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Department of Geography and Environmental Studies

Effects of Climate Variability on Maize (*Zea mays L.)* Production and Farmers Adaptation Strategies in Siraro Badawacho Woreda, Hadiya Zone South Nation Nationality and Peoples Regional State, Ethiopia

By:

Senait Ayele Lodebo

A Thesis Submitted to Department of Geography and Environmental Studies, Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Art in Geography and Environmental Studies (Specialization in Land Resources Analysis and Management)

Advisor: SintayehuTeka (M.Sc.)
Co-advisor: Bethlehem Abebe (M.A)

January, 2022

Jimma, Ethiopia

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Approval sheet-I

We, the undersigned, members of the Board of Examiners of the final open defense by Senait Ayele Lodebo have read and evaluated her thesis entitled "effect of climate variability on maize *(Zea mays L.)* Production in Siraro Badawacho Woreda, Hadiya Zone, SNNPR State, Ethiopia".

This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the Degree of Master of Arts in Geography and Environmental Studies with specialization in Land Resource Analysis and Management.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies through the candidate's department.

Declaration

I hereby declare that, the thesis entitled "effect of climate variability on Maize Production and Adaptation Strategies in Siraro Badawacho Woreda Hadiya Zone," submitted for the partial fulfillment of the requirement for the Master of Arts in Geography and Environmental Studies with Specialization in Land Resource Management and Analysis, is my original work and has not been presented in any other university and all sources of material used for this thesis have been duly acknowledged and references are listed at the end of the main text.

Author's Name: Senait Ayele Lodebo

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Place: Jimma University, College of Social Sciences and Humanities.

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ACRONYMS AND ABBREVIATIONS

ACZ	Agro-Climatic Zone
ASALs	Arid and Semi-Arid Lands
CACC	Canada's Action on Climate Change
CEEPA	Center for Environmental Economics and Policy in Africa
CC	Climate Change
CV	Climate Variability
DAs	Development Agents
ECRGE	Ethiopia's Climate-Resilient Green Economy
EEA	Ethiopian Economic Association
FAO	Food and Agricultural Organization
FAOSTA	Food and Agricultural Organization Statistic
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GO	Governmental Organization
GTP	Growth and Transformation Plan
IFPRI	International Food Policy Research Institute
ITCZ	Inter Tropical Convergence Zone
IPCC	Intergovernmental Panel on Climate Change

MDGs	Millennium Development Goals
MoARD	Ministry of Agriculture and Rural Development
Mo FED	Ministry of Finance and Economy Development
NAPA	National Adaptation Programmed of Action
NGO	Non-Governmental Organization
NMA	National Meteorological Agency
NMSA	National Meteorology Service Agency
PCGCC	Pew Center on Global Climate Change
SBWARD	Siraro Badawacho Woreda Agricultural and Rural Development
SERS	Special Report on Emissions Scenario
SNNPR	South Nation Nationality and Peoples Region
SPSS	Statistical Package for Social Science
SSA	Sub Saharan Africa
UNDP	United Nations Development Program me
UNEP	United Nation Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
USGCRP	United States Global Change Research Program
WB	World Bank
WMO	World Meteorology Organization

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ABSTRACT

Siraro Badawacho Woreda is one of the dominant maize producing areas in Ethiopia. However, its production was influenced by climate variability. The major objective of the study was to assess the effect of climate variability on maize production and productivity in Siraro Badawacho woreda. To achieve the objective of the study, cross sectional research design and mixed research approach were used. Stratified, purposive and simple random sampling techniques were employed at different levels. The research also sought to establish the different adaptation measures and copping strategies. Data was acquired by administration of designed questionnaires to 278 systematically selected household heads and 30 years climate data was obtained from NMAE Hosanna station from 1989-2019. The data collected on rainfall, temperature and maize yields were analyzed using Microsoft Office Excel 2010 and SPSS software version 26 to generate frequency tables, pie charts, and graphs. Descriptive statistics, annual mean linear and trend line for climatic data trend and, spearman correlation coefficient was used to evaluate the association of climate variability and maize productivity, and binary logistic model were employed. The finding of meteorological data indicated that, minimal and maximal annual temperatures were increasing in 0.0679°c and 0.1278℃ per year respectively. In contrary, annual rainfall was decreasing in20.244mm per year. The survey result indicates that maize productivity was decreasing as altitude decrease and increasing as altitude increase inversely as temperature increase maize productivity was decreasing. The finding of this study indicates that among 13 variables selected for binary logistic regression model, eight of them were at $P<\alpha(\alpha=0.05)$ significantly associated with maize productivity; sex of respondent, total maize farmland size, temperature and rainfall fluctuation have negative association especially during Bega and Tsedey season. The study therefore recommended that the Ministries of Environment and Natural Resources together with Agriculture, Livestock and Fisheries do create awareness on Climate variability and its effects on maize yield. Even though most of the population may have been aware of climate variability, the study identified need for additional awareness creation.

Key Words: Climate change; Maize productivity; Maize Production; variability

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

The climate system is an open system that is in dynamic equilibrium or steady state over a given period. If this steady state is disturbed as a result of significant change in one or more of the components making up the system or the solar energy powering the system, the climate system will move over time to a new state. In this situation a change in climate is said to have occurred (Ayoade, 2010).

Climate variability ,thus, refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer whether due to natural variability or as a result of human activity (Banuri et a*l*., 2001). Important factors that play a role for climate variablity are the abundance of greenhouse gases in the earth's atmosphere that emanate from rising fossil fuel burning and land use changes continuing to emit methane, and other gases. Furthermore, the earth's temperature has increased by approximately 0.65°C – 1.06°C over the past 132 years. The IPCC (2014) report reviewed that the period from 1983–2012 was the warmest of the 30 year period for the last 1400 years in the Northern Hemisphere. Climate variability and climate change are among the major environmental challenges of the 21st century (Eshetu et al., 201A6).

Climate variability is hence different from climate variation. Climate variability may be due to internal processes and or external forces. Some external influences such as changes in solar radiate on and volcanism occur naturally and contribute to the total natural variability of climate system.

Climate variability has main impacts on global food production and may require greater effort than the ongoing adaptation. In the meantime, greater risks to food security may be posed by changes in year-to-year variability and extreme weather events (Lemi & Hailu, 2019). Historically, low precipitation events have been attributed to many of the largest falls in crop productivity (Jaramillo et al., 2011). Even small change in mean annual rainfall has an impact on productivity (Moat et al., 2017). Additionally, both higher mean temperature and changes in precipitation patterns will cause a shift in agricultural land use and crop suitability, affecting agricultural productivity along with farmer incomes and food security (Lichtfouse and Impact, 2018).The most distressful event by posing tremendous negative effects on several sectors of the world is climate change _(IPCC, 2014).

The negative consequences of climate variability in Africa are already happening as frequent floods, droughts and shift in marginal agricultural systems (Collier et al., 2008). Sub-Saharan Africa (SSA) is arguably the most vulnerable region to many unpleasant effects of climate variability due to a very high dependence on rain-fed agriculture _(Cooper et al., 2008).

Ethiopia is among the most vulnerable countries in SSA due to its great reliance on climate vulnerable economy (Conway and Schipper, 2011).Ethiopia is characterized by diverse climatic conditions ranging from humid to semi-arid environments. Its climate system is largely determined by the seasonal migration of the inter tropical convergence zone (ITCZ) and a complex topography

In Ethiopia, more than 80% of the people depend mainly on agriculture for their livelihood, rendering them very vulnerable to climate variability and change(Yohannes and Mebratu, 2009). The projected reduction in the Ethiopian agricultural productivity due to climate change can reduce average income by 30 percent over the next 50 years(Gebreegziabher et al., 2011).

Adaptation is an essential strategy to enable farmers to cope with the adverse effect of climate variability which in turn increase the maize production of the poor farm households. Adaptation methods on the side of smallholder farmers may make it better to undertake the challenge of climate variability_Thus, it is essential to adapt maize crop to current and future climate variability since most peoples' livelihoods and living values are affected by the effect of climate change. Therefore, this study intend to explore impact of climate variability on maize production, with undertaking valuable research that would provide important understandings; concerning historical climate variability of study area, climate variablityadaptation strategies in maize production and farmers insights and adapting the adverse effects of climate variability in Siraro Badawacho Woreda, Hadiya Zone, South Nation Nationality and Peoples Region

1.2. Statement of the Problem

Climate variability has already caused a negative impact on agriculture, because of increasing severe weather patterns. The global climate change and the weather extremes associated with climate variability are challenging both developed and developing countries_(IPCC, 2013). Climate induced food shortages and chronic diseases are affecting millions of people in developing countries. Climate variability has the potential to undermine sustainable development, increase poverty, and delay or prevent the realization of development (Araya et al., 2010) Similarly, year to year crop production is substantially influenced by climate variability even in high yield and high-technology agricultural areas mainly due to spatial and temporal variability of precipitation (Lemi and Hailu, 2019).

Several studies have determined Ethiopia to be susceptible to the impacts of climate variablity over the coming 50 years (Gilliland 2016). Additionally, the spatial and temporal variability of precipitation is highly variable. The successes and failures of crops have always been subject to prevailing environmental factor ,that production is increasingly vulnerable to risks associated with new and evolving climatic variability of crop pose significant challenges to smallholder farmers (Mwaura and Okoboi, 2014).

Small holder farmers in developing countries are the first victims of climate variability effects. Ethiopian agriculture is one of the most vulnerable sectors to current climatic variability and projected climate change, potentially exposing millions of people to recurrent food shortages and episodic famines (IPCC, *2007*).

The climate variability effect studies, particularly seasonal and annual variability and crop yield reduction has greater help for crop planning, for selection of crop varieties/ suitability, for crop management practices, for plant protection measures and related farm operations. During the normal and above normal rainy seasons, the crop can get sufficient water from the soil to satisfy its water requirement, but if the rain is below normal, the plant cannot satisfy its need. The temperature variation can also determine the crop yield. Crop management practices based on crop diversification, adjusting the planting date and choice of variety are the adaptation strategies most readily available to farmers to deal with the effects of climate variability and change (LeBlanc B D., etal 2011). However, despite the importance of maize to the country, production especially in the last two decades has been poor. The reasons for this include the high cost and increased adulteration of inputs, low and declining soil fertility, decreasing land sizes, limited access to affordable capital and low absorption of modern technology (Ministry of Agriculture, 2009). Besides the, policymakers have begun to diagnose the increasingly adverse role being played by climate variability on maize production. Erratic weather conditions have been blamed for a succession of maize crop failures forcing the Ethiopia government to import maize to feed its population.

There are limited studies on the effects of climate variability on crop production in Ethiopia and world. (Admassu, 2004; Bewket, 2009; Karanja,2009).

Admassu (2004), studied the impact of rainfall variation on crop production for the entire Ethiopia. The results of this study show no significant correlation between total annual, *Kiremt* and *Belg* rainfall, and production of maize in most parts of the country.

Woldamlek Bewket (2009), studied the relationship between rainfall variability and crop production in the Amahara region, and reported existence of significant correlations between crop production and rainfall and concluded that farmers are vulnerable to food insecurity partly due to rainfall variability in the region. However, most of such results were gave attention on multi cereal crops. It is important to analyze the impact of climate variability at individual crop.

Karanja (2009), attempted to analyze the impact of climate variability on individual crop. However, most of such results were mainly focused on the impact of temperature on production, but failed to include the precipitation components and associate climate change with maize production. Therefore, the researcher to fill knowledge gap and putting the above issue into consideration, this study endeavored to associate effect of climate variability (temperature and rainfall) with maize production and how adaptation strategies enhance maize production at Siraro Woreda Hadiya Zone.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of the study is to examine effects of climate variability on maize production and farmers' adaptation strategies in Siraro Badawacho Woreda, Hadiya Zone, SNNPR, and Ethiopia.

1.3.2. Specific objectives

The specific objectives of the study include:

- ❖ To examine climatic variability of Siraro Badawacho woreda (temperature and rainfall Pattern) for the last 30 years
- ❖ To investigate effects of climate variability on maize production in the study area
- ❖ To identify major adaptation strategies practiced by small holder farmers in response to adverse effects of climate variability.

1.4. Research Questions

1. What are the major features of temperature and rainfall pattern in the study area?
2. How climate variability affects maize production in the study area?
3. What are adaptation strategies practiced by small household farmers in the study area?

1.5. Scope of the Study

Spatially, the study was undertaken in Siraro Badawacho Woreda Hadiya Zone SNNPR, Ethiopia. The Woreda consists of twenty-three rural kebeles. Out of twenty-three kebeles in the Woreda, the study focused on three kebeles. Thematically the study focused on the investigation of the effect of climate change and variability on maize productivity in the Woreda. It also considers the adaptation strategies employed by smallholder farmers. However, this study did not look into other factors that affect maize products such as pests and soil fertility. Temporally, the study was conducted in the time frame from January 2021 to July 2021.

1.6. Significance of the Study

The purpose of this study is to examine the effect of climate change (temperature and rainfall fluctuation) on maize production. The output of the research may help farmers to adjust themselves to the current and future impact of climate variability and build their adaptive capacity. Moreover, the study attempted to examine persistent information of farmers' on climate change and their adaptation strategy to adverse effects of climate change and variability problems in the study area.

The study may also be relevant to develop policies because it intends to create awareness of how climate change significantly affects maize production. It might also guides policymakers and other stakeholders on how climate change adaptation strategies in maize production and implicate on to food security problems in the country can solved. Besides, it may also fill the existing literature gap on the impact of climate variability and farmers' adaptive strategies.

1.7. Limitation of the Study

Although large sample size was required to deal with the issue under investigation, due to limitation of time and budget the study focused only on three kebeles, and data were obtained from those limited areas to represent the whole Siraro Badawacho Woreda Administration. So, when area coverage decreases, the transfer ability of the findings of the study may slightly be affect the study, may also take more time to acquire the relevant data. Additionally, covid 19 was a limitation which was faced in my study.

1.8. Definition of Key Terms

Adaptation: - The (IPCC, 2014).defined adaptation as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Climate: - is the average weather condition of a given area which is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years World Meteorological Organization (WMO), 2016).

Climate change: - refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer whether due to natural variability or as a result of human activity (Banuri et al., 2001).

Climate variability: - Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from variations of anthropogenic external forcing (external variability)(IPCC, 2007).

Effects: - Defined as the short and long-term effect, positive and negative, direct or indirect effect of intervention on economic, social, institutional and environment (Rovere and Dixon, 2007).

Global Warming: This is an increase in the concentration of greenhouse gases as a consequence of anthropogenic actions, where the consequence is an increase in the concentration thus absorbing more emitted gases which are remitted back to the earth leading to adverse climatic phenomenon (UNFCCC, 2007)

Greenhouse gases: These are gases that are emitted into the atmosphere through anthropogenic actions or natural causes and they absorb and remit the infrared radiation to the earth (IPCC, 2017).

Maize *(Zea mays L.):* - is an important cereal crop of the world and it ranks the second after wheat and the third in Ethiopia after teff and wheat.

Maize Yield: It refers to the measure of maize grains produced from a unit of land expressed as kilograms per hectare.

Vulnerability: it is the level at which humanity is exposed to serious climate ramifications and has less ability to protect itself from the risks presented by the changing climate (UNFCCC, 2007)

1.9. Organization of the Thesis

This study was organized in to five chapters. Chapter one includes background, statement of the problem, objectives, research questions, and significance of the study, delimitation, limitations, definition of terms and organization of the thesis. Chapter two mainly concerned with review of some relevant literature. Chapter three presents profile of the study area and methods for the analysis. Chapter four explains the finding of the study in line with research objective. Finally, Chapter five concludes the ideas discussed in preceding chapters and forward the possible recommendations for policy implication as well as for the implementers of the intervene

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Concepts of Climate Variability

2.1.1. Concepts of Climate, climate Change, Climate variability and Adaptation Strategies

Climate; is the average of weather condition of a given area, which is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years (WMO, 2016).Climate is usually defined as the "average weather" or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years

Climate change: refers to a change in the state of the climate that can be identified by changes in the mean and /or the variability of its properties. That persists for an extended period, typically decades or longer whether due to natural variability or as a result of human activities on a climate change which, it is attributed directly or indirectly to human activities that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (FAO, 2008).

Climate variability, is the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events for a given period of time (e.g. a month, season or year) (Stone, 2015).

According to (WMO, (2007).The Climate Change define "climate" as the average state of the weather over time with period generally being 30 years. Whereas weather is a short-term phenomenon, describing atmosphere, daily air temperature, pressure, humidity, wind speed, and precipitation (IPCC, 2013).Climate variability's change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate variability may be due to natural internal processes or external forces or to persistent anthropogenic changes in the composition of the atmosphere or in land use_ (IPCC,2012).

Climate variability represents variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather event (WMO, 2011). The term is often used to denote deviations of climatic statistics over a given period from the long-term statistics related to the corresponding calendar period(Belay,2014)Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing (external variability).

Adaptation is a process by which strategies to moderate, cope with and take advantages of the Consequences of climatic events are enhanced, developed, and implemented _ (UNDP, 2007). According Bowyer, also defined adaptation as the process or outcome of a process that leads to a reduction in harm or risk of harm, or realization of benefits associated with climate variability and climate change. According to (Adgeet al,2007)adaptation to climate change is defined as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

2.1.2. Causes and Manifestations of Climate Variability

The Earth's climate has changed many times during the planet's history, with events ranging from ice ages to long periods of warmth. During the last centuries natural factors such as volcanic eruptions or the amount of energy released from the sun have affected the Earth's climate on a smaller scale (Gebremichaell et al., 2014) By the 1950s and early 1960s, it was becoming clear that human activities were releasing CO2 fast enough to significantly increase its atmospheric abundance(Mwaura & Okoboi, 2014). Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions (IPCC, 2010). The primary cause of climate variability is increase in the concentration of carbon dioxide and other greenhouse gases in the atmosphere because of human activities mainly fossil fuel burning and removal of (Gebremichaell *et al*., 2014).

At global scale, the main cause of greenhouse gas (GHG) emissions is from carbon dioxide (70%), primarily from burning of fossil fuel (petroleum) while the other sources for GHG are methane (CH_4) and nitrous oxide(N_2O) caused by deforestation and agricultural activities, particularly the use of pesticides and fertilizers(Yohannes and Mebratu, 2009). Greenhouse gases and aerosols affect climate by altering incoming solar radiation and out-going infrared (thermal) radiation that are part of Earth's energy balance. Changing the atmospheric abundance or properties of these gases and particles can lead to a warming or cooling of the climate system_(IPCC, 2007).

2.1.3. Manifestations of Climate Variability

One of the biggest environmental challenges that are bedeviling mankind in this 21st century is the changing climate across the globe(Datta, 2013). Climate change causes variability of temperature and precipitation as well as the frequency and severity of weather events. Changes in physical and socio-economic system have been identified in many regions. It will have wide-ranging effects on the environment, and on socio-economic and related sectors, including water resources, agriculture and food security, human health and biodiversity_(UNFCCC, 2007).

Rising temperatures also will cause shifts in crop growing seasons which affects food security and changes in the distribution of disease vectors putting more people at risk from diseases such as malaria (Fiseha *et al.*, 2012). Rising Temperature will potentially increase rates of extinction for many habitats and species(UNFCCC),2007)The depletion of natural resources, as a result of increased environmental and demographic pressures, tends to aggravate the severity of climate change impacts(IPCC, 2012).The magnitude and rate of the climate change effects on health, agriculture, food security, forest, hydrology and water resources, coastal area, biodiversity, human settlement, energy, industry, and financial services increasing_(UNFCCC), 2007).

2.2. Major Features of Climate Variability

Climate variability could be damaging to countries in South East Asia, Latin America, Africa, (particularly Sub-Saharan countries), as they are largely being dependent on rain-fed agriculture and under heavy pressure from food insecurity and often famine caused by natural disasters such as drought, is likely to be seriously affected(Omoyo et al., 2015). Climate variability related events like the occurrences of frequent and extensive droughts in recent decades, spreading of malaria in highland areas which have never experienced before, loss of biodiversity and decline in wildlife number have been observed (Araya & Stroosnijder, 2011). Furthermore, the country has recently experienced flood hazard which has killed more than 500 people in Dire dawa in 2006 (UNEP, 2006). According to(Chabala et al., 2013) climate variability has affected the rainfall characteristics mainly by becoming late being erratic or torrential, and in turn resulting in, unseasonal and unusual occurrence of drought and/or also causing several flooding.

2.3.1. Temperature Variability

Air temperature is one of the most predominant and very vital elements of climate for it is very observable and has invaluable effect on life and livelihood of human beings(Solomon, 2015).The year-to-year variation of annual minimum temperatures expressed in terms of temperature differences from the mean and averaged very high. According to the national program for how Ethiopia can adapt to climate change, it has also become warmer in the last fifty-five years. The minimum temperature has increased by 0.37 degrees Celsius per decade between 1951 and 2006 (NMS, 2007).

In case of Ethiopia, annual temperature has rapidly increased in the last five decades. The mean annual temperature rose by 1.30C per year or by 0.280C per decade during 1960- 2012. The frequencies of hot days and nights have also showed an increasing trend during these years. While the average number of 'cold days' has decreased by 5.8% between 1960-2003, the average number of 'cold' nights per years has decreased by 11.2% (UNDP, 2010). In the coming 100 years, the average temperature in Ethiopia has projected to increase from 23.080C during 1961 - 1990 to 26.920C in 2070-2099 (WB, 2010). However, there is also significant temperature difference temporally and spatially. Between 1951 and 2006, the annual minimum temperature in Ethiopia increased by about 0.37°C every decade.

2.3.2. Rainfall Variability

Ethiopia has diverse climates, ranging from semi-arid desert in the lowlands to humid and warm (temperate) in the southwest. Mean annual rainfall distribution ranges from a maximum of more than 2,000mm over the Southwestern highlands to a minimum of less than 300mm over the Southeastern and Northwestern lowlands (Tsega, 2013). Several studies conducted by both development organizations and research institutions support the development of rainfall variability. Farmers and pastoralists are experiencing that the rain is becoming more unpredictable– or is failing to appear at all. In some places the rain falls more heavily and the degraded soil is unable to absorb this rain which falls over a shorter period. According to Kassahun (2013), the farmers in the central part of the country have lost up to 150 tons of soil per hectare. The rains wash away the topsoil, which helps to make the soil fertile. In total, Ethiopia loses three billion tons of humus soil annually due to erosion_ (Stern, 2010).

Rainfall variability is the major source of risk for farmers who depend on crop production. There are two important rains in Ethiopia- the 'Kiremt' and 'Belg'. The Belg rains usually begin in March and May in South West and advancing northwards affecting most of the country from July through September. The Kiremt rain constitutes about 90% of the crop production harvested during October -December (CSA, 2011). Historically the country has been prone to extreme weather variability. Major droughts that led to dreadful famines and floods struck different parts of the country were results of the absence of rainfall in the March to May _ (World Bank, 2010).

