2023-03

Impact of Climate Change and Variability on Major Crops And Adaptation Strategies; The Case Of Minjar Shenkora District, North Shewa Zone , Amhara Region State, Ethiopia.

Asinakech Welde

BAHIR DAR UNIVERSITY
COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES
DEPARTMENT OF NATURAL RESOURCE MANAGEMENT

IMPACT OF CLIMATE CHANGE AND VARIABILITY ON MAJOR CROPS AND ADAPTATION STRATEGIES; THE CASE OF *MINJAR SHENKORA DISTRICT*, NORTH SHEWA ZONE , AMHARA REGION STATE, ETHIOPIA.

By

Asinakech Welde

March, 2023

Bahir Dar, Ethiopia

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF NATURAL RESOURCE MANAGEMENT

IMPACT OF CLIMATE CHANGE AND VARIABILITY IMPACT ON MAJOR CROPS AND ADAPTATION STRATEGIES; THE CASE OF *MINJAR SHENKORA DISTRICT*, NORTH SHEWA ZONE, AMHARA REGION STATE, ETHIOPIA.

By

Asinakech Welde

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENT AND CLIMATE CHANGE.

Advisor: Solomon Adissu (Ph.D.)

March, 2023

Bahir Dar, Ethiopia

APPROVAL SHEET

As members of the board of examiners, we examined this thesis entitled "**Impact of Climate Change and Variability on Major Crops and Adaptation Strategies in *Minjar Shenkora District*, North Shewa Zone, Amhara Regional State of Ethiopia**" by **Asinakech Welde**. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of "Master of Science (MSc) program in **Environment and climate change.**

Board of Examiners

Tatek Belay (Ph.D)		14/7/2015
Name of External Examiner	Signature	Date
Melese Gebreyies (Ph.D)		27/3/2023
Name of Internal Examiner	Signature	Date
Abebe Aschalew(Ph.D)		27/3/23
Chair person's name	Signature	Date

ii

DECLARATION

This is to certify that the thesis entitled "**IMPACT OF CLIMATE CHANGE AND VARIABILITY ON MAJOR CROPS AND ADAPTATION STRATEGIES IN *MINJAR SHENKORA DISTRICT*, NORTH SHEWA ZONE, AMHARA REGIONAL STATE OF ETHIOPIA**" by **Asinakech welde** (ID.No. BDU1300577)", submitted in partial fulfillment of the requirements for the degree of Master of **Environment and Climate Change** of Department of Natural Resource Management, Bahir Dar University, is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I received during this investigation have been duly acknowledged.

Asinakech Welde	[signature]	18/07/2015E.C
Name of the student	**Signature**	**Date**
Solomon Adissu (Ph.D.)	[signature]	18/07/2015 E.C
Name the Advisor	**Signature**	**Date**

ACKNOWLEDGEMENT

First of all, I would like to thank the almighty God for the untold and all-time grace that gave me the enthusiasm to start and complete this study. Secondly, I would like to express my deepest gratitude to my advisor Solomon Addissu (Ph.D.) for his supervision, valuable guidance and intellectual encouragement, and critical and constructive comments from the early design of the proposal to the final write-up of the thesis. I would like to express my deepest thanks to my beloved family and Mr. Habitamu Melese, crop production officer at *Minjar Shenkora* District Agriculture and Rural Development Offices **(**MSDARDO), for their unlimited support in providing valuable information. I would like to give my sincere thanks to Mr. Abebe Misganaw for his kindness, and moral and technical support from the beginning of the study up to the final draft submission. I also want to thank Minjar Shenkora District Agricultural development office, farmers, and National Meteorological Agency (NMA) for providing with the necessary information, guidance, and assistance during data collection.

Finally, my deepest gratitude also goes to Oda Bultum University for financial support to study for my master's degree in Environment and Climate Change, Regular Program at Bahir Dar University.

ABBREVIATIONS AND ACRONYMS

CCV	Climate Change and Variability
CSA	Climate-smart Agriculture
ETCCDI	Expert Team for Climate Change Detection Monitoring and Indices
FGD	Focus Group Discussion
GHG	Greenhouse Gas
KII	Key Informant Interview
MSDARDO	Minjar Shenkora District Agriculture and Rural Development Office
NAPA	National Adaptation Program of Action
NASA	National Aeronautics and Space Administration
NMA	National Meteorological Agency
NMSA	National Meteorological Services Agency
PCI	Precipitation Concentration Index
RAI	Rainfall Anomaly Index
SPSS	Statistical Package for Social Science
SSA	Sub-Saharan African

ABSTRACT

Ethiopia is one of the developing countries in which agriculture is the primary source of its economy. Being dependent mainly on rainfall, this sector has been adversely affected by climate change and variability.The main objective of this study was to investigate the impact of climate change and variability on major crops and adaptation strategies in Minjar Shenkora District. Primary and secondary data were collected for the study. Primary data were collected from household questionnaires, key informant interview (KII) and focus group discussion (FGD); whereas, secondary data were collected from the major crop data collected from 2000-2013 at Minjar Shenkora District Agricultural and Rural Development Office (MSDARDO) and climate data from National Meteorology Agency from 1990 to 2020 and National Aeronautics and Space Administration (NASA) power data . 342 sample households were random selected from three kebeles (Wolde Giorgies, Bolo Sallsia and Korma) which are located at different agroecology. The data were analyzed using Statistical Package for Social Science (SPSS) version 26 and R-software and Microsoft excel 2010. Multivarite regression anlaysis, correlation, trend analysis, Precipitatin concentration index, rainfall anomaly index, and coefficient variance and extreme rainfall and temperatures indices were used to anlyze the data. Mann-Kendall test estimate test were applied to identify the existing trend analysis. Accordingly, decrease in rainfall and an increase in temperature were recorded. Also, the results of Correlation Coefficients indicated that the duration of annual, summer, belg rainfall and Temperature had a strong positive, moderate negative, and weak positive relationship with teff, wheat, lentil, chickpea, and sorghum yield in the study area respectively. The multivariate regression analysis revealed that -20, 59, 47, 50 and 43% of the variance in teff, wheat, lentil, chickpea and soughum respectively could be explained by the climatic variables. The findings also revealed that rainfall and temperature variations have an impact on crop yield, but the impacts differ by crop in this district. Therefore, the farmers have used adaptation mechanisms such as ;- improving seed varieties, crop diversification, planting trees, soil and water conservation, changing planting dates, irrigation, water harvesting, and Growing short-maturing crops. Thus studies should be investigated on the impact of climate change and variability on major crop and its adaptation.

Keywords: Adaptation strategies, Climate change, Climate variability, Crop production, Impact.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF APPENDEX TABLE

LIST OF APPENDEX FIGURE

CHAPTER ONE. INTRODUCTION

1.1. Background of the Study

Most developing countries like Ethiopia depend on rain-fed agriculture; the effects of global warming on productive crop lands are likely to threaten both the welfare of the population and the economic development of the countries (Abid *et al*., 2014; Amogne *et al*., 2017; Solomon *et al*., 2016; Zegeye, 2018).

Variability of climatic elements, especially rainfall and temperature, may affect agricultural production as they influence the production elements like soil moisture and soil fertility, length of the growing season, and increased chance of extreme climatic conditions, although with special variations. The degree of impacts of climate change differs from one agro-ecology to another (McGuigan, *et al*., 2002; Leta, 2011).

Crops are dependent on light, temperature, moisture, and carbon dioxide (CO2) concentration to produce the grains and other crop products that are so essential to our nutrition, health, and well-being, Climate change threatens to modify both the coverings that characterize different crop production systems and the associated yield variability and production and financial risk. The temperature has major effects on photosynthesis and respiration, plant growth (Samuel *et al*.,2019; White,2018).

Ethiopia's climate variability and change are mainly manifested through the variability of decreasing rainfall and increasing temperature (Melese,2019). Moreover, rainfall and temperature patterns show large regional differences, Rainfall, and temperature in the region show substantial decadal variability (Bewket and Conway, 2007). Because Ethiopia has great geographical diversity and is mostly mountainous. The climate varies greatly from hot and arid in the lowlands to cool and temperate in the highlands. The mean annual temperature is from 17-29°C in the lowlands and 11-20°C in the highlands. Evidence shows that since 1960 the mean annual temperature of the country has risen by about 1.3°C, an average rate of 0.28°C per decade, and spatial and temporal rainfall variability has been increasing (Zegeye, 2018).

