COLLEGE OF SOCIAL SCIENCES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

Farmers' adaptation strategies to the impacts of climate variability in Haramaya Woreda, Ethiopia

BY: TIREZA HAILE

ID NO: GSR/7206/14

December, 2023

Addis Ababa, Ethiopia

Addis Ababa University

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BY: TIREZA HAILE

ID NO: GSR/7206/14

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A Thesis Submitted to the Department of Geography and Environmental Studies, College of Social Sciences of Addis Ababa University in partial fulfillment of the requirement for the Master of Arts in Climate Change and Adaptation.

January, 2023

Addis Ababa, Ethiopia

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APPROVAL SHEET

This is to certify that the thesis prepared by Tireza Haile entitled Farmers' response and their adaptation strategies to the impacts of climate variability in Haramaya Woreda, Ethiopia is submitted in partial fulfillment of the requirements for the degree of Master of Arts in Geography and Environmental Studies (specialization in Climate Change and Adaptation) compiles with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Declaration

I declare that, this thesis prepared for the partial fulfillment of the requirements for the Degree of Master of Arts in Geography and Environmental Studies (specialization in Climate Change and Adaptation) entitled "Farmers' response and their adaptation strategies to the impacts of climate variability in Haramaya Woreda, Ethiopia" is my original research work prepared independently by my own effort with the close advice and guidance of my adviser. I also declare that this thesis has not been presented in any university and all sources that I have used or quoted have been indicated and acknowledged by means of complete references.

Name: **Tireza Haile**

Signature: ______________________

Data of Submission: **January, 2023**

Acknowledgment

I would like to acknowledge and express my deep gratitude to God for the blessings, guidance, and strength provided.

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Acronyms and Abbreviations

AEZ: Agro Ecological Zone

CEEPA: Centre for Environmental Economics and Policy for Africa

HHs: HouseHolds

HWFEO: Haramaya Woreda Finance and Economic Office

IIRR: International Institute of Rural Relocation

IPCC: Intergovernmental Panel on Climate Change

KII: Key Informant Interview

NMA: National Meteorological Agency

NOAA: National Oceanic and Atmospheric Administration

UNDP: United Nations Development Program

UNEP: United Nations Environment Program

UNFCCC: United Nations Framework Convention on Climate Change

UNISDR: United Nations International Strategy for Disaster Reduction

Abstract

The main purpose of this study was to investigate farmers' response and their adaptation strategies to the impacts of climate variability in Haramaya Woreda, Ethiopia. Descriptive and explanatory research design and mix of qualitative and quantitative research approaches were used. Questionnaires from 292 Households were collected. To analyze the data, simple descriptive statistics, linear panel regression model and MNR were employed. The result revealed that, an average of 716. 8 mm precipitation and 16.73℃. Of temperature was recorded in the past 30- years. Productivity has strong and positive correlation with precipitation and temperature. The farmers have different adaptation strategies for the adverse effects of climatic change in the area. In the questionnaire open ended question the HHs reply are arranged in the following themes. The MLR revealed that, Age, Educational background, Household size, sex, membership of FBOs and Farm size are found significant at with less than .05 sig value. And, the Crop productivity year temperature and rainfall reveled that, precipitation (in mm) and year are found significant at with less than .05 sig value. This shown that, then the variable has a significant association with the productivity trend in the study area. And recommended that, crop diversification, modifying the farming calendar, employing physical and biological soil and water conservation practices, using different types of crop varieties, and other agronomic activities are needed in the study Wereda.

Keywords: temperature, Rainfall, crop yield productivity, adaptation and climate variability

Chapter One:

Introduction

1.1. Background of the Study

The term "climate change" refers to ‘’variations in the atmosphere's normal state that result from both natural and man-made variables, such as the concentration of greenhouse gases and aerosols in the atmosphere and the earth's orbit, volcanic activity, and crustal movements’’. Global warming, which leads to climate change, is the term used to describe the average rise in worldwide temperature. This megatrend is expected to cause significant future changes on a global scale. The UN Intergovernmental Panel on Climate Change (IPCC) provided substantial scientific evidence regarding its impacts in its fourth report on climate change (IPCC, 2007), and that evidence has since gained widespread acceptance. Additionally, the ongoing rise in global temperatures has exposed people to adverse climate change impacts (IPCC, 2007).

Globally, hydro climatic variables have altered mostly as a result of human activity; these changes influence the distribution behavior of rainfall and temperature at various scales (Anose et al., 2021). Despite academics, policymakers, and practitioners seeking scientific, technological, and political responses, climate change has become a more formidable challenge for the world than any other phenomenon. Agriculture is likely to see the greatest impact from climate change, which will have implications for both national and international food security (Kumar, 2007).

As per (Stephan, 2021) ‘’the changes in climate in Eastern Africa region, where Ethiopia is geographically located have an important impact on land suitability and in particular, on rain fed crop production’’. Changing patterns of temperature and precipitation and manmade land degradation affect the suitability of land for agricultural use. For example, 19 to 23 ha of suitable land are lost per minute due to soil erosion and desertification (Stephan, 2021), mainly in connection to climate change and variability

Scientists are worried about the prospect of global climate change because it could have a negative impact on smallholders' livelihoods, agricultural output, and food security (rainfall and temperature). Agricultural, water resource, forestry, human health, biodiversity, and other biophysical and economic activities could all be negatively impacted by climate change, as well as those involving wildlife and biodiversity. Since rain-fed agriculture in the third world is dependent on the whims of nature, the effects of climate change are severe(World Bank, 2008). The inconsistency on climate has influence economically, and notes that agriculture is backbone of developing countries but the most influenced one by the climatic changes (Boko et al., 2007), (Müller et al., 2011) and (Wheeler and Braun, 2013).

Ethiopia is famous on the availability of varieties of climatic conditions and on its various agricultural and ecological statuses that is considered as conducive for the plantation of crops and animals (Funk et al., 2012). However, nowadays the country is faced a changed climatic conditions because of the proportion of agriculturalists shared above eighty percent of the total and their reliance on rain. This directly affected the farmers in which their life is depending on agriculture and on the natural rainfall. Previous empirical papers implied that, the critical constraint of the country's trial to secure in its food and alleviating poverty. The area in which above eighty percent of the nation's population is depended on and above forty percent of the nation's gross domestic Product are supported and about eighty percent of its productive is depended on is agriculture (MoFED, 2006). To show this in example, in 2006 an overflow of rivers caused in a death of above seven hundred years and migration of nearly 250,000 and in private and public properties and totally over one million dollar is loosed (Asaminew E., 2013), (Kindie T., et al.,2016).

In Ethiopia climatic change has impacts on different products. Supporting this, Desta (2019) revealed that the climatic variabilities have impact on wheat (Triticum Aestivum) among smallholder farmers in Gibe Woreda of Hadiya zone, southern Ethiopia. Climate change has a potential impact on the productivity of potato in eastern Ethiopia (Simret, 2022) and, (Tesfa et al., 2022) found that, climate change negatively impacts agriculture, animal output, water quality, and epidemic disease outbreaks. Education, income, farm size, access to extension services, and weather information impacted climate change adaptation measures are significant. Also, climate change resulted on farmer's adaptation strategy in Ethiopia. The study of Simret (2022), pointed out that, proper choice of adaptation options, awareness, support, credit and inputs reduce the negative impacts of climate change.

1.2. Statement of the Problem

Climatic changes have critical effects, especially in the agriculture sector, which is already very sensitive (IPCC Panel, 2014). A traditional, rain-fed agricultural system is facing a serious threat from climate change. Particularly, the production (availability) of food is declining at an alarming rate. 56% and 21% of crops in Sub-Saharan Africa and Asia, respectively, are expected to be negatively impacted by climate change by 2050 (Smith et al . 2007).

Climate is a major factor in determining agricultural output, particularly in developing nations like Ethiopia where agriculture is largely dependent on natural conditions as opposed to the managed environmental conditions in industrialized nations. So, agricultural yield would be more affected by climate change than crop output in poorer nations. The fragility of the food supply will be made worse by temperature rise, which will result in lower yields and poorer quality of food crops. Similar to how variations in rainfall patterns such as intense rainfall concentrated in one month have a disastrous impact on agricultural productivity (Mendelsohn, 2009).

It is noted that, climatic changes has been counted and will be continued in the future. This implies that, it is important to comprehend how farmers react to the changing environment and how they have adapted in order to develop effective adaptation methods in the future. Studies show that farmers can make adjustments to lessen the adverse effects of climate change (Mertz et al., 2009).

Ethiopia, the second-most populous nation in Africa, has a very weak economy and precarious agro-ecological circumstances. Agriculturalists particularly the ‘’smallholder farmers in Ethiopia have been facing severe climate related hazards, in particular highly variable rainfall and severe droughts that negatively affect their livelihoods. Anticipated climate change is expected to aggravate some of the existing challenges and impose new risks beyond the range of current experiences’’. Sub-Saharan Africa is predicted to see the greatest effects of climate change on agricultural production, which suggests that the poorest and areas with the most food insecurity will face the greatest challenges in dealing with the negative effects of climate change. The current climate fluctuation is a problem to Sub-Saharan African smallholder farmers. (Cooper et al., 2008) then ‘’with a business-as-usual development, climate change is expected to pose challenges beyond the current experiences'' (Cairns et al., 2013). Smallholder farming communities rely primarily on climate-controlled agriculture and forest resources for their livelihoods; therefore, climate change can have both direct and indirect effects on their overall well-being. For instance, a slight rise in temperature can diminish agricultural output at lower latitudes, and potential production decline has been observed in many regions of the world (IPCC, 2007).

Though there are a number of struggles to mitigate the ''GHG emissions'', the most usual climate conditions are become unavoidable (IPCC, 2012), then this puts the ''agricultural adaptation and risk management strategies'' has gain attentions. Due to the reason that, the agriculture is the most important income of small holder farmers particularly in the rural communities of under development countries like Ethiopia, set strategies to adapt the agriculture is become the most critical measurement so as to support the life of the poor's and so as to mitigate food insecurity. This could be reduced the ''climate vulnerability of rural communities by making them better able to adjust to climate variability and change and helping them cope with adverse consequences'' (Adger et al., 2007; Hellmuth, 2007; Bryan et al., 2009; IPCC, 2012). Consequently, studies on the ''adaptation strategies'' in the agricultural areas are in need of enhancement at every level to identify ''appropriate adaptation strategies'' and ''to support the adaptation process through policies guided by scientific evidence''.

Due to output decline and instability brought on by climate inconsistency, food scarcity and its results particularly in the nations which are under-development is common. Due to these countries are reliant on the weathers of climate, ecological deprivation and socio-economic threats are the critical influential aspects of the nation's farmers World Bank, 2008; Rao et al., 2011; Thornton et al., 2009; Van de Steeg et al., 2009; Schlenker et al., 2010).

Small-scale farmers must embrace climate-smart methods if they want to assure resilience. Despite the critical role that climate wise practices play in improving resilience as well as production, lowering greenhouse gas emissions, and combating environmental degradation, small-scale farmers have not generally adopted them. (FAO, 2010; FAO, 2013; Fanen et al., 2014). The majority of research often concentrate on how climate change will affect agriculture and how to take action (Mburu, 2013; Rao et al., 2011; Schlenker et al., 2010; Van de Steeg et al., 2009; Sivakumar et al., 2005), only Deressa (2009) investigated the determinants of reworking approaches (Deressa et al., 2009). Like farmers in every other region in Ethiopia, farmers in the Haramaya woreda are harmed by climate changes, which have turned into frequent natural disasters across the nation. In the cases when inconsistent precipitation even in the summers, there are probabilities of deficiency and deductions in crop yield and plant varieties. And, there are also cases especially in the latter months of the year where damaging rainfall raining and resulted in water overflown, land would be swept and soils would be eroded.

The microclimate, soil relief, and crop physiology of crops have all been disrupted by the rise in temperature (IPCC, 2007). Droughts, floods, annually river runoff, and decreased water availability have all been noted as being major factors in the production of crops and livestock. Food insecurity in the area is a major challenge. These climate shocks have exacerbated the negative impacts on the livelihood of poor farm households as they have the lowest capacity to adapt to climatic conditions (MoARD, 2012). Generally, this diverse climate in the study area influences the livelihood activities of the farming community. However, the HHs in Haramaya Wereda replying to the inconsistency of climatic conditions using a variety of methods to adapt. But, as far as the student researcher’s knowledge there is no study conducted what are the existed methods used to adapt the climatic inconsistencies and their results.

The study of Harrissson et al (2017), were a comprehensive and covers climate change impacts on agricultural production in Eastern and Middle African Countries. The study of Mekasha (2020) is limited within the trends of temperature and rainfall, but did not relate it with farmer’s adaptation strategy. The study of Simret (2022) is limited to tomato. As a result, there was significant knowledge gap and low practice of climate smart practices.

The investigation of factors influencing the adaptation techniques selected by smallholder households to adjust to climate change has also received scant attention in the literature on climate change. These are the information gaps that this study aims to fill.

1.3. Objectives of the study

1.3.1. General Objective

The general objective of this study is to examine farmers’ response and their adaptation strategies to the impacts of climate variability in Haramaya Woreda, Ethiopia

1.3.2. Specific Objectives

The specific objectives of the study are:

1. Analyze the trends in temperature and rainfall patterns during the last 30 years.
2. Assess the trend of crop yield productivity in the study area.
3. Explore adaptation strategies used by farmers in response to the adverse effects of climate variability

1.4. Research Questions

To address the objectives, the study was guided by the following research questions;

1. What are the patterns of temperature and rainfall in the study area during the last 30 years?
2. What is the trend of the crop yield productivity among the farmers in the study area?
3. What is the impact of climate variability on crop yield productivity?
4. What type of adaptation strategies do farmers use against the adverse effects of climate change and variability in the study area?

1.5. Scope of the Study

Geographic delimitation

The current study is delimited within Haramaya which is one of the woredas in the East Hararghe zone, Oromia Region, Ethiopia. It is named from the Haramaya Lake that is found in the Woreda.

Thematic areas

Thematically, the study framed within the following five variables: Temperature, Rainfall, Crop Yield productivity and Small holder’s farmer’s Adaptation Strategy. Thus, the study framed on the two climatic variables i.e. temperature and rainfall only. The study delimited within the crop yields (Chat, fruits and vegetables).

Time Frame

The last thirty years i.e. 1993 to 2022 of temperature and rainfall trends of the study area included. The data on the trend of crop yield productivity of the small holder farmers within the last thirty years and the strategies they have been adopted for the rainfall and temperature changes also incorporated.