2.3.1. Effects of Climate Variability on Maize Production

Currently, climate variability is expected to have significant effects on crop production in the medium to long term period if the present rates of global warming continue unabated. Experiments and model predictions have shown that climate variability through increased atmospheric CO_2 concentration, and the resulting rise in temperatures and changes in rainfall pattern, amount and variability affect crop production negatively in a multifaceted way. Increased CO_2 concentration increases yield by increasing rate of photosynthesis, leaf area index, and accumulation of non-structural carbohydrates, biomass and decreasing stomata conductance and transpiration loss of water (Chauhan,et *al*,2014). Average optimum temperatures for temperate, highland tropical and lowland tropical maize lie between 20 and 30°C, 17 and 20°C, and 30 and 34°C, respectively (Jones, and Rah man., 2007). Projected climate variability will adversely affect maize production in East Africa. Multiple studies indicated that East Africa could lose as much as 40% of its maize production by the end of the 21stcentury (Conway & Schipper, 2011) Bank, 2015). In fact, under intensified and prolonged drought conditions some of the regions may become unsuitable for farming activities. This will cause a reduction in farming land and/or a reduced length of growing season, as well stopping the production of some food crops and prompting food shortages (Collier et al, 2008)and search for other alternative food crops.

Maize (*Zea mays L.*) is one of the major food crops in Ethiopia, both in terms of the area cover and the overall amount of production (CSA, 2011). Maize is a long-cycle crop which is planted during the *belg* season between March and April and harvested between September and December. The climatic variables that have the greatest influence on maize growth are temperature and rainfall (Moges, 2016). The overall predictability of these climatic elements is imperative for the day-to-day on-farm operations as well as yield estimates (Mahoo et *al*., 2013).

Maize can grow at higher temperatures compared to many other cereals and therefore a suitable crop for warmer conditions (CSA, 2011). The main effects of climate variability on maize production will be changes in regular crop planting times, length of growing season, and shifts in suitable crop types or cultivars_ (Mahoo et *al*., 2013).

2.6. Adaptation Strategies to Climate Variability Effects

Adaptation is an essential strategy for reducing the severity and cost of climate variability effects. It measures help farmer's guard against losses due to increasing temperatures and decreasing precipitation. Enhancing the ability of communities to adapt to climate variability or manage climate variability risks requires addressing pertinent locally identified vulnerabilities, involving stakeholders, and ensuring initiatives are compatible with existing decision processes (Butler &Huybers,2013).Therefore, planning adaptation as well as adapting to climate change requires an understanding of current conditions. It requires an understanding of the adaptive capacities and livelihood strategies of the local population who are directly affected by the effects of climate variability and who must cope with the realities of multiple pressures (Nhemachena, 2008). According to CEEPA, (2006),the adaptation process is driven by a number of factors. Firstly, more experienced farmers are more likely to take up an adaptation measure. Free extension advice about either livestock or crop production also strongly increases the probability of the farmer adapting to climate variability. Greater distance to the market where outputs are sold diminishes the probability of adaptation. The level of education (measured in years) also greatly increases the probability of adaptation. It appears that larger farms are more likely to adapt to climate change _(World Bank, 2011).

According to (Yesuf et al., (2008), farmer's adaptation of climate change adaptation strategies is influenced by frequent and more accurate climate information from meteorological centers, formal and informal institutions, access to credit and extension information, amount of seasonal rainfall, geographical location, household size, age and literacy of household head. Adaptation to climate change is the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides(Oseni & Masarirambi, 2011). he most effective adaptation approaches for developing countries are those addressing a range of environmental stresses and factors. Strategies and programs that are more likely to succeed need to link with coordinated efforts aimed at poverty alleviation, enhancing food security and water availability, combating land degradation and reducing loss of biological diversity and ecosystem services, as well as improving adaptive capacity. Sustainable development and the Millennium Development Goal (MDGs) are necessary backdrops to integrating adaptation into development policy _(UNFCCC, 2007).

2.7. Barriers to Farmer's Adaptation to Climate Variability

2.7.1. Major adaptation challenges

Experience has shown that identified adaptation measures do not necessarily translate into changes because there are context specific social, financial, cultural, psychological and physical barriers to adaptation (IPCC,2007). Factors influencing Ethiopian farmer's decision to adapt include income, access to extension, credit, and weather information (early warning system); insensitive and weak governments guiding principle (mechanisms) for irrigation(Bryan et al., 2009). Lack of access to appropriate seed, property rights and market service were also other hard mentioned in Ethiopia

2.8. Conceptual Framework

The conceptual frame work for this study was indicate that CV brought the changes in the amount of temperature and rainfall, drought, flooding and spreading of disease and pests, among others. This led for effects on environments such as forests, soil resources, water resources and socio-economic effects like agriculture and human health. However, the changes happening as a result of climate variability leads to vulnerability of the people especially in rural household. The vulnerable groups devise different strategies including the accumulative, adaptive and coping strategically goals to minimize the effects of climate variability. Each of those developments is reflected back on the feature of small households. Among these accumulative, coping and adaptive strategies together with other devices lead to climate resilient and sustainable development. Conversely, survival strategies would derive vulnerable groups to migration that end to unsustainable livelihood. Among these accumulative, coping and adaptive strategies together with other devices lead to climate resilient and sustainable development. Conversely, survival strategies would derive vulnerable groups to migration that end to unsustainable livelihood. This is briefly sketched in (Figure 1).

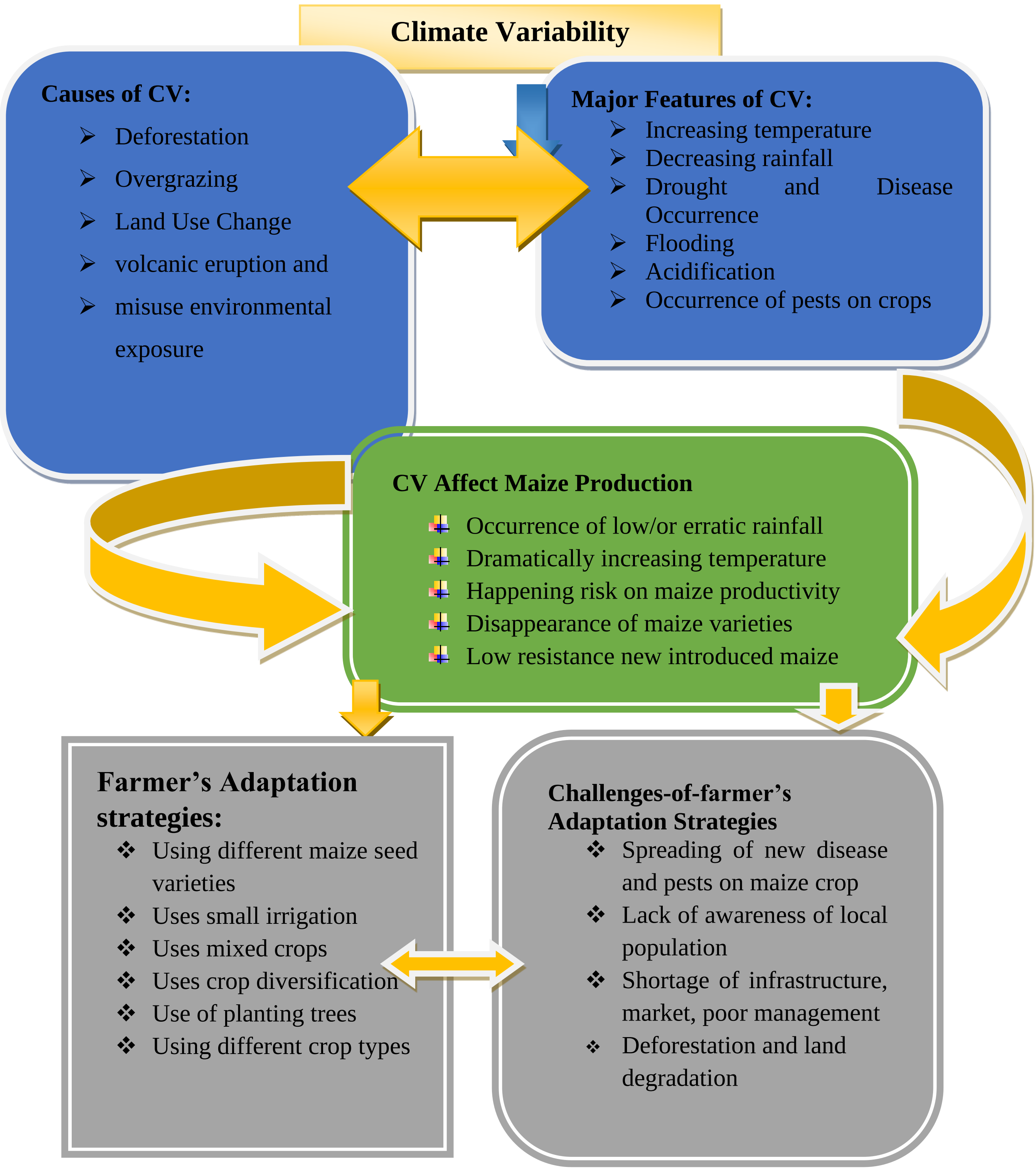


Figure 1: Conceptual Framework of Climate Variability

Source: Developed by Investigator (2021)

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area.

3.1.1. Location and Size

Siraro Badawacho woreda is one of the 13 Woreda's in Hadiya Zone, SNNPR State of Ethiopia. It is one of the major maize producing Woreda's in the zone; which is located in the northern part of the Southern Ethiopia. Geographically, the absolute location of the woreda is between $7^0$9'00" to $8^0$15'00" north latitude and $38^0$10'00" to $38^0$1'00"east longitude (figure 2). The capital town of the woreda is Hanicha that is located at a distance of 365km south of Addis Ababa. It is along the way towards Wolaita Sodo and about 120km far from Hawassa, SNNP regional city. It is also about 97km far from Hosanna, which is the capital town of Hadiya zone. The relative location of the woreda is bounded by misrak-badawacho woreda to the west, wolyta zone to the south, Kembata tembaro zone to the north, and Halaba special woreda to the north east and by east aris Oromia zone to the east (addise, et *al.*, 2014). Land area of Siraro Badawacho woreda is estimated to be 18650 hectares. The woreda elevations range from 700m to2000 m above sea.

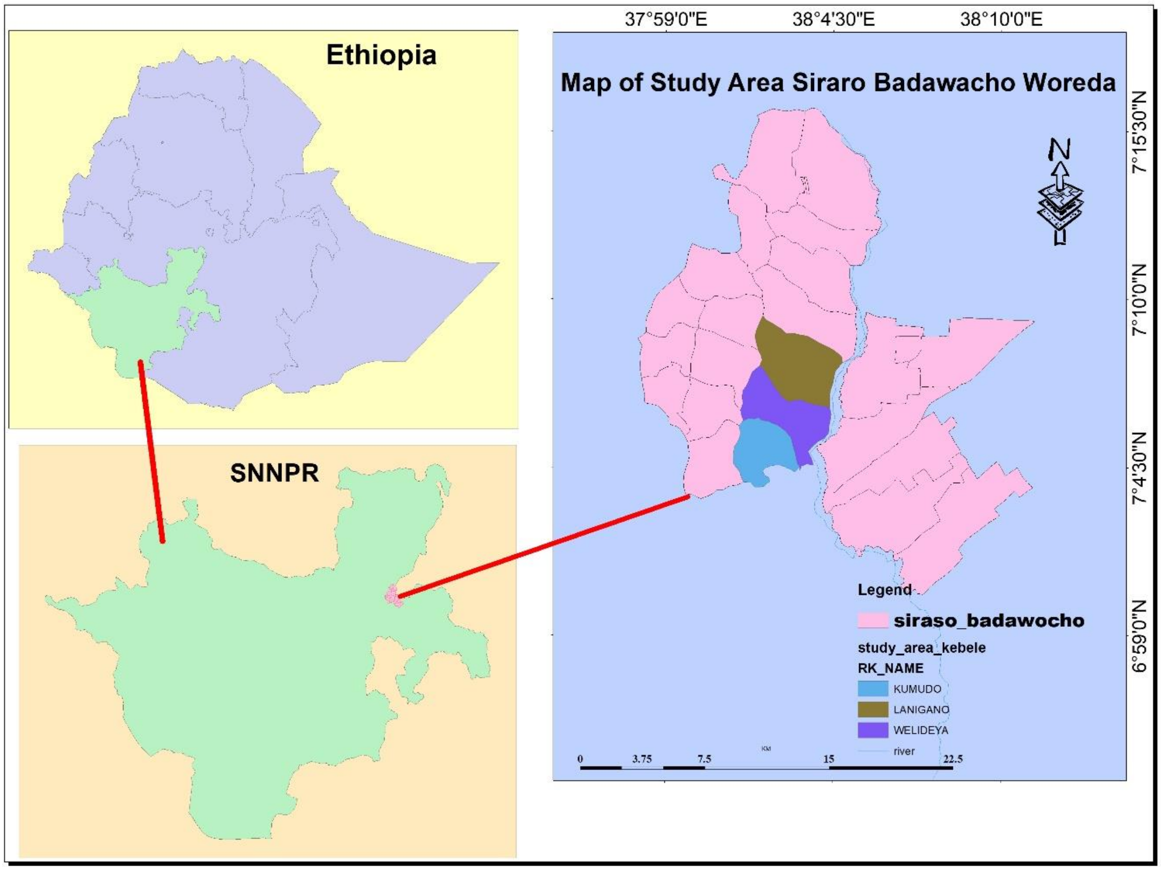


Figure 2: Map of Study Area

Source: Own Construction (2021)

3.1.2. Topography

Topography of a particular geographic entity has dimensional implication upon the development of physical infrastructure, human way of life, the type of crop production, the land use conditions and types of flora and fauna that exists. The topography of the study area is characterized by plain, plateau and rugged, which are generally from moderate. The elevation range between 700-2000m.s.la; of which 35%intermediate land and 65% low land. The slopes of the study area categorized as gently sloping and moderately sloping. The largest areas in study kebeles are gentle sloping (SBWAO, 2019).

3.1.3. Soil Type

Soil type of this woreda is characterize as silt; sandy loam; clay dark in color and with high water holding capacity. It is a fertile soil that different crops, fruits and vegetable were produced. The soils are classified as silt loam to clay loam texture characteristic (SBWAO, 2011).

3.1.4. Climate

The rainfall and temperature data for the study area was collected from National Metrological Agency of Ethiopia, hosanna branch (NMAE, 2019). The mean annual temperature is 15.20^0c and 33.7^0c. The mean minimum and maximum temperatures are13^0c and 24.7^0c. The rainfall pattern generally bimodal. The main rainy season in the area is summer *(Kiremt)*, which ranges from June to August with maximum rainfall and two minimum seasons: the spring *(Tsedy)* and autumn *(Maher)*, with little rainfall. The dry season winters winter (*Bega*)in the area is mostly from October to February, which limits the water availability in the study area. The months with maximum rainfall land temperature are July and February respectively. Siraro Badawacho is classified into *Woinadega* (35, %) and *Kola* (65, %) agro-climatic zones (SBWAO, 2019)

3.1.5. Natural vegetation

The woreda has various types of vegetation in responses to the variation of soil, climate and human activities. At present time, matured and naturally grown tree are observed in the church compounds, school and in same homestead. In the remaining area, natural vegetation is very much degraded. some of the major indigenous tree (shrub species) which still survive in the area includes 'Warka' (*Ficus Vaita*), 'Bisana' (*Croton Macrostachyus*), 'Cheba' (*Acacia Nilotica*), 'Digetta' (*Calpurnia aurea*),'Woira' (*Olea Africana*). There are a few remnants of these local forests in some church compounds, streams, river banks and in sacred places (SBWAO, 2011).

3.1.6. Major Economic Activities

3.1.6.1. Agriculture

Agriculture, like in other parts of Ethiopia, the main stay of the community in the study area is characterized by mixed farming system, where the rural people of the woreda is dependent on both crop and livestock production for their living. According to (Siraro Badawacho Woreda Agricultural Office, 2014), land use data, the woreda has a total of 18650 ha: of total 12000 ha is Annual crop land; 3000 ha is Perennial crop, 1106.7ha is grazing land, 602.2 ha is Natural forest, 1800.23 ha is Cooperative and Private Forest included bush land, 600.25 ha is Cultivable land;

occupied by constrictions 60.24ha and 60.43 ha is unproductive land. All of the farmers are dependent on rain feed Agriculture. The need for increased production led to the over exploitation of almost all available lands, regardless of its suitability for crop production. Among the crop verities that grow in the Woreda, maize and ‘teff “are leading cereals. In addition, sorghum chickpea, etc. grown in the area. The average farmland holding is 0.77 ha. Oxen as serve primary source of traction power (SBWARD, 2014).

3.1.7. Demographics and Socio-economic Characteristics of the Study Area

Based on central statistical agency (CSA, 2007), Siraro Badawacho Woreda has a total of 98,375 of whom 48,548 were men and 49,827 women, 23,539 or 23.93% of its population were urban dwellers. The ethnic groups who live in Siraro Badawacho were the Hadiya, Kembata, Wolaita and Oromo. Haddiyisa, Wolaitigna and Amharic languages are commonly spoken in the area. The majority of the inhabitants are Protestants, with 91.8% of the population reporting that belief 4.79% practiced Ethiopian orthodox Christianity and 2.51% were catholic Christianity and 0.9% was Muslim religious followers. Economically, agriculture serves as the main economic base and means of livelihood to the majority of the people and characterized by traditional cash crop farming mixed with livestock husbandry as it includes both crop and livestock production.

3.2. Research Methodology

3.2.1 Research Approach and Design.

In order to achieve the intended objectives to investigate used survey research design. The rationale behind employing descriptive survey design was being concerned with describing the characteristics of an event and specific predictions with narration of facts and characteristics about a situation to describe effects of climate variability on maize production and adaptation strategies in *Siraro Badawacho Woreda*.

3. 2.2 Sources and Types of Data

This study employed both primary and secondary data. The sources for primary data include questionnaire, focal group discussion (FDG) and key informant interview (KII). Regarding the secondary data sources, published and unpublished documents were used. Published documents like journal articles, books and different related literature and the temperatures and rainfall of last thirty years (1989-2019) of Siraro Woreda, Hosanna station was occupied from National

Meteorology Agency of Ethiopian was referred. Unpublished data like maize production figures collected from the study woreda agricultural office and NGO working on maize was referred.

3. 2.3. Study Population, Unit of Analysis and Sampling Frame

Study population: Participants for the effective achievement of this study were those who can provide tangible information. They were the household heads in the woreda to whom the questionnaire was distributed. The study populations also included the woreda Agricultural Office workers. These participants were the focus of the researcher to gather sufficient information, because they were directly concerned bodies to give detailed information with regard to impact of climate change on maize production and adaptation strategies. Therefore, the sampling frames for the study were maize producer household heads in woreda. The target populations of the study were the woreda households.

3.3. Sampling Design

3. 3.1. Sample Size Determination

To determine the sample size of the study, the level of precision or sampling error, the confidence level and the degree of variability in the attributes was considered. In this regard, the researcher used the following simplified formula of (Yamane, 1967).It uses to calculate the sample size with 95% confidence level and ±5% level of precision.

$$n = \frac{N}{1+N(e)2}$$ Where**,**

n = Sample size

N =Total Household

e =level of precision

$n= N/[1+N(e)^2]$

Where: n= is the sample size, N is the population size and e are the level of precision

1=is the probability of an event to occur

The above formula was used to get the sample size:

n = 910/1+910(0.05)2

n = 910/1+910(0.0025)

n = 910/ 1+2.27

n = 910/3.27 n= 278

Then proportional allocation sampling methods was used to determine the sample HH for each kebele as it was the following

Table 1: Proportional of Sample Households from each Kebeles.

No	Names of kebeles	(ACZ)	Altitude (m)	Total household	Sampled household	Sample size determination	Percentage
1	Wolidaya	Temperate/ Woinadega	1900m asl	360	110	n = N×n/N =360×278/910 =110	40%
2	Langano	Low land/kola	700masl	300	92	n=N×n/N 300×278/910 =92	33%
3	Qumudo	Low land/kola	1000m asl	250	76	n=N×n/N 250×278/910 =76	
Total	3	3	3	910	278	278	100%

3.4.2. Sampling Technique

This study was conducted at Siraro Badawacho Woreda in Hadiya Zone South Nation Nationality People's Region. The total household in the three kebeles was 910 and out of this, stratified random sampling technique was employed to group the samples into strata. The researcher selected sampled Kebeles and household heads, through multi stage sampling techniques. In the first stage, the study area Siraro Badawacho was selected purposive because, it is one of drought prone areas in the region and it has two distinct agro-ecological zones; namely *kola* and *Woinadeg*a .Langano *and* Qumudo from kola 65% (700-100 masl) and Woldeya from *Woinadega* 35% (1800-2300 masl).In the second stage, based on knowledge of the researcher about the area and severity of the problem in which a large number of affected farmers household are found; In the thirdly stage, three Kebeles namely Woldeya, langono and kumudo were selected based on their severity, erratic rain fall, increasing of temperature and decreasing maize productivities, then they are situated using through stratified random sampling method. Then from the three Kebeles with a total of 910 HHHs were selected. In the fourth stage, Sample household heads were selected by using simple random sampling technique from the three selected Kebeles to make the respondents as much as possible representatives of the target population.

The sampling procedure considered different parameters such as wealth status, male and females headed households. Moreover, about 6 DAs (Development Agents) and 3 officials from the Woreda's agricultural and rural development offices were selected for in depth interview as key informants.

3.5. Instruments and Procedures of Data Collection

3.5.1. Questionnaire:

Semi-structured questionnaires is scheduled and filled by the enumerators. The questionnaire included both open-ended and close-ended questions used to get adequate information from the survey. The questionnaire was first prepared in English and latter it was translated into Haddiyisa so-that the enumerators and respondents can easily understand the questions. Thus, the questionnaire was employed together quantitative data from rural household maize producer farmers. This aim at getting insights about the existing impact of climate change and adaptation practiced in the study area. In order to conduct the survey, four enumerators who are able communicate in local language (Haddiyisa) and Amharic languages were recruited. Before conducting actual data collection, pre-test was undertaken by taking 10% of the total sample size (28HHH in order to check consistency or reliability of questionnaire for the study. After pre-testing the questionnaire, it was redesigned based on the pretested result to undertake the actual data collection. The questionnaire was administered by enumerators through door-to-door survey for majority of the households and at their place of work for some households.