Temperatures are also very much modified by the varied altitude of the country. In general, the country experiences mild temperatures for its tropical latitude because of topography. For the IPCC mid-range emission scenario, the mean annual temperature will increase in the range of 0.9 -1.1 °C by 2030, in the range of 1.7 - 2.1 °C by 2050, and in the range of 2.7-3.4 °C by 2080 over Ethiopia compared to 1961-1990 normal. Historical climate analysis for Ethiopia indicates that the mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade (IPCC, 2007).

Climate change and variability are one of the biggest challenges in our world (Helen *et al*., 2021). It is predicted to have adverse consequences on the world's ecosystems, economies, and societies. Observational evidence from all continents and most oceans shows that many natural systems are being affected by climate changes, particularly temperature increases, Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gases concentrations, This increasing level of emissions of greenhouse gases has caused a rise in the amount of heat from the sun trapped in the earth atmosphere, heat that would normally be radiated back into space (IPCC, 2014). Climate change is a worldwide environmental threat that seriously affects agricultural productivity and it affects mankind in many ways, including its direct influence on food production (Lemi and Hailu, 2019).

The impact on agricultural activities in developing countries has been increasing because people are depend rain-fed on agriculture (Aschalew, 2014). Higher temperatures and reduce rainfall and increased rainfall variability caused by climate change depress/reduce crop yields (Aemro *et al*., 2012; Aschalew, 2014). Because, low-income countries where adaptive capacities are perceived to be low, weak institutional capacity, limited engagement in environmental and adaptation issues, and lack of knowledge, and agriculture-based economies (Aemro *et al*.,2012; Aschalew,2014; NASM, 2007; Temesgen *et al*., 2011). With the low adaptive capacity of Africa in general and Ethiopia in particular, people have developed traditional adaptation strategies to face the great climate inter-annual variability and extreme events (Solomon et al., 2016).

Rainfall is historically highly variable and there is no clear trend in the amount of rainfall over time. Studies of localized meteorological data alongside community perceptions indicate that seasonal change may already be occurring as there are declining and increasing trends in certain months of the year (Belay, 2016). The climate of Ethiopia is characterized by high annual, seasonal, and geographical variability. Amount and seasonal distribution of precipitation are varying annually and are difficult to predict, while the temporal distribution of rainfall during the growing season affects crop production significantly (Aynalem, 2020). Without adaptation climate change can be detrimental, with adaptation, vulnerability can be significantly reduced (Stone and Firdos *et al*., 2015).

Ethiopia is extremely vulnerable to drought and other natural disasters such as floods, heavy rains, frost, and heat waves (NMSA, 2007). Large parts of Ethiopia are dry sub-humid, semi-arid, and arid. The country also has fragile highland ecosystems that are currently under stress due to population pressure and associated socio-economic problems. Climate change and variability are affecting crop production (Helen *et al*., 2021). The increase in temperature and change in the rain patterns led to a decrease in crop yields (Mkonda *et al.*, 2018*)*. Some of the more common adaptation practices include making basic changes to farming systems by planting different crop varieties that may be more resistant to change, increasing the use of irrigation, or planting trees to create more shade and a cooler environment for crops that may be heat-stressed (Aynalem, 2020). This study was aimed at farmers to identify the impact of climate change and climate variability on major crops and adaptation strategies in the district.

1.2. Statement Problem

The impact is even stronger in Africa, where agriculture is truly important for daily subsistence, and where adaptive capacity is low. Therefore, it is crucial to increase the understanding of the actual climate change dynamics on agricultural activities and on the societies at the lower levels Abate,(2009) and There is growing interest in the likely impacts of climate change on agriculture, economic growth, and sustainable development. This is because the region has been experiencing increased drought in recent times due to increased temperature and reduced rainfall. Incidences of climate change include changes in soil moisture, soil quality, crop resilience, timing/length of growing seasons, the yield of crops and animals, atmospheric temperatures, weed insurgence, flooding, unprecedented droughts, sea level rises, and many more (Akinnagbe and Irohibe, 2014).

Among the Ethiopian regions, however, the Amhara is one of the most vulnerable areas to climate variability and change. The increased temperature along with a decrease in precipitation has become a serious problem in the region that frequently affected the agricultural sector. Crop-pest, livestock epidemics, hailstorms, drought, floods (Birtukan and Abraham, 2020) . The region is characterized by erratic rainfall, high land degradation, high population density, high rate of poverty and malnutrition. Irrigated agriculture is negligible in the Amhara national regional state, although 500 000 ha of land are considered to be suitable for irrigation agriculture. Moreover, the region, mainly due to natural hazards, uneven distribution of rainfall, land degradation and pest damage which all are related to climate variability. people are chronically food insecure and vulnerable people in the country. Generally, the rainfall in the Amhara region was characterized by irregular fluctuation of wet and dry years (Ayalew et al., 2012).

According to information obtained from Minjar Shenkora districts also faced with climatic change and variability because most people live in rural areas they endeavor to adapt to the possible impacts of climate change through local practices. Which is greatly climate-sensitive in its nature (MSDARDO, 2022).

Ayinalem, (2020), conducted a study on the Farmers' Responses to Climate Variability and Change in *Minjar Shenkora District* of North Shewa Zone of the Amhara Region, Ethiopia, the study was only focused on biophysical, institutional, and demographic factors affecting the adaptation strategies. However, it was not conducted on the impact of climate change and variability on the crop.

In this regard, there is no research conducted about the impact of climate change on major crops and adaptation strategies in the study area. So, this study was aimed to fill the above information gap to investigate the impact of climate change and variability on major crops and adaptation strategiesin Minjar Shenkora district, North Shewa of the Amhara region, Ethiopia.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study was to investigate the impact of climate change and variability on major crops yield and adaptation strategies in Minjar Shenkora District, Ethiopia.

1.3.2. Specific objectives

The specific objectives of this study were to:-

- ✓ Analyze the trends , variability and index analysis of temperature and rainfall for the past 31 years.
- ✓ Assess the impact of climate change and variability on Teff, Wheat, Lentil, Chickpea and Sorghum yield.
- ✓ Analyze the relationship between the temperature and rainfall with Teff, Wheat, Lentil, Chickpea and Sorghum yield.
- ✓ Identify the local adaptation strategies for climate change.

1.4. Research Question

- What is the trends, variability and index of temperature and rainfall for the last 31 years?
- What is the impact of climate change and variablity on Teff, Wheat, Lentil, Chickpea and Sorghum yield?
- What is the relationship between the temperature and rainfall with Teff, Wheat, Lentil, Chickpea and Sorghum yield?
- What are the local adaptation strategies for climate change?

1.5. Significance of the Study

Fundamentally, this research is important because understanding of the trend and variability of climate change and its adaptation strategies help stakeholders to predict the potential future changes, impacts on crops yield, and exsting adaptation strategies. It is believed that the findings of this study will be beneficial to researchers and academics involved in climate change and variability related research activities. The findings of this study will also be of vital importance to decision makers related to climate variability and change to undertake informed decisions. The knowledge gained through this study will help agricultural and rural development agents or professionals to better understand and promote adaptation strategies. In addition, it serves as a baseline data and backdrop for future research work in the areas of adaptation strategies for the choice of farmers' acceptance, including, feelings of indigenous knowledge and experiences to other farmers and utilizing them as a reference and motivating academic for future research work in the areas.

1.6. Scope of the Study

The study was limited to at Minjar Shenkora district. To assess the impact of climate change and variability impact on major crops and adaptation strategies . Crops are highly sensitive to the impacts of climate change and variability. The study's analysis focused first on climate trends , and index variabilty of temperature and rainfall, the impact of climate change and variability on major crops, the correlation between the temperature and rainfall with major crops and its adaption strategies in this district. Longitudinal research design was used.

1.7. Limitation of the Study

Some challenges occurred when conducting this study. One of the main problems faced during the study was some farmers were unwilling to give correct information on their socioeconomic and demographic situation, lack of annual major crops data , lack of related literature in the study area was taken as a limitation of this study. However, efforts were made by the researcher and able to get the required information despite these challenges.