1.6. Significance of the Study

Ethiopia is prone to the effects of climate change and variability, which is a generally recognized fact. Communities that significantly rely on livelihoods that are sensitive to climate change are particularly at risk and harmed. The problem is the most constraint in the soci0-econ0mic growth to the development efforts Ethiopia. Nevertheless, previous and current investments and disaster responses in the country are more focused on recovery from prevailing disasters than the development of adaptation strategies and enhancing adaptive capacities. This shows the need to reevaluate the nation's disaster intervention policies, which should move away from investing more in emergency and recovery operations in favor of reducing vulnerabilities and enhancing the capacity of people and communities to adapt. Such efforts should, however, be based on studies that generate empirical information regarding the problem at the local level in order to guide policy formulation and the development of pragmatic strategies. The data that will be produced is anticipated to add to the body of knowledge already available about the effects of climate change at the local level. Particularly, it would increase awareness of the real and possible effects of climate change on vulnerable populations and areas in the country. Building capacity and resilience is essential, as is mainstreaming gender into climate change discussions, so that both men and women can deal with the adverse effects of climate change. In addition to illuminating a previously murky region, the study will aid in the creation of appropriate adaptation and mitigation methods as well as practical solutions. The study is expected to be helpful not only just for populations at risk of disasters, but also for government policymakers and other stakeholders (donors, CSOs/NGOs, researchers, and advocacy groups) interested in hazard reduction. The study will have also implication for policy makers and implementers in the area.

1.7. Why This Research Matters

The reasons to carry out this research are two folded. First, there is a knowledge gap in the area the previous studies are limited cannot implicate the current studies case. For example the study of Harrissson et al (2017), were a comprehensive and covers climate change impacts on agricultural production in Eastern and Middle African Countries. The study of Mekasha (2020) is limited within the trends of temperature and rainfall, but did not relate it with farmer's adaptation strategy. The study of Simret (2022) is limited to tomato. As a result, there was significant knowledge gap and low practice of climate smart practices. Second, employing a study on the farmers' response and their adaptation strategies to the impacts of climate variability is considerable due to its significance. Note that, not only in the study area it could connate practical implications for different bodies. The study is expected to be helpful not only just for populations at risk of disasters, but also for government policymakers and other stakeholders (donors, CSOs/NGOs, researchers, and advocacy groups) interested in hazard reduction. The study will have also implication for policy makers and implementers in the area.

1.8. Limitations of the Study

Due to time, cost and data management constraints, the study was limited to: (1) to only three Kebelles of Haramaya Wereda. Therefore, researchers have to incorporate other Kebelles and Weredas. (2) Due to the unavailability of data the past thirty- years of perception and temperature climatic were included. (3) Only two climatic variability are considered. (4) Data collection techniques like Focus Group Discussion (FGD) were not conducted. Therefore, future interested researchers in the area have to be considered these limitations while conducting similar study. It was limited to incorporate eight years of data regarding the *belg* season of crop productivity due to the limited data of CSA.

1.9. Definition of Key terms and Concepts

Climate: refers to the typical weather for a place and time period over a 30-year time span. Climate is not the same as weather; rather, it refers to the typical weather patterns for a given area. The short-term condition of the atmosphere is described by the weather (IPCC, 2014)..

Climate change: is defined as a shift in the climate's condition that lasts for an extended period of time, usually decades or longer, and that can be detected by changes in the mean and/or variability of its attributes. It refers to any change in climate through time, whether brought on by internal natural processes or external factors including solar cycle fluctuations, volcanic eruptions, and anthropogenic alterations to the atmosphere's composition (IPCC, 2014).

Climate variability: is the term used to describe changes in the average condition and other statistics (such as standard deviations, the frequency of extremes, etc.) of the climate on all temporal and spatial scales outside of those of specific weather events (IPCC, 2014).

Impact: used to describe the immediate and long-term effects, positive and negative, direct or indirect, of an intervention on the environment, social, institutional, and economic conditions (Rover and Dixon, 2007).

Adaptation: is an adjustment in natural or human systems in response to present or anticipated climatic stimuli or their effects, which mitigates damage or takes advantage of advantageous possibilities (Glantz, 2009). The term "adaptation" also refers to the process of improving, developing, and putting into practice solutions to mitigate, cope with, and profit from the effects of climatic occurrences (UNDP, 2005).

1.10. Organization of the Study

The report document is constituted 5-chapters: (1) chapter one contained the introduction part i.e. background, problem's statement, basic research questions and objectives, the significances and delimitation. (2) Chapter two revealed related literature review and conceptual frameworks. (3) Methodology included design and approach, sources and data collection tools, quantitative and qualitative data analysis, and ethical considerations. (4) Results presented, interpreted and analyzed in chapter four. (5) The study's conclusion and recommendation incorporated in the last chapter.

Chapter Two:

Literature review

2. Introduction

This chapter included theoretical, empirical and conceptual framework of the study.

2.1. Theoretical Review Literatures

2.1.1. Climatic Variabilities

‘’Climate refers to a long-term variation in the atmospheric condition of a specific region or regions, and climate change means a gradual change in the climate system both by natural and artificial causes. Climate change is caused by the change in each component of the climate system such as atmosphere, hydrosphere, biosphere, cryosphere and lithosphere or by complicated interactions among those components. The causes of climate change are largely divided into natural causes and artificial causes. Natural causes include the change in solar activity, volcanic eruption, sea water temperature, ice cap distribution, westerly waves and atmospheric waves. On the other hand, artificial causes include carbon dioxide emission from industry and agricultural production activities, deforestation, acid rain and the destruction of the ozone layer by Freon gas, with global warming by the increase of greenhouse gases as the representative’’ (PACEST, 2007).

As per (Simane B, et al., 2016), world’s change in its climatic condition previously altered and will endure to conversion intensely, and the alteration is demonstrated in the regular deficiency, overflows, and scarcity that have endangered masses of persons and cattle in current eras. The In its quarter valuation statement, the interstate board on weather variation (IPCC, 2007) decided that climate variation is now up-to-the-minute with its versatile impacts on the mankind and the ecology.

Climate risk is a central part of livelihoods in Sub-Saharan Africa. Recurrent rainfall and temperature variations associated with climate change expose farming households to production shocks that shape their farming practices and strategies (Kubik and Maurel, 2016; Katengeza et al., 2019b; IPCC, 2022). A major component of rural livelihoods is agriculture, and exposure to production shocks has an impact on access to agricultural inputs, production, and livelihoods. Due to their heavy reliance on agriculture, absence of functioning insurance markets, and severe implications of a bad season, rural areas have certain characteristics (Rose, 2001; Dercon, 2005).

These changes in the geophysical climate have significant implications for human social behavior, and thus for social psychology. One of the principal messages of social psychology has consistently been that external forces are more important influences on individuals than is typically recognized by the layperson. Although psychologists have mostly focused on social aspects of the situation, such as other people and salient social roles and expectations, the physical environment clearly has the potential for a direct effect on behavior as well as effects moderated by social constructions of that environment. Additionally, climate change has become part of our social context: Social interactions affect both our perceptions of climate change and are affected by our experiences of climate change (Geiger & Swim, 2016; Whitmarsh & Capstick, 2018).

Variability of climates has significant influence of the products of agriculture. This resulted on environmental change and insecurity of foods. Most of the countries under developed productivity related with both HHs/farmers life and all humans. Based on the resent empirical views, focuses are shown on the influences of climate variabilities on productivity of crops. In spite of these various studies, there is no consistence on the influences of climate variabilities on productivity of crops (Song et al., 2010). But it can be said that, the influences of climate variabilities on productivity of crops is significant. It can be due to the hotness/coldness of climatic condition on crop's growth stages. Climate change causes an increase of illnesses, pests, and weeds, which increases the need for pesticides and herbicides. Second, the production of crops around the world is significantly impacted by present climate change (Dasgupta et al., 2018; Pranuthi and Tripathi, 2018; Rahman et al., 2018).

It is believed that, the influences of climate variabilities on productivity of crops negative. To this effect, precious studies revealed the agriculturalists methods used to adopt such variability. So as to adopt for example hotness, agriculturalists used variety of yields. This may be done by utilizing fertilizers or irrigations for the sake of keeping farm's fertility. There are also another strategies used different techniques aligned with the temperature is increased or decreased. When we see the research conducted on China, when the temperature is warming it is found that the productivity of rice in their study specific areas (Tao et al., 2008; Xiong et al., 2014; Wang et al., 2014). The study of (Masutomi et al., 2009) foretold that the increasing of hotness will continue upcoming years till the years of 2030, however, it was unable to project what will happened after 2030.

2.1.2. Rainfall Characteristics and Variability in Ethiopia

2.1.2.1. Onset of Rainfall

An onset of rainfall is the date which rainfall begins and accumulated for more than two days with at least 20mm when no dry spell lengths above 9 days occurred within the consecutive 30 days. The determination of rainfall onset date was made by different researchers without evaporation data input by setting different criteria that can affect the rainfall onset and end (Abiyot et al., 2014), (Kassie et al., 2014), stated that beginning of a period as the date when the precipitation accrued above two-days will be minimum twenty-mm and while there is no dry at least ten-days happened over the upcoming a month. An onset of rainfall may vary in different parts of the country. According to (Abiyot et al. ,2014), report that on average the rainy season started in DOY 84,117 and 92 at Gato, Wolkite and Hosana stations respectively in the Southern region of Ethiopia. According to (Taye et al., 2013) reported that on average kiremt rain start on 151th, 144th and 132th DOY) at Motta, Debre Markos and Dangla stations in Amhara region respectively.

2.1.2.2. The Rainy Season's Last Days

In the days when the periods of rainfall is ending it is gained yeield-crops which cultivate during could be apply kept wetness within ‘’ 75-125 mm’’ (Mersha ,2003) as cited by (Fitsume ,2009) also, the mean of 100-mm of wetness volume valor be exploited, but when the period is ending . Factors affecting the rains at the last seasons of the period tried to distinguish by scholars previously using various criterion and figures of evaporation (Abiyot et al., 2014).

2.1.2.3. Length of Growing Period (LGP)

The length of growing period (LGP) is determined by counting the number of days between the start and end of the rainy season. According to (Hadgu et al. 2014), LGP is the duration in days between onset date and cessation date. The LGP have a significant effect on yield of crops by affecting the crop water requirement of the crop. Generally, in Ethiopia rainfall variability, unreliable occurrences, insufficient amount, delay in onset dates, early cessation and short length of growing season caused significant reduction in 9 crop yield with reasonable amount almost all parts of the country. Kiremt growing season length and quality are affected substantially by the frequency and duration of dry spells within a season. A range of dryspell analyses showed that 3-

5 continuous days of no rain are quite common over most of the Kiremt region, but extended breaks exceeding 10 days are limited to the lowland areas of extreme western and northeastern Ethiopia where rainfall variability is high. Most of these long dry-spells occur towards the end of the season (Segele and Lamb, 2005).

2.1.3. Temperature and Rain fall Variability in Ethiopia

In Ethiopia, annual temperature has rapidly increased in the last five decades (1951-2005). Range of the hotness and coldness counted with the country. The country's upland areas of stretched from center-north ranged from ½ ^{0}c to 37^{0}c of the country's SE plains. As per (Tadesse et al., 2016), temperature's variation throughout the country blocked the yields due to its influence on rains and made two for the availability of keremt and bilg. This extreme temperature constrains ‘’crop production by limiting water availability’’ and growth of many plants Looking at the precipitation; there are two important rains in Ethiopia- the ‘kiremt’ and ‘belg‘.There is seasonal, inter-annual and inter-decadal rainfall variability in Ethiopia. Geographical location and topography lead the country to be vulnerable to rainfall variability. The strong inter annual and inter-decadal 10 variability in rainfall makes difficult to detect long term trends in the country. Studies showed that there is no statistically significant trend observed in mean rainfall in any season between1960-2006. However, rainfall variability is considered as the major source of risk for farmers who depend on crop production.

2.1.4. Climate Variability and Agriculture in Ethiopia

The most influential climatic variables affecting yields on a global scale are temperature and precipitation, as some studies indicating that they act nonlinearly. Year-to-year climate variability affects the growth, development and yield of crops. Interactions between temperature and precipitation might lead to reduced sensitivity to heat if enough water is available (Troy and Kipgen, 2015) and thus higher relative importance of heat. An increase in maximum temperatures (as climate or weather) can lead to severe yield reductions and reproductive failure in many crops. Higher temperatures and CO2 levels will likely change the wheat growth patterns and duration by shortening the growth cycle and altering the phenological stages (Tadesse et al., 2016).

Climate related impacts in Ethiopia include drought, floods, heavy rains, strong winds, frost, heat waves (high temperatures). Though, the historical, social and economic impacts of all of these hazards are not systematically well documented. Drought occurs anywhere in the world but its damage is severe in Africa in general and in Ethiopia in particular. Recurrent drought events in the past have resulted in huge loss of life and property as well as migration of people. The other climate related hazard that affects Ethiopia from time to time is flood. Major floods which caused loss of life and property occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 (NAPA,2007). In rainfall anomaly, the year-to-year variation of rainfall for the period in between 1951 to 2005 over the country expressed in terms of normalized rainfall anomaly averaged for 42 stations (NMA 2007). The country during those periods (1951 to 2005) has experienced both dry and wet years over the last 54 years. Historically the country has been prone to extreme weather events. Major droughts that led to dreadful famines and floods struck different parts of the country (World Bank, 2006). It also exacerbated the transient poverty. At country level, the average precipitation rate has been 2.04 mm per day 1961 to 1990. This precipitation is projected to decrease to 1.97 mm between 2070 - 2099 (NMA,2007). The problem is exacerbated by higher evaporation rates associated with increasing temperature.

2.1.4. Crop Production Factor

For agricultural production, crop production, which is the largest source of household income for most rural households in the highlands areas of Ethiopia assume that crop production per hectare by household is determined by the amount of inputs (labor, oxen power, fertilizer, seeds) used in the land management practices (manure or compost, burning, contour plowing, reduced tillage, intercropping) used and, the 'natural capital' of the plot [biophysical characteristics (plot size, slope, position on the slope, soil depth, color and texture and presence of gullies)] and the presence of land investments (irrigation, stone terraces, soil bunds and fences/live barriers), the tenure characteristics of the plot [whether a homestead or field plot; how plot acquired—i.e., whether allocated in prior land distribution, inherited, leased (sharecropped in almost all cases) or received as gift or borrowed], human capital (education, age and gender of household head), access to agricultural extension services, agro ecological factors that determine local productivity, (average annual rainfall, altitude) and random factors such as the weather and incidence of pests in a particular year on a particular plot (John Pender and Berhanu Gebremedhin 2007)

2.1.5. Adaptation Strategies of Farmers to Climate Variability

Adaptation is the process of improving, developing, and putting into practice solutions to lessen, cope with, and profit from the effects of climatic occurrences (UNDP, 2005). The degree to which farmers comprehend the problem, the implications, and their technological capabilities determines the adaptation strategy for the changing climate. Adaptation is an essential strategy to enable farmers to cope with the adverse effect of climate change and variability which in turn increase the agricultural production of the poor farm households (Conway and Schipper, 2011). In Ethiopia farmers have been practiced several adaptation mechanisms at local level. Different adaptation measures have been practiced to the ever-variable climate in different parts of the country among smallholder farmers. According to (Glwadys ,2009). Some farmers have adjusted their farming practices to overcome the impacts of climate change and variability. The most widely employed adaptation tactics in the various crop-producing regions of the nation include crop diversification, modifying the farming calendar, employing physical and biological soil and water conservation practices, using different types of crop varieties, and other agronomic activities. Changing of planting dates, changing of crop type, soil moisture conservation practices, expanding farmlands, crop diversification and farm income diversification are repeatedly reported adaptation options under small scale and subsistence farmers (Deressa et al., 2008). Also, according to (Yirga ,2007) farmers of Ethiopia practicing important adaptation options such as crop diversification, using different crop varieties, using short growing crop varieties, applying small scale irrigation, changing planting date and involving off farm activities against climate impacts. (Negash and Eshetu, 2016) reported that farmers of SNNPRS practicing different adaptation options against climate variability such as using different crop varieties, implementing soil and water conservation and using irrigation. Therefore, integrating local indigenous knowledge with scientific approaches is important for the successful planning and development of appropriate adaptation decisions. A key component of climate adaptation includes building resilience, where resilience is the capacity of a system to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes (FAO, 2009). Regarding Government or institutional adaptation strategies, there are a number of existing national policy initiatives, policies, programs and strategies that may directly or indirectly address climate change adaptation in Ethiopia. Accordingly, some of the most important policy and program documents that have relevance to climate variability or change adaptation include; environmental policy of Ethiopia particularly adaptation and mitigation to climate variability or change, agriculture and rural development policy and strategy, and national agricultural research policy and strategy. The ultimate goal is to reduce climate variability/change impacts through short and long-term development programs particularly in the areas of natural resource management, utilization, development and conservation. Accordingly, Ethiopian food security program (PSNP) and Ethiopian sustainable land management program (SLMP) are among the institutional adaptation strategies in Ethiopia and particularly in the study area. Thus considering the nature of the climate variability or change as a crosscutting issue, it will be useful to incorporate some of the climate variability or change adaptation interventions into the on-going national programs like poverty reduction as a sub component (Conway and Schipper, 2011).