3.5.1. Focus Group Discussion

Semi-structured discussion was used to obtain in-depth information from a group. Focused group discussion (FGD) was help to generate data on group dynamics, and allows a small group of respondents guided by a skilled moderator, to focus on key issue of the research topic. For, focus group discussions the investigator selected six respondents purposively based on socially respected within their community. This is because they have better knowledge on the present and past causes and consequences of climate variability on environmental, social and economic status of the study area. 6 different focus group discussions were conducted to generate information about household farmer’s attitudes, feelings, perception and experiences in adapting to the consequences of climate variability. In each Kebele three FGDs of household farmer groups were conducted. There was a total of six FGDs in different times and place and each group was have involved. Participants from local elders, local community leaders and agricultural extension workers, and was attended a total of 12 respondents who were not involve in household survey and the number of frequencies was conducted two times in each selected Kebeles. To guide the discussion, structured checklists was designed specific to the research issues, special attention was given to recruitment and training of enumerators. The moderators were get involve herself in the discussion and training was given for two on the method of leading the discussion. The FGDs was carried out in the local language (Haddiyisa) to make the participants feel more comfortable.

3.5.2. Key Informant Interview

Purposive sampling has been used to select key informants in this study. The researcher decided what needs to be known and find people who can and are willing to provide the information by virtue of knowledge or experience. Key informant interview was conducted to generate in-depth information with regard to the adaptive capacity, extent of vulnerability and, adaptation strategies of smallholder farmer households to the consequences of climate variability.

A total of fifteen key informants, five in each kebele (one Chairman, four Model Farmers and three Development Agents) and five from Woreda officials (two from Local leaders and three from the Siraro Badawacho Woreda Agriculture and Rural Development Office (SBWARDO) were interviewed. Elders who are older than 70 years, Kebele Administrators and Development Agents were members of key informant interview. Moreover, the Woreda agriculture and rural development officials were interviewed, about the cause and consequence of climate variability in the study area. Checklist containing different guiding questions was prepared and used.

3.5.3. Field Observation

Field observation was conducted to understand the study site. Direct field observation was undertaken to collect first-hand information. It can help to understand the local condition of the community in terms of the climate variability and related problems in affected areas, farm land

and adaptation strategies through walking across in the study area with the aid of visual photographs by preparing checklists. Both the biophysical and social environment in which farmers interact and respond was observed. Moreover, this was helped the investigator to reduce complexity and even to make the research work more successfully. Information obtained by this method helped to crosscheck information generated by other data collection method

3.6. Methods of Data Analysis

To analyze this data, both qualitative and quantitative data analysis techniques were employed. The quantitative data was analyzed using descriptive statistical techniques such as mean, standard deviation, coefficient of variation, percentages, frequency dealing with farmer's perception on climate change, and the past thirty years (1989-2019), meteorological data using SPPS version 26 was used to analyze descriptive results. Moreover, Microsoft excel sheet used to present patterns and trends of rainfall and temperature data.

Moreover; determination of variations in temperature annual trends of maximum and minimum temperatures and seasonal and annual rainfall trend patterns was computed. Annual Mean linear Trend models were used on mean temperature of seasons of different years to determine trend of mean temperature in the past consecutive 30 years. Additionally, to evaluate the association of climate data in especially and maize productivity spearman rank correlation coefficient used. Since Spearman's rank correlation coefficient measures the strength and direction of a monotonic association, it was possibly inappropriate for the researchers to draw a straight line through the points on each scatter plot to indicate a linear association. At the same time, this study used the binary logistic regression model to predict the effects of independent variable on dependent variables. Logistic regression was used to analyze the relationship between multiple independent variables and categorical dependent variables. Binary logistic regression is typically was used when the dependent variable is dichotomous (only two categories) and the independent variables are either continuous or categorical.

The general, formula for the binary logistic regression is presented as follows:

$$Li = \text{line}\ (Pi/1 - Pi) = Z_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_K X_K + €i$$

Where Li is the log of the odds ratio; e is the base of natural logarithms; α is a constant; X1, $X_2\ldots, X_k$ are explanatory variables; $\beta_1, \beta_2\ldots \beta_k$ are estimated parameters corresponding to each explanatory variable; k is number of explanatory variables; and €i is the random error. To test the overall good fitness of binary logistic regression model, Hosmer-Leeshawn test of goodness-of-fit was utilized.

Standardized precipitation index (SPI): The SPI was used to identify drought during the period under consideration using annual rainfall data. The SPI is a statistical measure to detect unusual weather events and then to determine how often droughts of certain strength are likely to occur. The practical implication of SPI-defined drought, as the deviation from the normal amount of precipitation, would vary from one year to another, it can be calculated as:

$$SPI = \frac{Xi - \overline{X}}{\sigma} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (2),$$

Where; SPI refers to rainfall anomaly (irregularity) on multiple time scales; x represents annual rainfall in the year t; x "represents the long-term mean rainfall; and σ represents the standard deviation over the period of observation (Kurukulasuriya and Mendelsohn. 2006a).

$$CV = x'' * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where CV is Coefficient of Variation, SD is Standard Deviation and x is mean.

The qualitative data was analyzed using narration and thematic coding.

3.7. Selection of Explanatory Variable

Variable is a characteristic of phenomenon that can take on different values. It includes dependent and independent variables. The variable that is used to describe or measure the problem under study is called the dependent variable. In this study, the household maize productivity is the dependent variable. For the binary logistic analysis, it is a dichotomous variable productivity increase, which is represented in the model by 1 if productivity is decrease 0. On the other hand, the variables that are used to describe or measure the factors that are assumed to have association the problems are called independent variables which are discussed below:

Table 2: Selection of Explanatory Variable

Variable name	Description	Expected sign
Sex of respondent	Male= “1” female= “0”	+/-
Age of respondent	Number of years	-
Marital status	Married, unmarried and divorced	-
Family size	Number of household members	+
Education level	Categorized in to 3	+
`Years of experience in farming	Number of years	+
Maize farm size	Total maize farm holding of the HH in hectares	-
Income	maize=”1”maize and land farm=”0”	-
Total maize income	Number of quintal	+
Existence trend of temperature	Increasing=”1” decreasing=”0”	+/-
Availability Rainfall fluctuation	Yes =“1” and No =“0”	-
Access to climate change information	Yes =“1” and No= “0”	+
Households using CV adaptation	Yes= “1” and No= “0”	+

3.7.1. Data Presentation

The collected data was analyzed and presented first for discussion and next for the users. Data was presented in an easy and simplified manner to be easily understood and easy to implement. The most data presentation styles are using tables, figures, histograms and diagrams that describe trends, patterns and cause-effect relationships. These data presentation styles were used during the realization of this research.

3.8. Research Validity and Reliability

The validity of this research was established based on its careful design and use of a variety of appropriate methods, techniques and tools through triangulation. It is expected that results from this study can be a pointer to similar situations in other climate change/variability Interventions with minimal adjustments to reflect the socio-economic, institutional and physical contexts and peculiarities.

Reliability concerns the extent to which a measurement of a phenomenon provides stable and consist result. Reliability is also concerned with repeatability. For example, a scale or test is said to be reliable if repeat measurement made by it under constant conditions was give the same result (Sperandei, 2014). In order to realize the reliability of this study, the consistency across the parts of measuring instruments were carefully done.

3.9. Ethical Consideration

This study maintained important ethical issues, before the beginning and during data collection each data collection of the study. Initially a formal letter was sought from Jimma University

Department of geography and environmental studies for Siraro Badawacho Woreda Administer and Siraro agriculture office. Additionally, the permission was sought from *kebeles* before conducting the study. Furthermore, a letter of informed consent was written and plainly read and explained to the households' questionnaires and conduct key informant interviews was consensual. Respondents were present with the consent form requesting for their authorization and described the objective, benefit of the study. In addition, the basic ethical issues considered in this study were: The culture, tradition and language of the respondents well respected starting from the pilot study, during focus group discussion .To ensure the anonymity of respondent and for the confidentiality of data; it was handled carefully and used for the purpose of this research only. The benefits from this study which involve building climate adaptation and reducing vulnerability in Siraro Badawacho *Woreda* maize producers' communities were well explained to the respondents. These justifications enhance respondents' interests in this research. After compilation of the final report, copies were made available to those informants who request them.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

This chapter presents demographic characteristics of the respondents, the link between demographic characteristics of respondents and maize productivity, existence of climate change, variability, and its impacts on maize production and accessibility of information and adaptation strategies to climate change of the study area.

4.1. Socio-demographic and Economic Characteristics of the Respondents

For this study, data were gathered from 278 respondents using simple random sampling methods. Hence, this section devotes itself to examine the general socio-demographic and economic characteristics of the respondents.

As it shown from(table3) below, the sex, distribution of the sample respondents is outlined with respect to male headed and female-headed household in the three *kebeles* of Siraro Badawacho *Woreda*. Accordingly, 200 (80.3%) were male headed and 78 (19.7%) were female headed households.

Based on the survey result, the number of household heads with the age range of 18 - 50 was computed 83% in the three *kebeles*. Therefore, the large number of the sampled households categorized under active age group under 50 years. Meanwhile, the number of elderly people accounts for only 17% they have their own contribution towards sharing their indigenous knowledge, skill, and experience from the ancient time to now.

When we see the education level of the respondents, (table 3) below reveals 30 (49.1 %), 31 (50.9%) and 22 (47.8%) were illiterate in Wolidaya, Langano and Qumudo respectively. And 29 (47.8%), 27 (44.2%) and 20 (32.7%) were enrolled 1-8 grades student in Wolidaya, Langano and Kumudo respectively. 2 (3.2%), 3(4.9%) and 4 (8.8%) respondents were grade 9-12 students in Wolidaya, Langano and Kumudo respectively. Totally, 202 (88. %) respondents are unable to read and write and 76 (12. %), 9(5.4%) of the respondents attended elementary and secondary grade levels respectively and no diploma and above.

Table 3: Socio-demographic and Economic Characteristics of Respondents

Socio-demographic and economic characteristics	*Kebeles*						Total	
	Wolidaya		Langano		Kumudo			
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Household Heads'Sex								
Male	80	86.	90	95	70	83.5	240	89.3
Female	20	14.	10	10	8	10.3	38	10.7
Total	100	100	100	100	78	100	278	100
Household Heads'Age category								
18-30	25	8.1	30	20.5	20	21.7	75	19.6
31-40	25	37.7	35	31.7	30	34.7	90	36.9
41-50	30	36	40	35.3	25	23.7	95	26.2
>51	5	18	10	10	3	19	18	17.2
Total	61	100	95	100	78	100	278	100
Household Heads' Education level								
Cannot read and write	40	49.1	31	50.9	28	47.8	180	49.4
Grade 1-8	29	47.5	27	44.2	20	32.7	80	45.2
Grade 9-12	2	3.2	3	4.9	4	8.6	18	5.35
Total	61	100	61	100	46	100	278	100
Household Heads'Marital status								
Married	70	80.3	75	77	65	80.4	200	79.1
Unmarried	5	1.6	10	11.4	7	10.8	35	7.7
Divorced	3	4.9	4	6.5	3	6.5	18	5.9
Widowed\widower	10	13.1	5	4.9	3	2.8	25	7.1
Total	61	100	61	100	46	100	278	100
Household Heads' sources of income								
Maize Farming	40	42.6	45	22.9	6	15	100	27.4
Maize farming and crop cultivation	60	57.3	65	77	43	87	178	72.2
Total	61	100	61	100	46	100	278	100
Household Heads' maize farm size								
0.25-0.5 hectare	25	22.9	35	47.5	20	17.3	80	30.4
0.6-1 hectare	43	39.3	46	45.9	23	11	100	44.6
Above 1 hectare	30	37.7	40	6.5	28	32.6	90	25
Total	61	100	61	100	46	100	278	100
Household Heads' family size								
0-4	33	26.2	43	44.2	22	36.7	98	35.1
5-8	40	32.7	50	40.9	30	52.2	120	41
9-12	25	40.9	9	14.7	6	13	58	23.8
Total	61	100	61	100	46	100	278	100
Household Heads' farming experience								
>10 years	25	26.2	45	44.2	30	41.3	100	36.9
10-20	58	32.7	70	45.9	25	52.2	153	42.8
< 20	20	40.9	5	3.6	3	6.5	28	20.3
Total	61	100	61	100	46	100	278	100

Source: Own survey, 2021

The survey result indicates that more than 49.4% of the respondents cannot read or write. Education assumed to have great impact on maize productivity, adaptation of new technologies and in turn enhance the capability to cope up with climate change impacts. Education is important to determine readiness to adapt new ideas, enables people to realize the diversification or specialization of livelihood activities and technology, within the framework of adaptation strategies on the impacts of climate change. Indeed, education on level of households assumed to increase participation of household implementation on climate variability, adaptation strategy. The higher educated household heads were increased their ability to find information, better understanding and application of new technologies as well as better ability to cope up with climatic risks.

Similarly, as shown in (Table 3) above, out of the total sample household respondents 79.1% were married, 7.7% unmarried, 6% were divorced and the remaining 7.1% of the respondent were widowed.

Likewise, the table above also assessed family size of the respondents. Accordingly, 51(35.7%) have the family size of 1- 4, 69(41%) have 5 - 8 and the remaining 40(23.8%) have above 9 children and the average household size was 5.4. There is minimal difference in the mean household size across the three *kebeles*, the smallest being for Kumudo (5.1), Wolidaya (5.4) and the biggest for Langano (5.7).Significant number of sample household respondents (about 27.4%) solely relied on maize farming. Overall maize is the most dominant primary livelihood activities followed by cash crop production, and the majority of respondents 153(74.2%) cultivate maize and cash crop at the same time. Langano, the large number of respondent 26(42.6%) depend on only maize farming, 14(22.9%) depend only on maize production in Wolidaya and in Kumudo 6(13%) of respondent were depend only on maize farming (See Table 3).The study indicated that 51(30.4%) of the household landholding size is 0.25-0.5 hectare, 75(44.6%) have 0.6-1.0 hectare and the remaining 42 (25%) of the respondent have more than one hectare.

The other variable that can play great role in maize productivity, in climate change study, is farming experience. Farmers who have long experience have more understanding of the impact of climate change and can easily use adaptation mechanisms. The survey data shows that 34(20.3%) respondents in the three kebeles have experience more than 21 years, accordingly, 25 respondents (40.9%) in Langano, 6 respondents (9.8%) in Wolidaya and 3 respondents (6.5%) in Kumudo have farming experiences of more than 20 years (see Table 3). This data supports the key informant idea that said maize has no log history in midland of Siraro Badawacho Woreda.

In general, more than 42% of respondents have 11-20year experience, 36.9% and 20.3% of respondents have below 10 years and more than 21 years' experience respectively. This implies that, experience increases the probability of adapting to climate variability.

4.2. Climate Variability Analysis

This part focused on the analysis of survey results and secondary data obtained from NMAE by generating statistical values such as mean, maximum and minimum annual temperature mean seasonal maximum temperature, total annual rainfall and seasonal rainfall trend analysis and interpretation. Thus, for comparison with the awareness of farmers who believe that temperature has increased and precipitation has been fluctuated, the following sections show the actual change in temperature and precipitation as recorded by National Meteorological Agency.

4.2.1. Analysis of Temperature Trends

In the period 19890-2019, mean annual maximum temperature of the study area varies between 26.9°C and 28.9°C. The lowest mean annual maximum temperature record is in 2011 and the highest record is in 2013 and 2014. The trend of mean annual maximum temperature of the study area was observed from 1989 to 2019 with interval of ten years. For example, mean annual maximum temperature between 1990 and 2000 was 26.6°C, 2001 to 2010 was 28.4°C, and from 1993 to 2020 were 27.9°C. There is a considerable increase in trend of mean annual maximum temperature over last three decades (1989-2019) in the study area. Both mean minimum and mean maximum temperature have shown increasing trends.

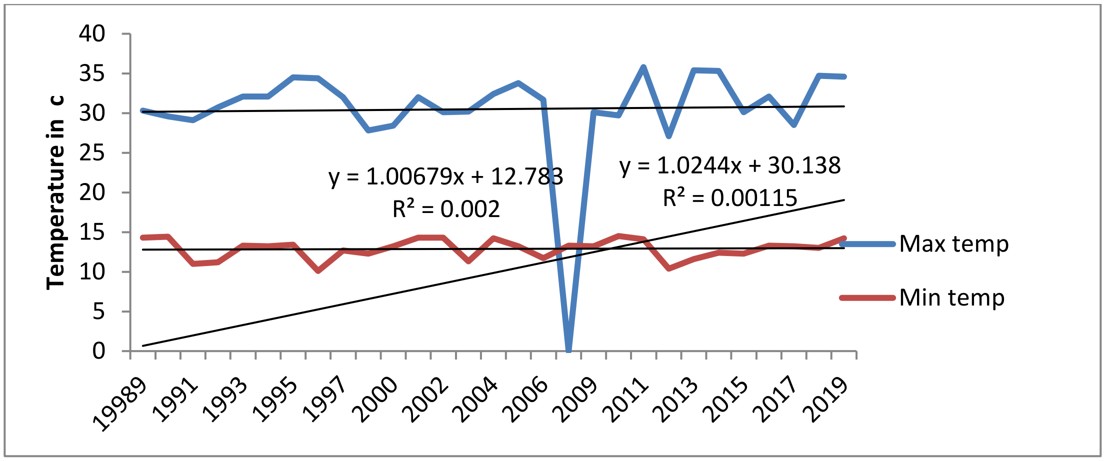


Figure 3: Temperature Trend of the study area from 1989-2019

Source: NMA Data, 2021

The minimum temperature was increasing with trend of 1.0679°C per year and having R^2 value of 1.078°C. Similarly, maximum temperature has shown an increasing with annual trend of 0.002°C per year and having R^2 value of 0.00115 (Figure 5). This coincides with the study of Haile (2018) that over the last decades, the mean maximum temperature in Ethiopia increased at about 0.2°C per decade. The responses provided by respondents, also goes in line with the meteorological data. Meaning local temperature has increasing over the last thirty years (see Table 4) from total respondents (57(93.4%), 48(78.7%) and 41(89.1%)) in Wolidaya, Langano and Kumudo respectively and totally, 86.9 % of household head responded temperature of the study area is increasing. In addition, 1.8% of respondents responded the temperature of area was decreasing and 11.3% were responded as temperature was not changed.

Table 4: Household Assumption on Temperature trend

Trend of temperature						
Question	**Responses**	**Frequency**	***Kebeles***			**Total**
			Wolidaya	Langano	Kumudo	
What is trend of temperature in your locality in last 30 years?	Increasing	Freq.	97	88	51	**236**
		%	93.4%	78.7%	89.1%	**86.9%**
	Decreasing	Freq.	3	4	2	**9**
		%	4.9%	0.0%	0.0%	**1.8%**
	No change	Freq.	8	13	10	**31**
		%	1.6%	21.3%	10.9%	**11.3%**
Total		Freq.	108	105	66	**278**
		%	100.0%	100.0%	100.0%	**100.0%**

Source: Own Survey, 2021

The field survey data provided in the above table indicates the rising of temperature in the study area. The study goes in line with Lundy & Ramirez (2011) study, that increases in seasonal mean temperatures have been observed across Ethiopia over the past 50 years, the majority of the temperature rise was observed during the second half of the 1990s. Additionally, some studies revealed climate variation is a phenomenon that will continue to cause severe or negative effect on yield throughout the world (Isacor, 2018). In addition, the average annual minimum temperature of the study area is 18.94°C. Mean annual minimum temperature varies between 15.12°C and 16.98°C during the last three decades. The lowest mean annual minimum temperature record in 1989 and highest record is in 2018. By the interval of 10 years (1989-2019) the last three decades has difference: in the first decade, it was 14.8°C, in the second decade 15.9°C and the third decade 14.393°C.

Table 4: Mean, standard devotion, Coefficient Variation of climate variability

Variables	Mean	StDev	CV
Max annual Temp (°C)	3.528	0.2	6%
Min annual Temp (°C)	1.087	0.5769	53%
Mean annual Temp (°C)	18.23	2.306	13%
Maize production(1000q)	5.836	.596	27%
Yield productivity(q/hectare)	16.94	4.975	29%

4.2.2. Analysis of Rainfall Trend

4.2.2.1. Annual Rainfall Trend and Variability

The rainfall in Ethiopia characterized as uni-modal and bi-modal systems depending on topography. The Southern part of the country (from southwest) has a mono-modal rainfall (single maxima) pattern in the months of June – September, and the rainy period ranges from February through November mainly in the southern and south- western part of the country, and decreases northwards (Badesso, 2017). The data obtained from NMAE for the period of 1989-2019 shows that total annual rainfall for study area ranges from 711 mm to 238.1mm with annual average of 162.594mm. The moist year in the record was in 1994 and the driest year was There is significant fluctuation in trend of annual rainfall over last three decades (1989-2019) in the study area. As it can be seen from the following figure 6, average annual rainfall has shown declining trend with annual amount of 20.244 mm per year and having R^2 of 0.367.

Table 5: Household Response on rainfall variability in the SBW

Rainfall amount and distribution	Frequency	Percent (%)
Increase	-	-
Decreasing	274	97.9
The same	4	2.1
Total respondents	278	100
Time of rainfall occurrences	Frequency	Percent (%)
Come early and goes early	35	12
Come early and goes late	22	8
Come late and goes early	190	70
Come late and goes late	25	9
Normal	4	1
Total respondents	278	100
Predictable	26	10
Unpredictable	252	90
Total respondents	278	100
Prediction of rainfall	Frequency	Percent (%)
Predictable	28	11
Unpredictable	250	89

Total respondents	278	100
Volume and amount of rainfall	Frequency	Percent (%)
Light	70	25
Heavy/erratic	200	71
Normal	8	4
Total respondents	278	100

Source: Own Survey, 2021

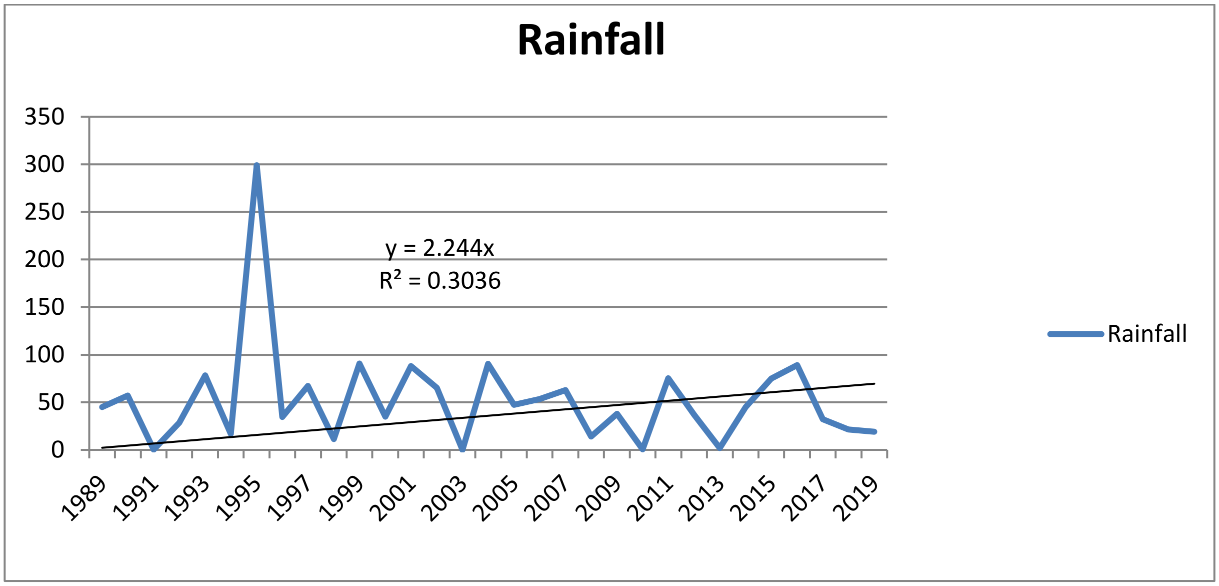


Figure 4: Annual rainfall trend and variability of the Study area, 1989-2019

Source: NMAE, 2021

Generally, the results of this study are contrary with that of Keller (2009) which asserts that climate change is already taking place now, the temperature in Ethiopia increased by about 0.2°C per decade and precipitation, on the other hand, remained stable over the last 50 years.