CHAPTER TWO. LITERATURE REVIEW

2.1. Concepts and Definition of Key Terms

Climate change: Climate change as a long-term continuous change (increase or decrease) to average weather conditions or the range of weather. Climate change has been identified as the greatest environmental challenge, and it will continue in the future across the world (Arega and Bazezew, 2021 ; Mahrous, 2019).

Climate variability: Climate variability is the climate that fluctuates yearly above or below a long-term average value. The climate varies over seasons and years instead of day to day weather (Zegeye, 2018). Climatic variability is the types of changes (temperature, rainfall, occurrence of extremes); magnitude, and impacts on public health, agriculture, food security, forest hydrology, water resources, coastal area, biodiversity, human settlement, energy, industry, and financial services (Belay, 2016).

Impact: is a powerful effect that hinders crop growth due to the strong influence of climate variability and affects crop production (Asfaw, 2020).

Crop production: crop production is the main livelihood of Ethiopia farmers and it is the process of growing and harvesting the above crops for own crop consumption and sale (Kebede *et al*., 2019). Crop production is an essential part of agriculture dealing with the cultivation, protection, harvesting, and storage of cultivated plants for human use. It is the total of all activities involved in producing, preparing, and processing crops (Asfaw, 2020).

Adaptation: Adaptation to climate change refers to the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation is a way to avoid losses due to increasing temperature and decreasing precipitation (Abid *et al*., 2014).

Climate change has one of the greatest challenges the world is facing today, climate change is a change of climate which is attributed directly or indirectly to human activity-induced actions such as the widespread use of land, the broad scale of deforestation, the major technological and socioeconomic shifts with reduced reliance on organic fuel, and the accelerated uptake of fossil fuels. Climate change is an environmental, social, and economic challenge on a global scale (Belay, 2016). It alters the composition of the global and/or regional atmosphere and natural climate variability observed over comparable periods. Climatic variability is the types of changes (temperature, rainfall, occurrence of extremes); magnitude, and rate of the climate change that causes the impacts on the area of public health, agriculture, food security, forest hydrology, water resources, coastal area, biodiversity, human settlement, energy, industry, and financial services (Ishaya and Abaje, 2008; Zegeye, 2018).

Most African countries, Ethiopia is frequently identified as a country that is highly vulnerable to climate variability and change land less. The agriculture sector has been playing a very significant role in providing in Ethiopia change (Amare and Simane, 2017). However, climate change remains the major challenge to the development of agriculture and food security.

Climate variability refers to the variation around the average climate including seasonal variation in atmospheric and ocean circulation such as the EI Nino and Southern Oscillations. Similarly, further defined as the shift from normal experienced rainfall patterns of seasons to abnormal rain patterns including temperature (Mkonda, 2018). Climate variability describes how climatic elements such as temperature and rainfall fluctuate over a period (Samuel *et al*., 2019).

Climate change affects agriculture and agriculture also affects climate change. Agriculture affects climate change through the emission of greenhouse gases (GHG) from different farming practices. Adverse climate change impacts are considered to be particularly strong in countries located in tropical Africa that depend on agriculture as their main source of livelihood (Aemro *et al*., 2012).

Climate variability is already imposing a significant challenge to Ethiopia by deterring the struggle to reduce poverty and sustainable development effort. The variability of rainfall and the increasing temperature was the cause of frequent drought and famine and putting a disastrous impact on the livelihood of the people (Temesgen *et al*.,2014). Climate variability has long posed a challenge to Ethiopia, affecting agricultural productivity, economic growth, and food security (Amogne *et al*., 2017; Dereje *et al*., 2020).

2.2. Trends of Climate Change and Variability in Ethiopia

Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase (IPCC, 2014). In addition to variations in different parts of the country, Ethiopian climate is also characterized by a history of climate extremes, such as droughts and floods; and increasing and decreasing trends in temperature and precipitation, respectively. The history of climate extremes, especially drought, is not a new phenomenon in Ethiopia. So, droughts have occurred in different parts of the country at different times. Even though there is a long history of droughts in Ethiopia, studies show that the frequency of droughts has increased over the past few decades, especially in the lowlands (Temesgen, 2010).

Ethiopia, researches conducted indicate that in the past few years, the rainfall pattern has shown a decreasing trend in amount and distribution, even though the significance of the change differs among different climate types (McGuigan *et al*., 2002). Rainfall variability and associated droughts have historically been major causes of food shortages and famine in the country (Bewket and Conway, 2007).

Increasing trends in frequencies of heat stress, drought, and flooding are projected to be continued for the rest of this century, and these are expected to have many adverse effects over and above impacts due to changes in mean variables alone. Rainfall amounts have decreased and become more unpredictable, and drought is prolonged. Temperatures have also increased. Consequently, there has been declining crop productivity and increasing food insecurity. Such a situation has increased the vulnerability of local community livelihoods to the impacts of climate change (Lyimo and Kangalawe, 2010)

Many studies on rainfall patterns of Ethiopia have been carried out with a range of spatial (national, regional) and temporal (annual, seasonal, monthly) scales. Different temperature, studies on rainfall did not show any consistent pattern or trends. Also found that summer rainfall in the central highlands of Ethiopia declined in the second half of the 20th century, while not finding such a trend over central, northern, and north western Ethiopia. Instead, they found a decline in annual and summer rainfall in eastern, southern, and south western Ethiopia since 1982. Various studies on the variability and trend of extreme rainfall events which were conducted in different parts of Ethiopia reported complex patterns for the daily indices examined (Yimer *et al*., 2018).

High levels of vulnerability and low adaptive capacity in the developing world have been linked to factors including reliance on the natural resource (Thomas *et a*l., 2007). Climate variability refers to the variation about the average climate including seasonal variation in atmospheric and ocean circulation such as the EI Nino and Southern Oscillations.

Similarly, defined as the shift from normal experienced rainfall patterns of seasons to abnormal rain patterns including temperature (Mkonda, 2018).

Climate change and variability and the increasing frequency of extreme climatic events such as floods and drought in the region are threatening the food production systems, livelihoods, and food security of hundreds of millions of people (Mahoo *et al*., 2013).

Studies indicate that crop productivity under future climate projections is expected to be affected by climate variability in the future. Minimum and maximum temperature and precipitation variability in the future climate will affect crop production, supply, and prices (Abadi, 2018).

2.3. Impacts of Climate Change and Variability on Agriculture

African countries' agricultural production depends almost entirely on rain water, a situation that makes particularly vulnerable to climate change. Increased droughts negatively affect food availability, as happened in the horn of Africa and southern Africa during the 1980s and 1990s. The impacts of climate in agriculture include decreased production of different crops mainly associated with recurrent droughts, floods, increasing crop pests and diseases, and shifts in growing seasons. In developing countries, the effect of climate change on the poor and agricultural communities is enormous, because their adaptive capacities are poor, and also, they have limited other means of production (Twumasi and Jiang, 2020).

The impact of climate variability and change on agricultural production is a global concern. Agriculture is the most important sector in Africa, but it is predicted to be negatively impacted by climate change (Melese, 2019). Climate change affects agriculture and food production through changing agro-ecological conditions (Helen *et al.,* 2021).

Climate change have negative consequences for agricultural production and has generated a desire to build resilience in agricultural systems. Environmental changes may affect many different aspects of agricultural production. With greater climate variability, shifting temperature and precipitation patterns, and other global change components, we expect to see a range of crop and ecosystem responses that will affect integral agricultural processes. Such effects include changes in nutrient cycling and soil moisture, as well as shifts in pest occurrences and plant diseases, all of which will greatly influence food production and food security. These changes are expected to increase abiotic and biotic stress, forcing agricultural systems to function under greater levels of perturbation in the future (Lin, 2011).

Many climatologists predict significant global warming in the coming decades due to rising atmospheric carbon dioxide and other greenhouse gases. As a consequence, major changes in the hydrological regimes have been also forecast to occur. Changes in temperature, solar radiation, and precipitation will affect crop productivity. Climate change will also have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand, trade, and regional comparative advantages. Agriculture is sensitive to short-term changes in weather and seasonal, annual, and longer-term variations in climate. For long-term changes, agriculture can tolerate moderate variations in the climatic mean (Khan *et al*., 2009)**.**

Impact of climatic changes on agriculture, Shift in climatic and agriculture zones, impact on agriculture soil, effect on soil organic matter and soil fertility, Reduce soil water quality, impact on crop productivity, impact on plant growth. Changing rainfall patterns, and increases in the frequency of droughts and floods have always adversely affected yields of rain-fed crops and livestock productivity in the country (Mashizha *et al*., 2017).