Some of the national adaptation strategies on crop production planed by NAPA are; enhancing erosion control, improve and changing management practices and techniques such as planting date, seedling rate, fertilizer application rate, engagement in obtaining food from other sources and income generating activities in times of crises, proper use of climate information for land use planning and early warning systems, grow crops which require less water (NAPA, 2007).

There are three major conceptual approaches to analyzing vulnerability to climate change: the socio-economic; the biophysical (impact assessment); and the integrated assessment approaches.

2.1.6.1. Econometric method

The econometric method has its roots in the poverty and development literature. This method uses household-level socio-economic survey data to analyses the level of vulnerability of different social groups. The method is divided into three categories: vulnerability as expected poverty (VEP); vulnerability as low expected utility (VEU); and vulnerability as uninsured exposure to risk (VER) (Hoddinott and Quisumbing 2003). All three share common characteristics in that they construct a measure of welfare loss attributed to shocks.

2.1.6.2. Vulnerability as expected poverty

In the expected poverty frameworks, vulnerability of a person is conceived as the prospect of that person: becoming poor in the future if currently not poor; or the prospect of that person continuing to be poor if currently poor (Christiaensen and Subbarao 2004). Thus, vulnerability is seen as expected poverty and consumption (income) is used as a proxy for well-being. This method is based on estimating the probability that a given shock, or set of shocks, moves consumption by households below a given minimum level (e.g. consumption poverty line) or forces the consumption level to stay below the given minimum requirement if it is already below that level (Chaudhuri et al. 2002).

2.1.6.3. Vulnerability as low expected utility

Vulnerability as the difference between the expected utility of consumption and the utility derived from some level of certainty equivalent consumption at and above, which the household would not be considered vulnerable. (Ligon and Schechter ,2003) applied this method to a panel data set from Bulgaria in 1994 and found that poverty and risk play roughly equal roles in reducing welfare. The disadvantage of this method is that it is difficult to account for an individual's risk preference, given that individuals are ill informed about their preferences, especially those related to uncertain events (Kanbur 1987).

2.1.6.4. Vulnerability as uninsured exposure to risk

The VER method is based on ex post assessment of the extent to which a negative shock causes welfare loss (Hoddinott and Quisumbing 2003). In this method, the impact of shocks is assessed by using panel data to quantify the change in induced consumption. (Skoufias, 2003) employed this approach to analyse the impact of shocks on Russia. In the absence of risk-management tools, shocks impose a welfare loss that is materialised through reduction in consumption. The amount of loss incurred due to shocks equals the amount paid as insurance to keep a household as well-off as before any shock occurs. The disadvantage of this method is that in the absence of panel data sets, estimates of impacts, especially from cross-sectional data, are often biased and thus inconclusive.

2.1.6.5. Indicator method

The indicator method of quantifying vulnerability is based on selecting some indicators from a set of potential indicators and then systematically combining them to point out the levels of vulnerability. These levels of vulnerability may be analyzed at: local, national, regional and global scales (Temesgen et al., 2008). These include: exposure to climate-related natural disasters and sea-level rise; human sensitivity, in terms of population patterns, development, natural resources, agricultural dependency and conflicts; thirdly, the index assesses future vulnerability by considering the adaptive capacity of a country's government and infrastructure to combat climate change (IPCC, 2014).

Two options are available for calculating the level of vulnerability using this method at any scale. The first is assuming that all indicators of vulnerability have equal importance and thus giving them equal weights (Cutter et al., 2000). The second method assigns different weights to avoid the uncertainty of equal weighting given the diversity of indicators used. In line with the second method, many methodological approaches have been suggested to make up for the weight differences of indicators.

2.1.7. Approaches to assessing adaptation to climate change in agriculture

Adaptation and mitigation are the two options to reduce the negative impacts of climate change. Mitigation refers to reducing climate change damages by reducing the emissions of greenhouse gasses. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001). Even though mitigation targets uprooting the major causes of climate change and offers long run solutions, adaptation is necessary given the current state of the world (Füssel, 2007) argues that a high emphasis should be given to adaptation mainly due to the facts that: human activities have already affected climate; climate change continues given past trends; the effect of emission reduction or mitigation takes several decades; and adaptation can be undertaken at local or national states as it is less dependent on the actions of others.

In agriculture, adaptation to climate change takes place at farm, national and global levels. Farm level adaptation depends on: technology (e.g. the availability of different varieties of crops and irrigation); soil types; and the capacity of farmers to detect climate change and undertake necessary actions (Maddison, 2006), (Kurukulasuriya and Mendelsohn, 2008a) and (Hassan and Nhemachena , 2008). National and global level adaptations depend on the identification of comparative advantages in the production of specific commodities in the face of climate change. The production of specific commodities depends on: local and international policy environments; world patterns of comparative advantages; and the responses of producers and consumers to the price signals of global markets (Schimmelpfennig et al., 1996), (Bradshaw et al., 2004) and

(Kurukulasuriya and Rosenthal, 2003).

Approaches to measuring adaptation to climate change in agriculture are divided into two models. These are the partial and economy-wide (general equilibrium) models. Economy- wide models are analytical models, which look at the economy as a complete system of independent components (industries, factors of production, institutions and the rest of the world). Partial equilibrium models alternatively are based on the analysis of part of the overall economy such as a single market (single commodity) or subsets of markets or sectors (Sadoulet and De Janvry, 1995). In agriculture, partial equilibrium models mainly analyze adaptation at farm or household levels (Maddison, 2006), (Kurukulasuriya and Mendelsohn, 2008a, 2008b), (Hassan and Nhemachena, 2008) whereas general equilibrium models are employed to analyses the impact and adaptation at national or global levels (Darwin et al., 1995), (Winters et al., 1996), (Yates and Strzepek, 1998), Nodrhaus and (Yang, 1996), (Deke et al., 2001) and (Roson, 2003).

2.1.8. Direct Impacts of Climate Change on Agriculture

2.1.8.1. Changes in Mean Climate

The nature of agriculture and farming practices in any particular location are strongly influenced by the long term mean climate state the experience and infrastructure of local farming communities are generally appropriate to particular types of farming and to a particular group of crops which are known to be productive under the current climate. Changes in the mean climate away from current states may require adjustments to current practices in order to maintain productivity, and in some cases the optimum type of farming may change. Higher growing season temperatures can significantly impact agricultural productivity, farm incomes and food security (Battisti and Naylor, 2009). In mid and high latitudes, the suitability and productivity of crops are projected to increase and extend northwards; especially for cereals and cool season seed crops (Maracchi et al., 2005), (Tuck et al., 2006) and (Olesen, 2007). Water is vital to plant growth, so varying precipitation patterns have a significant impact on agriculture. As over 80 per cent of total agriculture is rain-fed, projections of future precipitation changes often influence the magnitude and direction of climate impacts on crop production (Olesen and Bindi, 2002), (Tubiello et al., 2002) and (Reilly, 2003).

2.1.8.2. Climate Variability and Extreme Weather Events

While change in long-term mean climate will have significance for global food production and may require ongoing adaptation, greater risks to food security may be posed by changes in year-to-year variability and extreme weather events. Historically, many of the largest falls in crop productivity have been attributed to anomalously low precipitation events (Kumar et al., 2004), (Sivakumar et al., 2005). However, even small changes in mean annual rainfall can impact on productivity. As current farming systems are highly adapted to local climate, growing suitable crops and varieties, the definition of what constitutes extreme weather depends on geographical location. In many regions, farming may adapt to increases in extreme temperature events by moving to practices already used in warmer climate, for example by growing more tolerant crops. However, in regions farming exists at the edge of key thresholds increases in extreme temperatures or drought may move the local climate into a state outside historical human experience. In these cases, it is difficult to assess the extent to which adaptation will be possible (Salvatore et al., 2010).

2.1.8.3. Extreme Temperatures

Changes in short-term temperature extremes can be critical, especially if they coincide with key stages of development. When several crops are in the blossoming stage, just a few days of extremely high temperatures more than 32℃ can significantly affect yield (Wheeler et al., 2000).

Crop reactions to adjustments in growing circumstances can be nonlinear, display threshold responses, and be sensitive to a variety of stresses that have an impact on their growth, development, and ultimate yield. High temperatures have a short-term impact on the expression of genes and the responses of enzymes. These will have a long-term effect on carbon assimilation, growth rates, and ultimate yield.

2.1.8.3.4. Drought

There are several drought definitions, which typically reflect various viewpoints (Holton et al., 2003). It is customary to distinguish between a meteorological drought (often defined as low precipitation), an agricultural drought (defined as a lack of moisture in the soil or increased plant water stress), a hydrological drought (defined as lower stream flow), and a socio-economic drought (balance of supply and demand of water to society).

2.1.8.5. Heavy Rainfall and Flooding

Too much water can also have an adverse effect on crop yield. Widespread crop destruction can result from heavy rainstorms that cause flooding, and too much water can also have additional negative effects such soil water logging, anaerobicity, and slowed plant growth. Delays in farming activities are an example of indirect effects (Kettlewell et al., 1999).

2.1.9. Indirect Impacts of Climate Change on Agricultural Productivity

2.1.9.1. Pests and Diseases

Rising atmospheric CO2 and climate change may also impact indirectly on crops through effects on pests and disease. These interactions are complex and as yet the full implications in terms of crop yield are uncertain. Indications suggest that pests, such as aphids (Newman, 2004) and weevil larvae (Staley and Johnson, 2008), respond positively to elevate CO2. Respond positively to elevate CO2. Increased temperatures also reduced the overwintering mortality of aphids enabling earlier and potentially more widespread dispersion (Zhou et al., 1995). Evidence suggests that in sub–Saharan Africa migration patterns of locusts may be influenced by rainfall patterns (Cheke and Tratalos, 2007) and thus potential exists for climate change to shape the impacts of this devastating pest. Pathogens and disease may also be affected by a changing climate. This may be through impacts of warming or drought on the resistance of crops to specific diseases and through the increased pathogen city of organisms by mutation induced by environmental stress (Gregory et al., 2009). Over the next 10–20 years, disease affecting oilseed rape could increase in severity within its existing range as well as spread to more northern regions where at present it is not observed (Evans et al., 2008). Changes in climate variability may also be significant, affecting the predictability and amplitude of outbreaks.

2.1.9.2. Mean Sea-Level Rise

Sea-level rise is an inevitable consequence of a warming climate owing to a combination of thermal expansion of the existing mass of ocean water and addition of extra water owing to the melting of land ice (Pfeffer et al., 2008) This can be expected to eventually cause inundation of coastal land, especially where the capacity for introduction or modification of sea defenses is relatively low or non-existent. Regarding crop productivity, vulnerability is clearly greatest where large sea-level rise occurs in conjunction with low-lying coastal agriculture. Many major river deltas provide important agricultural land owing to the fertility of fluvial soils, and many small island states are also low-lying. Increases in mean sea level threaten to inundate agricultural lands and salinize groundwater in the coming decades to centuries, although the largest impacts may not be seen for many centuries owing to the time required to melt large ice sheets and for warming to penetrate into the deep ocean.

2.2. Review of Empirical Studies

Previous empirical studies on the themes i.e. family's climate adaptation, climatic change on crop yield production, climate trends and variability, impact of climate variability on different crop yield productions conducted in Ethiopia within the las ten years (2012-2022) have been reviewed. The summary of the authors (years), title of the empirical study, methodology employed and major findings of these papers summarized as:

A study by Belyineh et al (nd) using descriptive and multinomial logit model (MNL) found that agro-ecological locations, sex, family size, plot size, off-farm income, livestock holding (TLU), frequency of extension contact and training are the determinant factors influencing adaptation strategies. This study is limited to investigating the climatic changes i.e. temperature and rainfall. Desta (2019) co a study: influence of climatic inconsistency on wheat (Triticum Aestivum) Productivity and adaptation strategies among smallholder farmers in Gibe W oreda of Hadiya zone, southern Ethiopia. This study focused on the impacts of the climatic changes the adaptation strategies carried out by the farmers.

A longitudinal research design using panel data of 24 countries of 43 years i.e. 1970-2013 was employed by Harrissson et al (2017). The study is comprehensive and covers climate change impacts on agricultural production in Eastern and Middle African Countries. The study concluded that livestock production, labor force, temperature had a positive effect on agricultural production; modern agricultural inputs & perception had a negative effect. However, the result of the study cannot implicate the current studies case.

A study by Mekasha (2020) found that sex, age, educational level, family size, income level, access to climate information, livestock size, access to extension service and agro ecology have a significantly positive influence on the choice of adaptation strategies. Shewaye (2019), using Coefficient of Variation, Standard precipitation Index, Linear Regression and Marcove chain model reveled that here is increasing trend in temperature and decreasing trend in rainfall. The study is limited within the trends of temperature and rainfall, but did not relate it with farmer's adaptation strategy.

The study of Simret in the year of 2022 found that, proper choice of adaptation options, awareness, support, credit and inputs reduce the negative impacts of climate change in the potato growing. The study is limited to tomato. Suleyman and Nuredin (2020) conducted an article

(Impacts of Climate Variability and Climate Change and Adaptation Strategy among Small Scale Farmers of Kurfa Chele District, East Hararghe Zone, and Oromia Region, Ethiopia). As a result, there was significant knowledge gap and low practice of climate smart practices, in spite of the positive outlook to climate smart practices attributed to collapse of extension services over the years and particularly after devolution of governance. The focus of the study is about knowledge and practice of adaptation strategies. Tesfa et al (2022) climate change negatively impacts agriculture, animal output, water quality, and epidemic disease outbreaks. Education, income, farm size, access to extension services, and weather information impacted climate change adaptation measures are significant. Lastly. in the year of 2022 Zerihun et al using the 1986-2015 data and Coecient of variation & Mann Kendall non-parametric statistical test, the mean monthly rainfall of Western Amhara decreased during El Niño years and increased during La Niña years especially in the rainy season (JJAS) over the 30 years.