The results of meteorological data for rainfall during the rainy season especially from October to May showed decreasing and fluctuating trend for the last 30 years from 1989 to 2019. Trend analysis of rainfall data (Figure 6) indicates great variation in inter-annual rainfall. Regardless of this variation in inter-annual rainfall, overall rainfall amount was found to decrease over the years. Over the thirty-one years period (1989-2019) the lowest rainfall recorded occurred in 2003&2013 with an amount of 511 mm while the highest rainfall recorded within the period was 238.4mm in 1995&1996.

4.2.2.2. Seasonal Rainfall Variability

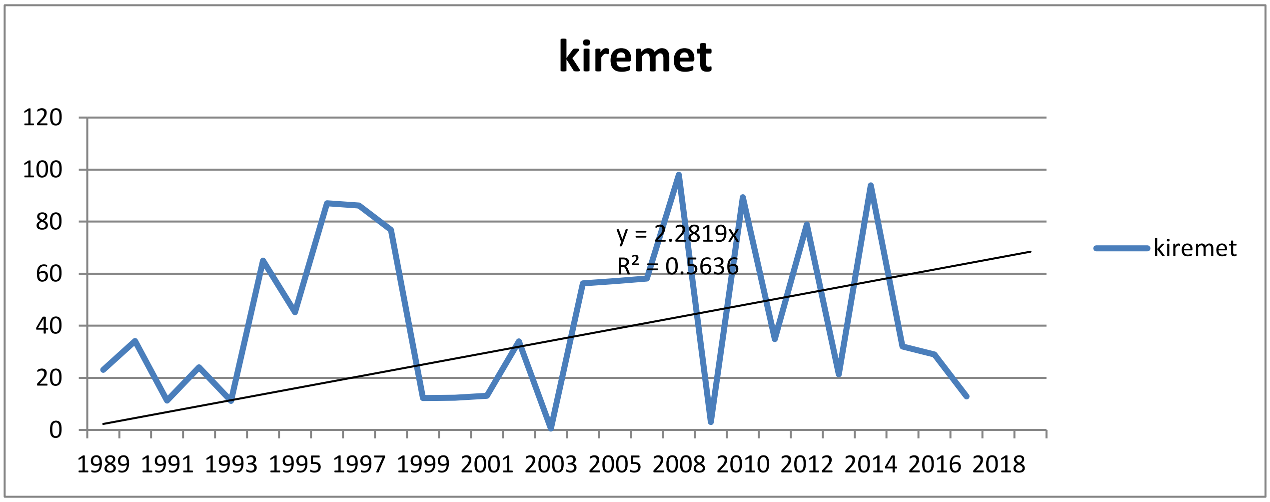
For the studied periods (1989-2019) the study area received bimodal rainfall i.e. main season, which starts from (June to September) and short season, which starts from (March to May) and the mean short season rainfall is 346.92 mm and mean of main season rainfall is 425.38 mm. The coefficient of variation (CV) of the short and main seasonal rainfall in the study area showed 55.4 % high variability and 17.5% less variability respectively based on degree of variability between the years 1989-2019. In line with other studies in Ethiopia, (2014) (Hadgu, 2013; Kassie et.al, 2013) reported that high coefficient variation in main rainy season. The short season rainfall showed a decreasing trend at a rate of 2.45 mm per a year while the main season rainfall also showed a decreasing trend at a rate of 0.44 mm.

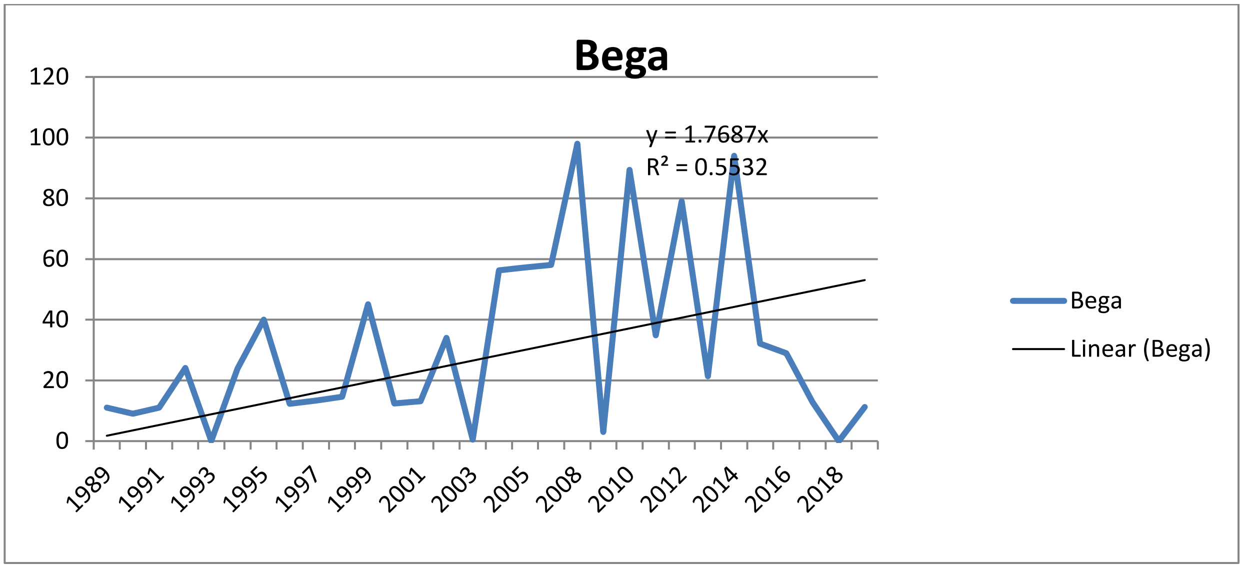
Table 6: Seasonal rainfall at Hosanna station (1989-2019)

Variables	Max	Min	Mean	SD	CV
Belg	668.50	204.20	359.72	111.26	39.7%
Kermit	806.30	486.20	420.01	89.73	24.5%
Tsedey	332.70	4.80	137.43	100.83	73.37

Source: NMA Hosanna Station (1989-2019)

With reference to seasonal trend, the *Kiremt* rainfall (June to August) is showing slightly decreasing trend and *Belg* (September to November) also decreasing. In addition, *Bega* (December to February) shows a relatively dry season and frost at the morning in *Tsedey* (March to May) which is maize flowering season shows some times very small rain rare and light rainfall and the month of May is very hot. Generally, all changes in seasonal trends are statistically significant.





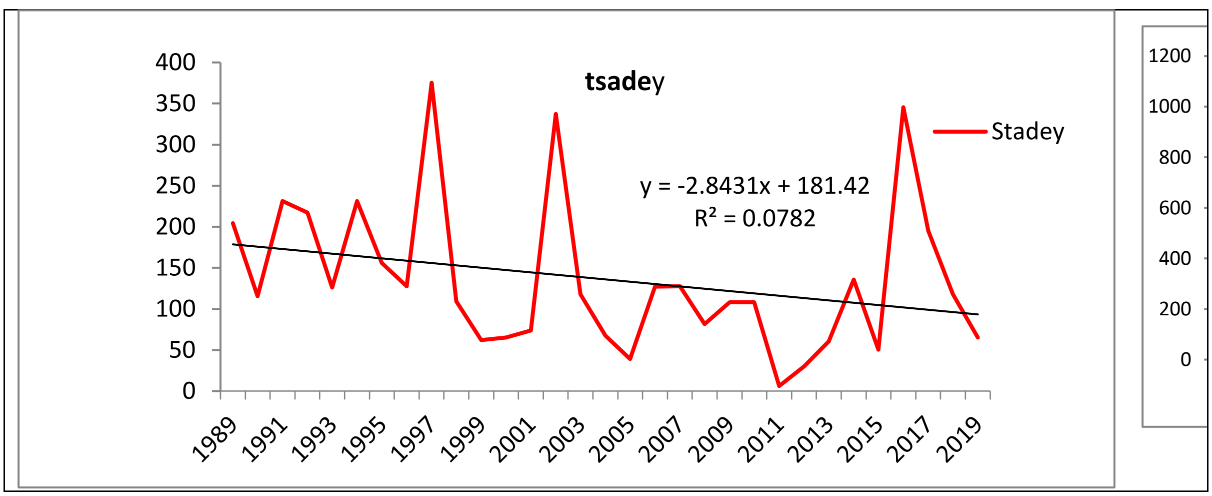


Figure 5: Seasonal rainfall Variablity in mm

Source: NMAE data, 2021

The rainfall has also shown high variation from season to season. The analyzed data shows that the area has three distinctive rainy seasons and one relatively dry season. The three rainy seasons are *Kiremt* (summer) June to August. Rainfall in *Kiremt* season, like other highland areas of Ethiopia, there is high amount of rainfall (Badesso, 2017). In this area, the average *Kiremt* rainfall for the period from 1989 to 2019 is 800 mm. It has shown decreasing trend with average annual decreasing of 6.9465 mm per year and have R^2 value of 0.00506 seen (Figure 7).

Tsedey (spring) season is the other season when the area has been receiving good amount of rainfall. In the study period, the average rainfall amount was 146.3 mm in the study period rainfall has shown decreasing trend, 49.1mm minimum rainfall and 375.3mm maximum rainfall. Additionally, in the *Tsedey* rainfall has shown decreasing trend, with average annual trend of decline of 2.84mm per year, and having 0.0782 R^2 values, which can be seen from the above (Figure 7).

Belg (autumn) *is* the other moist season its average annual amount of rainfall in the period of 1989-2019 was 169.6mm minimum and 1015.5mm maximum rainfall. The seasonal rainfall amounts were also showing variation from one decade to other. In the period 1989 - 2019, the average *Belg* rainfall was 504.6 mm and has shown decreasing trend with amount of 8.112mm, having 0.01089 R^2 value moreover this season is very important period for maize production.

Bega (winter) season i.e. December- February is the other season with low rainfall. Rainfall in *Bega* season, unlike in lowland area is identified with low amount in the study area. *Bega* is the driest season in the area. The average rainfall amount of the season in the study period was 172.9 mm, minimum and maximum of rainfall of the season was 50.1mm and 892.3mm respectively. *Bega* is the driest season in the area. The average rainfall amount of the season was 148 mm. The rainfall amount shows decreasing trend by annual amount 3.54 mm and having 0.0188 R^2 value.

In addition, regarding the observable change in the amount of rainfall and temperature within the three decades, the information acquired from elderly people and women during key informant interview (KI) reveals that the amount of rainfall is slightly decreasing, while the temperature is increasing. They also added that the onset of rainfall and cessation of rainfall shifted. Moreover, the duration, amount, and intensity of rainfall have changed. Similarly, the focus group discussion (FGD) result shows that there was difference in rainfall, temperature and frost in different decade. Regarding the rainfall, the respondents in FGD claim that the amount is much reduced from the biginig of 1990s up to 2019 but the intensity is high in short time, so this high intensity with short time is increasing land degradation rather than water percolation to the ground. They also claimed that some five decades ago (during the reign of Emperor Haile Selassie), the amount of rainfall was very high especially June and July. They asserted that it rained daily with high amount and long duration. However, in recent decades they believe that rainfall has become rare, low in amount, and high intensity with short duration. In addition, they said that if the rain is high and long, it results in high frost. In addition, the informants noticed that recent climatic trends show that temperature is increasing compared to half a century ago because of late coming and early cessation of the rainfall.

The (FGD) participants reported that:

"The rains are normally now starting late in March or April and ending before the crops could mature. However, the seasons appeared to have shifted as the rains could now start as late as March. We have a general feeling of uncertainty time to plant. Therefore, we needed an efficient weather forecasting system if we were to remain effective in farming. The unpredictability of rainfall patterns made faming a high risk business"

Annual and Seasonal Standard Precipitation Index as a Measure of Drought Annual standard precipitations normality (departure) for the past 23 years (1989-2019 in terms of drought frequency revealed that the study area experienced moderate drought with its SPI of -0.89 and -1.14 in 2014 and 2019 years respectively, while the rest of years were relatively moist.

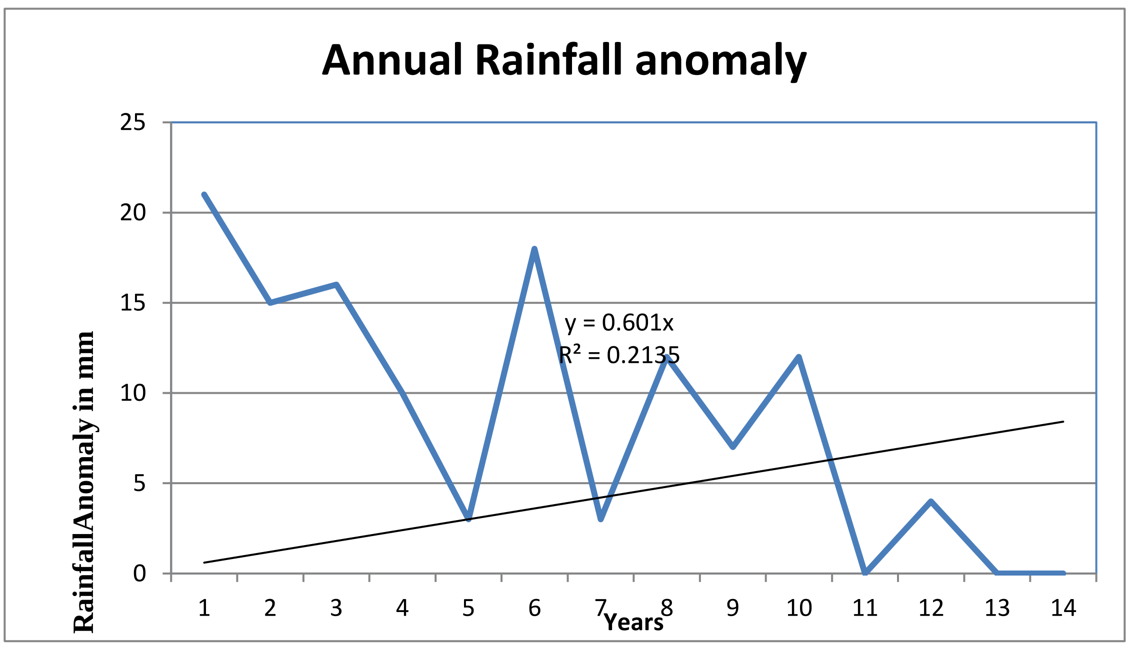


Figure 6 Annual SPI of Hadiya zone

Source: Analyzed based on NMA (2019)

4.3. Maize Productivity/Production

Maize productivity is operationally defined as the total maize collected/harvested from one hectare maize farm. The data of average maize productivity from 1990-2019 indicate that maize productivity was decreasing in low land and increasing in midland as it can be seen in the table below. Gradually, in midland, maize productivity in quintal per hectare was increasing and decreasing in lowland.

Table 5: Average Productivity of Maize in Study Area in (quintal/hectare)

Kebeles/agro-ecological zone	1990	1993	1996	1999	2002	2005	2008	2011	2014	2017	2019
Wolidaya	20.4	21.1	23.3	23.6	24.0	24.6	24.7	24.9.	25.1	25.5	26.0
Langano	20.6	20.2	20.	18.2	15.7	14.2	13.5	13.3	12.1	12	10.2
kumudo	19.6	19.4	19.0	18.3	17.5	17.3	15.5	14.9	13.6	12.7	9.8

Source (SBWAO, 2012)

The average maize productivity was 242.4 quintal per hectare in 1990 and 13.1 quintal per hectare 2019 in lowland, 16.2 quintal per hectare in 1990 and 24.8 quintal per hectare in 2019 and 14.5 quintal per hectare in 1990 and 23.2 in 2019 in mid land.

Data also indicated decreasing productivity in lowland and increasing in mid land area because with altitude decrease there is increase in temperature. This is in coincidence with other study where altitude and temperature have a fixed relation, called the lapse rate (0.6°C per 100m)

(Lundy & Ramirez, 2011).

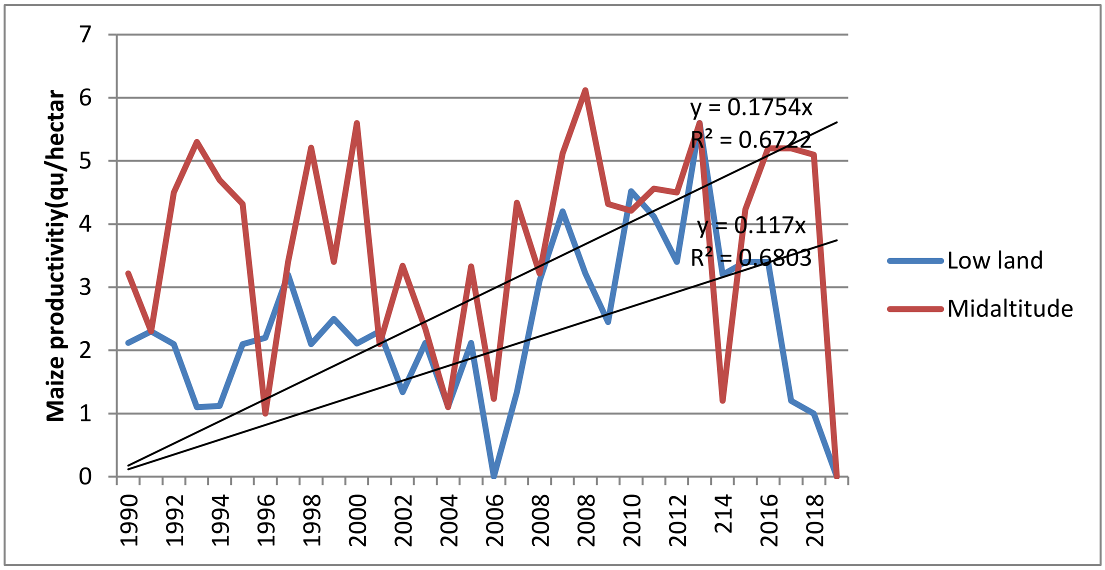


Figure 6: Maze Productivity (quintal /hectare)

Source: SWAO

Maize productivity in study area as show in the Figure 8 above, the liner equation indicate maize productivity in lowland decrease by 0.1745 quintal per hectare in every three years and also have -1.18082 R^2. Inversely, in midland productivity of maize was increasing by 0.1727 quintal on one hectare in three and have 0.409 R.

As Figure 9, below show, the three *kebeles* were selected in low and mid because maize suitability depends on altitude. Similarly, climate change will shift the suitability of maize to lower elevations over period of times, with the optimal altitude shifting from 1200 m at present to 1400 m in 2020 and 1600 m in 2050 in Central America (Lundy & Ramirez, 2011). This scenario generates different impacts at different altitudes, with the winners being smallholders at altitudes currently too high for the production of specialty-grade maize and the losers are those farmers currently at the lower viable bounds for production of specialty maize. As discussed in chapter three, Siraro Badawacho Woreda has two types of agro-ecological zone. All *kebeles* have changing impact though it is varying with altitude. The above figure helps us to understand the altitude of the selected *kebele.* As it can be seen from figure, Wolidaya *Kebele* was one of the 23*Kebele* in the Siraro Badawacho *Woreda* that is found in low altitude area, which is found to have an altitude below 1000m a.s.l. The secondary data of Ebongo Farmers' Cooperative maize processing which was founded by Wolidaya farmers in 1972 E.C indicated that from 1990 to

2019 the average maize trend was decreasing from 16350.7 quintal to 12437.3 quintal and 9070.1 quintal in the last three decade respectively. Respondents experience support increasing maize productivity in this *kebele* and this constitute 61% of the total respondents. 57 (93.4%) responded that maize productivity was decreasing in the last 30-years.

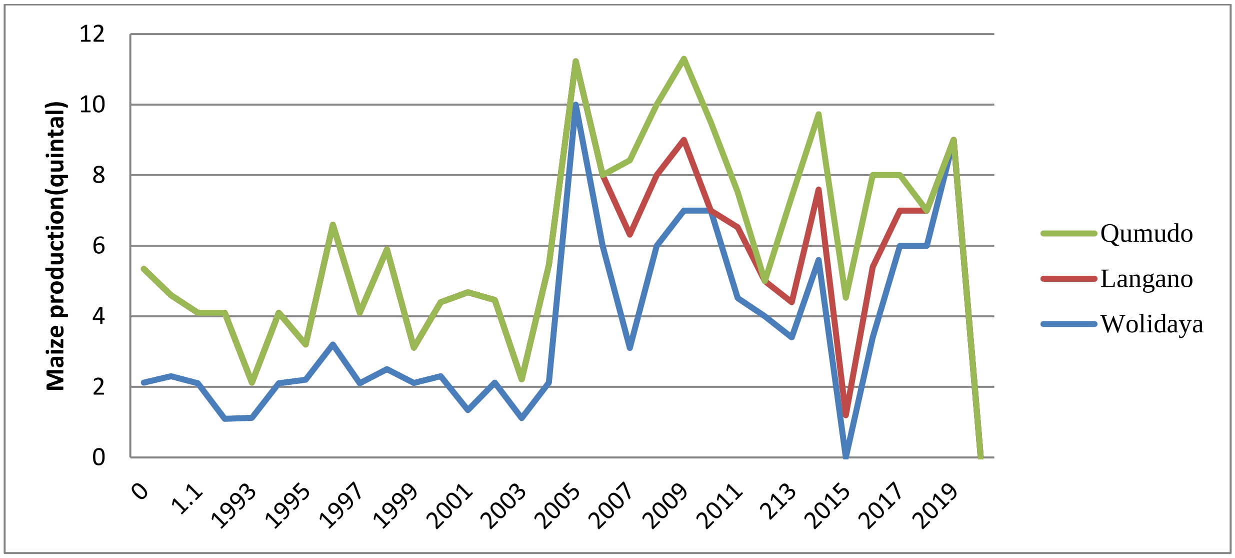


Figure 7: Total Maize Production of Selected Kebele

Source: Ebongo, Wolidaya and Weramo Maize Farmers' Cooperative, 2021

Wolidaya Kebele is found in mid altitude (Woina dega agro-climate zone) with an altitude of 2000 m a.s.l. Also secondary data of Weramo maize farmers' cooperative, which was founded by Wolidaya farmers in 1989 E.C, indicated that from 1989 to 2019 the average maize trend was increasing from 2041.14 quintals to 2327.78 quintals and 4928.5 quintal in last three decade 1990-2019. Respondents' experience also supported increasing maize productivity in the three *kebeles* among 75 total representatives of HH of the kebele 55(90%) responded that maize productivity was increasing in the last 30-years.