Increasing temperature and higher variability of rainfall influence Ethiopia's agriculture and are expected to worsen the existing bad conditions, which could lead to further increases in land degradation, soil erosion, deforestation, loss of biodiversity, and desertification (Aynalem, 2020). Crop management practices geared towards ensuring that critical crop growth stages do not coincide with very harsh climatic conditions such as mid-season droughts, the length of the growing period, and varying planting and harvesting dates are among the crop management practices that can be used in agriculture (Gebrehiwot and Veen, 2013).

2.4. Impacts of Climate Change and Variability on Crop Production

Most tropical regions in the world are vulnerable to climate variability because depend on rain-fed agricultural production and limited adaptive capacity owing to socio-economic conditions. The impacts of climate changes on these crop yields are urgently required for planning future food availability in the country. Because changing climate should have a significant impact on crop yields. Several studies have shown that the rate of temperature increase is higher at higher altitudes. Changing temperatures and erratic rainfall patterns are affecting crop production. Similarly, the loss of local crops, changes in cropping patterns, scarcity of water due to the drying up of water resources, and increasing incidences of diseases and pests have also been observed (Poudel and Shaw, 2016).

Changes in temperature, rainfall, and severe weather events are expected to reduce crop yield in many regions of the developing world, particularly sub-Saharan Africa (Lemi and Hailu, 2019)

Variability in climatic elements; especially rainfall and temperature adversely affect crop production as they influence soil fertility and the length of the growing season and causes crop damage, lower yields, income lose, harvesting difficulties, and increased pest and diseases because Climate change has an impact on rainfall and temperature (Haftu *et al*., 2022). Higher temperatures, reduced rainfall, and increased rainfall variability reduce crop yield and threaten food security in low-income and agriculture-based economies (Deressa *et al*., 2011).

Crop production is the main livelihood in Ethiopia farmers face socio-economic problems due to the impacts of climate change and variability. To reduce such effects; there is a need for research-based knowledge on the extent of climate change and variability and its impacts on crop production and crops are highly sensitive to the impacts of climate change and variability (Kebede *et al*., 2019).

The impacts of climate change on crop production were revealed by changes in the start of the farming season; including rainfall coming early or late, decrease in rainfall, increase in temperature and increase in farming problems, in particular, increase in soil erosion, loss of soil fertility and reduction in crop yields (Mekonnen, 2018). An increase in temperature and decrease in rainfall also leads to soil moisture loss. Erratic and insufficient rainfall particularly during the short rainy season, lack of improved crop varieties, poor farming practices, land degradation, and crop diseases were major challenges to crop production (Lemi and Hailu, 2019; Yimer *et al*., 2021).

Climate impacts are being felt today and greater impacts are unavoidable tomorrow. In Ethiopia, the temperature has been increasing annually at the rate of 0.2°C over the past five decades. This has already led to a decline in agricultural production. Cereal production in Ethiopia is expected to decline still (by 12%) under moderate global warming (Legesse *et al*.,2017).

Agricultural practices are climate-dependent and yields vary from year to year depending on climate variability, the agricultural sector is particularly exposed to changes in climate. Temperatures outside the range of those typically expected during the growing season may have severe consequences on crops, and when occurring during key development stages they may have a dramatic impact on the final product, even in case of generally favorable weather conditions for the rest of the growing season. Many studies highlighted the potential of heat stresses during the thesis stage as ayield-reducing factor (Moriondo, 2011).

Climate is one of the main factors for crop yield. Climate parameters, mainly rainfall,, and temperature, directly affect cultivation, and any change in them is bound to have a significant impact on crop yield and production. Few studies have already shown the considerable Most of the crops, especially rainfall and temperature, which consequently come under the key factors influenced by climate variation (Panda *et al*., 2019)

The variations in the meteorological parameters are more transitory and have paramount influence on the agricultural systems, although other parameters, like soil characteristics, seed genetics, pest and disease, and agronomic practices also do impact crop yields. Among these factors, pests and diseases cause a significant loss to world food production under different climatic conditions. The development and distribution of pests and diseases are governed by temperature patterns, rainfall or humidity, and seasonal length to a great extent (Khan *et al*., 2009). The impacts of climate variability are manifested by floods, droughts, erratic rains, and extreme events (Escarcha and Zander, 2018).

Increased climate variability means additional threats to drought-prone environments and is considered a major crop production risk factor. Based on these findings, current estimates suggest that climate change will bring dramatic shifts in agriculture: global warming of 2℃, as in the most optimistic forecasts, would reduce agricultural output by almost 25% (IPCC, 2014).

Climate change affects water balance, crop photosynthesis, and crop growth either directly or indirectly by affecting directly the crop physiological processes or indirectly by affecting the different crop growth factors such as relative humidity, wind speed, soil temperature, and atmospheric evaporative demand, climate change can decrease the crop rotation period, so farmers need to consider crop varieties, sowing dates, crop densities, and fertilization levels when planting crops (Abadi, 2018; Lemi and Hailu, 2019).

2.5. Climate Change Adaptation Strategies in Ethiopia

The adoption of climate change adaptation strategies aims to minimize the adverse effects of climate change on crop yields (Solomon et al.,2014). Technical efficiency, which occurs as a result of rationally adopting and using new technologies or improving old technologies to improve output, is affected by the flow of information, improved infrastructure, availability of sufficient funds/credit, and farmers' managerial skills. Better and appropriate managerial skills allow farmers to implement suitable measures against severe risks related to climate change that are likely to affect productivity. While there is the possibility of huge yield loss in the agricultural sector due to climate change variability, some studies have indicated that setting up suitable coping and adaptation strategies could enable the sector to benefit from future climate change (Twumasi and Jiang, 2020).

Adaptation to climate change refers to the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". Adaptation could be effected at different scales: individual or farm-level, and national or international level. Even though there will be some autonomous adaptation at the farm level, this adaptation is inadequate and needs the intervention of institutions like the government (Yibekal *et al*., 2013). Adaptation actions at the national or international level, how- ever, entail an understanding of the process of autonomous adaptations at the farm-level (Samuel *et al*., 2019).

Adaptation strategies commonly used by smallholder farmers include planting different crop varieties, incorporating crop residues into the soil, soil and water conservation practices, changing dates of planting, and irrigation, Earlier maturing, and more drought-tolerant common crop varieties, However, socio-economic and institutional factors affect climate change adaptation responses by smallholder farmers (Asfaw *et al*., 2013; Helen *et al*., 2021).

2.5.1. Crop diversification

Crop diversification is the most commonly used method to overcome climate change in Ethiopia. Greater use of different crop varieties in the same season could be associated with lower expenses and ease of access by farmers (Acharya *et al*., 2011). Crop diversification together with soil and water conservation and water harvesting practices were commonly used climate change adaptation strategies in eastern Ethiopia (Melese, 2019). Crop diversification is one of the most cost-effective ways of reducing uncertainties in farmers' income, especially among poor smallholder farmers (Feliciano, 2019).

Crop diversification together with soil and water conservation and water harvesting practices were commonly used climate change adaptation strategies in Ethiopia. This strategy is to avoid risks of total crop failure rather than maximizing yields of one particular crop and maximize the use of land, water and other resources and for the overall agricultural development in the country. It provides the farmers with viable options to grow different crops on their land (Legesse *et al*., 2012).

2.5.2. Planting tree

Tree planting is the process of transplanting tree seedlings, generally for forestry, land reclamation, or landscaping purposes (Akinnagbe And Irohibe, 2014). Trees can provide shade, biomass, and an additional source of income (i.e. fuel wood, charcoal) during the dry season, as well as numerous ecological functions Vegetable production, or market gardening, is a dry season strategy, to take advantage of the available labor force and make use of small reservoirs and wells to produce vegetables when prices are higher (Douxchamps *et al*., 2015).

2.5.3. Soil and water conservation

Soil and water conservation strategies are mainly used because of soil degradation and soil erosion, and because farmers, want to rehabilitate their fields. These activities are increasingly important today because climate changes to some extent are accelerating these processes (Melese, 2019).

