive statistics results that the main adaptation strategies used by farmers include the use of improved variety, soil and water conservation, planting trees & agroforestry, and use of irrigation & water harvesting. The multinomial logit model revealed determinant factors such as gender, age, family size, educational level, farming experience, access to extension service, access to climate information, lack of infrastructure, farmland size, agroecological zone, Tropical livestock Unit, and financial interest which has a positive and negative impact on different adaptation strategies in the study district. Given the main study outcomes, it is recommended that rural development approaches should be put into practice to support farmers in adapting to the climate-related impact and the risks they encounter more effectively.

Keywords: adaptation, climate change, climate variability, rainfall, temperature

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LIST OF ABBREVIATIONS AND ACRONYMS

BIC	Bayesian Information Criterion
CBD	Coffee Berry Disease
FDRE	Federal Democratic Republic of Ethiopia
FGDs	Focused Group Discussions
FMD	Foot & Mouth Diseases
GDP	Gross domestic product
GHGs	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
KII	Key informant interview
KNMI	Koninklijk Netherlands Meteorological Institute
masl	Meter above sea level
MDGs	Millennium Development Goals
MoSR	Ministry of Water Resources
NAPA	National Adaptation Programme of Action
NMSA	National Meteorological Services Agency
NVEO	Natural Volatiles & Essential Oils
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PANE	Poverty Action Network in Ethiopia
PPR	Peptides Petites Ruminate
SPSS	Statistical Package for Social Science
SWC	Soil and Water Conservation
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Chapter 1. INTRODUCTION

1.1 Background of the Study

On a worldwide scale, climate change hazards are increasing, and agriculture remains one of the most vulnerable sectors (Ado *et al.*, 2020; Alves *et al*., 2020 & Getahun *et al*., 2021) causing stress on food supply systems in different parts of the world (Getahun *et al.*, 2021). The climate system is warming, as shown by measurements of changes in global average air and ocean temperatures, widespread ice and snow melting, and rising world average sea level (Pachauri *et al.*, 2014). The IPCC (2018) report indicates that Over the past 100 years, the average surface temperature of the planet has risen by 0.6 ^{O}C, and this warmth has significantly changed precipitation and atmospheric moisture. The community and the world's major ecosystems can be greatly impacted by global climate change, particularly the less developed societies (Alves *et al*., 2020; Asfaw *et al.*, 2018).

According to Bimir (2022); Falco *et al*. (2012) & IPCC (2014) the impacts of climate change, like an increase in temperature and a decrease in rainfall, are hardly evident in Africa. Rainfed agriculture yields may drop by up to 50% by 2020 (Pachauri *et al.*, 2014), with smallholders being the notable affected. Temperature increases between 3 ^{O}C and 4 ^{O}C in Africa by the end of the 21th century (Bryan *et al*., 2010; Getahun *et al*., 2021). The effect of climatic variability and change is more severe in developing countries than the developed ones due to high vulnerability and least capacity to adapt to those changes (IPCC, 2018). Africa's high sensitivity to the impacts of climate change and irregularity is increased by widespread poverty, periodic droughts, and floods, dependency on natural resources and biodiversity, overdependence on rainfed agriculture, and conflicts that have ringed the continent (IPCC, 2018; Gebru *et al.*, 2020).

The climate of Ethiopia is considered to offer high variability annually, seasonally, and geographically (Paul *et al*., 2018). Rainfall is delayed by several weeks or stopped during critical germination periods, leading to short and long-term droughts with crop failures, food shortages, and famines. Likewise, when occurring during the dry season, rainfall can facilitate the spread of crop diseases (Evangelista & Young, 2013; Paul *et al*., 2018). Between 1951 and 2006, the mean annual temperature in Ethiopia increased by 0.37 ^{O}C every decade, and between 1960 and 2006, the mean annual temperature increased by 1.3 ^{O}C, at an average rate of 0.28 ^{O}C per decade (Asfaw *et al*., 2018; Mcelwee *et al.*, 2018). Thus, Ethiopia is commonly one of the greatest examples of being highly vulnerable to future climate change and variability (Alemayehu & Bewket, 2016). Consequently, between 80-95% of Ethiopia's agriculture is rainfed and the nature of Ethiopia's agriculture, primarily rainfed implies production is sensitive to the fluctuations of rainfall, at that moment the economy is extremely exposed to climate variability and extremes, which infers increase of land degradation, soil erosion, deforestation, loss of biodiversity, flood hazard, recurrent drought, scarcity of water and desertification (IPCC, 2014; Falco *et al.*, 2012 & Solomon *et al*., 2021). Although, the damage differs across different Agroecological zones (Chmura *et al*., 2021). Ethiopia is the 22th most vulnerable country and the 31th least organized country implies that it is vulnerable to, yet largely unaware of addressing climate change effects (Chmura *et al*., 2021).

Especially in the highland areas of Ethiopia, have exerted pressure on land resources, and this requests for policies and strategies directed to facilitating practices that could enhance adaptation and mitigation of climate change effects (Carthy *et al*., 2011; Mihiretu *et al.*, 2020). Mitigation efforts to reduce the sources of or enhance the sinks of greenhouse gas (GHG) will take time and require international cooperation. Adaptation, in contrast, can reduce climate-related hazards in human-managed systems on regional and local scales, often with a short principal time (Marie *et al.*, 2020; Hilemelekot *et al*., 2021). Adaptation can manage the impacts but cannot by itself solve the problem. Even with adaptation, there will be residual costs (Marie *et al.*, 2020). Smallholder farmers, for instance, can change to more adapted crop varieties, but they may have lower productivity (Gebru *et al*., 2020). Climate change adaptation is mostly location-specific, and its effectiveness depends on local institutions and socioeconomic settings (Molla *et al*., 2014; IPCC, 2018). Therefore, this research was designed to study climate change and variability adaptation strategies practiced by smallholder farmers in the Dangila district, Awi zone, Ethiopia.

1.2 Statement of Problem

The worst effects on Ethiopia's agricultural activities have resulted from precipitation, and temperature (West Africa, 2010). Which had previously been somewhat fixed but are now quite dynamic and changeable (Alemu & Mengistu, 2018; Falco *et al.*, 2012). Extremely inefficient mixed crop-livestock production dominates the agricultural sector (IPCC, 2014b). Soil degradation, inadequate supplementary services like extension, credit, marketing, and infrastructure, as well as climate variables like droughts and floods, are the main causes of low productivity. Similarly, Soil erosion within the Rural part of Dangila District is severe and the result of the steep and hilly topography, a low degree of vegetation cover, and environmental stress (Addisu Legesse, *et al*., 2020).

Various studies have revealed a strong correlation between fluctuations in rainfall patterns and Ethiopia's agricultural gross domestic product (GDP) (Abid *et al*., 2015; Abera *et al.*, 2018). However, farmers' current understanding of climate change and adaptation methods is inadequate to accurately predict the impacts of climate change or to develop effective adaptation strategies (Berhanu *et al*., 2021; Harmer & Rahman, 2014). As a result, governmen tal adaptation enterprises, policies, and innovation are also limited. Due to insufficient irrigati on capabilities, intercropping practices, and climate adaptation measures, a detailed review of literature and research is necessary to address these challenges (Legese, 2017; Akinnagbe & Irohibe, 2015). Farmers are vulnerable to the issue of climate change because agriculture is naturally dependent on rain for output. Climate hazards including flooding, environmental deg radation, unpredictable rainfall that comes and goes the expected period, crop pests and diseas es, and temperature rise all have an ongoing impact on agricultural production (Benti & Abara , 2019; Field *et al*., 2014). Several farmers have varying capacities for approaches to coping with the effects of climate variability and change. Farmers in the various agricultural zones are unable to adequately adjust to climate change and variation (Abid *et al*., 2015; Toni *et al.*, 2022). There is a lack of studies that explain the mechanisms and variables that influence far mers' adaptation to climate change and variability. In particular, there hasn't been any research involving establishments to the general capacity for adaptation of agricultural households in the Dangila district. The issue of understanding climate change impacts at the farm level can be enhanced by documenting local knowledge, attitudes, and practices; it is not well documented at the local level what and how adaptation is practiced (Tiyo *et al.,* 2015; Debela *et al.*, 2015). Subsequently, an adaptation strategy is necessary to cope with the negative effects of climate change and variability as well as to sustain the production and productivity of households (Techniques *et al*., 2016; Likinaw, 2022). Likewise, knowledge of the adaptation methods on the adjacent of smallholder farmers may make it better to tackle the challenge of climate change (Akinnagbe & Irohibe, 2015). Climate change's current and expected effects differ locally, nationally, and regionally (Mengistu *et al.*, 2014). The impacts of climate change on smallholder farms were locally specific and difficult to quantify due to variations and complexity of farming systems and farmers' livelihoods (Tiyo *et al.,* 2015).

Methods for adaptations that work effectively to protect subsistence farming's future, Policymakers, agricultural agents, NGOs, researchers, communities, and to a greater extent for subsistence farming all need to involve the local peoples of the study District. Hence, one of the districts particularly vulnerable to climate change and variability is Dangila district with irregular and/or unpredictable rainfall and increased temperature. This work has given directions to reduce/mitigate this issue for the shortage of practices and solutions aimed at coping with climate variability. Hence, it's crucial to understand how climate change and unpredictability impact households in establishing successful policies. To fill this gap, the aims of this study have been directed at assessing trends and householders' perceptions of climate change, identifying current adaptation measures, and determining the elements that affect adaptation.

1.3 Objective of the Study

1.3.1 General objective

The general objective of this study was to investigate farmers' perceptions and their adaptation strategies to climate change and variability in the Dangila District.

1.3.2 Specific objectives

The specific objectives of this research were:

- To analyze the trends of rainfall and temperature in the study area (1991 – 2022),
- To assess farmers' perceptions of climate change and variability in the study area
- To identify adaptation strategies used by farmers in response to climate change impacts in the study area.
- To examine the determinant factors to adapt climate change and variability in the study area.

1.4 Research Question

To achieve the research objectives and to assess the adaptation strategies of farmers to climate change in the study area the following research questions were formulated.

1. What are the trends of rainfall and temperature in the study area during the period of 1991 - 2022?
2. How farmer's perceptions of climate change and variability in the study area?
3. What are the current adaptation mechanisms to climate change and variability in the study area?
4. What are the determinant factors that affect adaptation strategies to climate change and variability in the study area?

1.5 Scope of the Study

The scope of the study is limited to the Dangila district of the Awi zone, Ethiopia. The study was used to determine temperature and rainfall trends and variability from the period 1991 - 2022.

1.6 Significance of the Study

The study has a significant contribution to local administration and other stockholders to minimize the impact of climate variability and create a healthy productive community at the local level. This study will also carried out for academic purposes and may contribute to policy making, and the extension agent use the findings of this study to help the community to better face extreme climate change. To provide significant information for another large-scale study to identify the gap that can be filled by material in the study area.

Chapter 2. LITERATURE REVIEW

2.1 Definitions and Concepts of Climate-related Terms

The climate is the long-term, average weather pattern as copied by elements like temperature, precipitation, and wind (Hameso, 2015; Teklewold *et al*., 2019). It's different from weather, which consists of short-term atmospheric conditions described in a variety of daily or weekly occurrences like temperature, rainfall, and humidity (Hameso, 2015). The phrase "climate change" (CC) refers to any change in the climate over a long period, whether it is the result of natural variability or human activity (IPCC, 2018; Atinkut & Mebrat, 2020). Climate variability (CV) is short-term, naturally occurring, and unaffected by human activities' unpredictability in the weather. One of the variables influencing climatic variability is the El Nino Southern Oscillation (IPCC, 2018; Fayera, 2022).

According to IPCC (2014); and Chinasho *et al*. (2017) adaptation is an adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. Climate change adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities (Timilsina, 2021). According to the study conducted by Darge (2023); and Madurga-Lopez *et al*. (2022), the adaptation and mitigation potential of developing countries to climate change are weakened as a result of poor building designs of agriculture, food insecurity, low income, deforestation, and conventional solid waste management systems. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climatic change and variability. It is all changes in a system, compared to a reference case that reduces the adverse effects of climate change (Chinasho, 2017; Gezie, 2019).

Climate change adaptation is viewed as a package of actions through which individuals or communities adjust themselves to the impacts or threats posed by climate change (Gebre *et al*., 2020). IPCC defines adaptive capacity as the ability of a system to respond successfully to climate variability and change, which includes adjustments in both, behavior and resources as well as technologies (Gebre *et al*., 2020; IPCC, 2014). It is the ability to prepare for, facilitate, and implement adaptation measures or the ability to absorb and withstand the impacts at any given time. It is determined by a range of many factors including level of wealth, technological capacity, timely access to information, possession of key skills, infrastructure, the existence of institutions, social capital, and equity (Akinnagbe & Irohibe, 2015). Vulnerability is the level at which society is unable to cope with the negative impacts of climate change and variability (Tazeze *et al*., 2012) and is a function of three main factors, expressed as a function of exposure, sensitivity, and adaptive capacity (Setargie, 2020).

According to Zeray (2017) and Setargie (2020) Exposure the climate change and what is affected, for example, how many people are living in an area that could be affected by drought or flood. Sensitivity is the direct effect of climate change on systems, for example, changes in crop yields (Zeray, 2017); Adaptive capacity is the ability of a system to adapt to climate changes, reduce adverse effects or take advantage of beneficial effects (Likinaw, 2022). Resilience is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress including change (IPCC, 2014).

2.2 Trend of Temperature and Rainfall in Ethiopia

Ethiopia is one of the most vulnerable countries to climate change and often signifies higher probabilities of droughts that have historically affected millions of farmers. The variability in rainfall patterns and drought have disrupted crop production and exacerbated food insecurity in many parts of Ethiopia (Asfaw *et al*., 2018b; Benti & Abara, 2019). Different trend analysis studies have been conducted in Ethiopia at different spatiotemporal scales and came up with mixed results. Trend analyses of temperature and rainfall show clearly a significant change of climate. In all seasons, the temperature was significantly increased while in the summer, annual rainfall was decreased and these could continue moving until 2050 year in Masha (Benti & Abara, 2019). Mengistu and his friends' study analyzed rainfall and mean maximum and minimum temperatures from 1634 grid points reconstructed using different statistical techniques and evaluated spatiotemporal variability and trend over the Upper Blue Nile Basin between 1981 and 2010. The mean annual maximum temperature showed increasi ng trends over the northern, central, and southern parts (20%) while declining trends were observed in the western part (13%) of the Basin. ii, The mean annual minimum temperature showed statistically significant warming trends over northern, central, southern, and southwestern parts (33%), while declining trends were observed in the western part and parts of the northeastern areas (14%) of the Basin. iii, The annual total rainfall showed increasing but statistically nonsignificant trends of 35 mm per decade. Similar statistically nonsignificant but increasing trends were observed for rainfall in winter, summer, and autumn seasons. Statistically non-significant declining trends were observed for spring (Mengistu *et al*., 2014).

2.3 Impact of Climate Change and Variability in Ethiopia

One of the largest issues facing the world today is climate change, which poses difficulties for the development of sustainable lives, food security, and economies, particularly in developing nations (Kibassa, 2013). Recent climate changes have had widespread impacts on human and natural systems (IPCC, 2014b). The impacts are Often strongest in Africa, because agriculture here is important for daily subsistence, and adaptive capacity is often low (Abera *et al*., 2018). Countries with limited economic resources, low levels of technology, poor information and skills, poor infrastructure, unstable or weak institutions, and inequitable empowerment and access to resources have little capacity to adapt and are highly vulnerable to climate change (Akinnagbe & Irohibe, 2015).