Langano was one of the *kebele* that is found in lowland area see (figure 9) with an altitude ranging from 700-900m to m a.s.l. Secondary data of Langano Farmers' Cooperative Maize Processing data indicate, from its establishment in 2008, the maize trend was increasing. Moreover, field survey indicated that 44 (95.6%) of the respondents experience increasing maize productivity in this *kebele*. Likewise, FGD with Wolidaya *kebele* household representatives indicated that maize does not produced in the *kebele* before 40 years because of climate change and now maize and other plants, which does not exist before, is being produced. In addition, this trend has relation with rainfall fluctuation.

Similarly, Gashaw(2017) reveals maize production area changed because suitable areas becomes too warm or prone to periodic drought. Many scientific justifications predicted maize sectors are likely affected due to climate variation over the next forty years (Lemi & Hailu, 2019).

Table 6: Trend of maize yield in different kebele (agro-ecology zone) as reported by respondents

Question	**Response**		**Kebele**			**Total**
			Wolidaya	**Langano**	**Qumudo**	
Is decreasing maize productivity in quintal/hectare?	yes	Freq.	55	80	40	175
		%	30.5%	55.1%	15.6%	61.3%
	No	Freq.	43	48	24	103
		%	93.4%	9.8%	4.3%	38.6%
Total		**Freq.**	**73.5**	**128**	**64**	**278**
		%	**100%**	**100%**	**100%**	**100.0 %**

Source: Own Survey, 2021

Farmers were asked to indicate the trends of maize productivity over the last thirteen years. About 57 (93.4%) of Kumudo *kebele* respondent believed that maize productivity is decreasing and the remaining 7(6.5%) responded productivity was increasing. Contrary to this, 73(90.1%) and 44(65.6%) respondent of Wolidaya and Langano assumed maize productivity was increasing in last 30 years. On the other hand, 6(9.8%) of Wolidaya and 2(4.3%) of Kumudo respondent responded that maize productivity was decreasing.

Generally, more than 93% of Kumudo *kebele* respondents claimed that maize productivity was decreasing. Inversely, more than 90% of Wolidaya and Langano respondents claimed that maize productivity was increasing in the locality. Likewise, as information collected from Kumudo FGD, in the area future sustainability and viability of maize production is indeed under threat due to the climate change. According to information obtained from elderly people during FGD, the amount of yield in quintal has gradually decreased from time to time because it is more vulnerable to climate change, especially during the late coming of rainfall. Also the data indicated increasing of maize productivity in lowland and decreasing in highland area because with attitudinal rising temperature is decreasing because altitude and temperature have inverse relation.

4.3.1. Impacts of Climate Change /Variability on Maize Production

The existence of climate change and variability in the study area is clearly seen from the analyses done in the above sections. Thus, climate change has a range of impacts on maize productivity of the area. The degree or severity of climate change impacts on maize productivity depends on agro-ecological zone. To evaluate the impact of climate change, spatially the effects of temperature and rainfall on maize productivity, the researcher used person's correlation coefficient model.

4.4. Correlations: Temperature versus Maize Yields (quintal/hectare)

To evaluate the association between climate element (temperature and rainfall) and maize production in different agro-ecology, person's rank correlation used to assess association between two variables. Since Pearson's rank correlation coefficient measures the strength and direction of a monotonic association(Hauke & Kossowski, 2011). It was possibly inappropriate for the researchers to draw a straight line through the points on each year productivity indicate a linear association with a significance of 0.05 to determine between mean temperature and yield in the period 1989-2019 as shown in Table 7 below .

Table 7: Correlation table of average maximum temperature versus mP quin/hec in the period 1990-2019

Correlations		
Variables	**(r_s) value**	**(p) value**
Temperature and maize Yield (quintal/ha) in midland	-.807**	.000(S)
Temperature and maize Yield (quintal/ha) in low altitude	.754**	.001(S)

(*S= Significant, NS= Not significant)

Source: Computed from Field Survey Data, 2021

As IPCC, (2007), concluded, slight warming decreases yield in seasonally dry and low-latitude regions. Climate variability affects virtually all aspects of agricultural and other water-intensive activities and has effects on a large proportion of households, with far economy like in most rural parts of agriculture in Ethiopia. However, as indicated in the previous section, the study area, particularly the kola and erratic rainfall. Therefore, impedes crops maturity and caused reduction in crop yield as a result of loss of soil fertility by soil erosion and moisture stress to have significant difference on the harvest and has deprivation of households' livelihood.

As one farmer from FGD noted;

"Even if we want to plant, it is now very difficult to know how to do it ,because it is now unpredictable ,if you try to plant in march, that might be how you perish your work and perhaps those that started early in April, might get something…."

As interviewed farmers claimed that there were reductions of crop yields because due to changes in rainfall and temperature patterns. From the interviewed households as indicated that the 15.52% 19.23% and 26.56% of respondents from low land and mid land respectively answered production per ha is increasing. This might be because of using different adaptation mechanizes that can increase their production against temperature and rainfall variation.

I. Lowland part of the study area

Concerning association of temperature and maize productivity in lowland, the above results show that p=0.00 which is less than 0.05, hence the relationship was significant, and then H_0 must be accepted. Negative correlation (r_s) -0.807 suggests that when there is an increase in temperature, yield harvested reduces and vice versa. These results may be associated with attack by pests and diseases associated with high temperature conditions. According to Gashaw et, al. (2009), maize has spread to lower altitudes, as a result of increasing temperatures and they attack maize crop consequently leading to low yields. These results are in line with to the findings of International trade center(ITC), (2009) which shows that increase in temperature inhibits photosynthesis and results in changes in planting periods, reducing growth and resulting in smaller yields

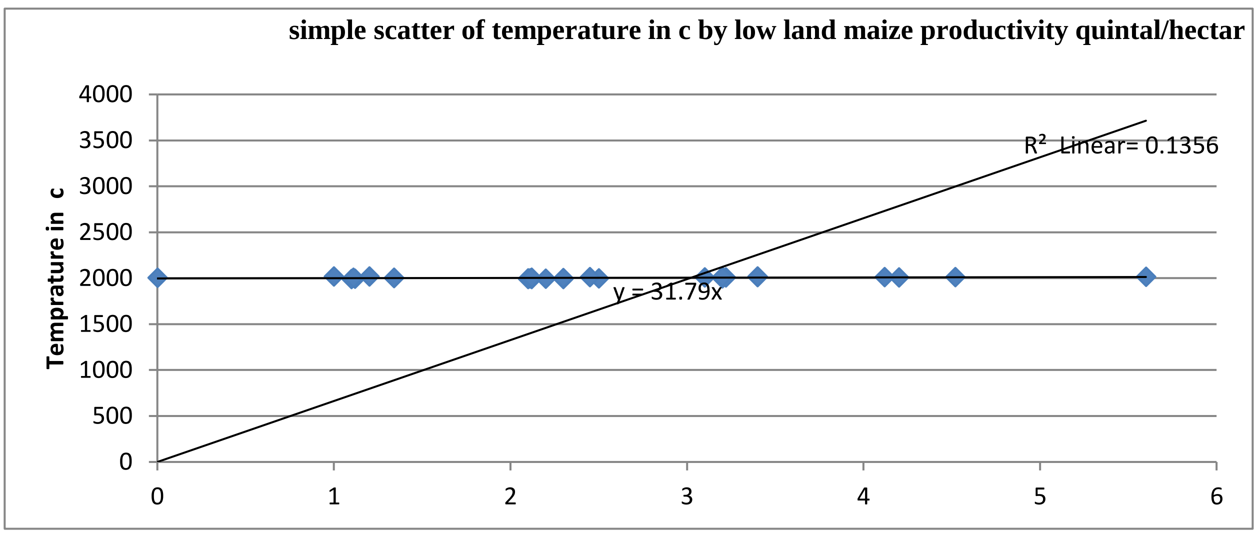


Figure 8: Correlation of Maize productivity quintal/hectare in lowland and temprature^{0}c

Source: Computed field survey, 2021

II. Mid altitude part of the study area

Similarly, the exponential correlation between temperature and the mid altitude of maize (1990-2019) harvested shows that p= 0.01, which is less than 0.05 hence the relationship was significant as seen on (table 8). In addition, it has positive correlation the value of (r_s); 0.754, this is suggests that when there is an increase in temperature, there is also an increase in productivity. Therefore, when temperature increases, more production is harvesting. This study come to an agreement with study of Moat *et al*., (2017) the raise of temperature is changing un suitable area for maize production into suitable in contrary suitable area into unsuitable. mature.

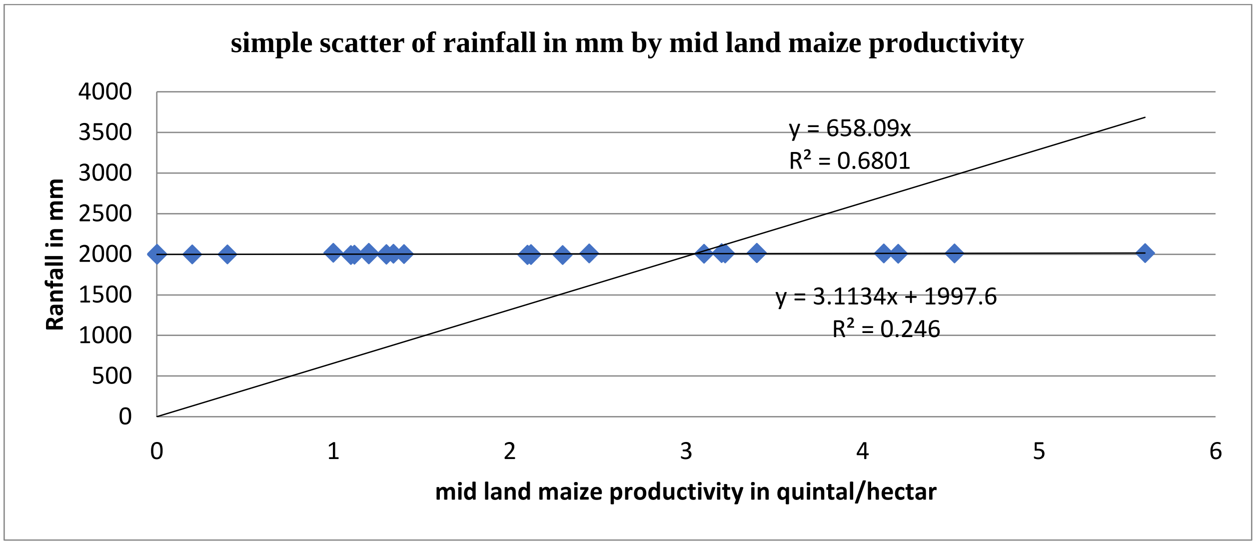


Figure 9 : Spearman's correlation coefficients of MP quin/hec and rainfall in mm

Source: Computed from Field Survey, 2021

4.4.1. Rainfall versus Maize Productivity

The correlation relationship between rainfall and maize productivity shown in the (table 8) indicates that, p=0.083 which is greater than 0.05, hence the relationship was not significant as whole but not seasonal. However, there was a positive relationship between the two positive correlations (r_s); 0.321 suggests that when there is a decrease in rainfall, the percentage of maize productivity also decreases and vice versa. Rainfall is therefore essential for full growth and maturation of healthy maize.

Table 8: Correlation of Rainfall and Maize Productivity

Correlations		
Variables	**(r_s) value**	**(p) value**
Rainfall in mm and lowland maize productivity quintal/hectare	.421	.083(NS)
Tsedey rainfall in mm and maize Yield (quintal/ha)	.862**	.010(S)
Bega rainfall in mm and maize Yield (quintal/ha)	.965*	.047(S)
Belg rainfall in mm and maize Yield (quintal/ha)	.536	.148(NS)
Kiremt rainfall in mm and maize productivity quintal/hectare	.219	.244(NS)

Source: Computed from Field Survey, 2021

This result is similar to research shows that maize, requires a high regime of soil moisture during the dry months(Zabel et al., 2014). Prolonged dry spells lower crop production and especially during the berry, expansion stage when maize requires sufficient water supply for berries to grow and

In addition, over 94% of respondents experienced the climate change impact on maize production. Specifically, the rise of temperature and fluctuation of rainfall have significant impact on maize production as shown. 53of the respondents (87%) at Kumudo from lower altitude believed maize productivity was declining in contrast with *Woinadega* and *dega* agro-climatic areas where Wolidaya and Langano54 (88.5%) and 42(91.3%) respectively) were confident that maize productivity is increasing. In addition, the rise of temperature decreases the area suitability for maize production in lowland areas of the *woreda*. In addition, survey data indicates that the households of three *kebeles* have experience on climate change affecting maize productivity either negatively or positively. 158 respondents or (64%) of respondent responded CV have impact on maize productivity and 120(36%) believe that CV have no impact on maize productivity.

As meteorological data is different seasonal rainfall, fluctuation and decreasing to evaluate its Association with maize productivity the researcher used spearman correlation.

The correlation between climate change and maize productivity prescribing was significant for *Bega* and *Tsadey* season. However, it was not significant in the remaining two seasons where they have positive correlation with maize productivity. *Belg* rain season has ($p<0.05$) 0.148 value of P and r_s less than 0.5 then this season has not significant correlation with maize productivity. Likewise *Kiremt* season has no significant association with maize productivity because it has 0.224 p values and has r_s 0.219. A *Bega* rainfall season has significant correlation with maize productivity its P vale is 0.47 and have 565 r_s. Additionally, *Belg* rainfall season is also highly significant for maize productivity with p is less than 0.5 and r_s value is greater than 0.5, generally the association of maize production and *Tsedey* rainfall season has correlation in 0.1 p value and r_s 0.662 erratic rainfall, late coming and early coming of rainfall in this season was highly significant. The two season have significant association with maize productivity so alternative hypothesis must be accepted.

During the FGDs, the participants explained that some other factors like maize disease, pests and maize weeds, which have been mainly emerged due to climate change, have contributed for maize failure in the study area. Because of these challenges, maize yield in the lowland area is declining from time to time. Comparing recent seasons' harvest with that of what farmers used to produce using similar inputs, all FGDs, key informants and most respondents indicated as current yield became lower in the area. In contrary, *Woreda* agricultural experts, FGDs and key informants were explained the existence of positive impact of temperature rising in Wolidaya and Langano especially as temperature increase maize productivity was increasing in these two *kebele.*

According to the results obtained from FGD and KII, *Belg* season rainfall is highly affecting maize production especially during the harvesting. As well, *Tsedy* season (early coming rainfall) is preferable because this season is the time of flowering of maize. Generally, the local communities perceived climate change impact in the study area due to erratic rainfall, late coming and early coming of rainfall.

This study goes in-line with the study of Gashaw *et al*. (2008) which predicted that climate change would shift the altitude range for maize to higher elevations over time, with the optimal altitude shifting from 1200 m at present to 1400 m in 2020 and 1600 m in 2050 in Central America. Likewise, climate change is putting maize production and the livelihoods of maize farmers and their families around the world at risk. Changes in temperature and rainfall patterns, as well as extreme weather events can impact production cycles and negatively affect maize production (Iscaro, 2014). In addition analyses of extreme temperature changes in various maize-growing areas indicate positive trends for maximum temperature, warm days, warm nights and warm spell duration; and negative trends for cool days, cool nights, and cold spell duration across different eco-agricultural environments (Moat *et al.*, 2017).

4.4. Some Characteristics of Respondents and maize productivity

To look at the link of some socio-demographic characteristics of respondents, maize productivity, the researcher used a cross-tabulation table and chi-square test. Null Hypothesis (H_0) of the study is no statically significant difference between respondents' socio-economic and demographic characteristics and climate variability, And Alternative Hypothesis (H_1) of the study is statically significant difference between respondents' socio-economic and demographic characteristics and their climate change and variability adaptation strategies.

Age of the respondent is used to known a most productive forces groups of that can play a decisive role in producing maize and using adaptation strategies to the climate change for their locality(Nuru, 2019)

Table 9: Age of respondent and maize productivity in different agro-ecology

Kebele	**maize yield in quintal/hectare**	**frequency**	**Age of the respondents**				**Total**
			18-30	31-40	41-50	51 and above	
Wolidaya	15-17	Freq.	22	19	13	0	25
		%	40.0%	39.1%	0.0%	0.0%	18.3%
	18-20	Freq.	7	17	8	1	19
		%	40.0%	17.4%	38.1%	9.1%	25.0%
	21-23	Freq.	5	11	9	2	16
		%	20.0%	21.7%	38.1%	18.2%	26.7%
	24-26	Freq.	3	9	8	8	18
		%	0.0%	21.7%	23.8%	72.7%	30.0%
Langano	15-17	Freq.	9	10	7	0	17
		%	33.3%	24.0%	33.3%	0.0%	24.6%
	18-20	Freq.	11	19	5	3	40
		%	50.0%	76.0%	33.3%	33.3%	55.7%
	21-23	Freq.	5	6	4	0	8
		%	16.7%	0.0%	33.3%	0.0%	9.8%
	24-26	Freq.	1	4	1	6	10
		%	0.0%	0.0%	0.0%	66.7%	9.8%
Qumudo	15-17	Freq.	7	1	7	0	4
		%	0.0%	0.0%	18.2%	0.0%	4.3%
	18-20	Freq.	6	5	9	0	13

		%	60.0%	12.5%	45.5%	0.0%	28.3%
	21-23	Freq.	6	6	4	4	18
		%	40.0%	37.5%	36.4%	44.4%	39.1%
	24-26	Freq.	2	8	3	5	19
		%	0.0%	50.0%	0.0%	55.6%	28.3%
	24-26	Freq.	0	13	5	19	40
		%	0.0%	20.3%	12.2%	65.5%	22.2%
Total		**Freq.**	**90**	**125**	**61**	**29**	**278**
		%	**100%**	**100%**	**100%**	**100%**	**100%**

Source: Field Survey, 2021

As the above table shows about 33 respondent age 18-30 (75.7%) were producing below 20-quintals maize from one hectare and (24.3%) of them were harvesting more than 20 quintals. Moreover, about 64 respondents age 30-40 (62.2%) of them were producing below 20-quintals maize from one hectare and (37.8) of them were producing more than 20 quintals. In addition, about 41 respondents 40-50 years, (47%) respondents were producing below 20-quintals maize from one hectare and (53%) of them were producing more than 20 quintals. The remaining 29 respondent (14%) were producing maize less than 20 quintal /hectare and (84%) of them were collecting more than 20 quintals. To evaluate the association of age of respondent and maize productivity was tested by Pearson chi-square as shows in the table below.

Table 10: Nexus between HH Age and Maize Productivity

Kebele	**Kind of test**	**Value**	**df**	**Asymptotic Significance (2-sided)**
Wolidaya	Pearson Chi-Square	1.092	4	.789
Langano		10.429	4	.045
Qumudo		1.608	4	.667
Total		**8.858**	**4**	**.078**

Source: Field Survey, 2021

Age is one of socio characteristics of the households, which have impact on maize productivity according to developed hypothesis. When Pearson's Chai Square value= 0.078 is greater than the alpha value (α = 0.05), the H_0 must be accepted. This implies that there is no statistically significant difference between age group in maize productivity. The Phi and the Cramer's values were also calculated to see the strength of the association. The calculated values were 0.058, which indicate that there is minor association between the two (0.058 is not closer to zero).

Sex is the other variables that have importance in livelihood and productivity particularly in maize farming community. Usually, under the agrarian economy in rural Ethiopia, women household heads are classified under poor rank, which also implies vulnerability to the impact of climate change.

Table 11: Gender of respondents and Maize Productivity

Kebele	**Sex of the respondents**	**Frequency**	**maize productivity yield in quintal/hectare**				**Total**
			15-17	18-20	21-23	24-26	
Wolidaya	Male	Freq.	9	13	15	15	52
		%	81.8%	86.7%	93.8%	83.3%	86.7%
	Female	Freq.	2	2	1	3	8
		%	18.2%	13.3%	6.3%	16.7%	13.3%
Langano	Male	Freq.	10	33	5	6	54
		%	66.7%	97.1%	83.3%	100.0%	88.5%
	Female	Freq.	10	2	3	0	15
		%	33.3%	2.9%	16.7%	0.0%	11.5%
Qumudo	Male	Freq.	2	12	18	12	44
		%	100.0%	92.3%	100.0%	92.3%	95.7%
	Female	Freq.	0	6	0	3	9
		%	0.0%	7.7%	0.0%	7.7%	4.3%
Total	Male	Freq.	21	58	38	33	150
		%	75.0%	93.5%	95.0%	89.2%	89.8%
	Female	Freq.	15	8	4	6	33
		%	25.0%	6.5%	5.0%	10.8%	10.2%
Total		Freq.	88	102	60	47	278
		%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Field Survey, 2021

As shown above (table 11) out of 8 female respondents of Wolidaya 2 (40%) were producing below 20 quintals from one hectare and in Langano *kebele* among 7 respondents 34(86%) were harvesting less than 20 quintals per hectare also from 2 Qumudo female heads 1(50%) was harvesting less than 20 quintals per hectare. To compare with male household, from the above table from 44 of Qumudo male respondents 30 (65%) of them produced more than 20 quintals per hectare and also from 52 Wolidaya male respondent 30 (57%) were gathering more than 20 quintals from one hectare. In contrary among 54 male respondents of Langano 43(79%) were producing less than 20 quintal per hectare. This indicate sex have impact on maize productivity as table below evaluated by person chi-square test. Because of Women-headed farmers were constrained by family labor because those women were responsible for both farming and household activities (Miheretu & Yimer, 2017).