Soil and water conservation (SWC) practices allow for increasing soil water content and maintaining humidity during dry spells through an improved soil structure (Douxchamps *et al*.,2015). Soil and water conservation strategies are mainly used because of soil degradation and soil erosion, and because farmers due to this, want to rehabilitate their fields. Today these activities are increasingly important because climate change to some extent is accelerating these processes (Temesgen *et al*.,2014).

2.5.4. Irrigation

Rainfed agriculture in Sub-Saharan Africa was remain vital for food security (Cooper et al., 2008). The use of irrigation is one of the least practiced adaptation strategies among the major adaptation methods identified in Ethiopia (Temesgen *et al*.,2014). Irrigation efficiency will become an important adaptation tool, especially in the dry season, because irrigation practices for the dry areas are water-intensive (Akinnagbe and Irohibe, 2014). The use of irrigation is one of the least practiced adaptation strategies among the major adaptation methods identified in Ethiopia (Melese, 2019).

2.5.5. Fertilizer

The application of mineral fertilizer increases yields, allowing farmers to build up food/financial reserves. Commercial fertilizers are applied to crops to increase crop yields. Before the 1950s, most farming occurred on small family farms with limited use of chemicals. The shift since then to larger corporate farms has coincided with the use of chemical fertilizers in modern agricultural practices (Douxchamps *et al*., 2015).

2.5.6. Crop varieties

Improved crop varieties (drought tolerant and/or short cycle) allow for increased productivity even during dry seasons (Douxchamps *et al*., 2015). Drought resistance refers to the ability long of a crop plant to produce its economic product with minimum loss in a water-deficit environment relative to water-constraint-free management. Drought tolerant and/or resistant to temperature stresses as well as activities that make efficient use and take full advantage of the prevailing water and temperature conditions, among other factors (Gebrehiwot and Veen 2013).

2.6. Conceptual Framework of the Study

In this section, the conceptual framework that guides the study was presented by building a model of interest. The framework includes different factors supposed to affect major crops (Teff, Wheat, Lentil, Chickpea and Sorghum) and adaptation strategies, particularly those which contribute to variation in the crops were to be considered climate variables factors. Under climate variables, rainfall ,maximum temprature and minimum temprature were considered as the study elements.

Farm households react to the perceived effects through various adaptation strategies, Such as soil and water conservation, crop diversification, changing planting dates, planting tree, improve crop varieties, growing short mature crop, irrigation and water harvesting. The conceptual framework of this study is presented below (Figure 2.1).

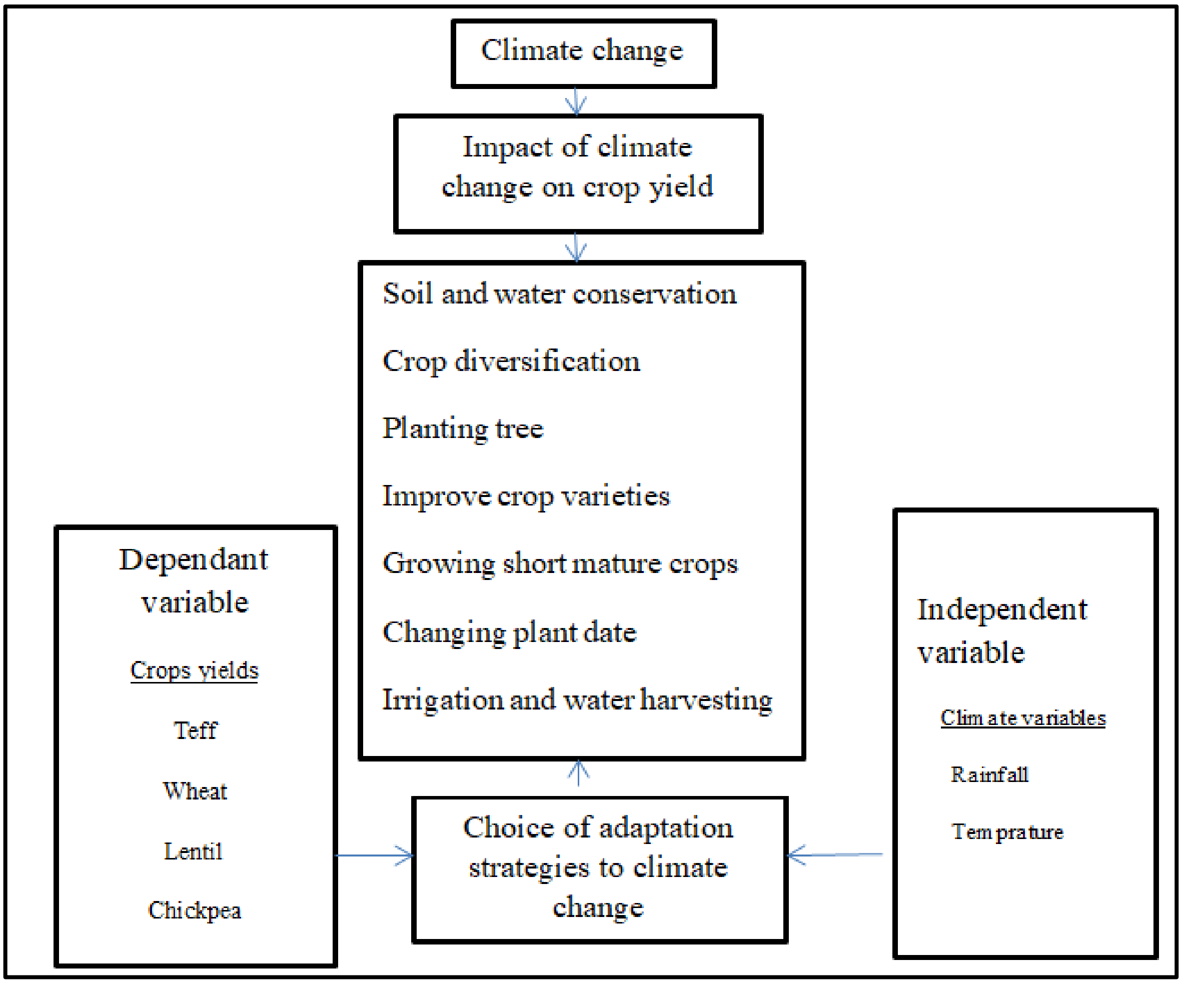


Figure 2. 1: Conceptual framework the study

Source: modified from (Bewuketu, 2017).

CHAPTER THREE. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1 . Location

The study was conducted in Minjar Shenkora District. It is located about 130 km south-east of Addis Ababa and located 260 Kms south of Debre Birhan twon. Geographically its location extends between 8^{0} 44’0’ and 9º 5’ 0’N and 39º 15’ and 39º 45’ East in (Figure 3.1). The district is bounded by Hagere Maryam and Berehet in the north direction, Fentale district in the east, Bosset district in the south and Lumena Ginbichu in the west directions. Minjar Shenkora district has a total area of 229,463 hectares.