Populations dependent on agriculture are particularly vulnerable to climate change through the climate-sensitive nature of their activities and because agricultural workers and smallholder farmers in developing countries tend to be among the most underprivileged and lowered (Adego *et al*., 2018). Rainfed agriculture will remain the dominant source of food production and the livelihood foundation of the majority of the rural poor in sub-Saharan Africa (Asfaw *et al.*, 2018a). Low levels of socioeconomic development, inadequate infrastructure, and lack of institutional capacity are often making subsistence farmers more vulnerable to climatic changes. These facts make Ethiopia more vulnerable to climatic factors including climate variability and extreme climatic events (Getahun *et al*., 2021). Currently, climate change and variability have already imposed significant challenges on Ethiopia by affecting food security, water, and energy supply, health, poverty reduction, and sustainable development efforts (Getahun *et al.*, 2021; Fayera, 2022). Furthermore, extreme weather events, such as droughts, floods, or landslides, may cause death to domestic animals. The adverse impact of climate change is not only these, particularly climate change/variability also has a significant impact on rainfed agriculture (Alemu & Mengistu, 2019).

Agriculture is the most vulnerable sector to climate change (Shiferaw, 2014; Gassner *et al*., 2019). Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. According to reports of Kebede *et al.* (2019), the projected yield reduction because of climate change in some poor countries could be as much as 50% by 2020. Under climate change, much agricultural land will be lost, with shorter growing seasons and lower yields. Akinnagbe & Irohibe (2015) argued that climate change affects agriculture and its effect is pronounced on the subsistence farmers, which have low adaptive capacity. Land *et al.* (2021) specify that under dry land conditions where the biological productivity is low and the majority of the poor are found, climate change is manifested not only by increasing temperature but also through changes in hydrological cycles characterized by both increased droughts and flooding. Climate change, in particular rising temperatures, can have both direct and indirect effects on animal production (Land *et al*., 2021). Heat stress (caused by the inability of animals to dissipate environmental heat) can have a direct and detrimental effect on health, growth, and reproduction. Changes in the nutritional environment (e.g. the availability of livestock feeds, and the quantity and quality of livestock pastures and forage crops) can have an indirect effect (Kebede *et al*., 2019).

In Ethiopia, vulnerability is high because a large portion of the population lives in densely populated areas that are susceptible to a variety of environmental conditions, including less rainfall, raised temperatures, recurrent droughts, and floods. Furthermore, because a significant portion of the population depends on rain-fed agriculture, a considerable portion of Ethiopia's population is sensitive to climate change. These small-scale farmers' levels of adaptability vary, and as a result of these three characteristics, Climate change will have a significant impact on Ethiopia. Due to its high reliance on rainfed agriculture, which is particularly susceptible to it, as well as its underutilization of water resources, low access to healthcare, high population growth rate, low level of economic development, limited capacity for adaptation, and poor road infrastructure in drought-prone areas, Ethiopia is particularly vulnerable to climate change and variability (Hameso, 2015).

2.4 Climate Change and Variability and its Impact on Ethiopia's Agriculture

Agriculture is the foundation of the Ethiopian economy. Since it drives the economy of the nation and takes the shape of agricultural production, animal production, forestry, fisheries, etc., (Miller *et al.*, 2018). Ethiopia's agricultural productivity is negatively impacted by climate change and variability, which results in decreased crop yield; decreased availability of livestock feed impacted animal health, increased tropical dryness, and increased desertification. The country's agricultural productivity may be severely hampered by variables related to climate change (Asfaw *et al*., 2018a).

The average annual rainfall of the country showed a very high level of variability over the past years, while the trend remained more or less constant (Asfaw *et al.*, 2018a). This variability of the rainfall and recurrent droughts in the country affects the lives of a lot of people whose livelihood is mainly dependent on subsistence agriculture (Mupangwa *et al*., 2011). This is because the Ethiopian economy is largely dependent on rainfed agriculture, which is heavily sensitive to climate variability and change. About 70% of Ethiopia is arid, semi-arid, or categorized as dry or sub-humid; these areas are susceptible to desertification and drought (Asfaw *et al*., 2018a). Increases in the frequency and severity of droughts are projected to adversely affect sustainable development based on cereal crop diversity and production (Pachauri *et al*., 2014). Droughts in Ethiopia can shrink household farm production by up to 90% of a normal year's output. Shiferaw (2014) noted that the poor performance of crop production in Ethiopia is related to declining farm size (due to population growth), land degradation, recurrent drought, and poor adoption of improved agricultural technologies. Plants and animals can reproduce, grow, and survive only within specific ranges of climatic and environmental conditions; and if conditions change beyond the tolerances of species, then they may respond by shifting the timing of life-cycle events (e.g., blooming, migrating); shifting range boundaries or the density of individuals within their ranges; changing morphology, reproduction or genetics; extirpation or extinction (Overton *et al*., 2009; Bakhsh & Kamran, 2019). Additionally, due to climate change, it is anticipated that weeds, pest animals, and drought will become more severe. While this won't necessarily result in a decline in all species, it may create new opportunities for the establishment of invasive species like weeds and pest animals, as well as some native species (Overton *et al*., 2009). Different crops have been impacted differently by different climate variables across different areas of agroecological zones.

Ethiopia has the highest livestock population in Africa and it stands as the tenth largest in the world (Asresie *et al.*, 2015). In both the highlands and the lowlands, livestock is a crucial source of many different social and economic benefits, including food, draught power, fuel, cash revenue, security, and investment. However, this industry is characterized by low productivity due to several issues, including inadequate feed, poor veterinary care, genetic instability, insufficient funding, ongoing droughts, and limited infrastructure and livestock research (Shiferaw, 2014).

2.5 Adaptation Strategies Used by Farmers in Response to Climate Change

Adaptation to climate change is a two-step process that requires that farmers first perceive climate change and then respond to the changes in the second step (Asrat & Simane, 2018; Bagambilana & Rugumamu, 2023). Mitigation and adaptation are the two methods for preventing the effects of climate change. Mitigation is the process of reducing greenhouse gas emissions to mitigate the effects of climate change. Natural or human systems must be modified in response to current or expected climatic stimuli or their consequences to minimize damage or take advantage of beneficial opportunities (IPCC, 2014). Although mitigation targets uprooting the major causes of climate change and offers long-run solutions, adaptation is important given the current state of the world (IPCC, 2018; Shiferaw, 2014). Adaptation efforts to the ongoing climate change and variability should begin by addressing the current climatic variability and implementing a climate risk management strategy (Alemayehu & Bewket, 2016). Having this Oseni and Masarirambi identify important agricultural adaptation mechanisms like adjusting the crop variety (i.e., planting a drought-tolerant or early maturing variety or the use of genetically modified), optimizing water use efficiency by improving irrigation facilities, cropping calendar to coordinate crop planting and the growing period with soil moisture availability based on seasonal climate/ rainfall forecast (Mohammed *et al.*, 2022; Oseni & Masarirambi, 2011). The adaptation strategies used in MNL model were crop diversification and the use of soil and water conservation practices, integrated crop and livestock diversification, engaging in off-farm income activities and rainwater harvesting (Hararghe, n.d.). Crop-diversification, soil and water conservation and seasonal migration were the three most frequently used and important adaptation measures pursued by households' in their study area (Atinkut & Mebrat, 2020). Farmers' adaptation decision is influenced by household size, the gender of household head, cultivated land size, education level, farm experience, non-farm income, income from livestock, climate information, extension advice, farm-home distance and number of parcels. However, the direction of influence and significance level of most of the explanatory variables vary with in their study area (Asrat & Simane, 2018). Based on descriptive statistics, the major adaptation strategies to climate variability as reported by (Berhanu *et al*. (2021) in their study area were adjusting the farming calendar, gathering fruits and roots, flood recession farming, and cultivation of short-maturing crop varieties. receiving aid rations, engaging in non and off-farm activities, and selling livelihood assets. Farmers' climate variability response is a clear indication of their capacity to adapt to the changes (Asrat & Simane, 2018; Berhanu *et al*., 2021). These strategies and/or responses include crop-livestock diversification and other good practices (mulching, organic fertilizer), Use of improved varieties, chemical fertilizers and pesticides, agroforestry, and perennial plantation, and diversification of income-generating activities (Fadina & Barjolle, 2018).

2.6 Determinant Factors to Adapt Climate Change and Variability

Several factors affecting farmers' adaptation include demographic and socio-economic factors; resources, services, and technologies; institutional and political factors; social and cultural factors; and cognitive and psychological factors (Berhanu *et al*., 2021; Dang *et al*., 2019). As a result, access to agricultural extension, credit, land, and improved technologies were seen as highly significant. Demographic and socio-economic factors, which represented the status and economic condition of farm households, also received considerable attention (Dang *et al*., 2019). Farmers' climate variability adaptation decisions were determined by age, family size, education level of the head of the household, livestock holding, farm experience, access to extension services, and access to weather information (Berhanu *et al*., 2021). The major determinant factor variables to farmers' adaptation to climate change and variability were education level, sex, age, productive labor force, wealth, farm experience, farm size, extension contact, soil fertility, access to climate information and credit service (Atinkut & Mebrat, 2020; Frehiwot, 2023). However, households who have long experience in farming, and have better education, and households who are male-headed and with aged farmers, with a more productive labor force, who own less fertile farmland, who have access to credit, extension service as well as accurate climate information were more initiated to adopt alternative adaptation options towards perceived changes in temperature and precipitation than their counter area (Frehiwot, 2023). The main problems identified are institutional factors, access to credit, lack of information, and irregularity of extension services (Juana *et al.*, 2013; Assoumana *et al*., 2016). The institutional factors that influence the adoption of new technologies are access to information via extension services (climate information and production technologies) and access to credit (Atinkut & Mebrat, 2020; Juana *et al*., 2013). According to the same author, farmers who have significant extension contacts have better chances of being aware of changing climatic conditions as well as adaptation measures in response to the changes in these conditions (Assoumana *et al.*, 2016). Insufficient access to inputs, lack of knowledge about other adaptation options, no access to water, lack of credit, lack of information about climate change, high cost of adaptation, and insecure property rights were the main climate change adaptation constraints(Chalchisa, 2016). Farmers' adaptation decision is influenced by household size, the gender of household head, cultivated land size, education, farm experience, non-farm income, income from livestock, climate information, extension advice, farm-home distance and number of parcels. However, the direction of influence and significance level of most of the explanatory variables vary with in their study area (Asrat & Simane, 2018). The other results conducted (Alemayehu & Bewket, 2017) showed that the significant factors affecting choice of adaptation strategies include perceived soil fertility status, perception of land tenure security, access to extension service, and ages of household heads. For the choice of coping options, agroecological zone, and access to markets, farmer-to-farmer extension, landholding size, access to information on climate change, rainfall amount, and educational level of household heads were the significant determinants.

Chapter 3. MATERIAL AND METHODS

3.1 Description of the Study District

3.1.1 Geographical location of the study area

The study was conducted in the Dangila district of the Awi zone Ethiopia. At an altitude of 1353-2454 masl, Dangila is one of the administrative towns in the Awi zone of the Amhara region in Northwestern Ethiopia. It is situated at 36° 35′ 30″ E and 37°0′ 30″ E latitude and 11° 05′ 30″ N and 11° 25′ 30″ N longitude. It is located at a distance of 470 km from Addis Ababa, 78 km from the capital of the region, Bahir Dar, and 36.4 km from the capital of Awi Zone, Enjbara. It is bordered by the Achefer district in the North, Fagta le Koma district in the South, Mesna Fagta le Koma district in the East, Jawi Gwangwa district, and Benshangul Gumz region in the West. The majority of the region's scenery is defined as having a flat top (Deressa *et al.*, 2011).

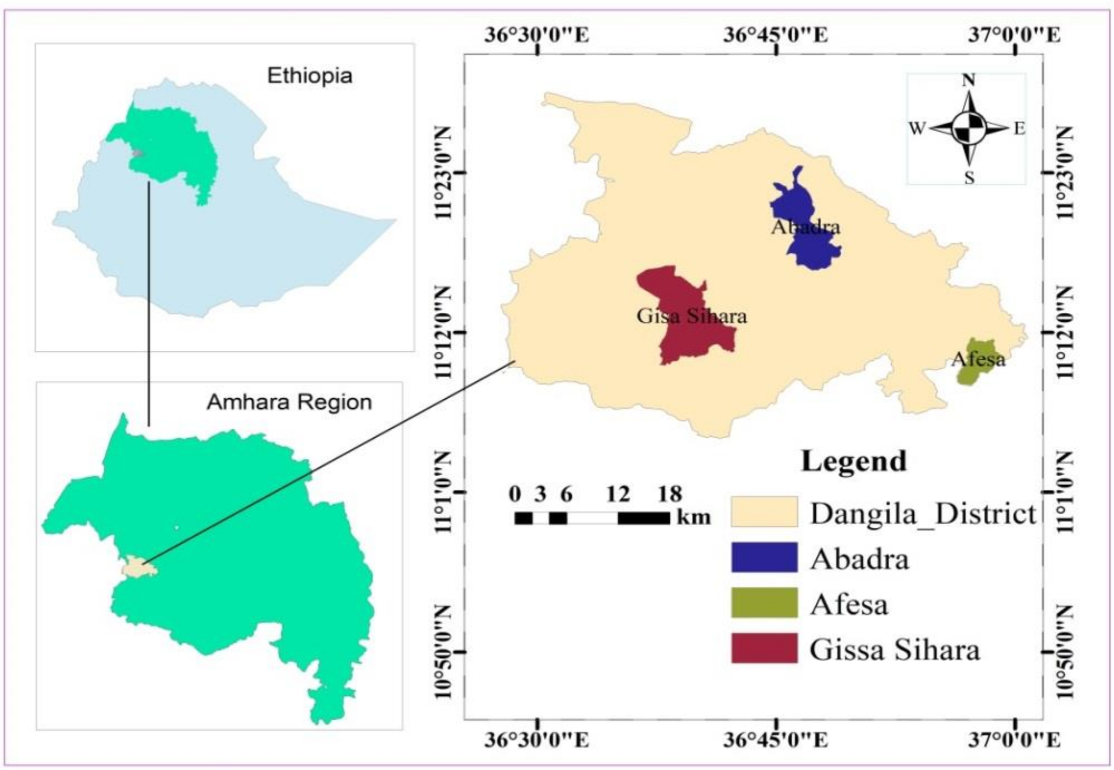

Figure 3.1 Location map of the study area and the study sites

3.1.2 Climate

The traditional and agroecological zones are the two most often used classification systems. According to the traditional classification system, this primarily depends on altitude and temperature. The district is divided into three major agroecological zones based on Ethiopia's traditional agroecological zones: Lowland (500-1500m), mid-highland (1500-2000m), and highland (2000m,&above) (Gudmundsson, 2001). The district has a mono-modal rainfall distribution with a main wet season from June to September. The occurrence of insect pests, crop diseases, and outbreaks of animal diseases is increasing.

3.1.3 Land use

Its surface area is 73,613.387ha, Terrain Mountainous 11%, Caves and Valleys 1%, Swampy 0.05%, Others 29.95%, Plain 58%, Land used for grazing 12,360ha/16%, Land for agriculture 46,270ha/62.8%, Covered with artificial forest 2802.455ha and 7631.154ha covered by natural forest, 382ha covered by wetlands (Genet *et al.*, 2015; Dangila Agricultural Development Office). The study area's primary economic sector is agriculture. Traditional, rainfed farmers farming on small individual holdings and traditional grazing on the flat cultivated ground make up the majority of the region's current land usage.

3.1.4 Farming system

The primary economic activity in the district is mixed farming, which is defined as the coexistence of crop and livestock operations. Several crops, including annual and perennial ones, can be grown using irrigation and rainwater systems. The most common cereal crops farmed in the region are finger millet, *teff*, wheat, and barley. Various vegetables such as onion, tomato, pepper, and cabbage, cash crops such as coffee, and fruit crops such as *papaya* and banana are also farmed in addition to grain crops. Crops are also farmed in the district utilizing the conventional irrigation technique (Mbedz & Gondo, 2010; Aneseyee, 2020).