Table 12: Nexus between Gender and Maize Productivity in different Agro-ecological

Kebele	Kind of test	Value	Df	Asymptotic Significance (2-sided)
Wolidaya	Pearson Chi-Square	1.092	4	.789
Langano		10.429	4	.015
Qumudo		1.608	4	.657
Total		**8.858**	**4**	**.041**

Source: Field Survey, 2021

Gender is one of socio characteristics of the households, which have impact on maize productivity. As the P (Pearson's Chai Square value= 0.041) is less than the alpha value (α = 0.05), the H_0 must be rejected. Meaning, there is statistically significant difference between males and females in maize productivity practice in the study area. The Phi and the Cramer's values were also calculated to see the strength of the association. The calculated values were 0.031, which indicate that there is high association between the two (0.031 is closer to zero).

This agrees with the argument that male household headed are more likely to producing maize and coping climate change than female headed households. Similarly, Haile, (2018) concluded that being male-headed increases significantly the ability and choice of households' climate change coping strategies Likewise, maize productivity was also examined in relation to their level of education level using the cross – tabulation and the chi-square test as it can be seen from the following table?

Table 13: Association of educational levels of the respondent's and maize productivity

Kebele	Education level of the respondents	Frequency	maize yield in quintal/hectare				Total
			15-17	18-20	21-23	24-26	
Wolidaya	Unable to read and write	Freq.	3	13	9	4	**29**
		%	27.3%	72.2%	56.3%	26.7%	**48.3%**
	Grade 1-8	Freq.	12	20	10	8	**29**
		%	72.7%	66.7%	37.5%	27.8%	**48.3%**
	Grade 9-12	Freq.	4	3	2	1	**12**
		%	0.0%	6.7%	6.3%	0.0%	**3.3%**
Langano	Unable to read and write	Freq.	6	19	0	6	**31**
		%	40.0%	55.9%	0.0%	100.0%	**50.8%**
	Grade 1-8	Freq.	6	15	6	0	**27**
		%	40.0%	44.1%	100.0%	0.0%	**44.3%**
	Grade 9-12	Freq.	5	0	0	0	**3**
		%	20.0%	0.0%	0.0%	0.0%	**4.9%**
Qumudo	Unable to read and write	Freq.	10	4	0	8	**22**
		%	55.6%	30.8%	0.0%	61.5%	**47.8%**
	Grade 1-8	Freq.	10	7	6	5	**20**
		%	100.0%	53.8%	33.3%	38.5%	**43.5%**
	Grade 9-12	Freq.	5	2	2	0	**4**
		%	0.0%	15.4%	11.1%	0.0%	**8.7%**
Total	Unable to read and	Freq.	36	36	9	18	**82**

	write	%	50%	50.7%	30%	73.0%	**49.1%**
	Grade 1-8	Freq.	29	32	18	10	**76**
		%	44.4%	45%	60%	27.0%	**45.5%**
	Grade 9-12	Freq.	6	3	3	0	**9**
		%	5.6%	4.3%	10%	0.0%	**5.4%**
	Total	Freq.	78	81	58	68	**287**
		%	100.0%	100.0%	100.0%	100.0%	**100.0%**

Source: Own survey, 2021

As the above table shows among 29 respondents who can an able to read and write 16(55%) were producing bellow 20 quintal per hectare, 80% and 63% of Qumudo and Langano *kebele* respondents were producing less than 20 quintal respectively. Among 82 unable to read and write respondents 55(67%) were producing below 20-quintals maize from one hectare and 27(33%) of them were harvesting more than 20 quintals. Moreover, among 76 respondents who attend grade 1-8, 48(63.2%) respondent were producing below 20-quintals maize from one hectare and 28(36.8) of them were producing more than 20 quintals. In addition, among 9 respondents who attend grade 9-12, 3(33%) respondents were producing below 20-quintals maize from one hectare and 6(66%) of them were producing more than 20 quintals.

Since the P- value (Pearson's chi-square test is .026) is less than α -value (α=0.05), the H_0 must be rejected. This indicates that there is statistically significant association between respondents' education levels and maize productivity at 0.05 level of significance. The calculated Phi and Cramer's Values (.026 each) indicate that there is a strong relationship between respondents' education level and maize productivity. Furthermore, education is likely to enhance farmer's ability to receive, interpret and comprehend information relevant to making innovative decisions in their farms (Desta, 2014).

Table 14: Association educational level of the respondents and maize productivity

Kebele	**Kind of test**	**Value**	**Df**	**Asymptotic Significance (2-sided)**
Wolidaya	Pearson Chi-Square	11.034	6	.087
Langano		22.551	6	.001
Qumudo		6.870	6	.333
Total		**14.297**	**6**	**.026**

Sources: Field Survey, 2021

Similarly, family size is also one of variables that have impact on maize farming. It is expected to have positive association with the maize productivity. It is the total number of person living in the household working for and dependent on household for their living. The respondents' CV adaptation and maize productivity was also examined in relation to their level of family size using the cross – tabulation and the chi-square test.

Table 15: Association family size of the respondent's with maize productivity

Kebele	**Family size of the respondents**		**Maize yield in quintal/hectare**				**Total**
			15-17	18-20	21-23	24-26	
Wolidaya	1-4	Freq.	19	12	0	8	30
		%	100.0%	33.3%	0.0%	16.7%	31.7%
	5-8	Freq.	0	25	35	20	80
		%	0.0%	66.7%	93.8%	27.8%	50.0%
	9-12	Freq.	0	0	1	10	11
		%	0.0%	0.0%	6.3%	55.6%	18.3%
Langano	1-4	Freq.	20	28	0	9	57
		%	100.0%	55.9%	0.0%	50.0%	60.7%
	5-8	Freq.	0	18	15	0	37
		%	0.0%	44.1%	100.0%	0.0%	34.4%
	9-12	Freq.	0	8	0	20	28
		%	0.0%	40.0%	0.0%	58.0%	11.9%
Qumudo	1-4	Freq.	16	13	0	10	39
		%	100.0%	53.8%	0.0%	38.5%	30.4%
	5-8	Freq.	0	10	12	9	41
		%	0.0%	46.2%	66.7%	23.1%	45.7%
	9-12	Freq.	0	0	24	30	54
		%	0.0%	0.0%	33.3%	38.5%	23.9%
Total	1-4	Freq.	28	31	0	11	70
		%	100.0%	50.0%	0.0%	29.7%	41.9%
	5-8	Freq.	0	31	33	8	72
		%	0.0%	50.0%	82.5%	21.6%	43.1%
	9-12	Freq.	0	0	7	18	25
		%	0.0%	0.0%	17.5%	48.6%	15.0%
Total		Freq.	60	126	30	37	278
		%	*100%*	*100%*	*100%*	*100%*	*100%*

Source: Own survey, 2021

Additionally, family size was other variable that hypotheses on effect on maize productivity by researcher. As above table shows among 70 household heads 1-4 family size, 59(83.3%) respondents were producing below 20-quintals maize from one hectare and the remain 11(15.7%) of them were harvesting more than 20 quintals. Moreover, among 72 respondents has 5-8 family size, 31(43%) respondent were producing below 20-quintals maize from one hectare and 41(57%) of them were producing more than 20 quintals. Similarly, among 25 respondents how has 9-12 family size, 25(100%) respondents were producing more than 20-quintals maize from one hectare.

Generally, the above data indecent a households how has more family size producing more productivity from the same maize farm land to evaluate the association family size and maize productivity by person chi-square see the below table.

Table 16: The respondent's family size nexus maize productivity

Kebele	Kind of test	Value	df	Asymptotic Significance (2-sided)
Wolidaya	Pearson Chi-Square	56.459	6	.000
Langano		50.859	6	.000
Qumudo		20.787	6	.002
Total		**114.369**	**6**	**.000**

Sources: Field survey 2021

As the P (P = 0.000) is less than the alpha value ($\alpha = 0.05$), the H_0 must be rejected. Meaning, there is statistically significant difference between small and large families in minimizing the impact of CV on maize productivity in the study area because of number of family work in maize farm. The Phi and the Cramer's values were also calculated to see the strength of the association. The calculated values were 0.000, which indicate that there is highly association between the two family size and maize productivity.

Similarly, Abegaz, (2011) mentioned that household size has mixed impacts on farmers‟ use of agricultural technologies. Larger family size is expected to enable farmers to take up labor-intensive adoption measures. Nevertheless, larger family size entails more economic dependency and more pressure on the household hence assumed to have negative effect on CV adaption strategies.

Correspondingly, in an agrarian society like Ethiopia, ownership of land, particularly cultivated land as well as ownership of livestock is referred to as productive assets. These assets are a prerequisite in the productive activities for agricultural production. As participants in the focus group discussion noted, land size and land fertility were the most important factors for differences in agricultural production and wealth disparities and differences in coping mechanisms. The researcher then sought to examine whether land holding per household varied among the samples including household land holding size. Farm size has great impact on understanding the impacts of climate change and on maize production. Hence, by appraising the yearly income respondents were selected by the land size that they have more than 0.25 hectare.

Table 17: Association with farm size and with maize productivity

Kebele	Maize yield in quintal/hectare	Frequency	Farm size in hectare			Total
			0.25-0.5 hectare	0.6-1 hec	> 1 hectare	
Wolidaya	15-17	Freq.	27	4	0	11
			50.0%	17.4%	0.0%	18.3%
	18-20	Freq.	17	8	0	15
		%	50.0%	34.8%	0.0%	25.0%
	21-23	Freq.	0	10	20	16
		%	0.0%	43.5%	26.1%	26.7%
	24-26	Freq.	0	31	27	18
		%	0.0%	4.3%	73.9%	30.0%
Langano	15-17	Freq.	25	0	0	15
		%	51.7%	0.0%	0.0%	24.6%
	18-20	Freq.	13	41	0	34
		%	44.8%	75.0%	0.0%	55.7%
	21-23	Freq.	0	23	13	6
		%	0.0%	10.7%	75.0%	9.8%
	24-26	Freq.	11	14	11	6
		%	3.4%	14.3%	25.0%	9.8%
Qumudo	15-17	Freq.	22	0	0	2
		%	25.0%	0.0%	0.0%	4.3%
	18-20	Freq.	26	17	0	13
		%	75.0%	30.4%	0.0%	28.3%
	21-23	Freq.	0	26	12	18
		%	0.0%	69.6%	13.3%	39.1%
	24-26	Freq.	0	0	13	13
		%	0.0%	0.0%	86.7%	328. %
Total		Freq.	81	174	62	278
		%	100%	100%	100%	100%

Source: Field Survey, 2021

Similarly, respondents' maize productivity was also examined in relation to their farm size using the cross – tabulation and the chi-square test. Accordingly, the ability of maize product and adapting CC of the respondent decreasing with increasing farm size, so that, the two are directly related. To confirm whether the observed association observed between income and access to residential land is statistically significant or not, the Pearson chi square was tested.

Additionally, farm size was other variable that suggested by having effect on maize productivity by researcher. As above table shows among 51 household heads 0.25-0.5-hectare maize farm, 50(98 %) respondents were producing below 20-quintals maize from one hectare and the remaining 1(2%) of them were harvesting more than 20 quintals. Likewise, among 74 respondents has 0.6-1 hectare farm size, 40(54%) respondents were producing below 20-quintals maize from one hectare and 34(46%) of them were producing more than 20quintals. Similarly, among 42 respondents how has more than 1 hectare farm size, 42(100%) respondents were producing more than 20-quintals maize from one hectare. Generally, the above data indecent a household how has more farm size producing more productivity from the same maize farmland. To examine the nexus between farmland size of the respondents' and maize productivity, the researcher used a chi-square test as follows.

Table 18: Farm size of the respondent's nexus maize productivity

Kebele	Kind of test	Value	Df	Asymptotic Significance (2-sided)
Wolidaya	Pearson Chi-Square	52.219	6	.000
Langano		44.109	6	.000
Qumudo		57.954	6	.000
Total		148.890	6	.000

Sources: Field Survey, 2021

As the above data indicated P-value of the variable is 0.000. This is less than the alpha value ($\alpha = 0.05$), the alternative hypothesis that suggested family size and maize productivity has significant association must be accepted. Meaning, there is no statistically significant difference between small and large family size in maximizing maize productivity in the study area. The Phi and the Cramer's values were also calculated to see the strength of the association. The calculated values were 0.000, which indicate that there is strong association between the two variables.

Moreover, variables: such as, source of income, farm Experience's and total maize income have no significant association with maize productivity.

4.5. Significant Explanatory Variables in maize productivity

In this study, thirteen explanatory variables were used. Based on the model results, sex, family size, temperature rising and rainfall fluctuation were found to have a negative significant, while the remaining variables; education level, farm size, persistent information and using adaptation strategy had a positive sign of association with maize productivity.

Table19: Explanatory variables in the logistic regression model (n=278)

Explanatory variables	B	S.E.	Wald	Df	Sig.	Exp(B)	93% C.I.for EXP(B)	
							Lower	Upper
Age of the respondents	-.907	.6657	4.125	1	.077	3.242	.980	5.127
Sex of the respondents	-4.95	2.22	0.45	1	.001	62.42	5.700	482.105
Marital Status	-.172	.448	.148	1	.701	.942	.374	3.896
Education level	1.93	.699	8.647	1	.006	.245	.041	.614
Farming experience	.898	.542	4.262	1	.071	.650	.202	1.003
Farm size in hectare	-2.16	.560	4.321	1	.038	.312	.113	.861
Family size	.529	.759	.062	1	.044	.217	1.361	9.473
Maize yield in quintal	1.278	.535	5.701	1	.076	3.591	1.361	9.473
Sources of income	-.304	.343	.789	1	.374	.738	.396	1.373
Temperature trend	-.839	.785	7.96	1	.032	6.322	.441	4.195
Rainfall fluctuation	-1.01	.419	5.915	1	.015	.361	.169	.771
Persistent information	2.56	1.003	6.556	1	.010	.077	.012	.472
Using adaptation strategy	1.107	.739	.021	1	.025	1.113	.292	4.248
Constant	-2.06	2.32	.878	1	.475	.327		

Number of observation: 278 B=regression coefficient Exp (B) =odds ratio

Sig. =significance S.E. = Standarderror,-2Loglikelihood= 178.165a

Cox & Snell R Square=.270, Nagelkerke R Square=.361

Source: binary logistic regression model output, 2021

Wald statistic: Alternatively, when assessing the contribution of individual predictors or independent variables in binomial logistic regression model, one may examine the significance of the Wald statistic. The Wald statistic, analogous/comparable to the t-test in linear regression, is used to assess the significance of coefficients i.e. test the effect of individual predictor while controlling other predictors. If the Wald statistic is located outside the lower and upper limit of a given confidence interval, null hypothesis is rejected and the independent variable is significant. The reverse is true when Wald statistic is located within the interval. In this model, Wald statistic test is used to assess the significance of an individual predictor.

B (β): This is the coefficient for the constant (also called the "intercept") and the independent variables of the model. In binomial logistic regression, the regression coefficients represent the change in the logit for each unit change in the predictor. Given that the logit is not intuitive, focus is given for a predictor's effect on the exponential function of the regression coefficient – the odds ratio.

S.E: This is the standard error around the coefficient for the constant.

Sig.: This is the chi-square test that determine whether the association between independent variable and depend variable is statistically significant by comparing the p-value (sometimes called the prob-value) of independent variable with the chose significance level. The association is statistically significant and null hypothesis is rejected when the p-value (value listed in the column called "Sig." is smaller than or equals to the specified significant level like .05 or .01 or 0.1. Whereas, when p-value listed in the sig. column is greater than the specified significance level, the association between the independent and dependent variable is statistically insignificant.

Exp (B): This is the exponentiation of the B coefficient, which is an odds ratio. This odds ratio is easier to interpret than the coefficient. It is used to interpret the relation between the independent variables and the probability that the dependent variable will be 1. The odds in favor of an event occurring is defined as the probability the event will occur divided by the probability the event will not occur. The odds ratio measures the impact on the odds of a one-unit increase in only one of the independent variables. Came up with different results as to what factors can influence maize productivity, considered the socioeconomic, cultural and technological characteristics as the decisive factors that determine maize productivity. To mention some, household characteristics (age, sex, family size, education level, and so on), farm characteristics (farm size, total maize income and income sores), and institutional arrangements (access to CV information, adaptation strategy, and adequacy of training on CV adaptation are to be considered. In addition, physical factors (temperature races and rainfall fluctuation).

Elaboration on Significant Explanatory Variables

Out of the thirteen variables, eight of them were statistically significant in the model while the rest were not significant at ($p<0.05$) probability level. Despite, their differences in relative of weighting factors.

The significant variables included sex, education level, family size, farm size, temperature rising, rainfall fluctuation, access to CV information and using CV adaptation strategy. Nevertheless, the rest were insignificant variables. The interpretations of the significant explanatory variables are given below.

Gender: is associated with negative associated with maize production. The result from binomial logistic regression model in the above indicates negative sign for sex variable (β of 3.95), which implies negative association between sex and maize productivity. This shows that as number of woman household increase reduce maize productivity and adapting CV. Since the Sig. statistic or p-value (0.001) is less than the chosen significance level (α= 0.05), the association between sex and maize productivity is statistically significant.

In other way, as Wald statistic of sex (0.45) is outside of 93 percent confidence (5.7-482) lower and upper so the developed research suggestion that there is significant association between sex and maize productivity. The result from binomial logistic model can be interpreted as, other variables being constant; maize production is decrease from male to female household by 52.42 intercept. This trend has significant implication for maize production as female might be less interested in the adapting new production systems of CV. Similarly, Nuru, (2019) in relation to gender, note that households headed by males have a higher probability of getting information about climate change and using adaptation than female households do.

Education level: It was assumed that education is associated with maize productivity. The result from binomial logistic regression model in the above shows positive sign for education level variable (β of 1.932), which implies positive association between education level and maize productivity. This shows that as level of education increases maize productivity by implementer reduce of CV adaptation strategy. Since the Sig. statistic or p-value (.006) is lesser than the chosen significance level (α= 0.05), the association between education level and maize production is statistically significant.

Wald statistic of binomial logistic model in education level (7.67) is outside of 93 percent confidence interval (.041-.514), the developed research suggestion that there is significant association between education level and maize productivity is accepted. In other way, decrease in one year schooling decreases the odds ratio in favor of non-defaulting by a factor of .145, ceteris paribus. This implies that education plays great role in raising the level of awareness, exposure to technologies, access to information and to CV adaptation strategy which increase production.

In approval of similar studies with in a country and abroad also shows, Scott(2011), the educational level has significantly influenced the choice of all adaptation strategies, educated and experienced farmers are expected to have more knowledge and information about climate change and the agronomic practices that they can use in response accordingly. Furthermore, Esayas et *al*.,(2019), observed a positive relationship between the education level of the household head and the adoption level of improved technologies and climate change adaptation to increase productivity.

Family size: this variable assumed that it is associated with maize productivity. The result from binary logistic regression model in the above table indicates positive sign for family size variable (β of 1.529), which implies positive association between family size and maize productivity. This shows that as the size of family increases, it also increases the people working in farm and productivity increase. Since the Significant statistic or p-value 0.044 is smaller than the chosen significance level (α= 0.05), the positive association between family size and maize productivity is statistically significant.

On the other side, as Wald statistic of family size (.062) is outside of 93 percent confidence interval (1.361-9.47), the result of the model suggests that there is significant association between family size and maize productivity hence it is accepted. The result from binomial logistic model can be interpreted as; other variables being constant, larger family size could lead to increase in maize productivity by 0.217. In other words, in family size increases the odds ratio in favor of defaulting by a factor of 0.217 ceteris paribus. This implies that family size play great role in maize production. This result is supported by the finding of Abraham Alemu, (2017)indicating farming experience facilitates the identification and implementation of any adaptation strategy and experienced farmers are expected to have more knowledge and information about climate change and the agronomic practices that they can use in response accordingly.

Farm size: It was assumed that farm size is associated with maize productivity. The result from binary logistic regression model in the above table indicates negative sign for farm size variable (β of -1.16), which implies negative association between maize farmland size and maize productivity. This shows that as the farmland size increases, it decreases the maize productivity and other variable that can affect maize productivity is constant. Meanwhile the Sig. statistic or p-value (.038) is lesser than the chosen significance level (α= 0.05), the negative association between farmland size and maize productivity is statistically significant i.e., the farmland size affects the variance in probability of implementer's embracing performance.

By 93 % confidence Wald statistic of farm size of farm size was (4.321) and with (0.113-0.861) interval, the result of the model suggests that there is significant association between farm land size and maize productivity hence it is accepted. The result from binomial logistic model can be interpreted as; extra variables being persistent, larger farmland could lead to reduction in maize productivity by. In other words, decrease in farmland size increases the odds ratio in favor of no defaulting by a factor of 0.217 ceteris paribus. This implies that farmland size play great role in affecting maize productivity practices.

This Constitute with what was expected earlier in the logical framework that a farmer require relatively large size das no largely affect household income as small farm size and not constitute to use different climate change adaptation strategies as farm size affect income of household. When comparing results of the same studies carried out with in a country, Farm size determines the decision to combine multiple strategies to cope with climate change. As confirmed by Taffesse *et al*. (2011), who reported that large scale farmers are more likely to adapt to climate change because they have more capital and resources.

Temperature trend: (Ameyu & Agricultural, 2017andWilliams et al., 2017) reported that temperature have correlation with maize productivity. The result from binary logistic regression model in the above table indicates negative sign for maize productivity variable (β of -0.839), which implies negative association between temperature rising and maize productivity. This shows that as the temperature increases, it also decreases the maize productivity by decreasing climatically suitability. For instance this variable is significant statistic or p-value 0.032 is a lesser amount of than the taken significance level (α= 0.05), the negative association between temperature rising and maize productivity is statistically significant.

Fatherly, as Wald statistic of temperature tend (7.96) is outside of 93 percent confidence interval (.441- 4.195), the result of the model suggests that there is significant association between temperature rising and maize productivity hence it is accepted. The result from binomial logistic model can be interpreted as; even if the remain variables is unchanged, temperature rising could lead to decrease in maize productivity 6.322. In other words, in temperature rising increases the odds ratio in favor of non-defaulting by a factor of 6.322 ceteris paribus. This implies that temperature rising play great role in maize production

Rainfall fluctuation: As well as it is expected to have associated with maize productivity. The outcome from binary logistic regression model in the above table indicates negative sign for maize productivity variable (β of -1.018), which implies negative association between Rainfall fluctuation and maize productivity. This shows that as the Rainfall fluctuation increases, it also decreases the maize productivity by decreasing climatically suitability and fluctuating season. Since the Sig. statistic or p-value .015 is minor than the chosen significance level (α= 0.05), the negative association between Rainfall fluctuation and maize productivity is statistically significant.