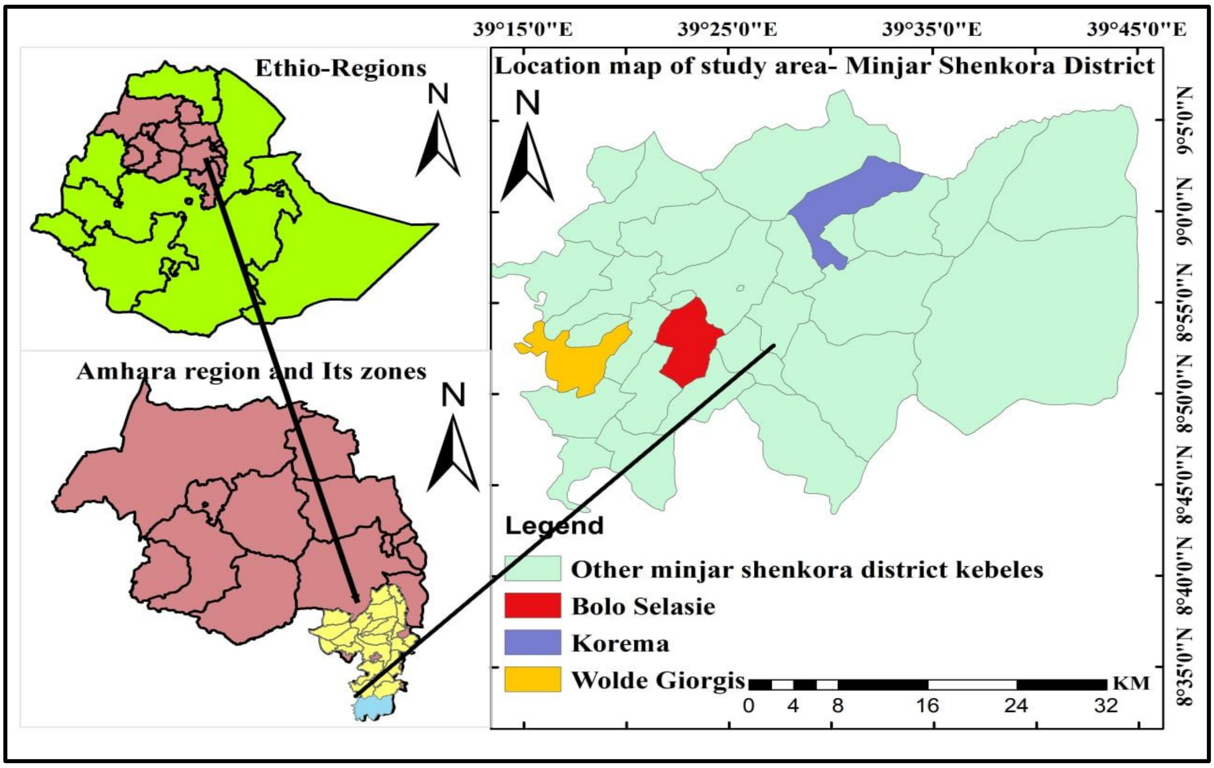


Figure 3.1: Location Map of the study area

3.1.2. Climate

Minjar Shenkora District has three agro-climatic zones, Dega (high altitude), Woina Dega (Mid altitude), and Kola (low altitude). The total area of the *district*, about 70.9 % found under the Woina dega, 24.8 % is kola and 4.3 % of ot the area is Dega respectively . Minjar Shenkora district is bimodal rainfall pattern (small belg and longer summer). This district receives main rainfall in Summer (June-Sep) or kiremt; season whereas short rainfall receives in fall (Feb-May) or belg season. The annual rainfall of the study area was 1028 mm. The district receives an average rainfall of 1028 mm and it has 13.21 °C minimum and 23.02 °C maximum temperatures (Tsedeke et al, 2021).

3.1.3. Topography

There are various types of landscapes in *Minjar Shenkora District*. It is covered with a relatively flat surface plane relief; it holds 84% , 14% of the study area is hilly and only 2% of the total area is mountains. The topography of the district lies on an average altitude of 1710 meters above sea level (Aynalem, 2021).

3.1.4. Soil type

The most dominant soil type in the study area is brown soil its coverage in the district is about 46.5% . Even though their area coverage is very low there are also other types of soils, these are gray soil, black soil, and red soil possessing a share of the total area of 19.5%, 19%, and 15% respectively (Tsedeke et al, 2021).

3.1.5. Population

Minjar Shenkora district has 27 rural and 2 urban kebeles with a total population of 148,493, of them 76,840 are males and 71653 are females (CSA, 2013).

3.1.6. Economic activity

The livelihood of the *Minjar Shenkora district* population is depends on Mixed Agriculture (livestock and crops production) like Major crop production such as Teff (*Erogratis teff*), Sorghum (*Sorghum bicolor*), Chickpea (*Cicer arietinum*), Wheat (*Triticum astevium*), lentil (*Lens culinaris*) grain and minor Crop production such as Barley (*Hordeum vulgare*), maize (*Zea mays*), common bean (*Phaseolus vulgaris*) and non-agricultural activities like trade, handcraft and daily laborer (Tsedeke et al , 2021).

3.2 Research design

This study employed longtudinal research design to assesses the overall activities of impact of climate change and variability on major crops and adaptation strategies in Minjar

Shenkora District with numerous population characteristics at one specific point in time and also make suggestions about a population based on the result of the sample.

3.2. Sampling Techniques and Size determination

In this study, Minjar Shenkora District was selected purposively because it is one of the districts in the north shewa zone where crop production is highly produced. The district has 29 kebeles and stratified into three agro-ecologies namely, kola, dega, and woina dega. From each agro-ecologies, one kebele was randomly selected and totally three kebeles (Wolde Giworgis from dega, Bolo Selassie from woina dega, and korma kebele from kola) were selected. Finally, 342 sample households were selected randomly from 2339 total households using the formula adapted from Yamane (1967) at a 95 % confidence level and 5 % level of precision. The formula is as follows.

$$\mathbf{n} = \frac{\mathbf{N}}{\mathbf{1+Ne^2}} \qquad \text{Equ (1)}$$

Where,

n= in number of sample size;

N= the total household size is 2339

e= level of precision (5%);

1= constant value

$$n = \frac{2339}{1+2339\,(0.05)2} = 342$$

Sample from each kebeles was selected through proportional allocation method.

$$ni = \frac{n*Ni}{\Sigma Ni}$$

Where,

ni= in the sample size of each kebele

n =is the total sample size of all selected kebele.

The total population of each kebele.

ΣNi=summation of the population of each sample size

Table 3. 1: Distribution of sample households

District	Kebeles	Agro ecological zone	Household	Male	Female	Sample
Minjar Shenkora	Wolde Giorgies	Dega	778	97	17	114
	Bolo Sallasia	Woina dega	849	105	19	124
	Korma	Kola	712	77	27	104
Total			2339	279	63	342

3.3. Methods of Data Collection

Primary data were collected from households questionary, key informants interviews, and focus group discussions. Secondary data were collected from Minjar Shenkora district agriculture and rural development office (MSDARDO); 13 years of major annual crop production data from 2000-2013 and Monthly climatic data of rainfall and temperature from 1990-2020 were obtained from National Meteorological Agency (NMA) and national aeronautics and space administration (NASA) from https://power,larc,nasa,gov/data-access-viewer. The study was compared National Aeronautics and Space Administration (NASA) Power and observed data. Due to the absence of daily data from meteorological station the researcher used National Aeronautics and Space Administration (NASA) Power data.

3.3.1. Household questionnaire

Questionnaire was used to generate quantitative and qualitative information at household level using a structured questionnaire. The study used both open-ended and closed-ended questionnaires which were thought to be helpful in achieving the objectives of the study. The questionnaires were prepared in english and then translated into Amharic (local language) to be used by all the sample respondents in this study.

3.3.2. Key informant interviews

The Key informant interview (KII) was conducted to gather relevant information for this study. These key informants were selected from each kebeles. Key informants are individuals who are knowledgeable about the study area and are elderly persons who lived in the area for 30 years. Kebeles tour was done with kebele agriculture development agents, local leaders, model farmers, professionals, and agriculture development officer to select key informants. During the tour, six key informants from each kebele with a total of 18 individuals were selected.

3.3.3. Focus group discussion

Qualitative research a method was conducted from similar backgrounds or experiences together to discuss a specific topic of interest. It is a form of qualitative research where questions are asked about their perception attitudes, beliefs, opinion or idea . Focus group discussion (FGD) are a good way to gather in-depth information about a community's thoughts and opinions on a topic. The course of the discussion is usually planned and most moderators rely on an outline, or guide, to ensure that all topics of interest are covered. Three focus group discussions were interview from each kebeles and the number of focus group participants in one group for each kebeles was six members.

3.4. Methods of Data Analysis

3.4.1. Descriptive analysis

Rainfall and temperature indices were computed using the RClimDex it was developed by the Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI).

R-software Microsoft excels and SPSS analysis methods such as descriptive statistical methods, correlation (bivariate). Descriptive statistics such as mean, standard deviation, frequency, and percentage are used to explain and describe the final result of the study and multivariate Regression analysis were used for crop with rainfall, maximum temperature and minimum temprature. The processed results of the study are summarized and presented by various tables, graphs, and pie charts. Z, p-value, and sen's slopes test have been computed and used. Coefficient of variability (CV), rainfall anomaly index (RAI), and precipitation concentration index (PCI) were analysed variability. The qualitative information gathered using; focus group discussion and key informant interviews were analyzed and interpreted.

3.4.1. Analysis of rainfall variability

precipitation concentration index is presented to be used in measuring the relative distribution of rainfall patterns. The concentration of rainfall in a year is an important aspect of the climate. An unbalanced distribution of rainfall suggests periods of rainfall excess and periods of drought which make plant and crop growth difficult. Rainfall concentration needs to be considered in the assessment and the prediction of soil losses by water erosion (Michiels *et al.,* 1992).