3.1.5 Irrigation activity

Water is now more readily available for irrigation in the district. The distribution of drinking and irrigation water, however, varies from Kebele to Kebele and from season to season for both cattle and other agricultural activities. The district's potential for surface and groundwater is too much for the existing population of people and animals. The management of drinking water sources and irrigation systems is the only issue (Naod, Legesse, et al., 2020).

Figure 3.2 Potato and Barley cultivation in Awise irrigation project area (G/Sihara Kebele) **(**Source: own field observation, 2023)

3.1.6 Topography

The majority of the region's scenery is defined as having a flat top with a minor fraction being undulating (Deressa *et al.*, 2011). It is known that the soil type is red soil 3.5%, black soil 2.7%, and brown soil 93.8% (Dangila Agricultural Development Office; Genet *et al.*, 2015 & Naod *et al.*, 2020).

3.1.7 Vegetation

The vegetation of the study area is mostly a plantation forest of Eucalyptus and natural tree species Cordia Africana (*Wanza*), different Acacia species, and *Missana* found in the district (Leyew, 2011). The natural vegetation in the lower catchment and command area is almost destroyed due to increased demand in the last decade for fuel wood construction timber and agricultural land due to population growth, and the non-rehabilitation of degraded agricultural areas (Leyew, 2011).

3.2 Method of Research Design and Data Collection

This research was designed to use an explanatory mixed research design. Hence, data were collected from sample households, field observations, key informant interviews (KII), focus group discussions (FGD), and KNMI climate explorers. Data related to the socioeconomic an d demographic characteristics of respondents and their perceptions of climate variability were collected using questionnaire survey and semi-structured (open-ended) questionnaires. KNMI climate explorer 0.5-degree monthly observation data (CHIRPS for rainfall and ERA5 for temperature) instead of metrological (observed) data were implemented because there were more missing metrological data. The survey questionnaire was pretested to 10% of the sample d households. Pretested Kebeles and participants were not involved in the actual survey. Follo wing pretesting, the survey questionnaire was adjusted and translated into Amharic, the local l anguage for consistent data collection development.

Household survey

A total of 138 households were included in the household survey, and structured and semi-structured (to some extent) questionnaires and interviews were conducted to gather information about different aspects of farmers' adaptation strategies to climate change and variability as well as their vulnerability to these factors. Also, significant socioeconomic elements were looked at, including access to agricultural extension services and climate data as well as land ownership.

Key informant interview (KII)

The KII was specifically chosen because of the significance of local households and their familiarity with current adaptation strategies for climate variability and change. Eight informants, including three local leaders, three model farmers, and two development agents, were included in the KII from each sampled Kebele. A semi-structured (open-ended) interview style was applied in this research to get in-depth information since it is flexible and obvious when there is ambiguity.

Focus group discussion (FGD)

In each sampled Kebele, the researcher chose eight people to represent one FGD. These individuals must have lived in the study area for at least 30 years, be well-liked in the community, and have a thorough understanding of the current and historical environmental, social, and economic conditions of the study area. Participants of the FGD include people with education, local elders, religious leaders, women, extension agents, and young farmers. Understanding the perception of climate change and variability, identifying current adaptation techniques, and evaluating the study area's determinants of adaption strategies were the main goals of the FGD.

Field observations

Field observation is used as a supplementary strategy to gather information that may supplement or contextualize information gained through other sources. It was done as part of the house-to-house survey. Important observations such as vegetation cover, terrain and relief, significant development interventions, farmer adaption techniques, and related information were noticed and recorded while photographs were being taken.

Document review

Documents from the Dangila District Agricultural Development Office were reviewed to acquire secondary data. Moreover, meteorological information from KNMI Climate Explorer's 0.5-degree monthly observations was used to determine the research area's temperature and rainfall distribution.

3.3 Method of Sampling Techniques and Sampling Size

This study employed a multi-stage sampling technique. Accordingly, the study district selected a purposive sampling method due to exposure to frequent climate variability a nd constrained by environmental and socioeconomic factors. The study district was twenty-nine (29) Kebeles and two sub-towns (Gissa & Chara) (Dangila District Agricultural Development Office, 2023). In the second stage, using the stratified random sampling method, 29 kebeles were stratified into three agro-climatic zones, namely, lowland (500-1500m), mid-highland (1500-2000m), and highland (2000m and above). In the third stage, three representative kebeles were selected randomly with one from each ago-ecological zone. The selected kebeles were Abadra from the lowland, Afessa from the mid-highland, and G/Sihara from the highland. Subsequently, a total of 2914 sample households were selected using a random sampling method. Sample household size was determined using the (Cochran, 1977) formula. It was used to determine the required sample size at a 95% confidence level, a 5% degree of variability.

$$n = z^2pq \big/ d^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1) \qquad \text{no} = \frac{\text{n}}{1+(\text{n}-1)/\text{N}} \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Where n = required sample size (N >10,000), Z = 95% confident limit (=1.96), no = Sample size when the population is less than 10,000, N = the total number of target populations, d = margin of error or degree of accuracy desired (0.05). Of 10 farmers nine of them answered yes, so the proportion (p) of taking any adaptation measures was, p $=\frac{9}{10}$ = 0.9 and No, q = $\frac{1}{10}$ = 0.1 taken as an experimental study. So, the researchers have prior information about adaptation measures.

Using, q = 1 - P = 1 - 0.1 = 0.9, N = total number of population d = boundary of error (5% = 0.05 Then, $\text{n} = (1.96)^2 * 0.1 * 0.9 \big/ (0.05)^2$

n= $(1.96)^2$*0.1 * 0.9 / $(0.05)^2$ = 138. Therefore, the sample size for this study is 138.

After determining the sample size for the study area, the next step was determining the number of households for each agro-ecological zone and the three sampled kebeles using the probability proportional to size method based on (Kirkman *et al*., 2013) formula:

$$ni = {n * Ni}/{\sum Ni} \qquad (3)$$

Where n = determined sample size the research paper was used, ni = households of the i^{th} Kebele, and Ni = total households of the i^{th} Kebele.

Table 3.1 Total number and sample households of the study area.

Agro-ecology	Kebeles	Total population	Total HH (Ni)	Sample HH (ni)
Lowland	Abadra	4365	882	42
Mid-highland	Afessa	8933	582	27
Highland	G/Sihara	9096	1450	69
Grand total		22,396	2,914	138

Source: Dangila District Agricultural Development Office (2023).

3.4 Method of Data Analysis

Data collected from various sources were analyzed using appropriate quantitative and qualitative data analysis methods. Quantitative data were analyzed using descriptive statistics such as mean, percentage, coefficient of variation, and standard deviation techniques using SPSS version 26 databases, and Excel 2013 were used to enter and evaluate the rainfall and temperature data. Qualitative data collected from KII, FGD, and observational notes were analyzed using thematic content analysis. Identifying themes, categorizing, paraphrasing, interpreting, and summarizing were performed. Also, Chi-square tests were used to compare the different perceptions of different dependent variables. Furthermore, the multinomial logit (MNL) model was employed to identify the determinant variables that influence HHs' adaptation strategies to climate change and variability, which is detailed in the following section.

Multinomial logit model (MNL)

In the present study, we used the MNL model to identify the determinants of farmers' adaptation decisions to climate variability and change. This model permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories. However, the model requires that HHs be associated with only their most preferred option from a given set of adaptation strategies. The probability of using adaptation measures by a given HH is independent of the probability of choosing another adaptation strategy. The MNL model is employed by many researchers to model climate change adaptation practices of smallholder farmers (Deressa *et al*., 2011; Hassan & Nhemachena, 2008). Hence, the multinomial logit model was appropriate to the model of climate change adaptation practices of smallholder farmers in this study area.

Y denotes a random variable with values (0, 1…J) and *X* set of variables. In this study, *Y* is a dependent variable and represents the adaptation strategies (alternatives) from the set of adaptation measures, whereas *X* represents the factors that influence the choice of the adaptation strategies, specified in the following general method (Kumissa, 2022; Engle & Gross, 2020).

$$prob(Yi = j) = \frac{e^{\beta jxi}}{\sum_{k=0}^{7} e^{\beta kXi}} \quad j = 0,1,2 \ldots\ldots 7, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Equation (1) is normalized to clear of indeterminacy within the model by assuming β0 = 0 and therefore the probabilities may be estimated as:

$$pro\left(Yi = \frac{j}{xi}\right) = \frac{e^{\beta jXi}}{1 + \sum_{k=0}^{7} e^{\beta jXi}} \quad j = 0,1,2 \ldots..j, \beta = 0 \ldots\ldots\ldots\ldots (2)$$

The maximum likelihood estimation of equation (2) yields the log-odds ratio

$$\ln\left(\frac{pji}{pki}\right) = X'(\beta j - \beta k) = X'i\beta j \quad if\ k = 0 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3)$$

The dependent variable of any adaptation option is therefore the log of odds about the base alternative.

Statistical and specification tests of MNL

Before carrying out the final model run, all the hypothesized explanatory variables were chec ked for some statistical problems like the issue of multicollinearity. Mainly, the multicollinear ity problem might be arising due to a linear relationship among explanatory variables and the problem is that it might cause the estimated regression coefficients to have wrong signs, smaller t-ratios for many of the variables in the regression, and high R-square values. Likewise, it causes large variance and standard errors with a wide confidence interval. Hence, it is quite difficult to estimate accurately the effect of each variable on the dependent variable.

There are different methods suggested to detect the existence of multicollinearity problem between the model explanatory variables. Among these methods, variance variance-inflating factor (VIF) technique is commonly used and also used within the present study to detect mult icollinearity problems among the explanatory variables. If the VIF of a variable exceeds 10 then that variable is alleged to be highly collinear (Hill *et al*., 2018). Therefore, the results of the test indicated that there is no severe problem of multicollinearity among the explanatory variables. Since the VIF for each explanatory variable was less than 5.

Additionally, the model specification test is conducted for the Multinomial logistic model. In this case, three models are estimated and the model comparison is undertaken using Bayesian Information Criterion (BIC) and chi-square statistics and the model with the lowest BIC was selected.

Model specification and variable selection of MNL

To fit the model of the response variable with other explanatory variables, one should check the variables that are included in the model by different information criteria. The variable selection was done by using forward selection from the starting small variable to the final including all variables that are desired to influence the choice of climate change adaptation strategies. The model specification was done by refitting the model after dropping the variables that were highly insignificant in explaining the model. Initially, the model ran nineteen independent variables with a response variable (model one) and we saw the result of the output. From the output, four variables have a large p-value which means more than 10%. Then by removing the variables refitting the model with the remaining fifteen explanatory variables was model two. Similarly, in model two high amount of p-value existed for three independent variables then we removed those three variables refitting the model of the remaining twelve explanatory variables with response variables (model three). The result of the measure of overall fitness of the three models is given in (Table 3.1) below. Bayesian Information Criterion (BIC) helps us to compare the fitness of the models. Accordingly, the second model is better than the first model hence the less BIC is the better that fits the model. After fitting the model, we conducted a Wald test and saw the p-value for each independent variable to determine the significance of each explanatory variable included in the model, the variables rainfall, temperature, and marital status have high p-values which indicates that these three variables are insignificant to the model. Based on this result refitting the model by dropping those three variables we get the third model. Therefore, the third model is better than the first and second models hence the third model has less BIC than the second and first models.

Table 3.2 Result of model selection test

Criteria for assessing model fit	Model 1	Model 2	Model 3
Log-likelihood	-144.549	-196.397	-246.477
Chi-square test	136.54	128.57	96.44
P-value	0.001	0.045	0.000
BIC	585.06	529.462	525.591

Goodness of Fit

The goodness of fit of the model was tested by Pearson chi-square or deviance; the p-value is 0.000 with a chi-square of 394.062. This indicates that the model goodness fits in well as shown in Table 3.3 below.

Table 3.3 Model Goodness of Fit

	Chi-Square	Df	P-value
Pearson	394.062	366	0.000

Table 3.4 Description of independent variables and hypothesis for its effect on dependent variables

Explanatory variables	Description	Expected sign
Sex_hh	Dummy, 0 = male and 1 = female	±
Age_hh	Continuous	±
Famlysize_hh	Continuous	±
Education_level_hh	Categorical, 0=Illiterate1=Read and write2=Primary Education complete3=High school complete4=Higher education complete	+
Farming_expria_hh	Continuous	+
Farmland_size_hh	Continuous	+
Acce_Exte_service	Dummy, 0 = yes, 1 = no	+
Financial problem	Dummy, 0 = yes, 1 = no	−
Acce_infrastructure	Dummy, 0 = yes, 1 = no	+
Acce_CC_Inform	Dummy, 0 = yes, 1 = no	+
TLU_hh	Continuous	±
AgroEcolo	Categorical 0= Lowland 1= midland 2= highland	±
Martial_stat_hh	Categorical 0= Married 1= Single 2= Divorced 3= Widowed	±
Incom_sour_hh	Categorical 0= Crop and animal production 1= only crop production 2= only animal production 3= Working out of agriculture	+

TLU_hh, Tropical Livestock Unit of the Households.

Climate trend analysis

The Mann-Kendall test was used to detect the trend of climate variables (rainfall and temperature) and the magnitude was analyzed by Sen's slope estimator. Mann–Kendall's test is a non-parametric method, which is less sensitive to outliers and tests for a trend in a time series without specifying whether the trend is linear or non-linear (Asfaw *et al*., 2018). The initial value of the Z test statistics /S/ is assumed to be zero, implying no trend. If a data value from a later period is found to be greater than the data value from an earlier period, then statistics /S/ is incremented by one. The overall result of all increments and decrements provides the final S value, which lies between -1 and +1. The null hypothesis of the Z test is no change has occurred during the time (no trend). Whereas the alternative hypothesis of the

Z test is a significant change has occurred over time. Mann Kendall and Sen slop tests are widely known and used by different authors to detect the trends of meteorological variables (Mohamed *et al*., 2022; Getahun *et al*., 2021; Anose *et al*., 2021; Wale *et al*., 2020; Ware *et al*., 2023 & Mohammed *et al*., 2018). The Mann–Kendall test statistics are given as follows (Bouklikha *et al*., 2021).

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sgn(xj-xi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)$$

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

$$sgn = (xj-xi)\begin{cases} +1 \; if \; (xj-xi) > 0 \\ 0 \; if \; (xj-xi) = 0 \\ -1 \; if \; (xj-xi) < 0 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\; (2)$$

Where sgn=significance, xj, and xi are the annual values in the year j and i (j>i) respectively. It has been documented that the number of observations is more than 10(n ≥ 10) the statistics are normally distributed with the mean value of zero and variance is calculated using Equation

$$Var(S) = \frac{n(n-1)(2n-5)-(x+a)^n = \sum_{t=1}^{m}(ti(ti-1)(2ti-5)}{18} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where n is the number of observations and ti is the sample time series. The test statistics Z is as follows;

$$Z = \begin{cases} \frac{S-1}{\sigma} \; if \; S > 0 \\ 0 \; if \; S = 0 \\ \frac{S+1}{\sigma} \; if \; S < 0 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (4)$$

The decision to either reject or accept the null hypothesis is then made by comparing the calculated Z with the critical value at a chosen level of significance. Sen’s Slope Estimator is also a non-parametric test by which the true slope (change per year) of a trend is estimated (Getahun *et al*., 2021; Bouklikha *et al*., 2021). Sen’s test is used when the trend is assumed to be linear, i.e. $f(t) = \delta t + B \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (\mathbf{5})$

Where f(t) increases or decreases the function of time, i.e. the trend δ the slope and B intercept (constant). The slope of each data pair δi is calculated as:

$$\delta i=\frac{xj-xk}{j-k} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (6)$$

Where j>k and, if there is n number of xj in the time series, we get as many as N slope estimates of δi. Then the values of δi are ranked from small to large; the median of which is the Sen's slope (δ):

$$\delta=\begin{cases} \delta\left[\frac{N+1}{2}\right] \ if\ N\ is\ odd \\ \delta\left[\frac{1}{2}\right]\delta\left[\frac{(n+2)}{2}\right] \ if\ N\ is\ even \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(7)$$

Positive Z indicates an increasing trend while negative Z values show decreasing trends. In this Analysis, the MK test to detect a trend in precipitation, temperature, and stream flow time series is statistically significant at a significant level 99% confidence interval) and =0.05 (or 95% confidence interval). At the 5% and 1% significance levels, the null hypothesis of no trend is rejected if Z>1.96 and Z>2.576, respectively.