Additionally, Wald statistic of maize productivity (5.915) is outside of 93 percent confidence interval (.169- .771), the result of the model suggests that there is significant association between Rainfall fluctuation and maize productivity hence it is accepted. The result from binomial logistic model can be interpreted as; other variables being constant, larger Rainfall fluctuation could lead to decrease in maize productivity 0.361. In other words, in Rainfall fluctuation increases the odds ratio in favor of non-defaulting by a factor of 0.361 ceteris paribus. This implies that Rainfall fluctuation play great role in maize production. This is consistent with other studies Lundy & Ramirez, (2011) and Oriana *et al*., (2015) (2004) where changes in temperature, rainfall patterns and humidity were directly related to increased incidences of agricultural production. This is understandable because changes in temperature, timings of seasons and rainfall patterns may lead to increased populations of weeds in grasslands, and incidences of pests and diseases of grasses and crops (Nuru, 2019).

Persistent of information on climate change:

Persistent of information: the other factors affecting farmers' decision in CV adaptation strategy practices for maize productivity. This variable has odd ratio and P value of .077 and 0.010 respectively and have regression coefficient (2.56) this is indicate positively associated to farmers' information persistence to CV adaptation mechanisms and maize productivity significant at 1% level of significance. The odd ratio indicates that the probability of maize productivity increased by 0.077 times as the household heads have hay information towards Adaptation practices maize productivity is increased.

In this study, it was expected farmers with access to climate change information were more likely to observe changes in climate and were therefore more likely to adapt than those without access to climate change information. As well, this study also hypothesized that there would be a positive relationship between availability of CV information and adaptation to climate change. The marginal effect of lack of attention of the household head on implementing CV adaptation strategy practice with a value of 2.567 implies that keeping other factors constant, the likelihood of implementing CV adaptation is increased maize productivity by 2.567% as the household heads are paying high attention for information.

Using of adaptation strategy, the result from binary logistic regression model in the above table indicates positive sign for adaptation strategy variable (β of 1.107), which implies positive association between using of adaptation strategy and maize productivity. This shows that as the using of adaptation strategy increases, it also increases maize productivity. Since the Sig. statistic or p-value .025 is minor than the chosen significance level (α= 0.05), the positive association between using of adaptation mechanism and maize productivity is statistically significant this studs concede with (Iscaro, 2014 and Jaramillo *et al*., 2011).

Wald statistic of adaptation strategy also (0.021) is outside of 93 percent confidence interval (0.292-4.248), the result of the model suggests that there is significant association between climate change and variability adaptation strategy using and maize productivity. The result from binomial logistic model can be interpreted as; extra variables being constant, using of adaptation mechanism could lead to increase in maize productivity 1.113. In other words, as using of adaptation strategy increases the odds ratio in favor of defaulting by a factor of 1.113ceteris paribus. This implies that using of adaptation strategy play great role in maize production

To test the overall good fitness of a binary logistic regression model, Hosmer-Lemeshow test of goodness-of-fit was utilized. Accordingly, the P-value found to be 0.634, which is greater than the alpha value (α = 0.05). Hence, the null hypothesis would be accepted. Therefore, the model is a good fit.

Hosmer - Lemeshow Test

Step	Chi-square	Df	Sig.
1	8.115	10	734

4.5.6. Climate variability Adaptation Strategies

Analyzing adaptations made by all respondents revealed that an integrated farming system was considered to be one of the most important adaptations in response to climatic variability. In Siraro Badawacho *Woreda*, farmer's ability to adapt climate variability is limited due to lack of knowledge and economic resources, and their vulnerability is put emphasis on by heavy dependence on the climate, because farmers depend on the rain fed agriculture system. Given the diversity of the constraints they faced, the general capacity to cope to climate variability is currently very low. There are no good national action plans which take into account short or long term climate variability. Various adaptation strategies were being employed by farmers in response to climate variability in the study area (Figure 11). Surveyed households who have observed climate variability in the last years were asked about their primary adaptation strategies in the face of climate variability.

Accordingly, farmers used different climate variability adaptation mechanisms to reduce the impact of climate variability. Among the adaptations measures, majority of farmers have used changing crop type/varieties (30.3%) and soil and water conservation (24.1%) in order to minimize and/or optimize the opportunities of climate variability. These strategies were employed in order to adapt erratic and unreliable rainfall, increased heat stress and drought. Change crop types/varieties enable farmers to reduce the risk of crop fail and yield reduction. Soil and water conservation activities done by the campaign made by agricultural extension services from the local government and NGOs and was used to avoid the risk of flooding, land degradation, conserve soil and water as well as improve soil moisture and organic matter retention, hence ensuring increased crop yields.

In addition, farmers have employed crop diversification (9.2%), cropping technologies (15.9), changing planting date (13.8) and using irrigation (4.1%). On the other hand, 2.6% of the farmers did not use any of the adaptation options. Previous studies are in agreement with these results. For instance, major adaptation strategies used by farm households include changing crop varieties, crop diversification, adoption of soil and water conservation measures, changing planting dates, supplementary irrigation and water harvesting are considered as a better strategy for adapting climate variability impact in Ethiopia (Tessema *et al* (2013). Similarly, Mengistu (2011) also reported that irrigation, changing crop types/varieties and soil and water conservation practice are commonly used climate change adaptation methods by the farming community of Adiha.

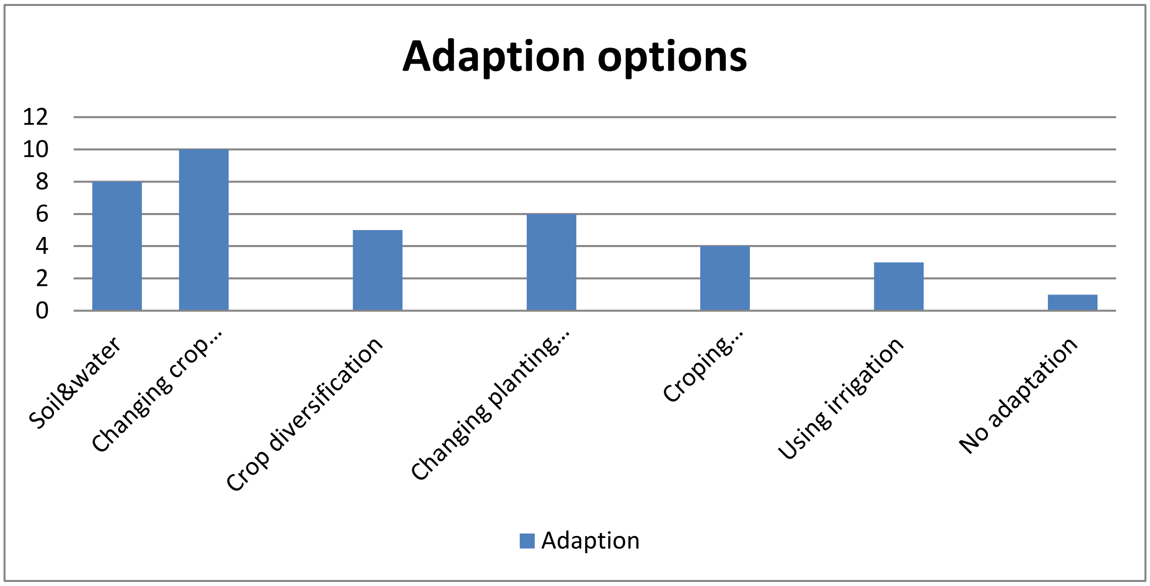


Figure 11: Climate variability adaptation measure in the SBW

Source: Own survey, 2021

4.6. Major Challenges of Adaptation Strategies on Climate Variability

Despite all efforts to minimize the variability in climate, the world needs to adapt to the upcoming changes as well. This adaptation to climate variability is necessary to prevent societies from disasters and disruption ((Pavanello, 2014). However, several socio economic challenges have been hindering farmers' effort to undertake various adaptation mechanisms to in response to the existing climate variability effects on their likelihoods (Assefa and Abay, 2011). The data from survey questionnaire reveals that the major factor that impeded farmers' attempt to adjust themselves and their likelihood to climate variability include; 37% Spreading of new disease and pests on maize crop, 21% lack of awareness of the local population about climate variability and its impacts, 16% is fluctuation of price of agricultural products while increasing cost of fertilizers and other commodities to be bought from markets, 15% shortage of infrastructure (FTC, veterinary services, roads and markets and health centers etc.), 8% absence of markets in the nearby areas to sell our agricultural products and the remaining 3% is other reasons such as poor management of resources, lack of institutional capacity as mentioned by respondents in the study area (table 18).

Table 20: Major Challenges of Adaptation Strategies

Challenges of adaption strategies	Frequency	%
Spreading of new disease and pests on maize crop	90	37
Lake of awareness of local population	60	21
Fluctuation of price on agricultural products	46	16
Shortage of infrastructure	43	15
Absences of market	23	8
Lake of institutional capacities	3	1
Poor managements of recourses	6	2
Total	278	100

Source: Own Survey, 2021

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study was conducted to investigate the effect of climate variability on maize production in the two different agro-ecological zones of Siraro Badawacho *Woreda*. Langano and Qumudo *Kebele* were selected from lowland agro-ecological zone, Wolidaya from mid agro-ecology.278 sample households were selected to conduct this study. To achieve the objective of the study, both descriptive and inferential statistics were employed to investigate the impact of climate variability on maize productivity. This socio-economic and adaptation related variables in controlling climate effects play a crucial role for the betterment of agricultural practices. The size of land area is an important factor, especially for large family size households, since a larger area enable them to spread their risk from adverse climate effects and to reduce the net effects from the change. Larger maize production land area may provide better opportunities for efficient use of resources and the possibility of growing different maize seeds types.

The analysis of temperature data obtained from (NMAE) Hossana station in 2021 for last thirty years, the minimum annual temperature was increasing of *in 0.0679^{o}c and 0.1278℃ p* three decades in Siraro Badawacho woreda and maximum annual temperature was also increasing in 0.079^{0}c with 0.47 R^2The majority of respondents aware regarding temperature trends increasing and revealed that rainfall fluctuating in study area have over the thirty years (1989-2019).

The study also assessed farmers' adaptation strategies of climate variability and the extent to which these adaptation strategies have influenced their current practices with respect to adapting with changes in temperature and precipitation. Most of the interviewed farmers for the studied kebeles perceived that they have observed the changing temperature and precipitation, such as reduced amount of rainfall (59.7%), increasing temperature (60%), shift in the timing of rainfall and shortened period of raining days. They also stated that these changes have been affecting their farming activities. Given this perception and depending on the farming system, farmers have practiced several adaptation mechanisms.

5.2. Recommendation

Based on the findings of this study, the researcher would like to recommend the following: On the basis of this study, the following recommendations have been drawn to reduce the impacts of climate variability within the study area:

- Irrigation activities should be implemented in the plain areas where rivers can be used best, as this helps to overcome the hazards created on agricultural sector in the periods of rain shortage particularly in low land part of the study area.
- There should be promotion activities to enhance farmers' participation on awareness creation activities as it is highly needed in the field of climate variation or weather forecast
- Educating and raising the awareness of the local communities, to adopt climate variability impact on maize production should be under taken by the Woreda agricultural office and extension agents.
- If farmers are depending only on agriculture, they could easily be sensitive to and affected by the adverse effects of climate variability. Therefore, encouraging local farmers to get engaged in various occupations which may be under taken low capital such as bee keeping, poultry and other off farm activates other than agriculture is worthwhile to resilience.
  - Minimize the risk related with climate variability.
  - Building the capacity of rural community through;
  - Providing effective level of fertilizer with reasonable price.
  - Providing training to practitioner and facilitating modern livestock breeding practices.
- Additional meteorological stations are needed to exactly record the climate data and assist to determine any changes in long term climate variations with full confidence since the numbers of available climatic stations in the study area are few in number. So, continuous climate data collection and recording should be maintained.
- encouraging local farmers to get engaged in various occupations which may be under taken low capital such as bee keeping, poultry and other off farm activates other than agriculture is worthwhile to resilience; Minimize the risk related with climate variability.

- Building the capacity of rural community through; providing effective level of fertilizer with reasonable price.
- Improving infrastructure (roads, markets, schooling storage and distribution and extension services) and the like.

Finally, further studies which could address the adaptation and coping mechanisms, and the existing challenges in various agro ecological conditions should be conducted so as to provide more options to policy formulation and enhance sustainability of livelihood of rural community in the face of changing environment.

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APPENDICES

Appendix I: Field Survey Questionnaires for Households

My name is Senait Ayele Lodebo

Dear household head, as one of maize producer, your household has been selected that could be used to assess the effect of climate change & variability in maize production. I assure you that, all the information will be provided are special for academic purpose and not otherwise. Therefore, you are kindly requested to respond truthfully to the following questions.

I thank you in advance!

Region--- Zone--

Woreda--- Kebele --

Questionnaire Number-----------------------

Please read each item separately and indicate your response by putting a tick (□) mark under one of these alternatives.

Section1: Socio-demographic Characteristics of the Respondents

1. Sex: {1}.Male ☐ {2}. Female ☐

2. Age: {1}18- 30 ☐ {2} 31-40 ☐ {3}. 41-50 ☐ {4}>50 ☐

3. Marital status: {1} Married ☐ {2} unmarried ☐ {3} Divorced ☐

4. Educational status: {1} Unable to read and write ☐{2}. Read and write☐

{3}Elementary school (Grade1-8) ☐ {4} secondary school (grade9-12) ☐

{5} diploma and above ☐

5. Years of experience in farming: _____________

6. Number of members in household_________________________

8. Number of household members who work on the farm________________

9. What is/are your means of livelihood or major source/s of income? {1} maize production {2} Crop production {3} Mixed farming {4} other _________________________

10. If maize production, what is the size of maize farm (hectares) ____________________________

11. What is your annual yield from the maize production? (in Quintal) __________

Section 2. Questions Related to Maize Productivity

1 In the last 30 years, is maize productivity increase in your locality? ☐ Yes ☐ No

If yes what is the reason ____

2 In the last 30 years, is maize productivity decrease in your locality? ☐ Yes ☐ No

If yes what is the reason ____

3. In this time is your farm land suitable for maize production? {1}☐ Yes {2}☐ No

If **yes** from when {1} ☐ after 10 years {2}☐ from 10- 20 years

{3}☐From 20- 30 years {4}☐ before 30 years

If **no** from; {1}☐ after 10 years {2}☐ 10- 20 years

{3}☐20- 30 years {4}☐ before 30 years

7 In the last 30 years is there fluctuation in maize production in your area?

{1} ☐ Yes {2}☐ No

If **yes** {1} Increased☐ {2} Decreased ☐ {3} Stable ☐

8 Do you remember the best maize production year's in the last 30 years _______________and worst year's ______________________

What is the reason for high production? ___________________________________

What is the reason for low production? ____________________________________

Section 3: Climate Change Trends of the Study Area

1. Do you think that climate change has been occurred in your area?

{1} yes ☐ {2} No☐{3} I don't know ☐

If yes, for how long have you noticed the changes?

☐ Less than 10 year ☐ from 10-20 years ☐ More than 20 years

2. If your answer in Q. No 1 is yes, what is/are indictors of the climate change? (You can choose more than one responses)

{1} Repeated drought occurrence ☐ {2} Increase in the occurrence of maize disease ☐

{3} Increase maize insects ☐ {4} Decrease and /or dry out of water source ☐

If others (specify)……………………………………………………………………

3. How do you characterize the weather of this area in terms of its temperature?

{1} very hot ☐ {2} hot ☐{3} moderate ☐{4} cold ☐{5} very cold ☐

4. Do you think that there is any change in temperature trend in your area in last 10 to 30 years?

{1} yes ☐{2} No ☐ {3} I don't know ☐

5. If yes, for Q.No-4, how?

{1} Increase very much ☐ {2} moderately increase ☐

{3} decreases ☐ {4} Decrease very much ☐

6. How do you characterize the weather of this area in terms of its precipitation?

{1} very high ☐{2} high ☐{3} medium ☐ {4} low ☐{5} very low ☐

7. Do you think that there is any change in precipitation trend in your area in last 10 to 30 years?

{1} yes ☐ {2} No ☐ {3} I don't know ☐

8. If yes, for Q. No 7, how?

{1} Rainfall increase ☐{2} Rainfall decrease ☐{3} Fluctuation in rainfall ☐

9. Do you get information on rainfall and other weather conditions?

{1} Yes ☐{2} No ☐

10. If yes, for Q. No. 9, from where?

{1} Radio ☐ {2} Television ☐ {3} Meteorological staff ☐ {4} Agric. Extension ☐

11. Have you noticed any climatic changes' negative impact on maize production?

{1} ☐ Yes {2} ☐ No

If yes what? ____

Section: 4 Adaptations to Climate Change

1. Do you adopt any strategies or measures to reduce the effects of climate change on your farming activities?

   {1} ☐ Yes {2} ☐ No

2. If yes, for Q. No.1, from where do you get the strategies or measures?

{1} Indigenes knowledge ☐{2} Agriculture officer ☐{3} NGO ☐

{4} If Others ____

3. What are the major climate variability adaptations measures you to have practiced in the response of climate variability effects in your farming activities? (Multiple answers are possible) {1}. Soil and water conservation {2}. Changing planting date {3}. Selection of crop verities {4}. Using cropping technologies {5}. Using Crop diversification and irrigation

4. What are the major factors that hinder you to adapt the effects of climate variability? (Multiple answers are possible) {1}, Poverty {2}, Poor market accessibility in the area {3}, Lack of infrastructure {4}, others (specify)

Appendix II: Interview Checklist for Key informant (KII)

Interview Checklist for Experts

Name ______________________

Position ______________________

Education /profession__________

1. In the last 10-30 years, is there maize production fluctuation in your locality?

☐ Yes ☐ No

If yes what is reason?

2. What are the impacts of climate change on maize productivity in Siraro Woreda?

3. Do you think that the maize productivity trends because of climate change? How? _

4. What is the pattern of rainfall over the past 30 years:

(1) Decreasing (2) increasing (3) stable

5. What is the pattern of temperature over the past 30 years:

(1) Decreasing (2) increasing (2) stable

6. What is the effect of climate change on maize production? ______________________

7. Are you experiencing climatic suitability for maize production in the last 10-30 years in your locality? (1) Yes (2) no

8. What is your maize yield per 0.25-hectare in your area in the last 30yers?

9. What activities are done by government and non-government institutions to cope with the effects of climate variability at your area?

10. What are the main challenges to overcome the effects of climate variability and how do you think they can be improved?

Appendx III: Interview Checklist for Key informant (KII)

Name_________ Age__________
Sex_________ Education ________ Kebele: ____________

1. Is there a problem of climate change and climate variability in your locality?

2 What is your perception on the general trend of temperature and rain fall pattern; the magnitude /intensity, frequency and its distribution of rain fall; the duration of rain fall (onset and cessation) and period in which rain start and end falling?

3. What are the major impacts of the climate variability on maize productivity?

4. Are there alternative system practices as adaptation strategy to cope with climate change in general climate variability in particular?

5. What is your adaptation strategy which is entirely based on endogenous knowledge of the local community?

6. What activities are done by government and non-government institutions to cope with the effects of climate variability at your area?

7. What are the main challenges to overcome the effects of climate variability and how do you think they can be improved?

Appendix IV: Checklist for Focus Group Discussions (FGD)

1 Do the prevailing rainfall and temperature patterns are affecting maize production in your locality? How?

2. Do the prevailing rainfall and temperature patterns are affecting the environment in your locality? How?

3. Are there any factors contributing to reduce climate change effect on maize production in your area?

4. What is the best adaptation strategies employed by government, peoples and nongovernmental organization?

5. Is there any adaptation options to minimize climate variability?

Thank you for your kind co-operation

Appendix V

Annual maximum temperature of Siraro Badawacho woreda 1989-2019

Years	jan	Feb	mar	Apr	May	Jun	jul	Aug	sep	oct	nov	dec
1989	32.6	32.7	33.8	32.22	30.3	30.6	30.7	30.6	29.34		30.85	31.77
1990	32.8	32.84	33.3	31.57	30.89	29,16	29.15	30.01	30.76	30.35	30.21	30.76
1991	32.7	33.82	31.9	30.63	30.54	29.59	30.47	30.47	32.35	29.71	31.23	30.41
1992	29.6	28.73	30.5	31.58	31.64	31.05	32.38	32.38	32.22	33.28	33.27	31.98
1993	28.8	28.9	29.9	31.72	32.25	33.31	31.6	32.45	33.31	34.19	34.56	31.23
1994	31.2	31.43	30.4	31.38	31.19	30.59	30.72	31.77	33.05	33.05	33.02	31.65
1995	29.2	29.7	30.9	28.93	30.5	29.70	30.3	29.69	30.4	32.55	29.8	29.41
1996	29.4	31.8	32.6	32.54	33.08	30.39	27.6	28.3	28.5	29.98	32.4	31.8
1997	32.2	32.25	32.1	33.39	33.65	31.5	29.69	30.03	30.48	29.93	30.57	29.49
1998	30.8	29.1	31.4	32.01	30.12	29.6	30.87	29.47	30.17	30,67	30.29	31.72
1999	31.7	31.92	31.7	33.65	33.60	31.8	29.6	30.50	29.58	30.16	30.54	30.41
2000	28.5	30.92	32.0	33.75	31.80	29.65	29.18	30.70	32.03	29.23	32.11	32.18
2001	32.8	34.53	34.4	32.0	27.8	28.1	28.4	29.5	32.0	28.00	30.1	32.0
2002	32.4	33.8	33.4	31.7	30.2	30.1	29.7	30.6	31,7	29.9	30.7	32.0
2003	32.3	33.3	32.3	31.1	29.3	29.5	30.6	30.6	31.0	32.0	28.8	32.3
2004	34.6	33.6	32.0	30.1	29.0	29.2	34.8	34.7	31.8	29.8	29.2	29.0
2005	29.2	30.9	30.6	31.6	33.9	30.6	31.1	29.3	33.8	30.3	30.0	29.0
2006	30.0	32.0	29.7	31.1	33.5	32.56	30.7	28.2	30.7	28.2	30.7	30.2
2007	30.4	30.6	29.6	30.4	32.6	33.8	29.3	33.1	29.5	29.9	31.4	31.5
2008	30.2	30.6	33.1	33.9	29.4	32.3	30.7	31.2	31.9	33.5	32.9	29.8
2009	29.4	30.6	30.8	31.8	29.6	29.1	31.0	32.1	33.8	33.54	31.8	28.0
2010	26.6	27.4	29.1	31.8	29.4	30.8	32.9	32.4	32.9	31.7	29.3	28.0
2011	29.3	29.3	29.9	29.3	31.0	27.59	29.1	30.1	32.4	33.8	33.4	30.5
2012	30.1	NA	29.1	33.1	30.4	32.2	31.2	30.3	30.1	30.4	29.1	29.3
2013	29.4	32.3	30.7	31.2	30.1	31.9	33.5	32.9	29.8	30.6	29.4	29.6
2014	30.8	30.8	29.6	29.1	31.0	32.10	33.1	3.8	31.5	28.0	26.6	27.4
2015	29.1	31.8	29.4	30.8	32.9	32.4	32.9	31.7	29.3	28.0	31.1	29.3
2016	29.9	30.0	29.5	29.1	27.5	30.4	32.4	33.8	33.4	30.5	29.6	27.7
2017	27.7	29.2	29.4	29.3	29.6	29.6	29.1	30.7	32.0	29.2	32.1	32.1
2018	32.8	34.5	34.4	32.0	37.8	28.1	28.4	29.5	32.0	28.0	31	32.
2019	32.4	33.4	31.7	33.8	30.2	30.1	29.7	30.6	31.7	29.9	30.0	31.3