Precipitation concentration index was used to evaluate the distribution of the seasonal, and annual distribution of rainfall. Precipitation concentration index is used to indicate the hydrological risks of floods and drought occasions in the study area. The distribution of annual and seasonal rainfall was evaluated by using a (Oliver's, 1980; De Lui *et al*., 2000; Asfaw *et al*., 2017) described as follows:

$$\textbf{Annual PCI} = \frac{\sum_{i=1}^{12} P^2{}_i}{[\sum_{i=1}^{12} P_i]^2} * \mathbf{100} \qquad \text{Equ (2)}$$

$$\text{Seasonal PCI} = 25 * \frac{\sum_{i=1}^{4} P^2{}_i}{[\sum_{i=1}^{4} P_i]^2} \qquad \text{Equ (3)}$$

Where: Pi = the rainfall amount of the i^{th} month; Σ = summation over the 12 months for annual and four months for seasonal rainfall. The precipitation concentration index was also calculated on a seasonal scale for the dry season (Oct–Jan), the small rain season (Feb–May), and the main rain season June–Sep (Ademe *et al*., 2020).

According to Oliver (1980), precipitation concentration index values of less than 10 indicate uniform precipitation distribution of rainfall, values between 11-15 moderate precipitation distribution of 16 and 20 indicate irregular precipitation distribution, and values of 21 and above indicate strong irregularity of precipitation distribution.

Rainfall anomaly index (RAI), was used as a descriptor of rainfall variability (Daniel *et al*., 2017). Rainfall anomaly index was used to evaluate the variability pattern and drought level in this district. The rainfall anomaly index was used to calculate the negative and positive anomalies of rainfall fluctuations in a certain region. It helps to identify the drought period by determining the dry and wet years of the recording period (Agnew and Chappel 1999; Asfaw *et al*., 2017; Haji and Solomon, 2016; Kushabo *et al*., 2019).

$$\boldsymbol{Z} = \frac{\mathbf{Xi} - \bar{\mathbf{X}}\mathbf{ı}}{\mathbf{s}} \qquad \text{Equ (4)}$$

Where: Z is standardized rainfall anomaly; (Xi) is the annual rainfall for the historical record; $(\bar{X})$ is the mean of annual rainfall and s is the standard deviation of the annual rainfall for the historical observation (31) year. The drought severity classes are; extreme drought Z>-1.65), severe drought (−1.28>Z>1.65), moderate drought (− 0.84 > Z > − 1.28), and no drought (Z>−0.84).

Coefficient of variation (CV) is a statistical measure of the dispersion of data points in a data series around the mean. The coefficient of variation represents the ratio of the standard deviation to the mean, and it is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from one another. The coefficient of variation shows the extent of variability of data in a sample about the mean of the population (Abdi, 2011). Coefficient variations (CV) were used as a better indication of the level of variability of both the yearly total and monthly rainfall amount of the study district (Kushabo *et al*., 2019).

Rainfall variability is classified as less variable (CV < 20), high (CV > 30), moderate (20 < CV > 30), severe (CV > 40%), and CV > 70% indicating extremely high inter-annual variability of rainfall. Hence the higher the value of coefficient of variation (CV) the higher the variability of rainfall in the study region and the reverse is also true. The value of CV can be computed (Kushabo *et al*., 2019; Ademe *et al*., 2020; Belay *et al*., 2021; Getahun *et al*., 2021) using an equation.

$$\mathbf{CV}(\%) = \frac{\boldsymbol{\sigma}}{\bar{\mathbf{x}}} * \mathbf{100} \qquad \text{Equ (5)}$$

Where: where CV is the coefficient of variation, σ is the standard deviation and $\bar{X}$ is the mean precipitation of the recording period.

3.4.2. Correlation between the climate variable with Major crop

The statistical correlation coefficients between crop yield and climatic variables namely rainfall and temperature were used to assess the strength and the direction of the relationship, and significance of the relationship between Teff (*Erogratis teff*), Wheat (*Triticum astevium*), lentil (*Lens culinaris*), Chickpea (*Cicer arietinum*) and Sorghum (*Sorghum bicolor*) and 31 year climate variables and Meteorological data with NASA data. Focus was made on annual data 1990-2020 to understand how the events impact on major crops.

Correlation Analysis: A correlation is a measure of the linear relationship between two variables. It is used to describe the strength and direction of the relationship between two normally continuous variables. This method provides the degree of relationship between two variables. Pearson Correlation coefficient (r) analyses were used to analyze the relationship between crop yields expressed in to/ha with temperature (maximum and minimum) , annual rainfall, seasonal rainfall, and meteorological data with national aeronautics and space administration (NASA) power data. The value of r always lies between –1 and +1, A value of the correlation coefficient close to +1 indicates a strong positive linear relationship, A value close to –1 indicates a strong negative linear relationship. A value close to 0 indicates no linear relationship. For this study, the value of r was calculated using the Pearson correlation coefficient equation (Asfaw, 2020; Agbo, 2021; Brien and Scott, 2012).

Multivariate Regressions Analysis; - Regression of several dependent variables on one or more explanatory variables was analyzed by R-software (climate variable and crops). Regression is particularly useful to understand the predictive power of the independent variables on the dependent variable once a contributing relationship has been confirmed. To be particular, regression helps a researcher understand to what extent the change of the value of the dependent variable causes the change in the value of the independent variables, while other independent variables are held unchanged:

$$Y = \alpha + \beta 1X1 + \beta 1X1 + \cdots \beta nXn + e \qquad \text{Equ (6)}$$

Where Y, α, and □ remain to be the dependent variable, a constant amount, and the error respectively. But the number of independent variables is now more than one (Brien and Scott, 2012).

3.4.3. Trend test

Trend analysis has been carried out on seasonal and annual base for climate variables such as temperature (seasonal and annual temperature) and precipitation (seasonal and annual). Similarly, annual trends of the yield of teff, wheat, lentil, chickpea, and sorghum for in this district.

The Mann–Kendall test and Sen’s slope method were used to assess the statistical significance of the trend (Daniel *et al*., 2017). The non-parametric trend is widely used in many subjects and is useful for detecting significant trends. This method is predominantly useful in studying the trend of rainfall and temperature (Getahun *et al*., 2021; Haftu *et al*., 2022).

Sen's slope developed by Sen (1968) has been widely used to calculate the magnitude of trends in the long terms rainfall and temperature data. In this test, a score of +1 is awarded if the value in a time series is larger, or a score of -1 is awarded if it is smaller. which is then compared to a critical value, to test whether the trend in rainfall is increasing, decreasing or no trend rainfall can be determined. A positive value is an indicator of an increasing (upward) trend and a negative value is an indicator of decreasing (downward) trend. The trend obtained by the mann-kendall trend test was tested for significance and normalized test statistics (z-score) were used to check the statistical significance of the increasing or decreasing trend of temperature and rainfall values and tested using the mann-kendall trend significance test with the significance level of 0.05 ($Z\alpha/2 = \pm 1.96$).

Hypothesis testing: H0: μ= μo (there is no significant trend/stable trend in the data).

HA: μ ≠ μo (there is a significant trend/ unstable trend in the data) If–$Z_{1-\alpha/2} \leq Z \leq Z_{1-\alpha/2}$ accepts the hypothesis or else rejects H0.

The absence or presence of a statistically significant trend was evaluated using the Z value. In a two-tailed test for trend, the null hypothesis H0 should be accepted if $|Z| < Z_{1-\alpha/2}$ at a given level of significance. Generally, the mann-kendall test (Mann, 1945) was applied using the formula:

$$\mathbf{Z} = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}}; \ \textbf{for} \ \ s > 0 \\ 0 \ \textbf{for}; \ \ s = 0 \\ \frac{S+1}{\sqrt{VAR(S)}}; \ \textbf{for} \ s < 0 \end{cases} \quad \text{Equ (7)}$$

The positive value indicates an upward trend and the negative value indicates a downward trend. For trend, the null hypothesis, H0 (no trend) is considered if $Z < Z\alpha/2$, whereas rejected (H1) is if $Z > Z\alpha/2$, where α is the significance level and $Z\alpha/2$ the standard normal distribution for α/2 (Daniel *et al.,* 2017; Asfaw *et al.,* 2017; Getahun *et al.*, 2021 and Sintayehu and Tulu, 2021).