Analysis of coefficient of variability/CV/

The CV is a unitless normalized measure of the dispersion of a probability distribution. It expresses the standard deviation as a fraction of the mean and is useful when interest is in the size of variation relative to the size of the observation. It is expressed as the ratio of the standard deviation to the mean (Araya *et al*., 2021; Bekele *et al*., 2017).

$$CV=\left[\frac{S}{X}\right]*100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8)$$

Where CV is the coefficient of variation; X is the average (mean) long-term rainfall and S is the standard deviation of rainfall. The CV was used to compare the long-term variation of wet season rainfall to that of individual years. According to Addisu *et al.* (2015), Climate variability is used to describe the level of variability of rainfall events as less variable (CV< 20), moderately variable (20 CV 30), high variable (CV >30), very highly variable (CV>40%), and CV>70% indicate extremely high inter-annual variability of rainfall. Thus, using information from the KNMI Climate Explorer's 0.5-degree monthly observations, the study attempted to assess the district's monthly and annual average rainfall during 31 years (1991-2022).

Chapter 4. RESULTS AND DISCUSSIONS

4.1 Climate Variability and Trend in the Study Area

4.1.1 Variability and trend analysis of rainfall in the study area

Annual and seasonal rainfall variability (1991-2022)

The mean annual rainfall of the area from 1991-2022 was 1697.5 mm with a standard deviation (SD) of 152.63 and 8.99 % of the coefficient of variability (Table 4.1 & Appendix 1). The years 2009 (1422.8 mm) and 2017 (2023 mm), which have 600.2 mm ranges, have the lowest and highest rainfall, respectively (Figure 4.1 & Appendix 1). As presented in Table 4.1, the summer (*Kiremt*) rain season was found to be the season when high amounts of rain (1234.4 mm) were received with relatively low variation (CV=7.62 %). The second-highest amount of average rainfall (261.2 mm) was received during the spring (*Belg*) season. It was a short rainy season when the area gets important rain for their livelihood with high levels of variability, 35.26 % of the coefficient of variation. Contrary to this, the winter (*Bega*) season, was the season with the least amount of rain (201.9 mm) recorded, and the rain at this time was not as demanded as compared to the summer and spring seasons. This study is in line with the findings of Bansal (2020) & Kothari (2017) who reported that summer is the main season contributing the highest to the annual rainfall received in different parts of the country.

Table 4.1 Annual and seasonal total Rainfall variability

Variables	Minimum	Maximum	Mean	Std. Deviation	CV (%)
Bega (winter)	104.1	356.4	201.9	66.17	33.27
Belg (spring)	109.5	541.7	261.2	91.96	35.26
Kiremt (summer)	1095.3	1450.9	1234.4	93.96	7.62
Annual	1422.8	2023	1697.5	152.63	8.99

Regarding variability, low to high levels of variability were recorded in the seasonal for annual rainfall. This implies that the pattern of rainfall was comparatively stable during the main sowing season as compared to other seasons. Getachew & Manjunatha (2021) initiate that the rainfall pattern in the *Kiremt* season was less variable than the rain in the *Belg* season

(March to May) in the south Gonder zone of the Amhara regional state of Ethiopia. Just as the summer season annual rainfall also showed less annual and inter-annual variability in the study area, 7.62 % of the coefficient of variability. This is in disagreement with the output of Duba *et al*. (2021) & Weldegerima *et al.* (2018) conducted in the Northern Oromia zone and conducted in the Tigray regional state of Ethiopia respectively. Both researchers concluded the presence of moderate inter-annual variability of rainfall in their specific study area. In contrast, this finding is more or less in agreement with the finding of Solomon *et al.* (2021) conducted in drought-prone areas of the Amhara regional state of Ethiopia which indicated that the annual and seasonal rainfall totals showed that the area has moderate to very high rainfall variability.

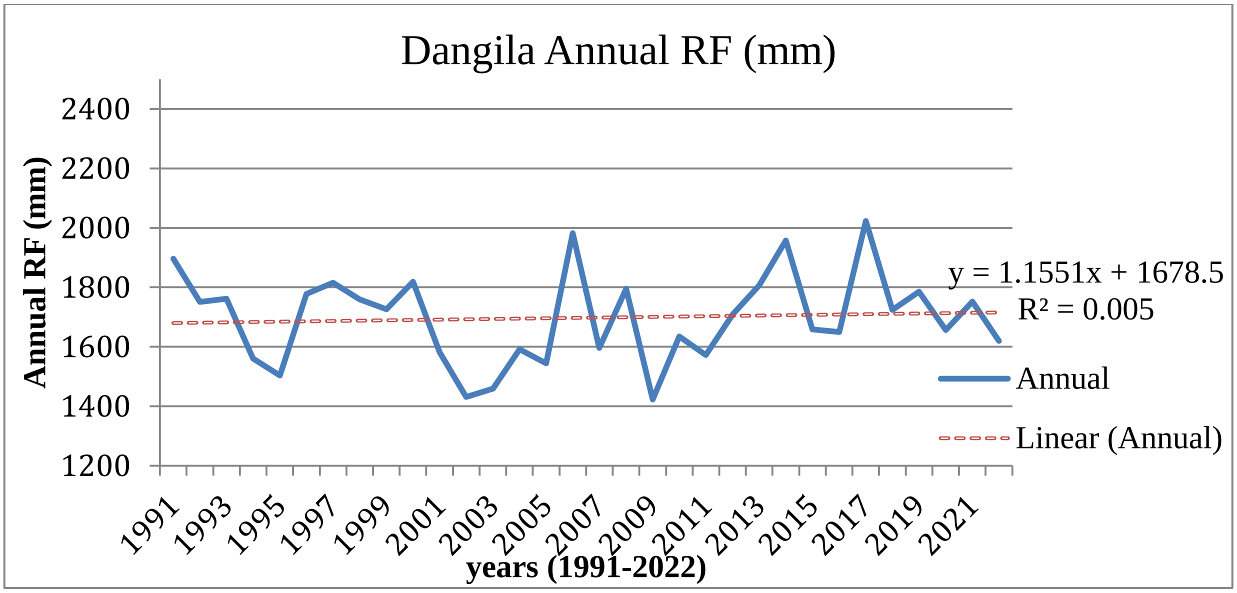

Figure 4.1 Annual average rainfall pattern and trends

Trend analysis of annual and seasonal rainfall (1991-2022) in the study district

In winter (*Bega)*, summer season, and annual, the rainfall showed a non-significant increasing trend. However, there is a non-significant decreasing trend of rainfall in the spring (*Belg*) season because Sen's slope is negative and the calculated p-value is greater than the significance level alpha=0.05. Therefore, in the study area statistically insignificant increments in winter *(Bega)*, summer season (June – September), and annual rainfall by 0.69, 1.57, and 1.38 respectively. However, there is a statically insignificant decrement in spring *(Belg)* seasonal rainfall by 0.69 of Sen's slope (Table 4.2).

Table 4.2 Seasonal and annual RF of Mann Kendall's trend test & Sen's Slope estimator

Mann Kendell's test, (H0: There is no trend; Ha: There is trend)

Season	Sen's slope	MK Stat(S)	Kendall's tau	P-value	α
Bega (winter)	0.685	32.0	0.064	0.615	0.05
Belg (spring)	-0.686	-16.0	-0.032	0.807	0.05
Kiremt (summer)	1.573	58.0	0.116	0.355	0.05
Annual	1.383	18.0	0.036	0.782	0.05

**p-value < α (alpha) = 0.05, one should reject the null hypothesis H0 and accept the alternative hypothesis Ha; P-value > α (alpha) = 0.05, one cannot reject the null hypothesis H0.*

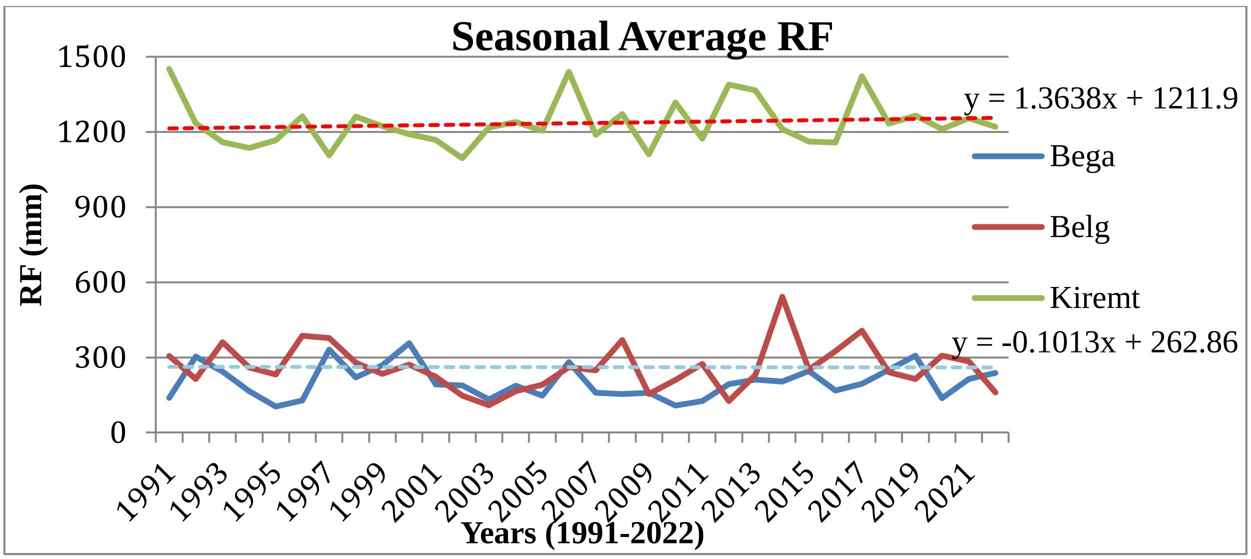

Figure 4.2 Seasonal Rainfall Trends in the Study Area

Studies that are lined with our analysis are conducted in different areas. Among these, Miheretu & Yimer (2018) conveyed that there is an increase in the annual rainfall and also in the seasonal rainfall has occurred during the time 1978- 2007 in Ethiopia. Another study in the central highlands of Ethiopia (D. Bekele *et al*., 2019) reported that the annual and summer (June–September) rainfall exhibited statistically insignificant increasing trends which strongly agrees with our results. The rainfall trend and variability analysis at the Awash River basin by Getahun *et al.* (2021) was also one that does not fit our study. The result indicated that summer season rainfall shows insignificantly increasing trends in five stations out of 12 stations. Similarly, Bekele (2022) investigated the groundbreaking trend analysis of annual and seasonal rainfall variability in the Amhara regional state and the result showed that the trend of annual rainfall was increasing in most of the stations. The Lake Tana Basin Analysis of Rainfall Trends by Yasuda *et al.* (2022) shows that except for the Adet station, all other stations revealed an increasing trend of annual and summer rainfall.

On the other side, Mohammed *et al.* (2018) described a significant decline in the summer and annual rainfalls for the eastern, southern, and southwestern stations from about 1982 to the study period. On the other hand, Toni *et al*. (2022) attempted to cover relatively wider spatial coverage in Ethiopia; and the result indicated that there was a significantly decreasing trend in summer rainfall in some stations across the country which strongly disagrees with our findings. Similarly, Taye & Moges (2021) reported a decreasing trend of summer and annual rainfall which continued with a faster downward trend that started around the end of the 1910s in Ethiopia. Another investigation by Dibaba *et al*. (2020) showed that the precipitation was both increasing and decreasing trends among stations over the upper Blue Nile river basin of Ethiopia.

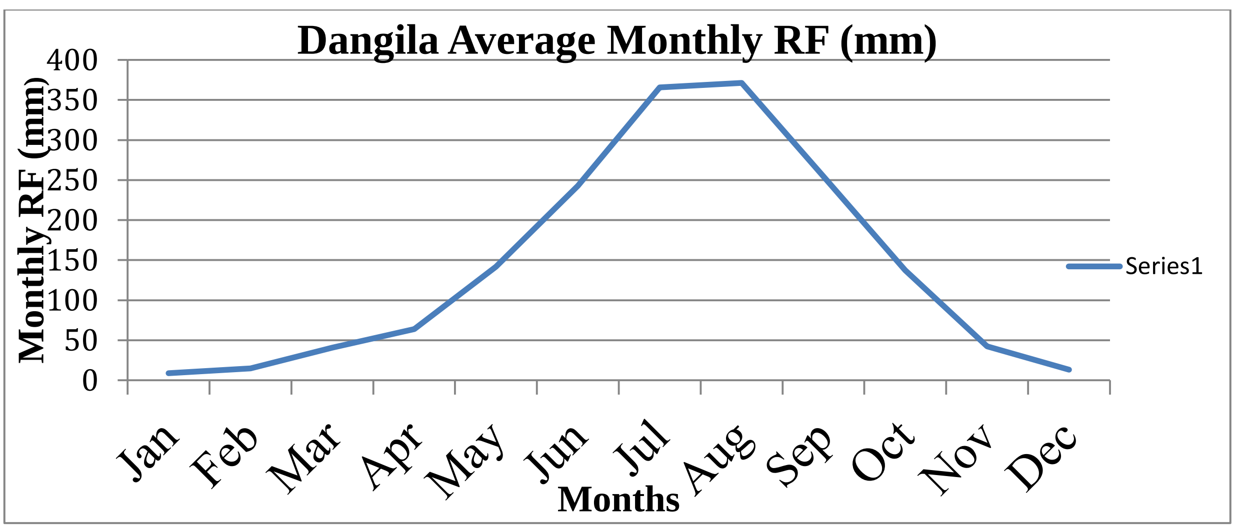

Figure 4. 3 Average monthly rainfall distribution and trend

The rainiest months in the Dangila district are June, July, August, and September, whereas December, January, and February also get the lowest precipitation. The wettest month is August, which receives an average rainfall of 371.36 mm, while the driest (least rainy) month is February, which receives an average rainfall of 9.006 mm (Figure 4.3 & Appendix 1).

4.1.2 Variability and trend analysis of temperature in the study district

Distribution and trend analysis of annual temperature (1991-2022)

One of the factors affecting an area's state and climate is its temperature. The country's average annual lowest temperature has risen by around 0.37 ^{O}C (Kojwang & Larwanou, 2015; Conway & Schipper, 2011 & Hirpha *et al*., 2021) while the average annual maximum temperature has increased by roughly 0.1 ^{O}C (Bimir, 2022; Simane *et al*., 2016). Similarly, the temperature distribution in the study area was characterized by a general trend of increase and shows monthly and annual variability. As indicated in figures 4.4 and 4.5 from the year 1991-2022 the minimum and maximum average annual temperature of the district were illustrated. The average minimum and maximum temperature of the district ranged between 13.3 ^{O}C (1999) and 14.06 ^{O}C (2019) and between 23.7 ^{O}C (1993) and 25.3 ^{O}C (2009) in the past three decades respectively. Therefore, the warmest and the coldest year in the district were 2009 and 1999 (Appendix 1). The maximum, mean, and minimum temperature trend in the study area revealed that there is an increasing trend both in the annual maximum, annual mean, and annual minimum temperature trend as the calculated P-value of all are 0.00 lower than the significance alpha level =0.05, as indicated in table 4.3 below. One should accept the alternative hypothesis Ha and reject the null hypothesis Ho. The maximum and annual mean temperature in the last 31 years (1991-2022) increased by 0.93 ^{O}C with 0.03 ^{O}C and increased by 0.62 ^{O}C with 0.02 ^{O}C last 31 years rate of increments respectively. And also, the annual minimum temperature trend in the study area was statically significant increasing trend by 0.3 ^{O}C decadal with 0.03 ^{O}C yearly increasing rate.