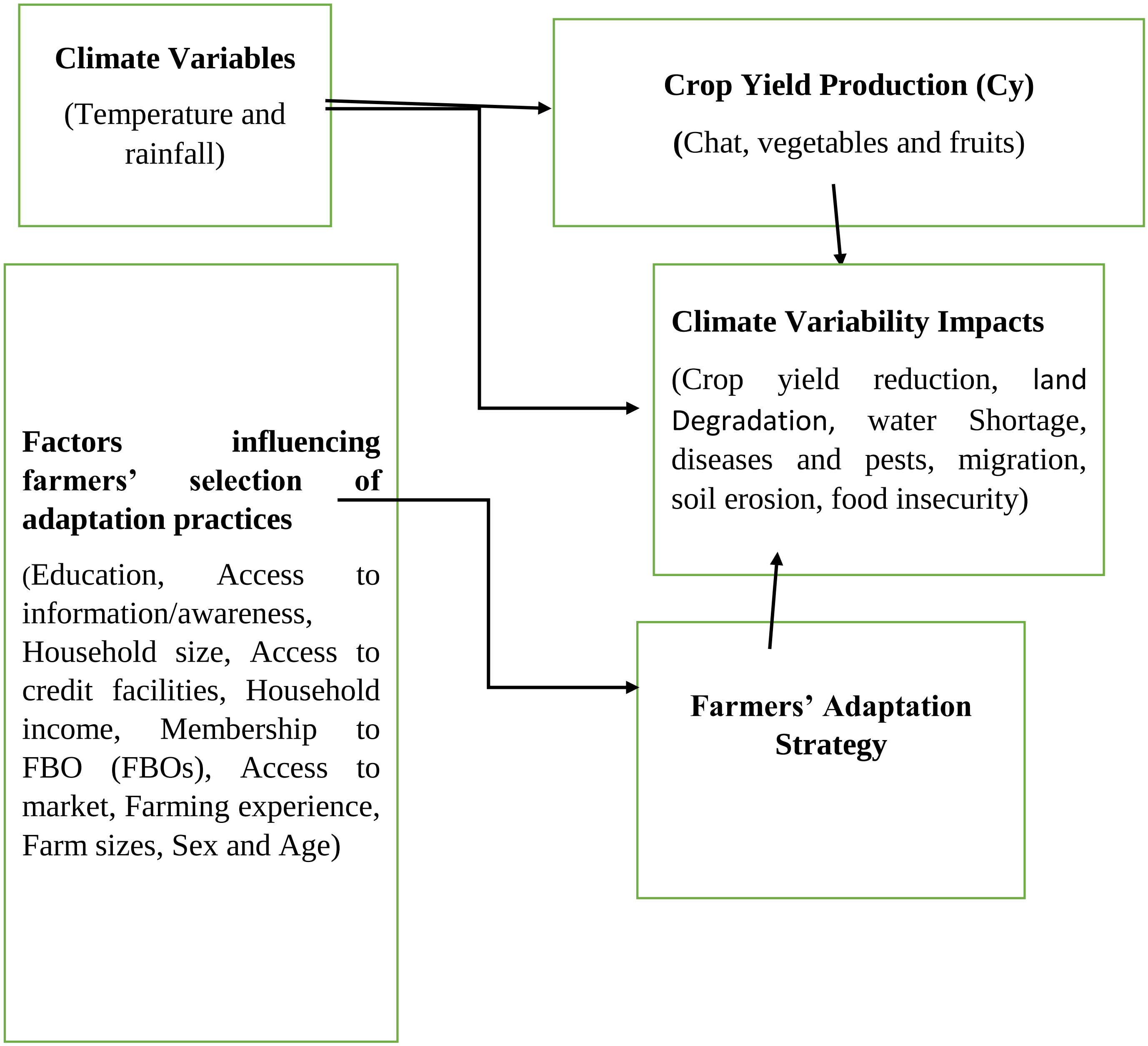
The aforementioned studies are not focused on different variables of climatic variabilities, different crop yield productions and farmer's adaptation practices. The area needs more investigation because of the factors variability and geographic area differences. In order to address these gaps, the current study focuses on:

- crop yield production i.e. Chat, vegetables and fruits which are common in Haramaya Wereda;
- examining the climatic changes of rainfall and temperature over the las thirty years (1993 to 2020)
- The farmer's i.e. small holder farmer's response and their adaptation strategies for the climatic changes occurred in the area.

2.3. Conceptual Framework

The main purpose of the study is to investigate Farmers' adaptation strategies to the impacts of climate variability with special emphasize on the trends in temperature and rainfall variability; trend of crop yield production; and, ''adaptation strategies used by farmers in response to the adverse effects of climate variability''. A framework of analysis is developed based on a review of theoretical and empirical literature. To this end, the following conceptual framework is developed.

Figure 2.1. Conceptual Framework of the Study



The independent variables in the current study are:

1. Climate Variables i.e. Temperature and rainfall)
2. Factors influencing farmers' selection of adaptation practices includes Education, Access to information/awareness, Household size, Access to credit facilities, Household income, Membership to FBO (FBOs), Access to market, Farming experience, Farm sizes, Sex and Age)
3. Climate Variability i.e. Crop yield reduction, land Degradation, water Shortage, diseases and pests, migration, soil erosion, food insecurity, this affected the selection of adaptation strategy in the study area.

The dependent variables in the current study are:

1. Crop yield productivity included Chat, vegetables and fruits)
2. Farmers' Adaptation Strategy

Chapter Three

3. RESEARCH METHODOLOGY

3.1. Description Haramaya Wereda

3.1.1. Location

The present study is conducted in Haramaya Woreda, Haramaya is one of the woreda in the East Hararghe zone, Oromia Region, Ethiopia. It is named from the Haramaya lake that found in the woreda. The word Haramaya is come from two Oromo language word's Hara means Lake and maya means name of person so Haramaya means the 'lake of maya'.. It is situated at 9^{0}21’-9^{0} 24’ North latitude and 41^{0} 55’-4158’ East longitude. There are 33 kebeles and 2 urban administrations in the woreda. Those rural communities who residues in the woreda are followed almost the same farming system (Mebrat, 2019). The present study focuses on the three kebeles, namely Adele Waltaha, Haro Adii and Korkee, which are found in the selected area of Haramaya Woreda.

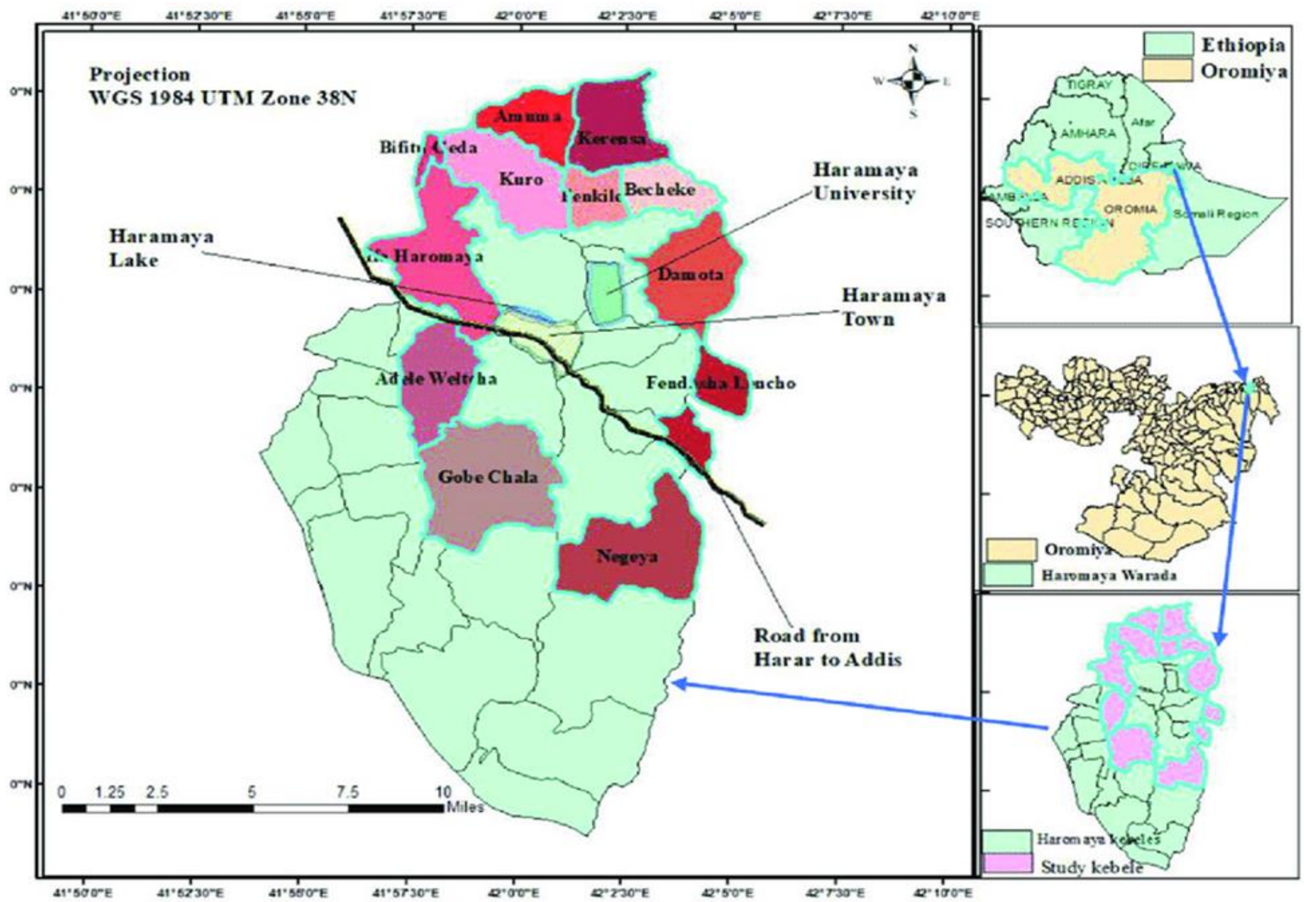


Figure1. The Geographical Location of Haramaya Wereda

(Source: Google Map, 2023)

3.1.2. Soil and Landscape

The landscape of Haramaya Woreda is distinguished by its variance from marshy to lowland and pleatues. Highland areas of Haramaya ranges 1600 meters to 2100 meter of asl. The major soil type in the Woreda is silt and irrigated soil, clay loom 33% soil sandy soil1 3.5% and sandy loom 33.5% and black soil 20% well-drained sandy soils irrigation practices adopted in the area is some small-scale irrigation has been started to practice especially (Nigussie, 2019).

3.1.3. Climate and drainage

The study area has two ago-ecological Zones Woyinedega (humid and warm) 34% and kola (Dry and hot) 66 % with relatively low rainfall and high temperature (CSA, 2007). The mean annual rainfall of range from 400 to 1050 mm and rainfall of the woreda is bimodal, which is locally called Belg and Meher (Liamblia N. Robia, 2014). Haramay's average temperature between 9.4°C and 24.18°C the minimum RF accounts 118- mm (NMA, 2011). The main staple food crops grown in the area under the rain-fed system and irrigation are Maize and sorghum, Sweet Potato, HWARDO (2018). From these major food crops of the study area, chat and vegetables have main cash crops of the locality.

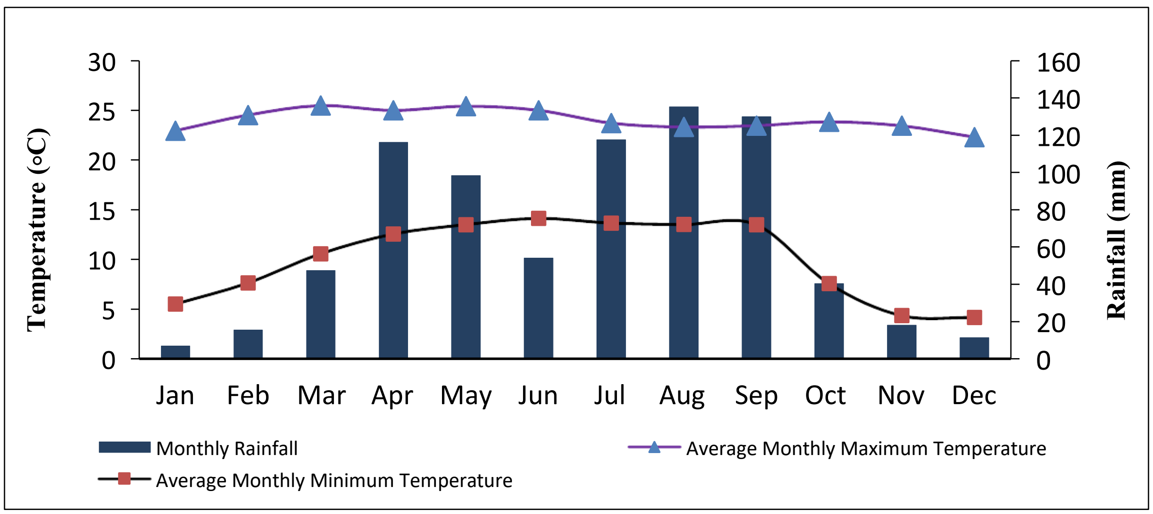


Figure 2. Average monthly rainfall, maximum, and minimum temperature of Haramaya Woreda (1988-2021).

(Source: National Metrological Agency)

3.1.4. Vegetation and wild Animals

The vegetation is characterized by tropical forest trees, shrubs, and short grasses that grow naturally. Mainly, trees growing in the study area such as the Aeschynomene aspera (Shola), Afrocarpus gracilior (Zigba). Huge area that had covered by large shrubs and forests has been clear-cut for human need satisfactions and changed by unusual tree types. Then, the woodland in the area were widespread but cutting of these forests because of high people's expansion (HWARDO, 2021).

3.1.5. Demography

According to Ethiopian Statistics Service (ESS, 2022) conducted Haramaya Woreda has, a total population of 412,685 of them 209,401 is men and 203,284 are women. ''The majority of the inhabitants are Muslim with 84.92% of the population, 10.08% Ethiopian Orthodox Christianity, and Protestants account 5%.'' The native language spoken in the study area is the Oromiffa and Amharic as a second language.

3.1.6. Economic activity

Agriculture mixed farming of crop production dependent on rain-fed and irrigation practices and seasonal and livestock rearing is serving as the main economic base and means of livelihood to the most of the people of the study area. Cash crop farming chat, vegetables, coffee small scale trading, and enterprises, few are employed in governmental and NGO (HWAFEO, 2021) Social services in Education. In Haramaya woreda livestock is also an important source of household income and food (MWWAO 2010).