from NMAE Hossana substation

Annual minimum temperature of Siraro Badawacho woreda 1989-2019

Years	jan	Feb	Mar	apr	May	jun	jul	Aug	Sep	oct	Nov	Dec
1989	14.1	13.2	12.5	13.2	14.6	12.6	12.3	12.7	12.5	12.6	12.8	13.2
1990	12.2	12.3	12.5	12.4	12.6	12.8	13	12.6	12.14	12.8	12.6	12.9
1991	13.5	13.1	12.4	11.8	11.1	12	12.2	13.2	12.6	11.9	12.1	12.9
1992	12.2	13.3	14	13.6	13.3	12.9	12.5	12.7	12.6	12.7	12.8	13.2
1993	12.7	13	13.5	12.9	12.5	12.8	12.9	14	13.9	13.7	12.6	NA
1994	13.4	13.2	13.9	13.8	14.2	13.8	12.5	13.3	13	13.9	12.8	12.5
1995	12.3	12.8	13.6	NA	12.9	13.2	14.2	14.2	12.8	11.7	10.8	10
1996	9.6	10.3	13.9	12.8	12.5	12.8	13.8	12.5	12.7	13.7	13.1	13
1997	13.8	13.5	15	14.1	13.3	13.8	14.5	13.5	13.4	13.5	12.8	12.5
1998	14	14.2	15	15.1	15.5	NA	14	14	13.1	12.5	12.6	12.5
1999	14	13.5	13.4	13.2	13.5	12.6	11	12.5	12.2	NA	11.9	11.4
2000	12.3	13.39	13.3	12.58	12.74	12.21	12.26	12.91	12.80	12.4	12.99	12.53
2001	12.9	12.56	13.0	12.12	13.04	12.12	12.5	-NA	-NA	-NA	11.85	12.44
2002	12.3	12.84	13.1	12.78	13.1	12.58	12.63	11.55	12.55	12.17	11.93	12.69
2003	12.8	12.19	13.7	13.67	13.16	12.19	12.34	12.54	12.55	12.38	12.85	12.37
2004	12.8	12.53	13.3	13.31	13.45	12.62	-NA	12.56	12.31	11.94	12.82	12.8
2005	12.7	14.53	13.7	14.14	13.81	13.78	13.25	13.67	12.76	12.73	12.29	12.31
2006	12.8	13.6	13.7	13.92	13.59	13.13	12.80	13.26	13.38	13.32	12.84	12.72
2007	13.3	13.34	13.7	13.63	13.9	13.71	13.13	12.4	12.6	11.96	-NA	12.81
2008	13.3	12.5	13.2	11.4	11.1	12.8	13	12.6	NA	13.14	12.91	12.81
2009	13.5	13.2	13.7	14.52	14.29	13.4	13.35	13.8	12.5	13.1	12.95	13.4
2010	13.5	14.35	14.4	14.91	14.53	13.4	14.4	13.81	13.5	13.55	13.68	13.99
2011	13.3	14.21	14.6	14.55	14.76	14.11	NA	13.67	12.76	12.73	12.29	12.31
2012	13.7	14.84	14.7	14.81	14.06	13.89	13.5	13.83	13.7	14.05	13.38	12.62
2013	12.3	12.84	13.1	12.78	13.1	12.58	12.63	11.55	12.55	12.17	11.93	12.69
2014	12.7	14.53	13.7	14.14	13.81	13.78	13.25	13.67	12.76	12.73	12.29	12.31
2015	13.3	14.45	14.3	13.77	13.28	13.65	13.66	13.04	13.01	13.70	13.98	13.73
2016	13.7	14.09	14.4	13.94	14.27	14.13	13.95	13.87	14.05	13.38	12.62	13.38
2017	NA	14.4	14.1	13.73	13.92	13.4	13.9	13.39	13.97	13.6	12.8	12.9
2018	13.4	13.58	13.5	12.98	13.1	13.12	13.22	12.87	13.7	13.14	13.63	12.36
2019	12.7	14.08	14.4	14.05	13.36	13.74	13.28	13.73	13.94	13.29	12.78	13.88

from NME Hossana substation

Rainfall data of Siraro Badawacho woreda 1989-2019

Years	Jan	Feb	mar	Apr	May	jun	jul	aug	sep	oct	Nov	dec
1989	13.9	57.3	112.4	104.9	47.3	160.9	160.1	145.3	56.3	7.8	75.5	50.5
1990	12.4	74.5	90.4	176.5	165.1	130.3	24.5	10.5	3.7	12.1	57.8	156.2
1991	0.2	112.7	47.4	95.2	112.7	178.6	180.2	110.4	134.8	125.6	64.1	123.7
1992	0.0	17.7	0.8	18.4	16.8	122.2	183.2	125.3	183.1	126.0	78.5	110.0
1993	0.4	36.3	61.4	45.3	88.6	125.3	245	100.7	170.0	183.2	29.8	120
1994	0	26.0	19.0	51.2	86.1	17.7	178.1	153.6	108.0	124.9	112.4	119.9
1995	0.8	0.6	0.1	0.5	66.0	111.5	101.8	160.7	237.0	179.4	169.5	1115.5
1996	0.3	11.3	24.0	3.2	0	31.9	82.4	198.7	79.5	79.7	171.6	1722.0
1997	0.0	2.6	36.8	51.1	9.9	47.3	139.2	167.1	193.1	189.7	188.0	122.0
1998	0.2	19.6	1.60	35.9	0.0	70.2	188.9	122.3	198.5	100.0	183.2	78.0
1999	0	21.5	37.3	12.8	3.0	49.1	198.0	112.5	170.0	84.9	45.9	61.8
2000	0.1	5.9	31.0	26.2	8.0	54.0	176.4	13.0	123.5	61.5	89.7	110.10
2001	99.1	43.1	17.9	19.8	56.0	60.8	199.9	118.9	188.3	90.3	67.4	198.4
2002	192	5.8	12.4	21.8	93.0	45.2	73.0	201.1	198.0	1220.6	100.0	125.3
2003	0.5	17.9	8	34.1	56.9	44.8	84.2	199.2	149.3	128.3	178.2	83.7
2004	0.0	0.5	31.0	61.8	20.5	67.0	119.0	145.1	189.4	130.0	135.9	138.5
2005	0.7	19.0	18.4	52.4	2.8	9.7	89.2	128.0	190.9	74.2	100.0	80.2
2006	0	98.2	16.9	19.7	88.9	160.0	47.9	178.8	123.4	123.5	132.1	0
2007	43.3	120.5	14.5	93.0	130.6	90.1	120.0	134.0	197.8	141.1	154.0	93.8
2008	0	95.2	43.1	67.6	9.0	90.3	39.7	100.4	199.0	132.0	182.0	106.6
2009	0	139.3	56.1	78.0	97	120.0	88.60	125.3	183.2	244.2	145.2	112.9
2010	18.6	45.3	120.0	7.3	34.2	75.9	162.8	186.9	101.2	183.2	100.7	120.8
2011	11.7	28.1	153.9	172.0	71.8	93.0	128.8	152.5	120.2	117.9	115.6	1210.1
2012	17.8	112.0	63.9	72.0	92	43.9	7.5	100,0	190.4	198.0	152.1	190.6
2013	33.4	150.3	85.0	90.2	45,8	89.3	173.0	175.9	189.0	134.6	122.0	110.0
2014	132.3	6.2	13.4	190.1	82.3	4.0	56.3	177.7	192.2	128.0	134.4	125.7
2015	0.9	124.7	67.9	91.0	150.0	56.9	14.8	188.9	165.0	156.3	178.3	181.9
2016	5.6	57.1	190.3	192	100.3	100.1	85.8	130.3	200.0	173.8	123.2	109.4
2017	146	76.5	32.8	0.8	31.8	96.0	43,8	113.3	199.0	133.4	124.0	125.7
2018	36.8	80.2	72.0	56.3	0.9	23.8	166.9	120.3	202.1	208.6	189.5	0
2019	65.9	11.6	17.8	21.9	18.5	78.0	100.0	111.1	198.9	187.6	125.1	66.5

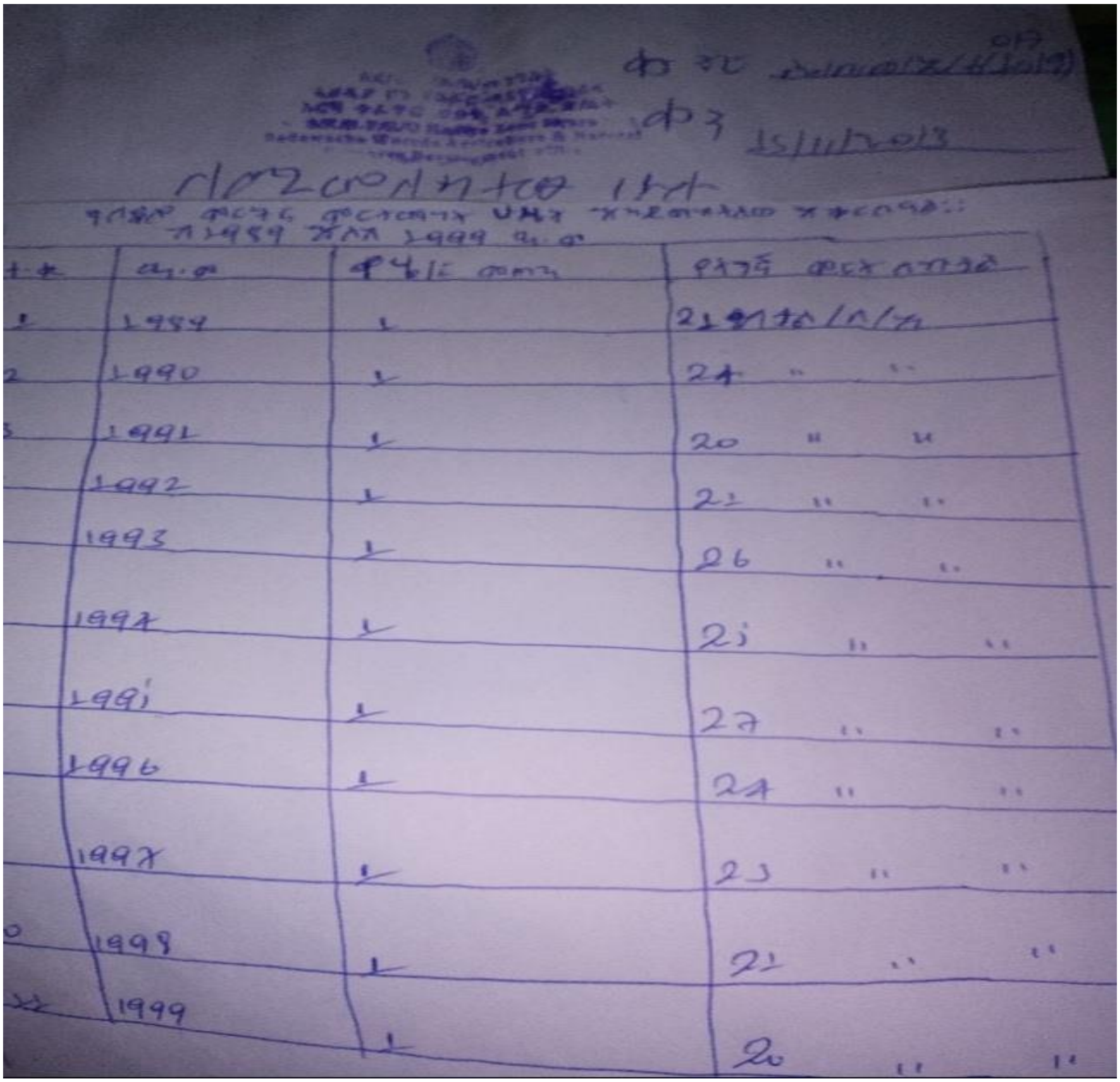
NMAE Hossana substation

Climate data of the study area from 1989-2019

Sources: NMAE, 2021

Appendix VI

Maize trend of Wolidaya from the establishment of Ebongo farmer cooperative working of maize processing

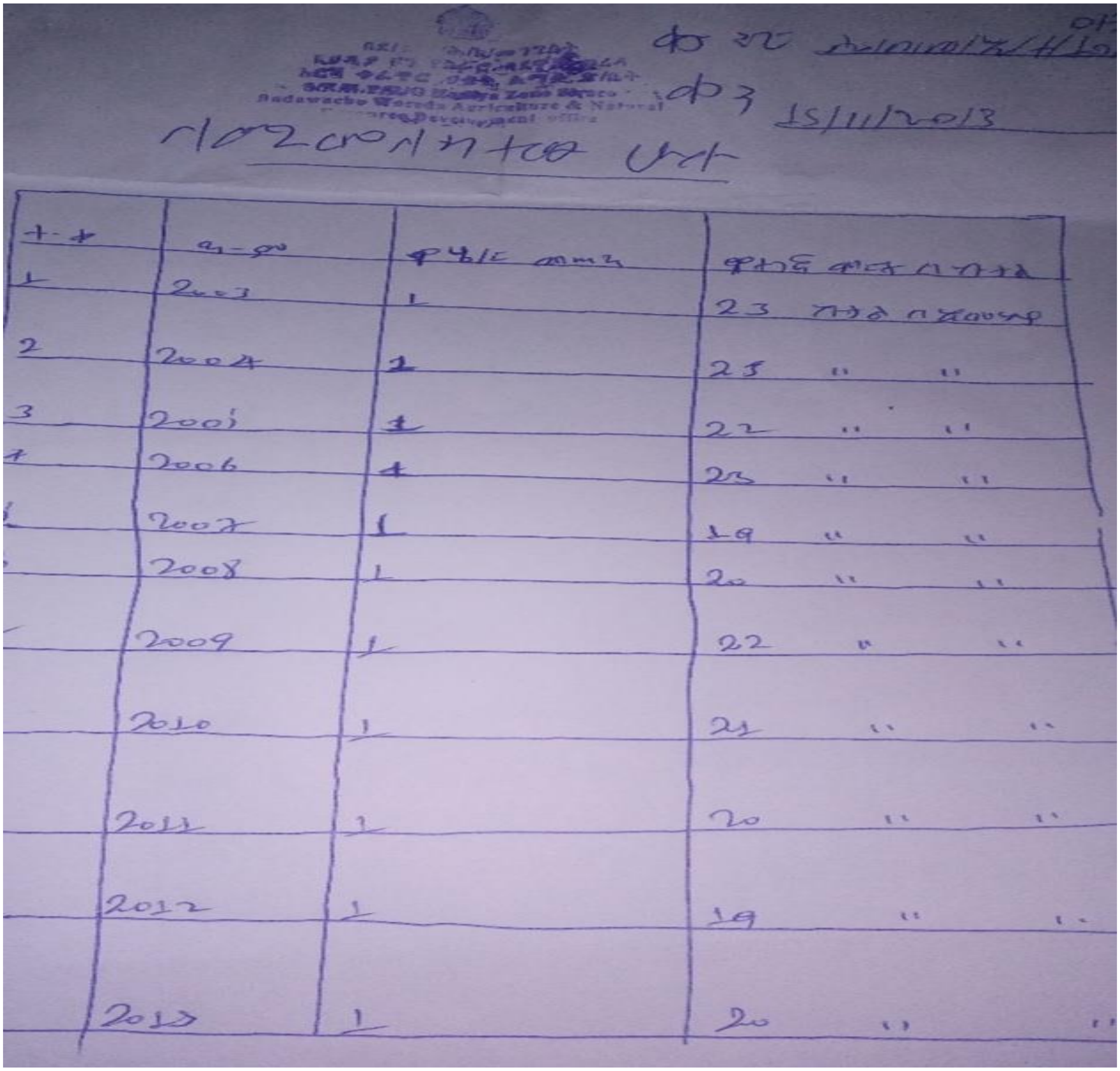


15/11/2013

ተ.ቁ	ዓ.ም	[illegible]	[illegible]
1	1989	1	21 [illegible]
2	1990	1	24 " "
3	1991	1	20 " "
	1992	1	21 " "
	1993	1	26 " "
	1994	1	25 " "
	1995	1	27 " "
	1996	1	24 " "
	1997	1	23 " "
10	1998	1	21 " "
11	1999	1	20 " "

Source; Image taken from Ebongo farmer's association work of maize processing

Maize trend of Langano from the establishment of Langano farmer cooperative working of maize processing

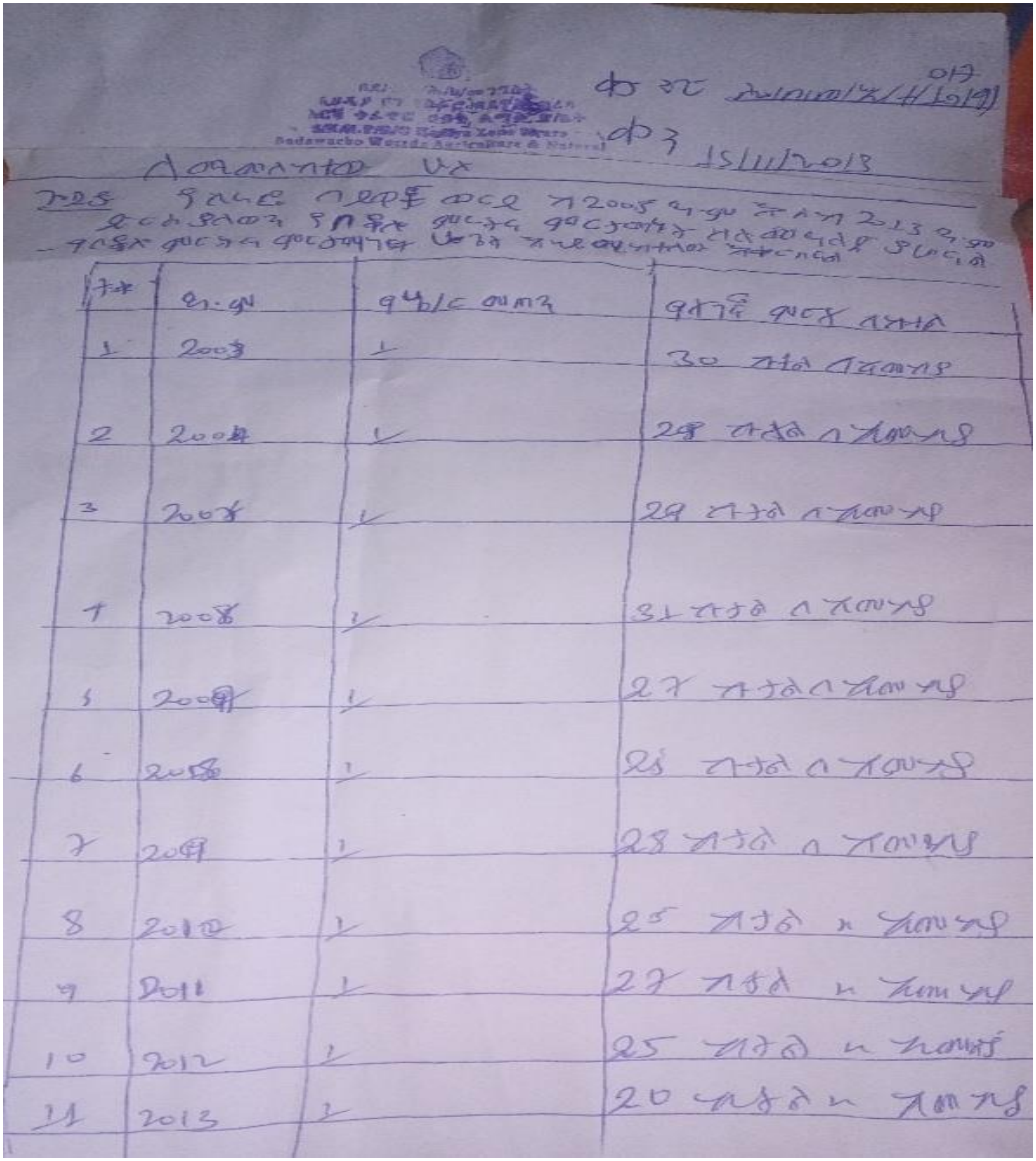


15/11/2013

[illegible]	[illegible]	[illegible]	[illegible]
1	2003	1	23 [illegible]
2	2004	1	25 " "
3	2005	1	22 " "
4	2006	4	23 " "
	2007	1	19 " "
	2008	1	20 " "
	2009	1	22 " "
	2010	1	21 " "
	2011	1	20 " "
	2012	1	19 " "
	2013	1	20 " "

Source; Image taken from Langano farmer's association work of maize processing

Maize trend of Qumudo from the establishment of Mechefera farmer cooperative working of maize processing



Source; Image taken from Mechefera farmers' association work of maize processing

Appendix VII

Raw data of three selected kebele maize production from 1989-2019

Years	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Wolidaya	3213.73	3157.370	3327.72	3240.71	3356.69	3471.21	3442.56	3427.68	3609.72	2034.86	3221.92
Langano											
Qumudo	341.640.4	3815.28	3645.86	3734.85	3786.5	3668.7	3564.5	3525.4	36243.9	3488.8	3367.8
Years	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wolidaya	2467.85	2210.96	2844.31	1005.32	2009.11	3155.22	2359.1	2642.26	1816.97	2708.09	1568.79
Langano								486.45	543.02	677.05	148.11
Qumudo	2425.8	2348.1	2216.5	224.87	2185.9	2267.1	2448.2.6	217.49	2089.8	2247.5	2028.3
Years	2011	2012	2013	2014	2015	2016	2017	2018	2019		
Wolidaya	2285.47	2326.07	1735.66	1419.45	3140.15	30863	5205.47	5570.97	6942.86		
Langano	424.398	639.38	5383.31	2925.77	3539.34	2553.39	3288.825	1921.8	2591.815		
Qumudo	2871.9	10472.5	7723.8	7145.2	7434.3	7761.5	6182	8261	9779.5		

Source: SBWAO 2011

Maize crop in study areas during tasselling stage.

Source: Researcher

Maize affected by prolonged drought during phonological stage

Source: Researcher

Maize planted late on the left and early on the right side

Source: Researcher