Table 4.3 Annual temperature variability and trend of Mann-Kendall trend test & Sen's Slope estimator

Mann Kendell's test, (H0: There is no trend; Ha: There is trend)

Annual	p-value	Alpha	Sen's slope	MK tau
T max	0.00	0.05	0.03	0.40
T mean	0.00	0.05	0.02	0.48
T min	0.00	0.05	0.03	0.50

**As the computed p-value is lesser than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha, the reverse is true.*

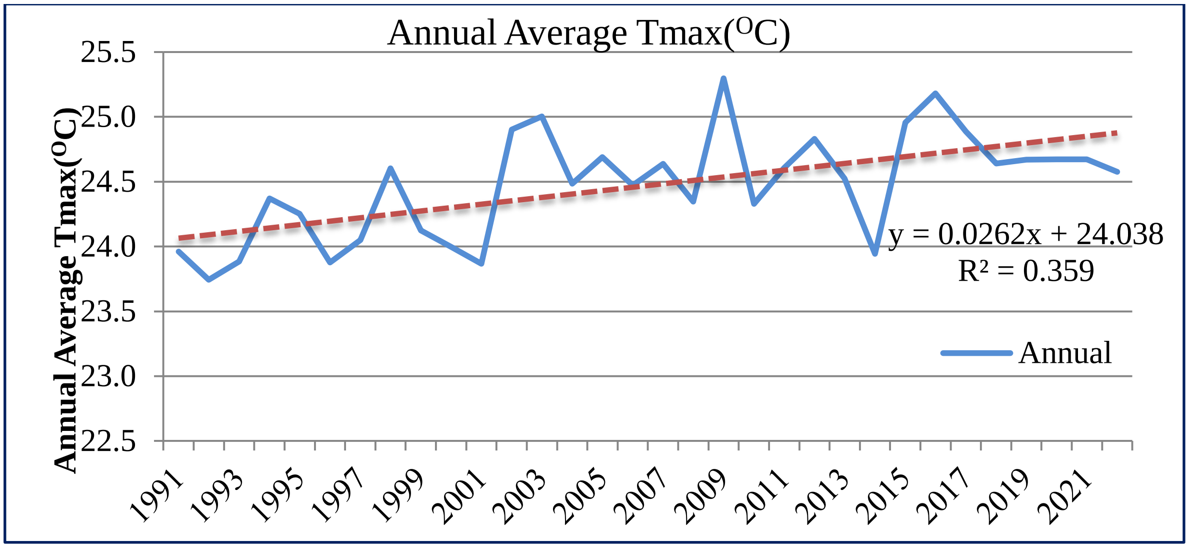

Figure 4.4 Annual Average Maximum Temperature Trends

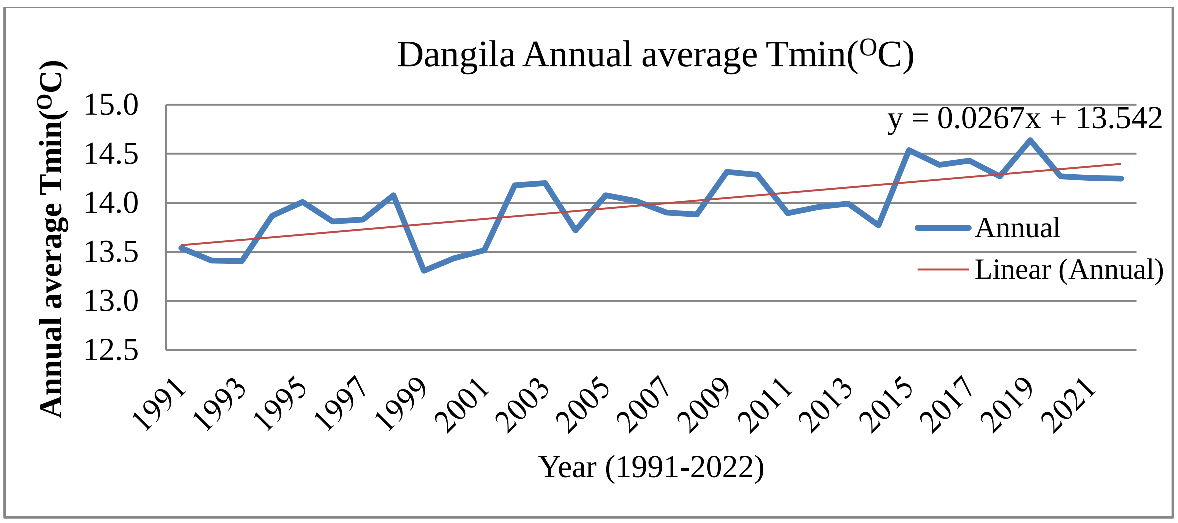

Figure 4.5 Annual Average Minimum Temperature Trends

In our analysis, the increasing trend of the temperature variable is lined and our results were in agreement with other studies (Misganaw, 2020; Asfaw *et al.*, 2018b; Lemma, 2016 & Mengistu *et al.*, 2014). Most specifically, Mihiretu *et al*. (2020) reported that the annual minimum temperature in Ethiopia increased by about 0.37 ^{O}C every decade, and between 1960 and 2006, the mean annual temperature increased by 1.3 ^{O}C, at an average rate of 0.28 ^{O}C per decade between 1951 and 2006. Strongly agree with our finding which is the annual minimum temperature in Dangila District increased by 0.3 ^{O}C per decade and the mean annual temperature increased by 0.2 ^{O}C per decade within the period 1991-2022. Another finding investigated by Mengistu *et al*. (2014) in the Blue Nile basin area indicated an increased annual average minimum temperature (0.8 ^{O}C) and average maximum temperature 1.4 ^{O}C per decade respectively whereas our finding the annual minimum and maximum temperature is increased by about 0.3 ^{O}C per decades.

In the decadal basis from the period 2006–2015, the observed global maximum temperature was 0.87 ^{O}C on average between 0.75 ^{O}C and 0.99 ^{O}C fluctuations, which is higher than the average of the 1850–1900 period (IPCC, 2018). This climate variable result strongly agrees with our result of mean maximum temperature which is 0.93 ^{O}C per three decades in the study period 1991-2022.

4.2 Farmers' Perception of Climate Change and Variability

Agricultural productivity is affected by natural rainfall. Households take climatic variability into account to lessen the effects of this problem. As a result, local households are better equipped to adapt to climate change (Haque *et al*., 2012; Techniques *et al.*, 2016). The household perspective of climate change offers a strong opportunity to employ effective adaptation strategies (Techniques *et al*., 2016). The findings of factors influencing the choosing of a particular adaptation strategy suggest the most significant effects on farmers' adaptation decisions as agricultural experience, educational attainment, gender, and farm size. Farming experience facilitates the identification and implementation of any adaptation strategy. Farming experience has significantly influenced the choice of all adaptation strategies (Assoumanza *et al*., 2016; Tazeze *et al.*, 2012). According to Kumari *et al.* (2014), educated and experienced farmers are expected to have more knowledge and information about climate change and the agronomic practices that they can use in response. Farm size determines the decision to combine multiple strategies to cope with climate change. This is confirmed by Chalchisa (2016), large-scale farmers are more likely to adapt to climate change because they have more capital and resources.

4.2.1 Farmers' perception of rainfall

More than 69 % of the sampled households from each agroecology and Kebele perceived that rainfall is decreased. On the other hand, 5.56 % of respondents in Dega higher than 4.17 % in Woyna Dega and 4.76 % in Kola explained that rainfall is increased. Correspondingly, 6.94 %

of respondents in Dega, 8.33 % of respondents in Woyna Dega, and 4.76 % of respondents in Kola perceived no change in rainfall (Figure 8). This implies that the change in rainfall occurred in both agroecology and kebeles have different perceptions by every farming community in the district. Similarly, Shankar (2018), found significantly different perceptions of farmers in different agroecology of the upper Blue Nile Catchment of Ethiopia.

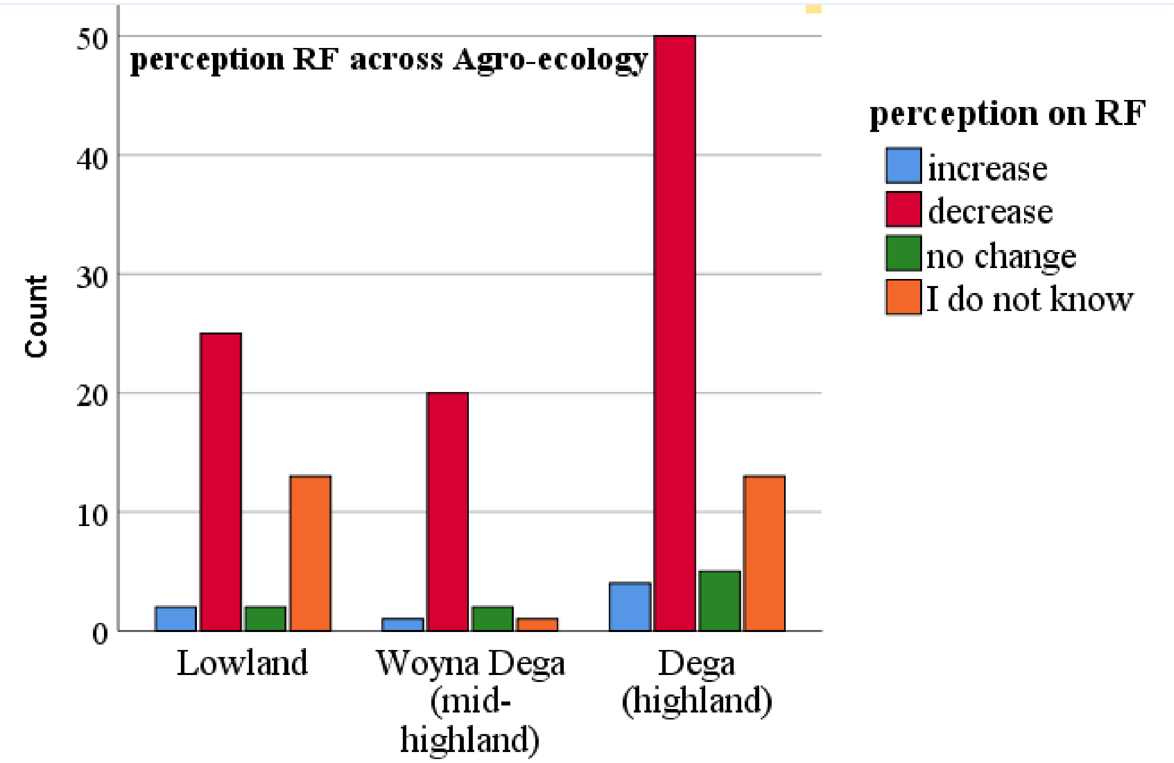

Figure 4.6 Farmers' perception of rainfall across agro-ecology and Kebele

In both sexes, the highest proportion of respondents male (68 %) and female (65.79 %) believed a decrease in rainfall, and the minimum proportion of respondents' male (4 %) and females (5.26 %) believed an increase in rainfall. However, a large number of female household heads (26.32 %) relative to male household heads (20 %) said I do not know about the perception of rainfall distribution in the district. Therefore, the cross-tabulation descriptive statistical analysis (Chi-square test) statistically has a significant variation of perception in rainfall by gender ($\chi2 = 2.407$, $P = 0.496$) (Table 4.4). It indicates that female-headed households are perceived less because they have less access to information, technology, and social institutions, while male-headed farmers have access to information due to their sociability, decision-makers, and participation in local institutions. Similar studies found significant differences in the perception of climate change between male and female household heads (Marelign *et al.*, 2019; Kidanu *et al.*, 2016). Shankar (2018) also found significant variation between the perception of males and females to rainfall change.

Table 4.4 Farmers' perception of rainfall over sex

Sex	Farmers' perception of rainfall over sex					**P-**
	increase	decrease	no change	I do not know	$\chi2$	value
Male	4 %	68 %	8 %	20 %		
Female	5.26 %	65.79 %	2.63 %	26.32 %	2.407*	0.492

*, is significant at 5 % level, (Source: own Survey, 2023)

4.2.2 Farmers' perception of temperature

As displayed in figure 4.7, most of the respondents from each agroecology (66.67 %) from Dega, 70.83 % from Woyna Dega, and 76.19 % from Kola perceived that temperature is increased. A small proportion of the respondents (9.72 % from Dega, 4.17 % from Woyna Dega, and 7.14 % from Kola) explained that the temperature has decreased. The remaining 16.67% from Dega, 8.33 % from Woyna Dega, and 11.90 % from Kola perceived no temperature change, and 6.94 % from Dega and 16.67 % from Woyna Dega and 4.76 % of Kola perceived that they do not know whether the temperature is changed or not (Figure 4.7). This indicates that the temperature change occurred in both agroecology and it was felt more or less equal by every farming community in the district. Similarly, Shankar (2018) & Bunu (2021) found insignificant variation in the perception of farmers to temperature change in different agroecology of the upper Blue Nile catchment in Ethiopia.

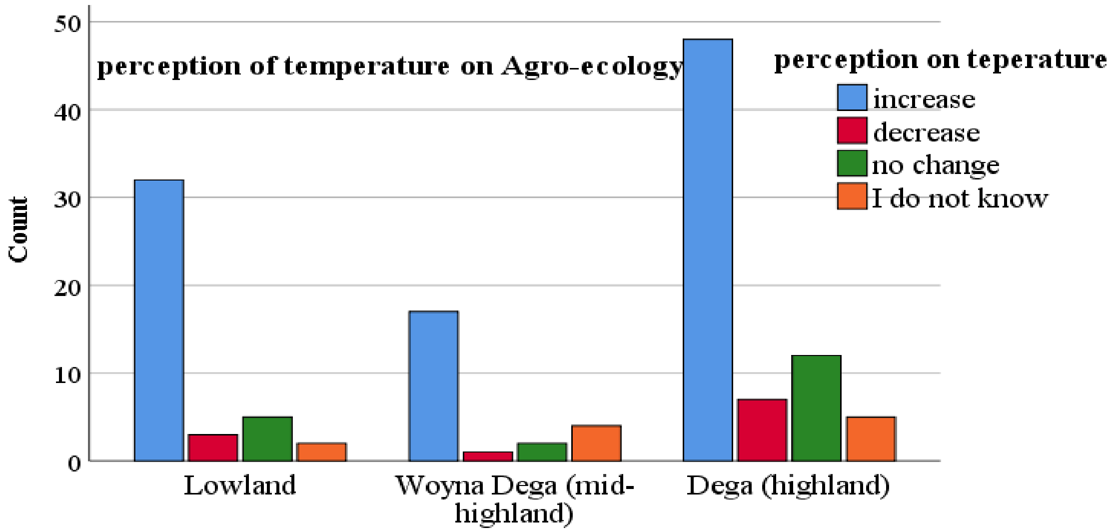

Figure 4.7 Farmers' Perception of Temperature across agro-ecology and Kebele

From the total of respondents, about 70 % of male and 63.16 % of female respondents perceived temperature is increased as well as 6 % of male and 13.16 % of female respondents said it is decreased. While 11 % of male and 18.42 % of female respondents perceive that they do not know about temperature change (Table 4.5). From the result female-headed households are perceived less since they have less access to information, technology, and social institutions, while male-headed farmers have access to information due to their sociability, decision-makers, and their participation in local institutions.

Table 4.5 Farmers' perception of temperature over sex

Sex	Farmers' perception of rainfall over Sex					**P-**
	increase	decrease	no change	I don't know	$\chi 2$	value
Male	70.00 %	6.00 %	13.00 %	11.00%		
Female	63.16 %	13.16 %	5.26 %	18.42 %	3.904*	0.272

*, is significant at 5% level, (Source: own Survey, 2023)

Similar studies found significant differences in the perception of climate change between male and female household heads (Marelign *et al*., 2019; Kidanu *et al*., 2016). The statistical analysis showed that there was a significant difference in the perception of male and female temperature change (Pearson Chi-square /$\chi 2$/ =3.904, P=0.272) (Table 4.5).