3.1.7. Education

Haramaya Woreda in terms of an educational facility, it has primary and secondary levels. According to Haramaya Woreda Education Office, in the Woreda 75 primary schools 2 high schools and 1 preparatory school and the number of student in the woreda 35022 males and 21425-- females total 56449 students in the woreda both Inadequate supply of textbooks and classroom furniture, lack of laboratory or inadequate supply of equipment, shortage of chemicals and lab-technicians, and no lab-technicians almost no library and high drop out and repeaters characterize most of the schools in Haramaya woreda (Nigussie, 2019).

3.1.8. Health

Health is among key indicators for a socio-economic development. According to the Woreda Health office report (2018), one newly, built primary hospital Haramaya town, 8- health center, and 36 Health posts at different parts of woreda are available. The real access to health services is limited especially in the rural area due to several reasons, of which lack of transportation, lack of infrastructure, physical facilities, drugs and other 23 consumable supplies are the major ones Woreda are communicable diseases such as malaria, Pneumonia, soft tissue injury upper Respiratory disease treat Infection and Intestinal parasites and malnutrition are the common and top diseases.

3.2. Research Approach and Design

The study used descriptive and explanatory research design and mix of qualitative and quantitative research approach. The present study was conducted based on ‘’longitudinal research design using panel data’’ from various sources including CSS, ministry of agriculture and agriculture secretariat. To examine the same variables (temperature, rainfall and crop yield) and to detect any changes that might occur over a period of time, a longitudinal study that uses 30 years of data was employed. Longitudinal studies are a type of correlational research in which researchers observe and collect data on a number of variables without trying to influence those variables (Lauren Thomas, 2022). To implement a longitudinal study, data collected through two choices: collecting own data and using secondary data like temperature and rainfall already available.

The study covered selected Kebelles of the Wereda over the period between1993 to 2022 having estimated a production function. The study established that temperature and rainfall has effect on the production of Chat, fruits and vegetables production. A mixed methods approach using qualitative and quantitative data was employed. Quantitative data is collected through household survey and using secondary data on the patterns of temperature and rainfall during 30 years. The qualitative data collected is on adaptation strategies among the ‘’smallholder farmers’’ used in response to climatic change and variability in the study area.

3.3. Data Types and Sources

Primary and secondary data were together used in the present study as source of information. The ‘’Primary data’’ were collected through a household survey. Household surveys was conducted with farmers living in Haramaya woreda. Respondent farmers were asked to share their ‘’perception and experiences of the trend of rainfall and temperature ‘’and it was triangulated with meteorological data analyses.

3.4. The Study’s Population, Sample Size and Sampling techniques

This study used a multistage sampling procedure. In the first stage of the multistage sampling, Haramaya (Oromia regional state) was purposively selected, because in this Woreda, majority of the local communities are farmers and their livelihood is entirely dependent on crop cultivation. In addition, the area is highly vulnerable to the impacts of climate change which threatens farmer’s livelihoods and the sustainability of agriculture. In the Wereda there are 33 rural Kebeles. To select the representative sample, the researcher identified total household heads in collaboration with the Haramaya Woreda land administrative office. Through simple random sampling of lottery method, three sample *kebeles* i.e. Horo Weltia, Adi and Korke were selected by using a probabilistic simple random sampling technique. This is to give an equal chance to all those people of the target *kebeles* to be involved with being sample respondents. The sample size respondents size was determined by using a formula developed by (Yamane, 1967) to determine the required sample size at 95% confidence level with degree of variability = 0.05 for sample households.

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

Where:

n= is the sample size,

N= is the population size (total household size) i.e. 1953

e-is the level of precision i.e. 0.05

$$\boldsymbol{n}= \frac{\mathbf{1953}}{\mathbf{1+1953(.05)2}}$$

$$n = \frac{1953}{5.8825}$$

$$n = 332$$

Then from the total population i.e. 332 household heads were selected to be sample respondents for questionnaire. The following Table summarized the sample size, sampling technique and data collection instrument.

Table 3.1. Summary of the Samples

No	*Kebeles* and groups	Total HHs	Sample HHs	Sampling technique	Data collection instrument
1	Adale Woltahaa	711	117	Random sampling	Questionnaire
2	Qorke	624	102	Random sampling	Questionnaire
3	HaroAdii	618	102	Random sampling	Questionnaire
Total		1953	332		

(Source: Compiled by the researcher from HWFEO data, 2023)

3.5. Data collection instruments

Household survey questionnaire and documents i.e. (CSS), National Metrological Agency (NMA) used as data collection instruments in the study.

3.5.1. Household Survey questionnaire

For the present study, for the household's in the selected three Kebelles were used a survey that is managed of both ‘’ a structured and semi structured questionnaires’’. The survey was based on their after agreement. For that matter, a questionnaire having two parts was employed: Part One: profile of the households; part two: the climate Change related challenges and Farmers' Adaptation Strategy.

3.5.2. Key Informant Interview guide (KIIs)

The purposively selected Development Agents and Woreda experts of agriculture and rural development participated in the interview. In the KKI relevant information gathered about the extent of climatic changes and trend of the crop yield production over times and the farmer's responses as adaptation strategies for the climate variability effects in the study area.

The guidelines used in the current study were: What do you think that about the climatic change for instance temperature and rainfall variability in the study area are changed over years? What is the trend of the crop yield among the farmers in the study area over time? ‘’How does temperature and rainfall variability affect the farmers in the study area?’’ ‘’What does the farmer’s responses as adaptation strategies for the climate variability effects in the study area?’’ ‘’What response are provided by your office to the climate variability effects in the study area?’’

3.5.3. Document Analysis

The reasons to use documents is, data like the temperature, rainfall and crop productivity of the past 30 years is collected from documents of CSS and NMA organization. Thus, data about the last thirty years i.e. 1993 to 2022 was gathered from ‘’Central Statistical Agency (CSA)’’, ‘’National Metrological Agency (NMA)’’ and ‘’Environmental Protection Agency (EPA)’’ another relevant organizational, ministry of Agriculture and agriculture secretariat of Haramaya Wereda and Haramaya Woreda Finance and Economical Office was reviewed. To do this a checklist to record the last 30 years’ data on the variables namely temperature, rainfall and crop were used.

3.6. Methods of Data Analysis

3.6.1. Analysis of qualitative data

The reasons to use qualitative were: to enrich the findings with lively and detailed information that quantitative data does not always provide; to better understand the experiences the study area; to gain knowledge about the issues of under investigation. Therefore, qualitative data analysis has employed for that results of interview.

The researcher has followed the following steps to analysis the qualitative data: First, memos were prepared and recorded (audio and photo) with the consent of the Development agents and Kebellle administrations carefully the data. Secondly, the recorded data has labeled and archived. It was done in papers to copies the data held. The data have the basic information like, name of interviewee, location of interview. In the third place, the objectives; has reviewed. Fourth, the contextual data has analyzed. Fifth, it has carefully read through the data and has begun to code. Sixth, the summaries of the themes have identified. Seventh, the findings have interpreted and the contributions have assessed.

Another important step was triangulation of data sources. The triangulation was made qualitatively both the results of quantitative and qualitative data. It was conducted by cross checking of the results collected and analyzed through different instruments and methods. The triangulation has enabled the study to check the validity of the data and this study's findings. After triangulation qualitative data analysis has employed to made conclusions and recommendations and prepared draft report.

3.6.2. Analysis of quantitative data

The data were encoded and analyzed using SPSS Version 26. The data were analyzed using descriptive statistics like score mean, standard deviation frequency and percentage for the descriptive analysis.

To analyze the trend of the climatic variabilities of the past thirty years, the average (mean-value), mean, median, mode, maximum, minimum and SD of both temperature and rainfall were used. This is used to show the variation and the climatic changes over the 30-years. Besides, to analyze the trend of productivity of the past eight years, the average (mean-value), mean, median, mode, maximum, minimum and SD of crops were used. This is used to show the variation of the crops productivity. And the climatic variability's association with the income obtained from crop productivity on chat, coffee, cabbage, potato, maize and sorghum were analyzed using Chi-square. Also sex, educational background, access to information, access to credit facilities, membership of FBOs and access to market were analyzed through Spearman association or Chi-square to show their association with the total income from the different income generation. For these associations a p-value of .05 were used to determine their significant association.

To use the Multinomial Lo git Model, first the continuous and the categorical variables has been distinguished. The continuous variables i.e. '' Age, Educational background, Household size and Farm size'' their ''model fitting information'', ''Likelihood Ratio Tests'' and Parameter Estimates'' were interpreted. And, for these variables if the p- value is not greater than .05 and the AOR with its 95% confidence interval is above 1.0 value, ''for every one-unit increase in the continuous variable, the risk of the outcome occurring increase that may more times versus the reference category outcome. If the p is less than .05 and the AOR with its 95% confidence interval is below 1.0 value, for every one-unit increase in the continuous variable, the risk of the outcome occurring decrease that may more times versus the reference category outcome.''.

And, the categorical variables such as ''Sex, Access to information, Access to credit facilities, Membership of FBOs and Access to market'' their ''model fitting information'', ''Likelihood

Ratio Tests'' and Parameter Estimates'' were interpreted. For these categorical/ordinal variables if the p is less than .05 and the AOR with its 95% confidence interval is above 1.0 value, then the risk of the outcome occurring increases that many times versus the reference category outcome. If the p is more than .05 and the AOR with its 95% confidence interval is below 1.0 value, then the risk of the outcome occurring decrease that many times versus the reference category outcome.

The approach is given analyses to the farmers' strategies regarding crop based adaptation and what factors restraints farmers to be food insecure in a sustainable manner. Households was associated with their most preferred option from a given set of adaptation strategies to meet their food security. Other alternative of adaptations were also collected not to underemphasizing the known importance to smallholder farmers of using multiple adaptation strategies. Multinomial logistic regression (MNL) model was used to identify and interpret main socio-economic factors affecting adaptation practices against climate variability and its implication to food security in the study area.

For the data on the variables (temperature, rain fall and crop yield productivity) cob Douglass production function (following Eberhardt and Taal, 2012) to analyze the effects of climate change of rainfall and temperature on crop yield production of Chat, fruits and vegetables. Agricultural production (Y_{it}) and); was applied. Thus the study considered the following linear panel regression model:

$$Yit = \gamma i + \beta iXit + \mu it$$

Where:

Y_{it} is the annual value of crop yield production in the study area (*i)* at time *(t)*

Xit is a combination of both economic and climatic variables and is the error term.

$$X_{it} = [v_{it}, Cy_{it}, Rf_{it}, te_{it}].$$

This includes economic and climatic variables. The economic variables were crop yield production *(Cy)* while the climatic variables are Rain fall *(Rf)* and temperature *(te).*

The model for regression analysis then becomes:

$$Yit = \gamma i + \beta 1vit + \beta 2Cyit + \beta 3Rfait + \beta 4teit + \mu it$$

All the variables in the above equation are expressed in natural logarithms except temperature and precipitation.

3.7. Description of the variables

Table 3.2. Description of variables

Explanatory variable	Measurement	Description	Expected sign/effect
Education	Continuous	Educational background of the household head	+
Access to information	Dummy	0= have no access/low awareness; 1= have access	+
Household size	Continuous	Household size	-
Access to credit facilities	Dummy	0= if have not access to credit facilities, 1= if have	+
Household income	Continuums	Income of the Household	+
Membership to farmer-based organization (FBOs)	Dummy	0= if not Member of (FBOs), 1= if member	+
Access to market	Dummy	0= if have not access to market, 1= if have	+
Farming experience	Continuous	Farming experience in years	-
Farm sizes	Continuous	Farm sizes	-
Sex	Dummy	Gender of the HH: If 0=male, 1=female	-
Age	Continuous	Age of the household head	-

3.8. Ethical Consideration

A number of ethical considerations have been taken in to account from data collection to presentation. The collections were based on their consent. And the data were keep confidential and used for the purpose of the current research. The data were not manipulated and keep their originality. And, the researcher followed and doing as per the Addis Ababa University Ethical policy guideline.

Chapter Four:

Data analysis and Interpretation

4.1. Introduction

The present study's purpose was to examine farmers' response and their adaptation strategies to the impacts of climate variability in Haramaya Woreda, Ethiopia. Specifically, is aimed to analyze the trends in temperature and rainfall patterns during the last 30 years, to assess the trend of crop yield productivity in Haramaya Wereda and to explore adaptation strategies used by farmers in response to the adverse effects of climate variability.

For the purpose of the study data were collected from 292 households of three Kebelles via questionnaire; from five informants of experts in the Wereda; and secondary data from Central Statistics Agency and Ethiopian Metrology Agency. These data presented and analysed in the following sections of this chapter.

4.2. Response Rate

Table 4.1. Response Rate

Participants category		Distributed	Returned	Response rate
Kebelles	Haro Adi	102	94	92.2%
	Weltaha	117	103	88%
	Korke	102	95	93.1%
Total		327	292	89.3%

(Source: own survey, 2023)

As shown in Table 4.1, 327 questionnaires were distributed and 292 (89.3%) were responded. The questionnaires were distributed to three Kebeles of the Haramaya Wereda i.e. 102, 117 and 102 were distributed Haro Adi, Weltaha and Korke and 94 (92.2%), 103 (88%) and 95 (93.1%) were returned respectively.

4.3. Profile of the Respondents

Table 4.2. Demographic Features of the Respondents

Items		Frequency	Percent
Sex	Male	217	74.3
	Female	75	25.7
	Total	292	100.0

Educational background	Illiterate	132	45.2
	Read and write	81	27.7
	Primary (1-8)	53	18.2
	9-12	17	5.8
	12 complete	9	3.1
	Total	292	100.0
Marital status	Married	273	93.5
	Unmarried	6	2.1
	Divorced	8	2.7
	Widowed	5	1.7
	Total	292	100.0

(Source: own survey, 2023)

As shown in Table 4.1, 217(74.3%) of the total respondents are males and 75(25.7%) females. The majority or about 45.2% of the respondents cannot and those who can read and write are 27.7%. Only 18.2% of the study participants attended primary school (1-8). Whereas list number of the respondents with a share of 5.8% and 3.1% were 9-12 (high school) and Twelfth completed. Therefore, the participant households educational level is lower in the Study Area. Majority of the household's marital status were married i.e. 273 (93.5%); whereas, 2.1% were unmarried, 2.1% divorced and 1.7% widowed.

Table 4.3. Household size, income and farming experience

		Age	Household size	Household Income	Farming experience (in years)
N	Valid	292	292	292	292
	Missing	0	0	0	0
Mean		54.8493	8.9041	68013.6986	36.8048
Minimum		26.00	1.00	25000.00	14.00
Maximum		85.00	14.00	120000.00	70.00

(Source: own survey, 2023)

As shown in Table 4.3, the households were aged from 26 to 85 and the mean value accounted 54.85. This implies that, in average the household age was about 54.85 and the younger and older household aged 26 and 85 respectively. The households size in the study Kebeles ranged from 1 to 14 and in average the household size was 8.9. The household's annual income was from br. 25, 000 to br. 120,000 and the mean income of the households per year valued br. 68,013.7. The participants have also farming experiences of 14 years (minimum experience) and 70 years (maximum experience). in the study 217(74.3%) males and 75(25.7%) females were participated. The average farming experiences of the households laid with an age of 36.8 years.

Table 4.4. Farm size (Timad/ Fechasa)

		Total	Used Cereals	Used for Cash Crop	Used Grazing
N	Valid	292	292	292	135
	Missing	0	0	0	157
Mean		1.5873	.5313	.8168	.4472
Minimum		.50	.13	.25	.13
Maximum		3.00	1.00	2.50	1.00

(Source: own survey, 2023)

As shown in Table 4.4, in the sample the farm size of the households accounted in average 1.589 *Timad/Fechasa*; and the minimum farm size holds among the HHs was .5 *Timad/Fechasa* weher as the maximum farm size holds by the HHs is 3 *Timad/Fechasa.* Among these farm sizes, .53; .816; and, .447 *Timad/Fechasa* were used cereal, cash Crop and Grazing respectively. Thus, the majority is used for cash crops followed cereals whereas grazing valued the least number of farm size in the study area.

4.4. The Study's Descriptive Result

4.4.1. The Households Access to credit, market and information

Here below four variables named access to information/awareness about adaptation practices, access to credit facilities; membership of farmer-based organization (FBOs) and access to market results are provided.

Table 4.5. HHs Access to credit, market and information

Items	Frequency	Percent
Access to information/awareness about adaptation practices	75	25.7
Access to credit facilities	56	19.2
Membership of farmer-based organization (FBOs)	130	44.5
Access to market	222	76.0

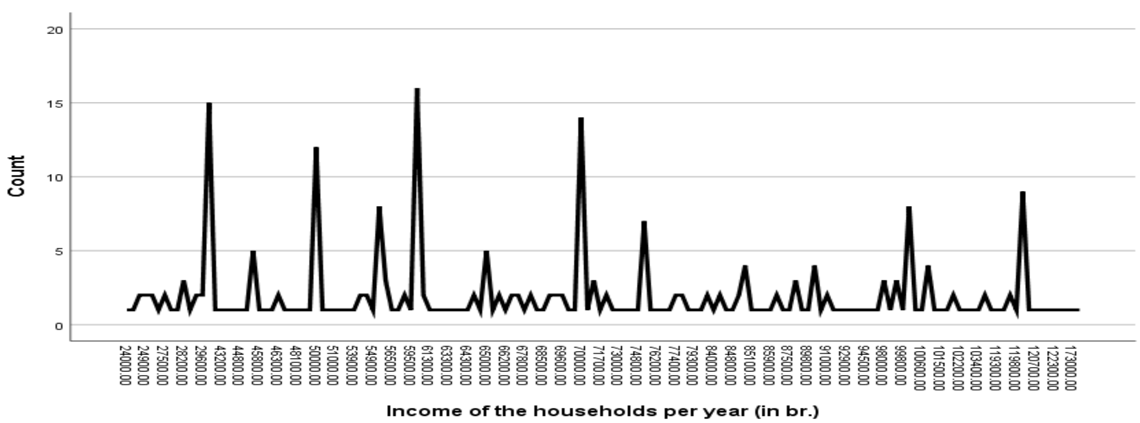
(Source: own survey, 2023)

In the study area, 75 (25.7%) of the HHs have access to information/awareness about adaptation practices. Those HHs have access to credit facilities accounted about 19.2%. About 44.5% of the HHs are members of farmer-based organization (FBOs) and most of the respondents with a share of 76% have access to market (Table 4.5).

4.4.2. Household's Income

House hold income of the HHs was computed their income per year, the result depicted in Fig. 4.1.

Fig 4.1. HHs Income in Br. (Annually)



(Source: Own Survey, 2023)

According Figure 4.1 above, the minimum income of the households per is 24,000 and the maximimu is 181,000. This shows, amongest the participants there is a range of 157,000 between the HHs obtained highest and lowest. Also, as shown in the below Table (Mean= 68,014; Median=69,550; Mode=60,000; and, Std. Deviation=27,337.38451). this shown that, in average the samples obtained about br. 68,014 per year and the median of the sample's income is 69,550.

The most HHs obtained 60,000. These figures indicated that, despite the range of maximum and minimum income is high the mean, median and mode are simillar.

These households are obtained income from chat, cabbage, sorghum, maize potato and coffee. All the participants (i.e.292) gained income from chat, with an average of br. 36730.48 per year. One-hundered fifty six HHs obtained income from cabbage with an average of br. 9989.68. 254 HHs gained an averge income of br. 14,044.88 from Sorghum. Out of the sample, 176 obtained an average of 12,644.88 br. from maize. Those obtained income from potato accounts 229 and their average annual income valued br. 7,323.58. Those obtained income from coffee (i.e. 292 HHs) accounted an average income from thie item was 25, 078 br per year.

From these figures, we can say that in the income of HHs in the three sample Kebelles of Haramaya Wereda depended on these crops and vegetables. And, Chat and Coffee is common income generatimg items. Whereas, cabbages and maize followed by potatoto and sorghum are less cultivated items in the three Kebelles.

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Table 4.7. Statistics of the HHs Income of the households per year (in br.)

		Income (chat)	Income (cabbage)	Income (Sorghum)	Income (Maize)	Income (potato)	Income (coffee)	Total (in br.)
N	Valid	292	156	254	176	229	292	
	Missing	0	136	38	116	63	0	
Mean		36730.4795	9989.6795	14044.8819	12644.8864	7323.5808	25078.9474	68,014/00
Median		35000.0000	6650.0000	15000.0000	11000.0000	5000.0000	25000.0000	69550.0000
Mode		30000.00	15000.00	15000.00	15000.00	5000.00	20000.00[a]	60000.00

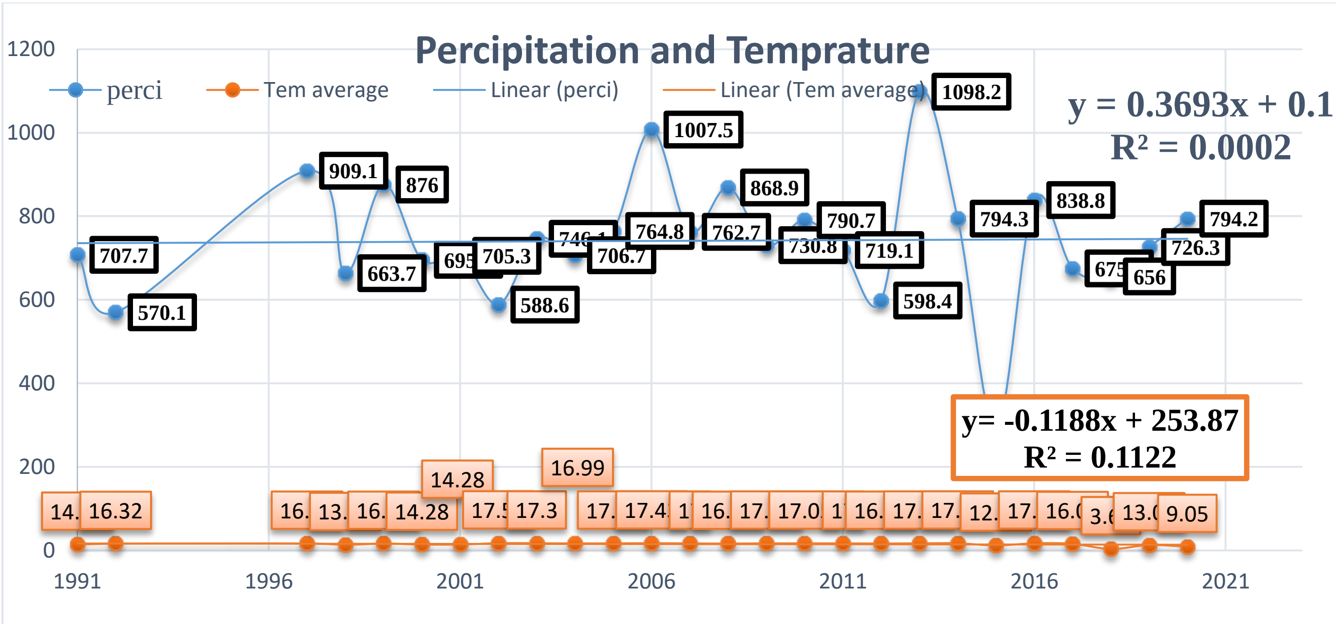
Std. Deviation	14526.59118	12261.2401	9651.90766	5375.15735	6593.82774	5242.14511	27337.3845
Range	55000.00	146500.00	114000.00	24000.00	54200.00	15000.00	157000.00
Minimum	9000.00	4500.00	2000.00	1000.00	1800.00	19000.00	24000.00
Maximum	64000.00	151000.00	116000.00	25000.00	56000.00	34000.00	181000
Sum	10725300.00	1558390.00	3567400.00	2225500.00	1677100.00	953000.00	20706690
a. Multiple modes exist. The smallest value is shown							

(Source: Own Survey, 2023)

4.4.3. The Trends of Temperature and Rainfall Patterns

The study aimed to analyze the ‘’trends in temperature and rainfall patterns’’ during the last 30 years. The data is limited trends ‘’in temperature and rainfall patterns’’ during the last 30 years the study area. I.e. Haremaya Wereda.

Fig 4.5. Trend of Precipitation and Temperature



(Source: Own Survey, 2023)

According to Fig 4.5 above the rainfall trend in the year 1991 70.7 mm and in 2021 is 794.2 mm. in the trend the highest is rainfall is accounted in the years 2013 with a value 1098.2 mm. Whereas the least rainfall is accounted in the year 2012. Regarding the temperature, the highest average temperature is 17.51 in 2002 and the lowest 3.64 in 2018. In the years were rainfall was high (1098.2 mm), the average temperature were 17.8 (above the average temperature). Whereas, during the years where rainfall was low (570.1mm) the average temperature was 16.5 (this is also above the average temperature).

Table 4.8. Statistics of the climatic change trends

Statistics	Precipitation (in mm)	Temperature (ave)
Mean	716.8815	15.4104
Median	726.3000	16.7300
Mode	.00[a]	14.28[a]
Std. Deviation	206.23097	3.08723
Minimum	291.00	3.64
Maximum	1098.20	17.51
Range	807.20	13.87
Sum	19355.80	416.08

a. Multiple modes exist. The smallest value is shown

(Source: own survey, 2023)

The Mean value of precipitation (in mm) and Temperature (ave) in the study area accounted 716.8and 15.4 respectively. The median values are also 726.3 and 16.7300 which are similar with the mean value. The difference between the max. (1098 mm) and the min. (3.64 ℃91) were 1098 mm; and, the difference between the max. (17. 2 ℃) and the min. (291 mm) were 13.87℃.

Table 4.9. Correlations

			Precipitation (in mm)	Temperature (max)	Temperature (min)	Temperature (ave)
Spearman's rho	precipitation (in mm)	Correlation Coefficient	1.000	.038	.503**	.482*
		Sig. (2-tailed)	.	.849	.008	.011
		N	27	27	27	27
	temperature (max)	Correlation Coefficient	.038	1.000	.292	.615**
		Sig. (2-tailed)	.849	.	.140	.001
		N	27	27	27	27
	temperature (min)	Correlation Coefficient	.503**	.292	1.000	.881**
		Sig. (2-tailed)	.008	.140	.	.000
		N	27	27	27	27
	temperature (ave)	Correlation Coefficient	.482*	.615**	.881**	1.000
		Sig. (2-tailed)	.011	.001	.000	.
		N	27	27	27	27
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

(Source: Own Survey, 2023

As shown in the above Table 4.9, the Spearman correlation coefficient of precipitation (in mm) has correlation coefficients of .038, .503 and .482 respectively with temperature (max), temperature (min) and temperature (average). This implies that, precipitation has strong correlation with minimum temperature followed by average temperature. And, the Spearman correlation coefficient of temperature (average) has correlation coefficients of .482, .615 and .881 respectively with precipitation (in mm), temperature (max) and temperature.

4.4.4. Crop yield Productivity in the study area

The second objective of this study was, assessing the trend of crop yield productivity in the three kebelles of Haramaya Wereda. The following Table 4.10 displayed Crop Yield Productivity main season (in Quintal) and Belg (in Quintal) from 1991 to 2022. The data is obtained from CSA and organized by the researcher. The productivity is in thousands of quintals.

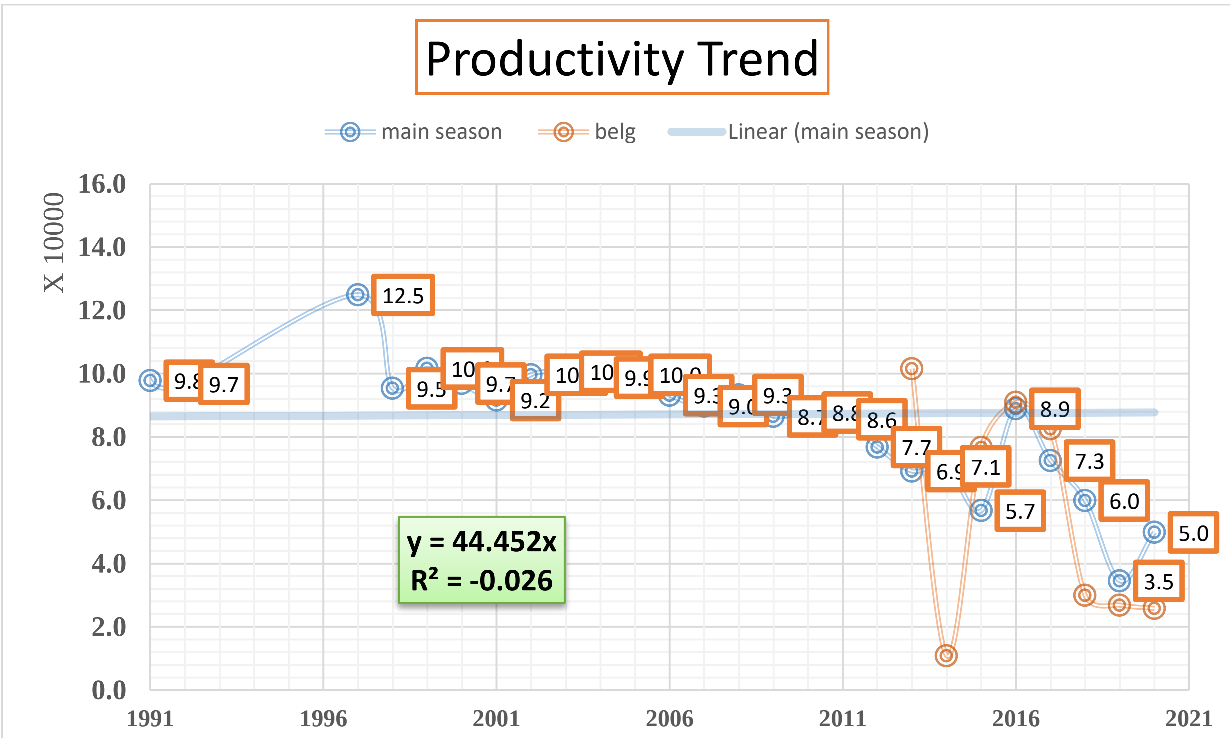
Table 4.10. Statistics of Crop Yield Productivity (n=27)

Statistics	Productivity ***main season*** (in Quintal)	Productivity ***Belg*** (in Quintal)
Mean	89264.4444	55674.7500
Median	93222.0000	53353.0000
Mode	34566.00[a]	10898.00[a]
Std. Deviation	22115.04867	35669.05488
Minimum	34566.00	10898.00
Maximum	134555.00	101582.00
Range	99989.00	90684.00
Sum	2410140.00	445398.00
a. Multiple modes exist. The smallest value is shown		

(Source: own Survey, 2023)

The valid years for the Productivity main season and Productivity Belg were 27 and 8 years respectively. And, as shown in the above Table, Mean or average of the Wered's Productivity main season (in Quintal) and Productivity Belg (in Quintal) valued 89264 and 55675 respectively. The maximum and minimum values of productivity in the main season (in Quintal) accounted 134,555 and 34,566 quintals per year.