4.2.3 Farmers' perception of anthropogenic causes of climate change and variabilities

Figure 4.8 shows agricultural activity is the highest percentage 55.80 % of major anthropogen ic causes of climate change and variability in the district. Similarly, Wiedemann *et al*. (2015); and Jones *et al*. (2014) agriculture affects climate change through the emission of GHG from different farming practices. Currently, the agricultural sector is the highest source of emissions in Ethiopia, contributing 51 % of the total emissions (Lo, 2016). Therefore, agriculture and land use change are major contributors to climate change. Next to agricultural activity deforestation (20.29 %) and overgrazing (10.87 %) have contributed to anthropogenic causes of climate change and variabilities in the district. According to IPCC (2018b), annual emissions from deforestation stand at 5.8 Gt CO_2, and around 17 % of global anthropogenic GHG emissions come from the forestry sector as a whole. Similarly, deforestation may account for up to 25 % of global total anthropogenic emissions and is said to be the largest single source category in the developing world (IPCC, 2018). Population pressure (8.70%) and burning of fossil fuel (4.35 %) affect anthropogenic causes of climate change and variability in the district. On the contrary, the energy sector fuel combustion (heating, cooking) and transport contribute to high GHG emissions. Biomass is the major source of household energy and estimates indicated that 95 % of the total energy consumption in the country was made up of biomass fuels consisting of fuel wood, animal dung, and crop residue (Mitike *et al.*, 2016; Bisare Bitire, 2022).

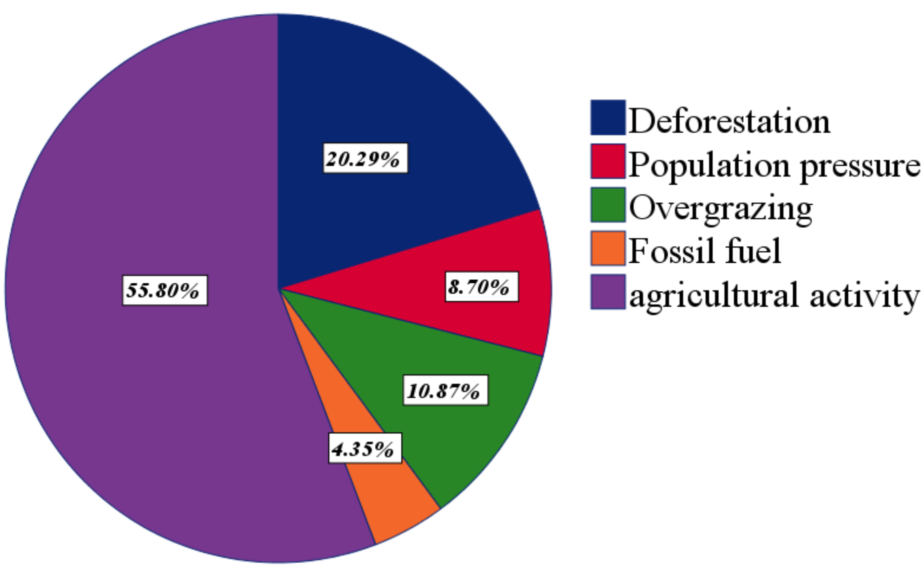

Figure 4.8 Farmers' perception of major anthropogenic causes of climate change &variability

4.2.4 Farmers' perception of rainfall duration/ Existence

The frequency of descriptive statistics of the respondents in the study area perceived rainfall duration/ existence from highest to lowest respectively was, unbalanced time & amount 55 (39.9 %), come late & stop early 43 (31.2 %), come late & stop late 28 (20.3 %), and come early & stop late 12 (8.7 %). This shows the decrease in rainfall and the presence of climate change in the district (Table 4.6). Similarly, different authors align perceptions and meteorological observations on rainfall which frequently stated indication of climate variability and/or change in the increase in unpredictable rainfall (Friedman *et al.*, 2019). Irregular appears more commonly used by farmers and only a few scientists have attempted to quantify what is meant by erratic using methods such as coefficient of variation (Byakatonda *et al.*, 2018), or associating unpredictable rainfall with periodic atmospheric phenomena such as El Niño (Ayanlade *et al.*, 2018).

Table 4.6 Farmers' perception of rainfall duration/ Existence

Rainfall duration/ Existence	Frequency	Percent
come late & stop early	43	31.2
come early & stop late	12	8.7
come late & stop late	28	20.3
unbalanced time & amount	55	39.9

(Source: own Survey, 2023): *No. of observation = 138*

4.2.5 Farmers' perception of the impact of climate change-induced hazards

Climate change impacts are the main reason for the decline in agricultural production (Kidanu *et al.*, 2016; Marelign *et al.*, 2019). In the district, different induced hazards affect farmers' livelihood which is caused by the impact of climate change and variability. Among those hazards Plant disease (54.3 %), shortage of water (35.5 %), livestock disease (23.9 %), and flood (22.5 %) were major and more frequent that affect farmers' livelihood due to having high potential to reduce agricultural productivity (Table 4.7). The result of KII respondents showed that different plant diseases such as CBD (coffee berry disease), downy mildew (onion disease), mango disease, and aphid and cutworm insects were common in the district. Among animal diseases that are common in the district are anthrax, FMD (foot & mouth diseases), and PPR (peptides petites ruminate). These common plant and animal diseases are caused by climate variability. The rest-induced hazards such as; human disease (13.5 %) and extreme heat (10.9 %) were less frequent and had less effect on farmers' livelihood and agricultural productivity in the district (Table 4.7).

Similarly, under all assessed emission scenarios the surface temperature is projected to rise over the 21th century, whereby, changes in precipitation will not be uniform (Lachgar *et al*., 2022). Extreme weather events including droughts and floods are frequent and can cause significant shocks to the agriculture sector, economy, and food security at the local level. Droughts and floods are highly uncertain, and there are serious implications for widespread crop failure, costly damage to infrastructure, and degradation of soil and land in many regions (IPCC, 2018). Changes in temperature and rainfall patterns may lead to an increase in weeds pest attacks and diseases affecting grasses and crops (Escarcha *et al*., 2018). Increased temperature leads to greater evaporation and thus surface drying, which increases the intensity and duration of droughts (Tiwari *et al*., 2021; Hussain *et al*., 2018). Similarly, the reported increase in livestock disease is consistent with the findings of studies by others that changes in temperature, rainfall patterns, and humidity are directly related to increased incidences of livestock disease (Escarcha *et al*., 2018; Narayanan, 2018).

Table 4.7 Farmers' Perception of Induced Hazards that affect farmers' Livelihood in the study area

Major induced hazards	Frequency	Percent (%)
Extreme heat	15	10.9
Plant disease	75	54.3
Livestock disease	33	23.9
Human disease	19	13.8
Flood	31	22.5
Shortage of water	49	35.5

4.2.6 Farmers’ perception of impacts of climate change and variability on resource availability

Most respondents in the district perceived a dramatic decrement in resources especially natural forest (73.9 %), irrigation water (52.9 %), agricultural productivity (55.8 %), and drinking water (55.1 %). While 48.6 % of the respondents perceived the increase of artificial forests especially farmers’ plant eucalyptus /*Bahir zap*/ tree on their farmland due to its economic benefit. In addition, 75.4 % of respondents in the district perceived an increase in land degradation (Table 4.8). This indicates that climate change and variability have many negative impacts on resource availability in the study area. Studies that are lined with our analysis were conducted in different areas across the country of Ethiopia. Among these, according to Lachgar *et al*. (2022), climate change has the potential to substantially alter agricultural systems. It will affect agricultural productivity characterized mainly by changes in precipitation, temperature, carbon dioxide (CO2) fertilization, climate variability, and surface water runoff (Gassner *et al.*, 2019).

Usually, current observations and climate projections suggest that one of the most significant impacts of climate change will likely be on the hydrological system and, hence, on river flows and regional water resources (Bahia *et al*., 2020; Goldstein *et al.*, 2019). Groundwater recharge is affected by land use and land cover change, urbanization, loss in forest cover, changes in cropping patterns and rotation, and changes in soil properties occurring over a long period that may affect infiltration capacity. However, precipitation and temperature will have direct effects as these combinations are useful for determining the availability of fresh water and the level of soil moisture, which are critical inputs for crop growth. Also, higher precipitation leads to a reduction in yield variability (Mali *et al.*, 2021), and higher precipitation will reduce the yield gap between rainfed and irrigated agriculture, but it may also have a negative impact if extreme precipitation causes flooding (Bohnert & Martin, 2022).

Table 4.8 Farmers' Perception of the Impacts of climate change and variability on resource availability

Resource availability	Increase		Decrease		No change	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Natural forest	24	17.4	102	73.9	12	8.7
Artificial forest	67	48.6	34	24.6	37	26.8
land degradation	104	75.4	25	18.1	9	6.5
Drinking water	23	16.7	76	55.1	39	28.3
Irrigation water	26	18.8	73	52.9	39	28.3
Agricultural production	35	25.4	77	55.8	26	18.8

4.3 Adaptation Strategies to Climate Change and Variability

During the HH survey, focus group discussions, and key informant interviews of farmers in the study District, the majority of respondents perceived climate change which is expressed in terms of unpredictable rainfall, late come and early stop of rainfall as well as an increase in temperature in the last three decades. In response to this, the descriptive statistics indicate that 96.38 % of the HHs have employed various adaptation strategies to the adverse effects of climate change and variability. However, the remaining 3.62 % of the respondents have not done adaptation measures. Similar results were reported by Destaw & Fenta (2021) in their study in the central Rift Valley region of Ethiopia indicating that about 95 % of the respondents were implementing various types of adaptation strategies to adverse impacts of climate change. The present result is also in agreement with the reports of Redda *et al*. (2022); Mutunga *et al*. (2017), & Usmail *et al.* (2023) They thought that the majority of the rural farmers in their study area have used various adaptations techniques to combat the negative effects of climate change. This is consistent with the findings from the key informant interviews and focus groups. However, the majority of HHs claimed that current adaptation strategies are insufficient for minimizing the negative effects of climate change on their way of life. This is because rural farmers typically implement simple adaptation strategies for the majority of the measures of adaptation. Moreover, these HHs that carry out climate adaptation activities were asked once more to list the main adaptation strategies they use to combat the negative effects of climate change and variability. Consequently, the adaptation techniques used by rural HHs encompassed improved variety, soil, and water conservation, planting trees and agroforestry, using irrigation and water harvesting, using fertilizer and pesticides, diversifying crops and livestock, not adapting, and diversifying income sources (Figure 4.9). Similar findings were reported by several authors Sesay *et al.* (2022) & Landaverde *et al.* (2022). Hirpha *et al.* (2020) indicated that diversifying crops, SWC, planting trees & agroforestry, and income diversification were the main adaptation practices employed by rural farmers in the Adama district, Central Rift Valley region of Ethiopia.

Conversely, some of the strategies reported by the same author such as changing the quantity of land under cultivation and irrigation crop farming were different from the adaptation strategies implemented in our study sites. This shows that some climate change adaptation measures are location-specific and also Destaw & Fenta (2021) considered in their study area which is Climate change adaptation strategies and their predictors amongst rural farmers in Ambassel district, Northern Ethiopia. Yet, some of the strategies reported such as terracing as soil and water conservation strategy and changing planting date were different from the adaptation strategies implemented in our study sites. This is supported by the findings of Kumari *et al.*(2023) & (Satour et al., 2020) who specified that climate change adaptation measures were area-specific and affected the socioeconomic condition. Building adaptive capacity is crucial for the effective selection and implementation of adaptation options (Lachgar *et al.*, 2022 & Slone *et al.*, 2022).

The majority of HHs use soil and water as a conservation technique, which shows how vulnerable the areas are to the effects of soil erosion, and when compared to other adaptation strategies, SWC was the one most frequently implemented by farmers in the research area to combat the negative impact of climatic variability on crop production.

Table 4.9 Current adaptation strategies used by farmers in the study district

Adaptation Strategies	Frequency	Percent (%)
Use improved variety	65	47.1
Soil and water conservation	79	57.2
Planting trees & agroforestry	61	44.2
Use irrigation & water harvesting	41	29.7
Using fertilizer and pesticides	49	35.5
Crop and livestock diversification	43	31.2
Diversify income source	16	11.6
No adaptation	31	22.5

Note*: a farmer can adopt more than one adaptation strategy.* (Source: own survey, 2023)

Use an improved variety

In the district among 138 respondents 65 (47.1 %) of respondents use improved variety as adaptation strategies (Table 4.9). FGD and KII expressed that farmers in the district use different types of improved varieties of seeds such as maize, teff, wheat, and other cereals and fruit seeds supplied by the government which are highly productive.

Soil and water conservation

Based on the household survey data collected from 138 households, the majority of the respondents 79 (57.2 %) use soil and water conservation as adaptation strategies. However, among interviewed household respondents, FGD and KII expressed that soil and water conservation practice as an adaptation strategy was performed mostly by the group of social community with the aid of the government month of January within a year rather than individual landowners (Table 4.9). It is mainly used because of soil degradation and soil erosion, and farmers due to this, want to rehabilitate their fields. These activities are gradually important today since the climate changes to some extent are accelerating these processes (Cherinet *et al.*, 2022 & Fayera, 2022).

Planting trees & agroforestry

Another major adaptation strategy in the district is agroforestry and perennial plantation. 61 (44.2 %) adapt to climate change by using planting trees & agroforestry systems (Table 4.9). Many studies have shown that agroforestry may offer many economic and environmental benefits. According to (deHaan et al., 2020), agroforestry has an important role in climate change adaptation by enhancing resilience to climate impacts on farming systems and it has a double potential to address climate change issues, GHG mitigation strategy through carbon sequestration and sustainable adjustment to changing conditions. Apart from its socioeconomic benefits agroforestry, through its effects on soil conservation, protection of biodiversity, and carbon sequestration is the most sustainable strategy (Khadka *et al*., 2021).

Use irrigation & water harvesting

Among 138 respondents 41 (29.7 %) adapt to climate change by Using irrigation & water harvesting (Table 4.9). Among interviewed household respondents, FGD and KII expressed that irrigation and drinking water are plentiful resources in the district. However, the distribution of drinking and irrigation water varies from Kebele to Kebele and from season to season. In contrast, the use of irrigation is one of the least practiced adaptation strategies among the major adaptation methods identified in Ethiopia (Kom *et al*., 2020).

Using fertilizer and pesticides

Among the current adaptation strategy of the respondents, 49 (35.5 %) of respondents, use fertilizer and pesticides to cope with climate changes and variability (Table 4.9). However, important studies have revealed the negative impacts of chemical fertilizers and pesticides (especially overuse) on the environment (Dhankhar & Kumar, 2023). Given the increase in agricultural pests and diseases, some farmers have no choice but must adapt to learning more sustainable farming practices, like organic farming or integrated pest management, because the long-term effects of high-input agriculture are contamination of soils and water, water scarcity, and losses in biodiversity. According to (Dhankhar & Kumar, 2023), they all have direct negative consequences on animal and human health.

Crop and livestock diversification

Crop and livestock diversification is the main method used by farmers to adapt to climate changes in Ethiopia (Zeleke *et al*., 2022). Farmers can face growing stress from climate change by implementing a diversified agricultural system which may be a productive way to build resilience into agricultural systems (Nazir & Lohano, 2022). Crop diversification (the practice of cultivating more than one variety of crops belonging to the same or different species in a given area in the form of rotations and or intercropping) is perceived as one of the most ecologically feasible, cost-effective, and rational ways of reducing uncertainties in agriculture, especially among smallholder farmers. Crop diversification improves soil fertility, controls pests and diseases, and brings about yield stability, nutrition diversity, and health (Nazir & Lohano, 2022). In contrast to the above facts and studies, only the minimum number of respondents (31.2%) use crop and livestock diversification to adapt to climate changes and variability in the district (Table 4.9).