Fig 4.5. Crop Yield Productivity (1991 to 2022)



(Source: Own Survey, 2023)

As shown in the above Figure, the productivity crops in the study area from 1991 to 2022 shows a decline from 9.8 (in thousands) of Quintal in 1991 to 5.0 (in thousands) Quintal in 2021. Therefore, the productivity of crops in the study area (Haramaya Wereda) show declining within the last thirty years.

Table 4.11. Correlations of Precipitation, Temperature and Productivity in the main season

Statistics			Precipitation (in mm)	Temperature (max)	Temperature (min)	Temperature (ave)	Productivity main season (in Quintal)
Spearman's rho	Precipitation (in mm)	Correlation Coefficient	1.000	-.079	.417*	.394*	.186
		Sig. (2-tailed)	.	.696	.030	.042	.352
		N	27	27	27	27	27
	Temperature (max)	Correlation Coefficient	-.079	1.000	.292	.615**	.121
		Sig. (2-tailed)	.696	.	.140	.001	.546
		N	27	27	27	27	27
	Temperature (min)	Correlation Coefficient	.417*	.292	1.000	.881**	.382*
		Sig. (2-tailed)	.030	.140	.	.000	.049
		N	27	27	27	27	27
	Temperature (ave)	Correlation Coefficient	.394*	.615**	.881**	1.000	.364
		Sig. (2-tailed)	.042	.001	.000	.	.062
		N	27	27	27	27	27
	productivity main season (in Quintal)	Correlation Coefficient	.186	.121	.382*	.364	1.000
		Sig. (2-tailed)	.352	.546	.049	.062	.
		N	27	27	27	27	27
*. Correlation is significant at the 0.05 level (2-tailed).							
**. Correlation is significant at the 0.01 level (2-tailed).							

(Source: Own Survey, 2023)

As shown in the above Table, the Spearman correlation coefficient of precipitation (in mm) has correlation coefficients of -.079, .417, .394 and .186 respectively with Temperature (max), Temperature (min), Temperature (ave) and Productivity main season (in Quintal). This implies that, precipitation has negative but less correlation with the maximum temperature. Whereas it has high correlation with minimum temperature followed with average temperature and productivity. On the other hand, productivity in the study area had a Spearman correlation coefficient values of .186 with precipitation, .121 with the maximum temperature, 382 with minimum temperature and .364 with average temperature. Thus, productivity of the main season in the study area correlated with the climatic variabilities of average and minimum temperatures; following these it has also correlation with precipitation.

4.4.5. Adaptation Strategies

The adaptation strategies used in the study area were also assessed and its results depicted in the following table.

Table 4.12. The risk Factors in the Area

Items		Kebelle			Total
		Haro Adi	Weltaha	Korke	
The yield of crops in your farm has declined	Count	94	103	95	292
	% within Kebelle	100.0%	100.0%	100.0%	100.0 %
The land in your area is Degraded from time to time	Count	75	103	95	273
	% within Kebelle	79.8%	100.0%	100.0%	93.5%
Water Shortage	Count	38	103	95	236
	% within Kebelle	40.4%	100.0%	100.0%	80.8%
Experienced diseases and pests	Count	94	103	95	292
	% within Kebelle	100.0%	100.0%	100.0%	100.0 %
The soil is eroded	Count	94	103	95	292
	% within Kebelle	100.0%	100.0%	100.0%	100.0 %
Insecure in food	Count	56	103	95	254
	% within Kebelle	59.6%	100.0%	100.0%	87.0 %

(Source: own survey, 2023)

As depicted in the above Table 4.12, the households in the three Kebele have replied that the yield of crops in the farm has declined, experienced diseases and pests and the soil in there are is eroded. But, water shortage and food insecurity are relatively has less experienced the household farmers of Haro Adi Kebelle. The farmers have different adaptation strategies for the adverse effects of climatic change in the area. In the questionnaire open ended question the HHs reply are arranged in the following themes.

Also, the ‘’adaptation strategies’’ as per the respondent’s response in the open ended question of the questionnaire for the risk factors can be summarized as follows:

1. For the Risk factor Crop yield decline: There is a cultural belief of praying for Rebi which is locally called Wedeja/Rabiki; Off-farming; Manual work in other places and Fertilizers i.e. urea and Dap.
2. For the Risk factor of Land Degraded: Soil water conservation and Terracing
3. For the Risk factor of Water Shortage: Pumping from underground or using Ground water and Fetching water from long distance
4. For the Risk factor of Diseases and pests: DDT, Herbicides, pesticides and rooting the weeds
5. For the Risk factor of Soil erosion: Planting grasses and/ Bushes; Terracing; Horizontal cultivation and Soil conservation
6. For the Risk factor of Insecure in food: Safety net and Changing items.

4.4.6. Descriptive results (Chi Square)

The following Table is intended to show the association of sex, educational background, access to information, access to credit facilities, membership of FBOs and access to market with household’s income.

Table 4.13. Descriptive Results (Chi Square)

Items			**Household income**		**Chi Square tests**		
			68,014 and less	**Above 68,014**	**X^2**	**Df**	**Sig**
Sex	Male	Count	97	120	20.066[a]	1	.000
		% within household income	63.4%	86.3%			
	Female	Count	56	19			
		% within household income	36.6%	13.7%			
Educational background	Illiterate	Count	64	68	3.371[a]	4	.498
		% within household income	41.8%	48.9%			
	Read & write	Count	44	37			
		% within household income	28.8%	26.6%			
	Primary (1-8)	Count	29	24			
		% within household	19.0%	17.3%			

		income					
	9-12	Count	9	8			
		% within household income	5.9%	5.8%			
	12 complete	Count	7	2			
		% within household income	4.6%	1.4%			
Access to information	No	Count	97	120	20.066[a]	1	.000
		% within household income	63.4%	86.3%			
	Yes	Count	56	19			
		% within household income	36.6%	13.7%			
Access to credit facilities	No	Count	116	120	5.194[a]	1	.023
		% within household income	75.8%	86.3%			
	Yes	Count	37	19			
		% within household income	24.2%	13.7%			
Membership of FBOs	No	Count	153	9	257.922a	1	.000
		% within household income	100.0%	6.5%			
	Yes	Count	0	130			
		% within household income	0.0%	93.5%			
Access to market	No	Count	35	35	.212[a]	1	.645
		% within household income	22.9%	25.2%			
	Yes	% within access to market	53.2%	46.8%			

(Source: own survey, 2023)

As shown in Table 4.8, using 68,014 (mean value of the HHS income as cut off the categorize into binary the farmer's annual income obtained annually are categorized in to two: (1) household income 68,014 and less and (2) Above 68,014327. As a result, sex is found statistically significant association with the outcome variable HHs income (since the Pearson Chi Square and Sig value accounted 20.066 and .000). Thus, male headed HHs are found to have more likely higher income relatively the females headed HHs. Educational background of the HHs is found statistically insignificant association with the HHs income. Access to information is found statistically significant association with the outcome variable HHs income (since the Pearson Chi Square and Sig value accounted 20.066 and .000). Thus, the HHs have information about adaptation strategies are found to have more likely higher income relatively the HHs have no information access. Access to credit facilities of the HHs is found statistically insignificant association with the HHs income. Membership of FBOs is found statistically significant association with the outcome variable HHs income (because the Pearson Chi Square (x2) =257.922 and Sig=.000). Thus, the HHs are members of Farmer Based Organizations are more likely higher income relatively than the HHs are not members of Farmer Based Organizations. Access to market of the HHs is found statistically insignificant association with the HHs income.

4.5. Multinomial Logistic Regression

4.5.1. Continuous Variables

The continuous variables of the current study were: Age, Educational background, Household size and Farm size. In this section the model fitting information, Likelihood Ratio Tests and Parameter Estimates are shown as below.

Table 4.14. Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	404.126			
Final	.000	404.126	4	.000

(Source: own survey, 2023)

As shown in Table 4.14 under the sig column, it is not greater than .05, then the ‘’model fit’’ the data better than the ‘’null model’’ with a significant amount. Continuing with the interpreting the results

Table 4.15. Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	248.234	248.234	1	.000
Age	19.285	19.285	1	.000
Educational background	.000[a]	.	1	.
Household size	24.804	24.804	1	.000
Farm size *(fechasa/timd)*	287.341	287.341	1	.000
The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.				

a. The log-likelihood values are approaching zero. There may be a complete separation in the data. The maximum likelihood estimates do not exist.

(Source: own survey, 2023)

As shown in Table 4.15, the continuous variables i.e. Age, Educational background, Household size and Farm size are found significant at with less than .05 sig value. This shown that, then the variable has a significant overall association with the outcome/the HHs income per year.

Table 4.16. Parameter Estimates

Household income		Exp(B)	95% CI for Exp(B)	
			Lower Bound	Upper Bound
Above 68,014	Intercept			
	Age	4.471	1.402E-59	1.426E+60
	Educational background	.356	.000	.[b]
	Household size	75450.227	.000	.[b]
	Farm size	1.635E+41	.000	.[b]

(Source: own survey, 2023)

The (p-value) is in the significance column, the AOR is in the ‘’Exp (B) column’’ and in the ‘’upper and lower limits’’ of the 95% confidence interval are presented. For the continuous variables if the p is less than .05 and the AOR with its 95% confidence interval is above 1.0 value, ‘’for every one-unit increase in the continuous variable, the risk of the outcome occurring increase that may more times versus the reference category outcome. If the p is less than .05 and the AOR with its 95% confidence interval is below 1.0 value, for every one-unit increase in the continuous variable, the risk of the outcome occurring decrease that may more times versus the reference category outcome.’’ In the current study the for every one-year age increase s to have annual income of the outcome HHs probability to have annual income above 68,014 of 4.471 more time to obtained annual income of br. 68,014 and less annually. For every one level increase ibn educational background among the HHs resulted to decrease the HHs annual income to obtain above 68,014 by about .356 more times of gaining annual income of br.

68,014 and less annually. For every one person increase in the HHs size resulted to decrease the HHs annual income to obtain above 68,014 by about 75450.227 more of gaining annual income of br. 68,014 and less annually. For every one *Timad/Fechasa* increase in the HHs farm size resulted to decrease the HHs annual income to obtain above 68,014 by about 1.635E of gaining annual income of br. 68,014 and less annually.

4.5.2. Categorical

Table 4.17. Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	360.075			
Final	3.864	356.210	5	.000

(Source: own survey, 2023)

As shown in Table 4.17 under the sig column, it is not greater than .05, then the model fit the data significantly better than the null model therefore, continuing with the interpreting the results/

Table 4.18. Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	3.864[a]	.000	0	.
Sex	12.459[b]	8.595	1	.003
Access to information	6.995[b]	3.131	1	.077
Access to credit facilities	3.864[b]	.000	1	1.000
Membership of FBOs	298.694	294.829	1	.000
Access to market	9.102[b]	5.237	1	.022
The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.				
a. This reduced model is equivalent to the final model because omitting the effect does not				

increase the degrees of freedom.
b. Unexpected singularities in the Hessian matrix are encountered. This indicates that either some predictor variables should be excluded or some categories should be merged.

(Source: own survey, 2023)

As shown in Table 4.18, the categorical variables i.e. only sex and membership of FBOs are found their sig value less than .05, then the two categorical variable has a significant overall association with the outcome.

Table 4.16. Parameter Estimates

Household income[a]		Exp(B)	95% CI for Exp(B)	
			Lower Bound	Upper Bound
Above 68,014	Intercept			
	[sex=.00]	92327701.953	92327701.953	92327701.953
	[sex=1.00]	.	.	.
	[access to information/ =.00]	49742404.910	.000	.[c]
	[access to information=1.00]	.	.	.
	[access to credit facilities=.00]	.211	.211	.211
	[access to credit=1.00]	.	.	.
	[membership of FBOs=.00]	7.921E-23	.000	.[c]
	[membership of FBOs=1.00]	.	.	.
	[access to market=.00]	1.006E-7	.000	.[c]
	[access to market=1.00]	.	.	.

(Source: own survey, 2023)

In the Table, the ‘’p-value’’ is in the significance column, ‘’the AOR’’ is in the ‘’Exp (B) column’’ and in the ‘’upper and lower limits of the 95% confidence interval’’ are provided. Generally, ‘’for the categorical/ordinal variables if the p is less than .05 and the AOR with its 95% confidence interval is above 1.0 value, then the risk of the outcome occurring increases that many times versus the reference category outcome. If the p is more than .05 and the AOR with its 95% confidence interval is below 1.0 value, then the risk of the outcome occurring decrease that many times versus the reference category outcome.'' As shown in Table 4.16, the probability of the female headed HHs are to the exp value extent of more times gaining annual income of br. 68,014 and less annually. The probability of the HHs have not access to credit are found 2.11 times to gain annual income of br. 68,014 and less annually than of those have access to credit.

4.5.3. Crop productivity year, temperature and rainfall

Table 4.19. Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	36.499			
Final	.000	36.499	3	.000

(Source: own survey, 2023)

As shown in the above Table 4.19 of the sig column, it is .000, meant by the model fit the data significantly better than the null model.

Table 4.20. Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	32.012	32.012	1	.000
Precipitation (in mm)	10.171	10.171	1	.001
Temperature (ave)	.000[a]	.000	1	1.000
Year	32.451	32.451	1	.000
The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.				
a. The log-likelihood values are approaching zero. There may be a complete separation in the data. The maximum likelihood estimates do not exist.				

(Source: own survey, 2023)

As shown in the above Table, the continuous variables i.e. Precipitation (in mm) and Year are found significant at with less than .05 sig value. This shown that, then the variable has a significant general association with the productivity trend in the study area.

Table 4.21. Productivity and precipitation

Productivity[a]		Exp(B)	95% Confidence Interval for Exp(B)	
			Lower Bound	Upper Bound
Less than the	Intercept			

mean value	Precipitation (in mm)	.788	1.064E-39	5.832E+38
	Year	336573.666	.000	.[b]
a. The reference category is: greater than the mean value.				

(Source: own survey, 2023)

As shown in the table, the ‘’p-value’’ meant by the value presented under the significance column, and AOR presented under the ‘’Exp (B) column’’ and in the ‘’upper and lower limits of the 95% confidence interval’’ are presented. For the continuous variables if the p is less than .05 and the AOR with its 95% confidence interval is not below 1.0, this revealed out that ‘’for every one-unit increase in the continuous variable, the risk of the outcome occurring increase that may more times versus the reference category outcome’’. And, unless the p is not less than .05 and the AOR with its 95% confidence interval is not below 1.0 value, ‘’for every one-unit increase in the continuous variable, the risk of the outcome occurring decrease that may more times versus the reference category outcome’’. Therefore, for every one mm increase in the precipitation the productivity to be greater than the mean value i.e. 89264 quintals increase that may .788 more times versus the reference category outcome.

4.6. Qualitative Data

The qualitative data were obtained from the three development agents (DAs), Administrators of the three Kebeles through interview, and the result is provided as follows.

QQ1. What do you think that about the climatic change for instance temperature and rainfall variability in the study area are changed over years?

The informant replied that, the climatic variability in the study area is not predicted. Some seasons there is high temperature and rainfall and other seasons the reverse may occur. But the variability of rain fall in the study areas is high. There are occasions where a sudden rain fall and overflows happened. Due to this, there are incidence of damages on human and animals. In such occasions it is expected that, there will be no or less productivity especially for the Sorghum, maize, sorghum and Sweet Potato. It is because the flooding is occurred during the July and August washed out these crops. And some rimes rainfalls are happened October and November when which damages Sorghum, maize and sorghum. There are also cases of rainfall scarcity this happened for consent years.

QQ2. What is the trend of the crop yield among the farmers in the study area over time?

The response of the informants can be summarized as:

The trend of crop yield productivity depended on many factors, the most important are

(1) Rainfall: since the households are deepened on the natural rainfall and the less practice of irrigation, the crop productivity depends on the amount of rain fall. Therefore, in the study area the trend of crop yield productivity ups and down in accordance with the ups and downs of rainfall.
(2) Agricultural provisions: this includes the inputs like (manure or compost, burning, contour plowing, reduced tillage, intercropping) used and, the 'natural capital' of the plot [biophysical characteristics (plot size, slope, position on the slope, soil depth, color and texture and presence of gullies).

QQ3. How does temperature and rainfall variability affect the farmers in the study area?

One DA replied that,

> *" though the NMA predicted the prevalence of rainfall in the area, sometimes the reverse occurred. And also the vice is happening. This uncertainty in the climatic variability is constraint to make ready the small holder farmers to adapt a certain adaptation strategy."*

QQ4. What does the farmer's responses as adaptation strategies for the climate variability effects in the study area?

The informants reply for the 'adaptation strategies'' was similar with the data obtained through questionnaire. The small holder farmers used off-farming; manual work in other places and fertilizers i.e. urea and dap. For the risk factor of land degraded, soil water conservation and terracing. For the risk factor of water shortage: pumping from underground or using ground water and fetching water from long distance. For the risk factor of diseases and pests: DDT, herbicides, pesticides and rooting the weeds. For the risk factor of soil erosion: planting grasses and/ bushes; terracing; horizontal cultivation and soil conservation. And, for the risk factor of insecure in food: safety net and changing items.

QQ5. What response are provided by your office to the climate variability effects in the study area?

The adaptation strategy provided by the offices of the Development Agents and Kebelle administrations are:

1. Awareness are created of about the significance of off-farming; manual work in other places and fertilizers like urea, dap etc
2. Programs in the occasions where there is consequents draught safety net programs are provided by government.

Kebelle Administrator of Haro Adi replied about the implementation of Safety net as:

> *"The safety program, which is at Woreda level, carried out three programs (1) Safety Net Support which provides for those who are unable to take part in work because of different reasons and for those who would like to receive these transfers register and provide verification of age (above 65 years only) or of their disability or chronic illness that prevents them from being able to perform a co-responsibility. (2) The livelihood support for those who have interest to enhance their work, will get livelihood support that enables them to graduate from the program and promote moving out of poverty. (3) The component i.e. institutional strengthening and program management supported the development and strengthening of project systems for targeting, monitoring and evaluation and management information system, payments, and citizen's engagement including social accountability and grievances redress mechanism."*

From these points the first component is more practical in the occasions where there are draughts and when the small farmers are not in farming works.

The DA of Haro Adi response on questiona reads as "if there is activity done by the Saftey Net that can relate with adaptation strategy?'' he replied as:

> *'' there are schemes that managed and operated nby the Saftey net officer under the agricultural secretariat at Wereda level. But some activities are related tamong the activities carried out by the safety net program at the kebelle where I am (Haro Adi) are making canals of course by stones where flooding is frequently occurred, forestation and terracing activities. …"*

And note that, the uncertainty of the rainfall needed attention because is not predicted. Therefore, a prevention measurement cannot taken.

Chapter Five:

Conclusion and Recommendations

5.1. Conclusion

The study comes up with the following conclusions:

Regarding the climatic mainly the temperature and precipitation variability in the study area, the in average about 716. 8 mm precipitation is recorded in the past 30 years. The trend of the rainfall is not shown statically significant declining within the studied period. Whereas temperature shows some increment from year to year and in averages it was recorded 16.73℃. Also in the study area temperature and rainfall has statistically significant correlation.

Considering the Crop Yield Productivity in the study area, the average of the Wered's Productivity main season (in Quintal) and Productivity Belg (in Quintal) valued 89264 and 55675 respectively. Here, the productivity shown some variation in the past 30 years i.e. the maximum and minimum values of productivity in the main season (in Quintal) accounted 134,555 and 34,566 quintals per year. Also, productivity has strong and positive correlation with precipitation and temperature.

As per the farmer's perception the yield of crops in the farm has declined, experienced diseases and pests and the soil in there are is eroded. But, water shortage and food insecurity are relatively has less experienced the household farmers of Haro Adi Kebelle. The farmers have different adaptation strategies for the adverse effects of climatic change in the area. In the questionnaire open ended question the HHs reply are arranged in the following themes.

In the three Kebelles of Haramaya Wereda, male headed HHs are found to have more likely higher income relatively the females headed HHs. Educational background of the HHs is found statistically insignificant association with the HHs income. Access to information is found statistically significant association with the outcome variable HHs income (since the Pearson Chi Square and Sig value accounted 20.066 and .000). Thus, the HHs have information about adaptation strategies are found to have more likely higher income relatively the HHs have no information access. Access to credit facilities of the HHs is found statistically insignificant association with the HHs income. Membership of FBOs is found statistically significant association with the outcome variable HHs income (because the Pearson Chi Square (x2)

=257.922 and Sig=.000). Thus, the HHs are members of Farmer Based Organizations are more likely higher income relatively than the HHs are not members of Farmer Based Organizations. Access to market of the HHs is found statistically insignificant association with the HHs income

The Multinomial Logistic Regression result revealed that, the continuous variables i.e. Age, Educational background, Household size and Farm size are found significant at with less than .05 sig value. This shown that, then the variable has a significant overall association with the outcome/the HHs income per year. Also, the categorical variables i.e. only sex and membership of FBOs are found their sig value less than .05, then the two categorical variable has a significant overall association with the outcome. And the MLR of the Crop productivity year, temperature and rainfall reveled that, the continuous variables i.e. Precipitation (in mm) and Year are found significant at with less than .05 sig value. This shown that, then the variable has a significant overall association with the productivity trend in the three kebelles of Haramaya Wereda.

5.2. Recommendations

From the findings the following recommendations are forwarding:

- Using mitigation mechanisms the yield crops declining from time to time is essential. Therefore, utilizing some adaptation for the improving, developing, and putting into practice solutions to lessen, cope with, and profit from the effects of climatic occurrences is needed. These HHs have to adopt crop diversification, modifying the farming calendar, employing physical and biological soil and water conservation practices, using different types of crop varieties, and other agronomic activities
- Increase the agricultural production of the poor farm households is mandatory. Among the recommendations for the study area are ‘’using different crop varieties’’, ‘’short growing crop varieties’’, put on ‘’small scale irrigation’’, varying planting period and engaging ‘’off farm activities’’ against climate impacts.
- Smallholder farmers in the study area utilize various soil and water conservation practices, including establishing physical structures such as terraces on slopes, soil bunds, micro trenches, micro-basins, and humidity conservation holes, to actively control risks and mitigate the adverse effects of global warming.

- Government or institutional adaptation strategies like creating policy initiatives, policies, programs and strategies that may directly or indirectly address climate change adaptation is also needed.
- There is no 'one-size-fits-all-solution'—adaptation can range from building flood defenses, setting up early warning systems for cyclones, switching to drought-resistant crops, to redesigning communication systems, business operations and government policies.

The agriculture offices in the Wereda have to be working on enhancing erosion control,

This study is limited to Haramaya Woreda and temperature and rainfall variabilities. Therefore future researchers:

- Have to include other Wereda Samples
- Incorporating other variabilities are needed to draw the conclusion.

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Annex I: Questionnaire

Household Survey Questionnaire

Dear Respondents,

This questionnaire is designed to collect data that are intended to examine Farmers' response and their adaptation strategies to the impacts of climate variability in Haramaya Woreda, Ethiopia. To achieve this purpose your response to the questions presented below has a great value. Thus, you are kindly requested to read and respond them clearly and genuinely.

Thank you for your response

Code: …………………………………… **Kebelle………………**

Part I. Personal information

1. Kebele____________
2. Age ________________
3. Sex:

(1) male______ (2) female_______

4. Marital status:

(1) married ___(2) unmarried____(3)divorced____(4) widowed____

5. Your means of Livelihood (multiple response is possible)

(1) Crop production ______ (2) Animal husbandry ______

(3) Mixed farming (4) Fruit and vegetable production ______

Part II: Factors influencing farmers' selection of adaptation practices

1. Household size………
2. Household Income…….
3. Farm size (Timad/ Fechasa) ……….
4. Your land area and you used for:

No	Land area (in Timad)	Used for
1.		Cereals
2.		Cash Crop
3.		Grazing
4.		
5.		
6.		

5. Your farming experience (in years)……..
6. Do you have access to information/awareness about adaptation practices?

Yes ☐ No ☐

6. Do you have access to credit facilities?

Yes ☐ No ☐

7. Are your member of farmer-based organization (FBOs)?

Yes ☐ No ☐

8.. Do you have access to market?

Yes ☐ No ☐

9. Your Crop Yield and income earned

Type of Crop Yield	Income earned Per year

Part IV: Climate Change related challenges and Farmers' Adaptation Strategy

1. Do you feel that the yield of crops in your farm has declined?

Yes ☐ No ☐

2. If your answer for number 1 is yes, what measurement you have taken?

____

3. The land in your area is Degraded from time to time?

Yes ☐ No ☐

4. If your answer for number 3 is yes, what adaptation practice you adopt?

____

5 Have you face Water Shortage?

Yes ☐ No ☐

6. If your answer for number 5 is yes, what adaptation practice you adopt?

____

7. Have you experienced diseases and pests?

Yes ☐ No ☐

8. If your answer for number 7 is yes, what adaptation practice you adopt?

____

9. Have noticed that the soil is eroded?

Yes ☐ No ☐

10. If your answer for number 9 is yes, what adaptation practice you adopt?

11. Are you insecure in food?

Yes ☐ No ☐

12. If your answer for number 11 is yes, what adaptation practice you adopt?

Annex II: Key Informant Interview

1. Sex
2. Age
3. Work Experience
4. Position
5. Academic Performance
6. What do you think that about the climatic change for instance temperature and rainfall variability in the study area are changed over years?
7. What is the trend of the crop yield among the farmers in the study area over time?
8. How does temperature and rainfall variability affect the farmers in the study area?
9. What does the farmer's responses as adaptation strategies for the climate variability effects in the study area?
10. What response are provided by your office to the climate variability effects in the study area?

Annex III: Checklist

No	Variables	Required data	Sources
1	Crop Yield production (Cy1)	Crop production of 1993 to 2022	CSA, NMA and HWFEO
2	Temperatures (te)	Mean Average Temperature of 1993 to 2022	CSA, NMA and HWFEO
3	Rain Fall (Rf)	Annual rainfall of 1993 to 2022.	CSA, NMA and HWFEO

Annex IV. Summary of previous empirical Studies

No	Author (year)	Title	Methodology	Major Findings
1.	Belaineh et al (nd)	Smallholder Farmers' Perceptions And Adaptation To Climate Variability And Climate Change In Doba District, West Hararghe, Ethiopia	Descriptive; multinomial logit model (MNL)	Agro-ecological locatic plot size, off-farm holding (TLU), frequ contact and training factors influencing adap
2.	Desta (2019)	Impact of climate variability on wheat (*Triticum Aestivum* l.) Productivity and adaptation strategies among smallholder farmers in gibe Woreda of Hadiya zone, southern Ethiopia	2000-2014 from NMA & agriculture office; 332 sample households; random sampling	Adaptation strategies: tolerant and early matu crop diversification, practices, changing pla other agronomic practic
3.	Harrissson et al (2017)	Estimating the effects of climate change on Agricultural production in Eastern and Middle African Countries: An Econometric Analysis	longitudinal research design using panel data of 24 countries 1970 to 2013	Livestock productio temperature had a agricultural production; inputs & perception had
4.	Mekasha (2020)	Climate variability impacts and determinants on choice of adaptation strategies among smallholder farmers: the case of Tocha Woreda, Dawro Zone, SNNPR, Ethiopia	Both qualitative and quantitative; data of temperature and rainfall from 1999-2018	Sex, age, educational income level, access to livestock size, access and agro ecology were the choice of adaptation and significantly.
5.	Shewaye (2019)	Rainfall variability and trends in eastern Ethiopia: implication for local level adaptation strategies	Coefficient variation, Standard precipitation Index, Linear Regression and Marcove chain model	There is increasing tren decreasing trend in rain
6.	Simret (2022)	Potential impacts of climate change on potato (*Solanum Tuberosum* l.) Production and adaptation options in eastern Ethiopia	GCM models; 1980-2017; MarkSim weather generator	Proper choice of awareness, support, cre the negative impacts o the potato growing
7.	Suleyman and Nuredin (2020)	Impacts of Climate Variability and Climate Change and Adaptation Strategy among Small Scale Farmers of Kurfa Chele District, East Hararghe Zone, Oromia Region, Ethiopia	Both quantitative and qualitative; FGD &questionnaire; research strategies were used. Data was gathered through Focus Group Discussions, questionnaires, chi-square test was used. Keywords	There was significant low practice of climate spite of the positive smart practices attribu extension services ov particularly after devol Adoption
8.	Tesfa etal (2022)	Rural household perception and adaptation strategies to climate	Cross-sectional and primary data	Climate change n agriculture, animal ou

		change and variability: in the case of Libo-kemkem Woreda, Ethiopia		and epidemic disease c income, farm size, a services, and weather i climate change adapt significantly
9.	Zerihun et al (2022)	Climate Trends, variability, and impacts of ENSO on rainfall amount in Ethiopia: A Case study in Western Amhara National Regional State	NOAA 1986-2015; Coecient of variation & Mann Kendall non-parametric statistical test	The rainfall varia (CV = 8.6%); also, t rainfall of Western during El Niño years a La Niña years especiall (JJAS) over30 years

(Source: compiled by the researcher, 2023)

Annex v: Images