4.4 Determinants of Farmers' Choice of Major Adaptation Strategies

Table 4.10 Parameter estimates of the multinomial logit climate change adaptation model

Explanatory Variables	Use improved Variety		Soil and water conservation		Planting tree & agroforestry		Use irrigation & water harvesting	
	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value
AgroEcolo	-1.217	0.052	-3.952	0.000	-.491	0.571	-.695	0.492
Kebele_resp	.175	0.819	.882	0.408	1.036	0.278	.112	0.945
Sex_hh	.814	0.161	.478	0.467	.925	0.188	1.040	0.173
Age_hh	-.095	0.026	-.113	0.022	-.116	0.037	-.059	0.271
Religious_hh	19.12	0.993	.231	0.39	17.85	0.996	.134	0.944
Famlysize_hh	.223	0.026	.107	0.343	.125	0.319	.318	0.025
Education_level_hh	-.016	0.934	-.152	0.473	-.144	0.553	-.539	0.188
Farming_expria_hh	.132	0.007	.107	0.048	.147	0.019	.103	0.095
Martial_stat_hh	.044	0.883	.0834	0.85	1.086	0.124	.091	0.865
Incom_sour_hh	1.14	0.147	2.126	0.029	.108	0.923	15.89	0.992
TLU_hh	-.041	0.407	-.105	0.084	-.048	0.463	-.180	0.049
Farmland_size_hh	1.48	0.000	.743	0.085	2.892	0.001	1.758	0.002
Acce_Exte_service	.085	0.875	2.526	0.028	.266	0.713	.736	0.359
Financial problem	-.315	0.526	-.461	0.449	-.090	0.886	-.368	0.613
Acce_infrastructure	.046	0.915	.848	0.074	2.732	0.005	1.09	0.055
Acce_CC_Inform	.809	0.069	.637	0.198	1.060	0.073	1.408	0.067

To estimate the coefficient of the parameter, no adaptation was taken as a base category.

Table 4.11 Variables having a significant effect on adaptation to climate change after paramet er estimated

Explanatory Variables	Use improved Variety		Soil and water conservation		Planting tree & agroforestry		Use irrigation & water harvesting	
	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value
AgroEcolo	-1.217	0.052**	-3.95	0.000***	-.491	0.571	-.695	0.492
Age_hh	-0.095	0.026**	-0.113	0.022**	-0.116	0.037**	-0.059	0.271
Famlysize_hh	.223	0.026 **	.107	0.343	.125	0.319	.318	0.025**
Farming_expria_hh	.132	0.007***	.107	0.048**	.147	0.019**	.103	0.095*
TLU_hh	-.041	0.407	-.105	0.084*	-.048	0.463	-.180	0.049**
Farmland_size_hh	1.477	0.000***	.743	0.085*	2.892	0.001***	1.758	0.002***
Incom_sour_hh	1.138	0.147	2.126	0.029**	.108	0.923	15.89	0.992
Acce_infrastructure	.046	0.915	.848	0.074*	1.354	0.011***	1.09	0.055**
Acce_CC_Inform	.809	0.069*	.637	0.198	1.060	0.073*	1.408	0.067*
Acce_Exte_service	.085	0.875	2.526	0.028**	.266	0.713	.736	0.359

Coeff. = Coefficient; base category= No adaptation; Number of obs = 138; LR chi2 (44) = 96.44; Prob > chi2 = 0.0000; Pseudo R2 = 0.2502;

****, ** and * significant at 1 %, 5 %, and 10 % levels of significance.*

Age of household heads

Age of the household head shows a negative correlation with the use of the improved variety, soil and water conservation, and planting tree & agroforestry at p-values of 0.026, 0.022, and p-value of 0.037 respectively (Table 4.11) For instance, a unit increase in age of household head results in a 0.095, 0.113 and 0.116 times decrease in the choice of using improved variety, soil and water conservation and using planting tree & agroforestry over no adaption. This implies that older farmers' are less likely to use improved variety, soil, and water conservation, and planting trees & agroforestry which require more labor. The probability of adapting using an improved variety, soil and water conservation, and planting trees & agroforestry decreases the older a farmer is. The result strongly agrees with Mutunga and his friend's result, Thus, younger households are more active and energized than older households in the application of using improved variety, soil and water conservation, and planting tree & agroforestry as a strategy (Mutunga *et al*., 2018). In contrast to this result, (Kom *et al.*, 2020) an increase in age means an increase in farming experience which would increase farmers' indigenous knowledge to respond to the hazards resulting in climate variability.

Family size of the household

Family size is positive and significantly correlated with the household decision to use improved variety and irrigation & water harvesting at a p-value of 0.026 and 0.025 respectively (Table 4.11) in which a unit increase in a family size the probability of using improved variety and use irrigation & water harvesting over no adaption increase by 0.223 and 0.318 respectively. Those households that have larger families have an opportunity to use various adaptation options in the face of climate changes and variability. The same is true in the findings of (Kom et al., 2020), a large family is associated with a higher labor endowment which would enable a household to accomplish various agricultural tasks, especially during the summer seasons.

Agroecological zone

Climate change has location-specific impacts on agricultural production and hence, farmers will have location-specific adaptation responses to adverse impacts of climate change (Below *et al*., 2012; Hinkel, 2011). The present study tested whether there is a significant association between agroecological zones and climate adaptation measures employed by the local farmers at the study sites. The results showed that the agroecological zone is negative and significantly correlated with the household decision to use improved variety and soil and water conservation over no adaptation. The present result is in agreement with (Atinkut & Mebrat, 2016), and Tesfaye & Seifu (2016) who reported that different farmers living in different agroecological settings employ different adaptation methods to the effects of climate variability and change.

Farming experience of household heads

This factor had a positive and strong effect on the major adaptation strategies. All adaptation strategies are influenced by this factor (Table 4.11). The study hypothesized that farmers who had more farming experience were more likely to adapt to climate change. This finding is in agreement with Mutunga *et al*. (2018), and Kom *et al.* (2020), and Similar studies reported by Tadese *et al.* (2022) noted that as they become more experienced in farming they adapt to climate changes and variability.

Access to climate information

Various studies in developing countries, including Ethiopia, report a positive relationship between access to information and the adaptation behavior of farmers (Etsay *et al*., 2019). Farmers who have important climate information have better chances of being aware of changing climatic conditions as well as adaptation measures in response to the changes (Ngcamu & Chari, 2020). Similarly, in this study access to climate information had a positive and significant effect on the major adaptation strategies in the district. It indicates households in the district can develop different adaptation strategies when they do get sufficient extension service and climate information.

Access to infrastructure

Infrastructure plays a role in the determinants of climate change and variability adaptation such as to get access to information about climate change adaptations and other farming practices and strategies. Hence farmers living far away from the administrative center in their district might have challenges with electricity, mobile phone connection, and the radio, which can make it difficult for them to hear new information about climate change and variability. In line with this, the result of this study shows that infrastructure has positive and significant effects on soil and water conservation, planting trees & agroforestry, and Use of irrigation & water harvesting (Table 4.11).

Farmland size of household heads

Farmland size has appeared to be positively and strongly significantly correlated with the use of improved variety, soil and water conservation, planting tree & agroforestry, and Use of irrigation & water harvesting at p-values of 0.000, 0.085, 0.002, and 0.002 respectively relative to the coefficient (Table 4.11). A similar result is confirmed by (Marie *et al*., 2020).

Financial problems of household heads

The implementation of new agricultural technologies requires sufficient financial wellbeing (Piñeiro *et al*., 2020; Tey *et al.*, 2017). Higher-income farmers may be less risk-averse and have more access to information; consequently, they develop good adaptation strategies to climate change and variability.

TLU (Total livestock unit)

Total livestock units of households significantly influence Soil and water conservation, and Use irrigation & water harvesting at 10% and 5% percent levels of significance (Table 4.11).

Chapter 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In the study area, the variability of seasonal rainfall was found to range from low to high levels. The winter (*Bega),* summer season, and annual rainfall trend were insignificant increases. However, there was a non-significant declining trend in the *Belg* (spring) season during 1991-2022. The annual maximum and minimum temperature trends in the study area were significantly increasing during the period 1991-2022. The annual minimum temperature and annual maximum temperature for the past three decades (1991-2021) scaled by about 0.3 ^{O}C decadal with 0.03 ^{O}C yearly increasing rate.

According to a survey conducted among farmers, it was observed that there has been a change in climate over the past three decades. The majority of farmers who participated in the survey reported an increase in temperature and a decrease in precipitation.

The study employed descriptive statistics to evaluate the current adaptation techniques being used by farmers. Farmers are pursuing various adaptation mechanism which includes improved variety, soil and water conservation, planting tree crops, agroforestry, using irrigation, water harvesting, using fertilizer and pesticides, diversifying crops and livestock, not adapting, and diversifying income sources. However, the adaptation method used by farmers is different from agro-ecology to agro-ecology in the study district.

The multinomial logit model was also used to identify the determinants that farmers take into consideration when selecting an adaptation strategy. Certain factors such as age, sex, family size, educational attainment, farming experience, access to extension services and climate information, lack of infrastructure, farm size, TLU, agro-ecological zone, and financial issues have an impact on the adaptation strategies used by farmers to cope with climate change and variability in the district.

5.2 Recommendations

Based on the main findings of this research the following recommendations are recommended.

- ☑ The local farming population in the research area should have access to updated metrological data. Soil and water conservation structures should be made simpler, and small-scale irrigation systems should be stepped up.
- ☑ All of the kebeles in the district's agroecological zones had households with a lower degree of adaptability. To help farmers adjust more effectively to the various climatic extremes they encounter, it is suggested to implement rural development strategies.
- ☑ To lessen the effects of climate change, particularly for the most vulnerable social groups, community and government should strengthen sustainable adaption techniques including soil and water conservation, use of better variety, planting trees and agroforestry, and use of irrigation and harvesting of water.
- ☑ Additional research on the effects of climate change and individual adaptation measures on societal livelihoods at the farm level is necessary to improve agricultural production and productivity using appropriate agricultural technologies and inputs (employ climate-smart agriculture).

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7. APPENDICES

Appendix 1: Rainfall and Temperature Variability and Trend Results

Table 7.1 Rainfall distribution of the study area (1991-2022)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Bega	Belg	Kiremt	Annual
1991	7.5	19.1	35.8	107	144.5	305	450.2	445	250.7	108	15.3	8.5	139.1	306.2	1450.9	1896.2
1992	7.9	13.4	25.3	113	61.6	216.5	330.1	450.8	236.4	218	55.9	21.6	303.1	213.6	1233.8	1750.5
1993	9.2	21	65.3	87.3	186.5	214.8	358.1	313	272.3	167	58.3	8.8	243.7	360.1	1158.3	1762
1994	8.8	15.9	19.5	41.3	182.6	266.4	314.9	311.4	242.9	82.8	58.7	15	165.4	259.3	1135.5	1560.2
1995	7.7	13.5	54.5	49.7	114.7	249.4	319.7	379.2	218.7	63.9	16.3	16.2	104.1	232.3	1167	1503.5
1996	12	15.4	96.4	99.6	174.8	231.4	375.9	384.2	271.1	80.8	21.9	13.9	128.6	386.3	1262.6	1777.5
1997	9.4	12.5	56.7	73.6	234.1	211.2	297	342.3	256.1	230	81.2	11.5	331.8	376.8	1106.6	1815.3
1998	8.5	16.2	37.7	30.9	193.8	294.3	326.4	391.9	248.6	179	24.2	8.9	220	278.6	1261.2	1759.8
1999	15	12.6	15.9	37.1	168.3	264.6	333.6	378.4	246.7	194	44.5	15.9	269	233.9	1223.3	1726.2
2000	8.6	11.1	19.2	118	123.2	241.7	333.3	396.3	219	278	59.5	10	356.4	271.8	1190.3	1818.5
2001	5.1	10.4	26.8	46.5	138.7	257.7	353.1	366.8	189.9	147	30.3	9.4	192	222.4	1167.5	1581.9
2002	11	9.7	43.9	37.5	56.3	244.1	331.5	303.7	216	139	30.6	8	188.9	147.4	1095.3	1431.6
2003	5.1	14.4	43.9	18.3	32.9	278.6	316.4	338.5	284	65.2	50.5	11.7	132.5	109.5	1217.5	1459.5
2004	6	12.2	19.3	91.6	41.6	233.9	386.4	342.4	277	120	52	9.6	187.1	164.8	1239.6	1591.5
2005	6.1	9.8	90.3	21.1	70.1	255.6	345.6	331.8	272.2	113	25.1	3.7	147.6	191.3	1205.1	1544
2006	8	12	17.4	37.6	194.2	266.6	435.6	467.8	269.3	208	37.5	27.7	281.3	261.3	1439.2	1981.8
2007	8.4	18	28.4	74.1	127.8	273.4	330.8	354.8	228.9	96.1	51	3.7	159.2	248.3	1188	1595.5
2008	20	9.4	17.8	125	217.4	248.6	389.4	391.5	241.1	102	26	6.7	154.2	369.9	1270.6	1794.7
2009	5.4	11.4	50.1	50.5	42.1	262.1	343.6	351.6	152.7	129	13.8	10.3	158.6	154.1	1110.1	1422.8
2010	10	10.4	23.8	44.3	131.4	230.1	407.6	370.4	309.3	72.6	16.7	8.3	107.6	209.8	1317.4	1634.9
2011	12	8.7	40.7	37.5	186.7	192.6	332.8	381.5	265.6	78.8	30.3	5	125.9	273.6	1172.5	1572
2012	5.7	8.5	30	15.2	72.4	235.4	425.3	455.1	273.2	81.4	85.8	21.1	193.9	126.1	1389	1709
2013	7.4	12.6	21.5	17.5	178.4	257.2	495.6	411.5	201.4	137	60.3	6.9	211.1	230.1	1365.7	1806.9
2014	7.1	12	160	139	231.1	217.4	323	329.1	341.6	160	24.2	12.8	204.2	541.7	1211.2	1957.2
2015	9.1	21.5	34.4	33.6	161.4	177.7	316.6	324.3	342.5	131	84.1	21.8	246.4	250.8	1161.1	1658.3
2016	8.4	17.7	41.1	31.2	235.5	196.3	384.9	365.8	210.2	142	11.6	5.4	167.6	325.5	1157.2	1650.2
2017	7.6	45.9	26.1	150	184	211.9	479.1	419.7	311.5	143	37.3	7	194.4	406.4	1422.1	2023
2018	7.5	22.5	49.8	33.7	134.1	236.8	358.8	365.4	271.4	135	89.9	18.8	251.2	240.1	1232.3	1723.6
2019	9.3	18.8	42.5	56.2	96.9	282.9	338.5	356.8	286.1	188	67.1	42	306.5	214.4	1264.4	1785.2
2020	10	11.5	22.3	82.2	191.6	259	326.7	368.8	256.8	104	12.3	11.7	137.8	307.6	1211.3	1656.7
2021	17	15.5	22.5	72	173.6	194.2	456.8	373.8	229.4	124	51.9	21.1	213.7	283.5	1254.3	1751.5
2022	7.7	16.3	22.8	67.1	54.3	267.7	389.4	320	243.3	177	38.5	15.4	238.3	160.5	1220.4	1619.1
Granc	342	342	342	342	342.3	342.3	342.3	342.3	342.3	342	342	342	342.3	342.3	342.3	342.3
Mean	9	15	40.7	63.8	141.8	243	365.8	371.4	254.2	137	42.6	13.1	201.91	261.2	1234.4	1697.5
SD.	3.3	6.82	29.4	37.7	61.59	30.95	52.44	43.01	40.7	52.1	23.1	7.95	66.061	91.87	93.971	152.64
CV(%	36	45.5	72.2	59.2	43.44	12.74	14.33	11.58	16.01	38	54.2	60.8	32.718	35.17	7.6126	8.9918
Min	20	45.9	160	150	235.5	305	495.6	467.8	342.5	278	89.9	42	356.4	541.7	1450.9	2023
Max	5.1	8.5	15.9	15.2	32.9	177.7	297	303.7	152.7	63.9	11.6	3.7	104.1	109.5	1095.3	1422.8

Table 7.2 Minimum temperature distribution of the study area (1991-2022)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Bega	Belg	Kiremt	Annual
1991	12.6	12.5	14.5	14.9	15.0	14.8	13.8	13.7	13.3	12.7	12.4	12.1	12.5	14.2	13.9	13.5
1992	11.7	11.8	15.0	16.1	15.5	14.5	13.5	13.2	12.7	12.9	12.0	12.0	12.1	14.6	13.5	13.4
1993	11.2	11.7	14.4	14.8	15.0	14.1	13.7	13.5	13.1	13.1	13.0	13.1	12.6	14.0	13.6	13.4
1994	13.4	13.5	13.9	17.3	15.2	14.6	13.3	13.7	13.0	13.1	13.3	12.2	13.0	15.0	13.6	13.9
1995	12.5	13.5	13.7	16.6	15.6	14.8	13.7	13.9	13.6	13.2	13.5	13.4	13.2	14.8	14.0	14.0
1996	12.2	14.2	14.9	16.4	15.1	14.2	13.6	13.9	13.5	13.0	12.4	12.4	12.5	15.1	13.8	13.8
1997	11.9	13.0	15.5	14.8	14.7	14.3	13.9	13.9	13.9	13.6	13.3	13.2	13.0	14.5	14.0	13.8
1998	12.9	12.6	15.8	17.9	16.1	14.7	14.1	14.3	13.9	13.2	11.9	11.4	12.4	15.6	14.2	14.1
1999	11.8	14.1	13.4	16.6	14.7	13.9	13.0	13.2	13.3	12.9	11.1	11.9	11.9	14.7	13.4	13.3
2000	12.1	13.2	14.8	14.6	15.1	14.0	13.6	13.5	13.3	12.7	11.9	12.3	12.3	14.4	13.6	13.4
2001	11.5	13.0	14.6	15.8	15.8	13.9	13.3	13.7	13.2	12.9	12.0	12.5	12.2	14.8	13.5	13.5
2002	12.4	14.2	15.6	17.0	16.8	14.7	14.4	13.9	13.2	13.0	13.3	11.8	12.6	15.9	14.0	14.2
2003	12.4	14.6	15.6	16.7	17.7	14.5	13.8	13.7	13.4	13.2	13.1	11.9	12.7	16.1	13.8	14.2
2004	12.3	13.1	15.1	16.3	15.6	13.8	13.5	13.7	13.1	12.5	13.1	12.7	12.6	15.0	13.5	13.7
2005	11.9	14.8	15.4	17.5	16.1	14.5	13.3	13.7	13.6	13.0	13.0	12.3	12.6	16.0	13.8	14.1
2006	13.4	14.4	15.5	16.3	15.1	14.1	14.0	13.5	13.3	13.6	12.8	12.2	13.0	15.3	13.7	14.0
2007	12.1	13.6	16.0	16.6	16.2	14.5	13.6	13.6	13.4	12.6	12.6	11.9	12.3	15.6	13.8	13.9
2008	12.9	13.5	15.8	15.5	15.1	14.1	13.7	13.6	13.6	13.0	12.9	12.8	12.9	15.0	13.8	13.9
2009	12.3	15.2	15.8	16.8	16.2	15.0	14.1	13.9	13.9	13.2	12.9	12.5	12.7	16.0	14.2	14.3
2010	12.7	14.1	15.3	17.2	16.1	15.1	13.9	14.1	13.7	13.4	13.1	12.8	13.0	15.7	14.2	14.3
2011	12.4	13.2	14.9	17.1	15.7	14.6	13.8	13.6	13.4	13.2	12.7	12.2	12.6	15.2	13.8	13.9
2012	12.4	13.6	15.2	16.1	15.8	14.4	14.0	13.6	13.6	13.0	13.4	12.4	12.8	15.2	13.9	14.0
2013	13.4	14.6	16.0	16.7	15.8	14.2	13.3	13.3	13.4	13.0	12.9	11.4	12.7	15.8	13.6	14.0
2014	12.6	12.7	14.9	15.7	15.0	14.5	14.2	13.5	13.3	13.6	12.7	12.4	12.8	14.6	13.9	13.8
2015	12.3	14.8	16.5	17.4	15.8	14.4	14.5	14.2	13.6	14.1	14.1	13.0	13.4	16.1	14.1	14.5
2016	12.3	14.7	17.6	17.7	15.6	15.0	14.1	13.6	13.6	13.6	12.2	12.8	12.7	16.4	14.1	14.4
2017	12.4	14.5	16.1	17.1	15.6	14.6	14.4	13.9	13.7	14.0	13.8	13.0	13.3	15.8	14.2	14.4
2018	12.5	15.0	15.5	16.2	16.0	14.5	14.0	13.6	13.4	13.5	13.3	13.7	13.3	15.7	13.9	14.3
2019	13.0	15.0	16.3	17.0	16.8	15.1	14.4	14.0	14.1	13.7	13.8	12.5	13.2	16.3	14.4	14.6
2020	11.3	14.3	15.1	17.5	16.2	14.9	14.3	14.2	13.8	13.2	13.2	13.3	12.8	15.8	14.3	14.3
2021	12.8	13.9	16.7	16.9	15.0	14.7	14.3	13.8	13.4	13.4	13.4	12.8	13.1	15.6	14.1	14.3
2022	12.9	13.7	16.5	16.7	16.4	14.7	13.9	13.9	13.7	13.1	12.8	12.5	12.8	15.8	14.1	14.2
Mean	12.4	13.8	15.4	16.5	15.7	14.5	13.8	13.7	13.5	13.2	12.9	12.5	12.7	15.3	13.9	14.0
SD.	0.6	0.9	0.9	0.9	0.7	0.4	0.4	0.3	0.3	0.4	0.6	0.5	0.5	0.8	0.3	0.3
CV(%)	4.5	6.7	5.8	5.2	4.4	2.5	2.7	1.9	2.3	2.8	4.9	4.4	4.2	5.5	2.3	2.5
Min	11.2	11.7	13.4	14.6	14.7	13.8	13.0	13.2	12.7	12.5	11.1	11.4	11.9	14.0	13.4	13.3
Max	13.4	15.2	17.6	17.9	17.7	15.1	14.5	14.3	14.1	14.1	14.1	13.7	13.4	16.4	14.4	14.6

Source; KNMI Climate Explorer data with 0.5 degree observation (1991-2022)

Appendix 2: Conversion Factors for Tropical Livestock Unit (TLU)

Livestock Type	Conversion Factor
Cow/Ox	1
Bull	0.08
Heifer	0.75
Calf	0.2
Hours/Mule	1.1
Sheep/Goat	0.06
Donkey	0.35
Chicken	0.013

Source: adapted from Teshome (2021)

Appendix 3: Photographs during the Field Survey

Figure 7. 1 Modern agronomic, and Livestock production system in the Study District

Figure 7.2 Household heads

Figure 7.3 Focus group discussion

Appendix 4: Household Survey Questionnaire

Bahir Dar University

College of Agriculture and Environmental Sciences Graduate Program

Department of Environment and Climate Change

Questionnaire completed by the Rural Communities of Dangila District

Dear Respondents: My name is Abaynew Mulat Yimenu, a Bahir Dar University graduate student. I am conducting research for the partial fulfillment of a master's degree in environment and climate change. The main objective of this questionnaire is to analyze the trend and farmers' perception of climate change and variability, understand farmers' current adaptation strategies for climate change and Variability, and assess the determinant factors that affect the selection of adaptation strategies. Therefore, the information that you provide is understood to help the concerned bodies in understanding farmers' knowledge of climate change and variability, its impacts, and their adaptive strategies. The response you give will not have any negative impact on you in addition to this you are not required to write your name. I would like to thank you for your cooperation.

Part I. Background information of the household head

Kebele of interviewer……………. Questionnaire number…………

1. Educational level of household head A. Illiterate B. Read and write C. Primary Education complete D. High school complete E. Higher education complete

2. Family size of household Male……………Female…………. Total…………………

3. Sex of household head…………………………………………………

4. Age of household head……………………………………………………..

5. Religious of household head………………………………………………..

6. Marital status A. Married B. Single C. Divorced D. Widowed

7. Income source of household A. Crop and animal production B. Only crop production C. Only animal production D. Working out of agriculture

8. Do you have extra income? A. Yes B. No

If the answer is yes place specify it……………………………………………………………..

9. Do you have livestock? A. Yes B. No

10. If the answer is yes how many livestock do you have?

A. Oxn…………. B. Cow…………. C. Donkey………. D. Goat…………………..

E. Sheep…….. ……F. Horse…………. G. mule……………………

11. Do you have your farmland? A. Yes B. No If yes how many hectares …………

12. Type of agriculture practiced A. Rain fed B. Irrigated C. Both

13. Do you have irrigable land A. Yes B. No

If yes how many hectares…………………….

14. Do you get extension services on crops and livestock? A. Yes B. No

15. Do you have access to credit from any source? A. yes B. No

If your answer is yes where do you get the credit?

……………………………………………

16. For how long did you practice farming?

……………………………………………………..

PART II. Adaptation strategies to climate change and variability

1. Do you think that it is possible to adapt to the impacts of climate variability-induced hazards?

A. Yes B. No

2. What is the solution taken in your farming area to adapt to climate change and variability-induced hazards? You can tick more than one tick mark.

No.	Adaptation strategies	0 if yes, 1 if no
1	Crop diversification	
2	Soil and water conservation	
3	Using drought resistance species	
4	Afforestation/planting tree	
5	Water harvesting	
6	Change crop calendar	
7	Use improved variety	
8	Using irrigation	
9	Using Fertilizer	
10	Diversify income source	
11	Seasonal migration	
12	No adaptation	

3. Who takes the responsibility to implement adaptation strategies? A. Governmental Organization B. Local community C. Non-governmental Organization D. Local community

4. Do you get agricultural support from the Government to practice adaptation strategies? A. Yes B. No

5. If the answer is yes list them…………………..…………………………………………
…………………………………………………………………………………………………

6. What are the obstacles to using adaptation strategies to climate change and variability?

A. Financial problem B. Small land size C. Reduced soil fertility D. Lack of skill

E. Shortage of input F. Age of household G. Lack of irrigation H. Lack of improved seed Variety

7. What are the determinant factors that affect adaptation strategies?

A. Lack of information B. Lack of infrastructure B. Distance from market C. Poor Communication with the extension worker

PART III. People's Perception of Climate Change and Variability

1. Do you think that is there climate change and variability in your area? A) Yes B). No

2. If the answer is yes what are the indicators of climate change and variability? You can tick More than one tick mark

No.	Indicators of climate change and variability	Put tick mark
1	Increase in temperature	
2	Decrease in temperature	
3	Increase in rainfall	
4	Decrease in rainfall	
5	Flooding	
6	Occurrence of drought	
7	Occurrence of disease and pest	
8	Decrease in river and stream water volume	
9	Drying wetland	
10	Drying of ponds	
11	Environmental degradation	
12	Reduce yield productivity	

3. Are you listening to climate change and variability? A. Yes B. No

4. From which source do you listen about climate change and variability?

A. Radio B. television C. From extension worker D. Governmental organization

5. What are the main causes of climate change and variability?

A. Natural factor B. Human Factor C. Both human and natural factors D. Governmental factor

6. If the answer is the human factor which factor is the majority cause of climate change and Variability?

A. Deforestation B. Population pressure C. Overgrazing D. Fossil fuel E. Industrialization

7. Is there a change in rainfall duration? A. Yes B. No

8. If the answer is yes how do express it? A. Come late and stop early B Come early stop late C. Come late and stop late D. Unbalance time and amount

9. Did you apply short-season growing crop and drought tolerance varieties?

A. Yes B. No C. I do not know

10. Do you practice water harvesting techniques?   A. Yes B. No

11. Have you adjusted livestock management? A. Yes B. No,

12. If your answer is yes, the kind of adjustments

A. Destocking

B. Changing type of livestock

C. Other specify ……………………………………………………………………..

………………………………………………………………………………………

PART IV. Assessment of the impact of climate change induced-hazards

What are the major hazards affecting the livelihood in your locality? Please Put a tick mark.

No.	Major hazards	Put a tick mark
1	Drought	
2	extreme heat	
3	livestock diseases	
4	Human diseases	
5	Flood	
6	pests and herb infestations	
7	shortage of water	
8	other (specify)	

2. How do you see the change in natural forest cover in your area?

A. Increased B. Decreased C. No change

3. what about the change in artificial forest cover in your area?

A. Increased B. Decreased C. No change

4. How do you see the problem of soil erosion over time?

A. Increased B. Decreased C. No change

5. Is there a change in drinking water availability?

A. Increased B. Decreased C. No change

6. What about the change in irrigation water availability?

A. Increased   B. Decreased   C. No change

7. How do you see the agricultural productivity status over time?

A. Decreased B. Increased C. No change

Checklists for Key Informant Interview (KII)

1. Date……….. Education status………………..your profession……………..

2. How long have you stayed in the area? ……………………………………..

3. Do you think there is climate change and variability in the Dangila district?

…….………………………………………………………………………………………

4. If yes, what are the indicators of climate change in the district? ………………………

5. What are the causes of climate change in the area?

…………………………………………………………………………………………

………………………………………………………..

6. What are the local people's coping mechanisms used to reduce the impacts?

…………………………………………………………………………………………

……………………………………………………………………..

7. What are the main challenges and how do you think they can be improved?

…………………………………………………………………………………………

…………………………………………………

8. Which agro-ecologies and *kebeles* are more vulnerable to the impact of climate change and variability in the study area?

9. Which groups of people are more vulnerable? ……

10. List down the main impacts of climate change/ variability on the community, On the Livestock, and the environment.

11. What are the impacts of climate change/ variability on people's health?

………….........……………………………………………………………………………

…………………………..

12. What is your role in climate change and variability-related hazards?

…………………………………………………………………………………………

…………

13. How does the government&/NGO support farmers concerning climate change and Variability? ……

14. Is there anything you want to add about climate change and variability?

…………………………………………………………………………………………………

………………………..

Checklists for Focal Group Discussion (FGD)

1. Is there any variability of temperature and rainfall in the Dangila district in the past 10 Years? If the answer is yes describe.…………………………………………………………

2. Is there climate change and variability in your locality?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………

3. What do you think about the causes of climate change? ……………………………

…………………………………………………………………………………………………

…………………………………………………………………………….

4. Can you explain any impacts on your livelihood and problems you face as a result of climate change and variability?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………….

5. What do you think are the local indicators of climate change and variability?

……………………..………………………………………………………………………

6. What are the main causes of climate change and variability?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………..

7. What are the major impacts of climate change and variability-induced hazards on people's health, livestock, and the environment?

……………………..…………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………

8. Who is more vulnerable to the effects of climate variability?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………

9. Do you think climate variability affects your livelihood? If the answer is yes how?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………….

10. To adapt what is the response of people, government, and non-governmental Organizations?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………

11. What are the barriers to coping with the impact of climate change and variability?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………….

12. Do you think that climate change will continue in the future?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………..

8. AUTHOR'S BIOGRAPHY

Abaynew Mulat Yimenu was born in April 1991 in Ethiopia. He attended elementary school in Badanie Zurzur and Secondary and Preparatory school at Gissa General Secondary & Preparatory School. The author also attended and graduated with his BSc degree at Wolaita Sodo University in Natural Resource Management from 2011-2013 E.C. After that, Abaynew was employed at Wolaita Sodo University, and In September 2014, he started his MSc-Degree to specialize in Environment and Climate Change at Bahir Dar University, College of Agriculture and Environmental Science. Since then, he conducted research on Smallholder Farmer's perceptions and Adaptation Strategies to Climate Change and Variability in Dangila District, Awi Zone, Ethiopia.