Similarly, the trend was quantified using Sen's slope method (Sen, 1968). A positive value of β indicates an 'upward trend' (increasing values with time), while a negative value of β indicates a 'downward trend. Here, the slope (Ti) of all data pairs is computed as (Sen, 1968).

The slope Ti between any two values of a time series x can be estimated from:

$$\mathbf{Ti} = \frac{\mathbf{xj - Xi}}{\mathbf{j - i}} \qquad \text{Equ (8)}$$

Where, xj and xi are considered as data values at time j and i (j > i) correspondingly.

The median of these N values of Ti is represented as Sen's estimator of slope which is computed as:

Q_{med} =T $(N_{+1})_{/2,}$ Equ (9), if N is odd

Q_{med}= [$T_{N/2}$ T $(_{N+2)/2})$/2] Equ (10), if N is even

A positive value of Qi indicates an increasing trend and a negative value of Qi shows a downward or decreasing trend in the time series.

3.4.4. Climate extreme indices analysis

Climate indices are defined as calculated values that can be accustomed to depict the climate and the climate changes. One of the advantages of the expert team for climate change detection monitoring and indices (ETCCDI) and other similar indices is their capability to synthesize a global product from regional information. Moreover, climate indices are comparatively easy to use, and they are also statistically reliable quantitative indicators of climate extremes. The projected changes in the extreme climate events will have impacts on the environment and society (Haftu *et al.*, 2022). Climate extremes indices are used for climate change monitoring and detection studies (Zhang *et al.*, 2004; Teshome and Zhang, 2019).

Table 3. 2: List of temperature and rainfall indices

Temperature extremes indices			
ID	Indicator name	Definitions	Units
SU25	Summer days	Annual count when TX(daily maximum)>25ºC	Days
TR20	Tropical nights	Annual count when TN(daily minimum)>20ºC	Days
TXx	Max Tmax	The monthly maximum value of daily maximum temp	ºC
TNx	Max Tmin	The monthly maximum value of daily minimum temp	ºC
TXn	Min Tmax	The monthly minimum value of daily maximum temp	ºC
TNn	Min Tmin	The monthly minimum value of daily minimum temp	ºC
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN	Days

Rainfall extreme indices			
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	Mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	Mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	Mm/day
R10	Number of heavy precipitation days	Annual count of days when PRCP>=10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
R95p	Very wet days	Annual total PRCP when RR>95th percentile	Mm
R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm

Source: Modified from Zhang *et al.*, (2004)

CHAPTER FOUR. RESULTS AND DISCUSSIONS

4.1. Demographic and socio-economic characteristics of the respondents

As shown in Table 4.1 out of the total 342 households 114 (33.3%) household heads were from wolde Giworgis which is situated in dega (highland) agro-ecological zone, 124 (36.3%) household head was from bolo Selassie which is situated in woina dega (midland) agro-ecological zone, 104 (30.4%) household heads of them from korma which is kola (lowland) agro-ecological zone.

Information on the demographic characteristics of respondents showed that 81.6% of the respondents were male and the remaining 18.4% are females . The mean value of age of the respondents household was 43. The experienced farmers are more likely to have more information and knowledge on changes in climatic conditions and crop management practices. The mean family sizes of the sample households were 4.6 with a maximum of eight and a minimum of were one (Table 4.1).

From the total, 72.81% of the respondents completed illiterate education, 22.81 % of respondents completed literate education, 3.8 % of respondents completed literate education and only 0.58% was secondary education. This implies, more than 73 of the respondents have not read and write. Education enhances farm productivity in the case of adopters of modern technology Education enhances the farming skills and productive capabilities of the farmers.

According to the survey data showed that the marital status of respondents, 74.6. % of respondents were married, 6.7% were single, 8.8 were divorced and 9.9 % were widowed.

According to the survey data showed that most of the total household heads in this study area were married. The mean value of farmland size of the sample households was 1.8 hectares with a maximum of 4 hectares and a minimum of 1 hectare (Table 4.1).

Table 4. 1: Characteristics of the sample household variables.

Continuous variable		Mean	
Age		43.0	
Family size		1.8	
Farmland size		4.6	
Dummy variable		Frequency	Percent
Sex	Male	280	81.6
	Female	62	18.4
Catagorical variable		Frequency	Percent
Marital status	Married	255	74.6
	Unmarried	23	6.7
	Divorced	30	8.8
	Widowed	34	9.9
Education level	Illiterate	249	72.81
	Read and write	78	22.81
	Primary school	13	3.8
	Secondary school	2	0.58
Total		342	100

4.2. Trend and Variability of Rainfall in Minjar Shenkora Districts

The annual rainfall of *Minjar Shenkora Districts* from 1990-2020 showed that decreased trends. The highest rainfall were 1148.3 mm and the lowest were 520.2 mm and the mean annual rainfall over the past 31 years is about 822.7 mm with a standard deviation of 183.4 mm and Coefficients of variation of 22.3% in (Table 4.2). This result is in line with Getahun *et al.,* (2021), reported that the coefficient of variation of the region (10.4%). The coefficient of variation result showed that rainfall is highly variable in this district.

Table 4. 2: Variability of annual rainfall

Station	N	Minimum	Maximum	Mean	Std. Deviation	Variance	CV
Arerti	31	520.2	1148.3	822.71	183.4	33644.6	22.3%

As shown in Figure 4.1 the annual rainfall decreased by about 5.3 mm every year between 1990 and 2020. The results in line with Gemeda *et al.*,(2021), reported that the annual rainfall has decreasing trend in parts of southwest Ethiopia.

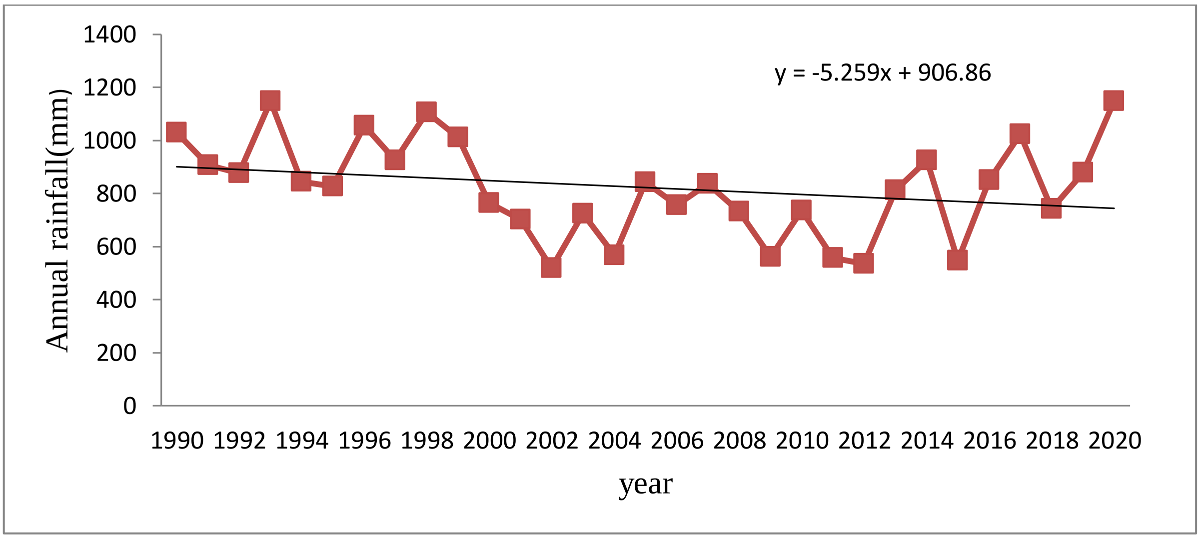


Figure 4. 1: Trend of annual rainfall

4.2.1. Trend and variability of seasonal rainfall

As shown in Table 4.3 kiremt rainfall shows a 21.4 % coefficient of variation, belg rainfall shows a 49.9% coefficient of variation. This indicates that there was high seasonal variability of rainfall. From the analysis, in belg season the varability was higher than that of variation in kiremt season rainfall. Generally seasonal rainfall observation coefficient of variation (CV) indicates high variation. The main rain season have significantly greater rainfall than the small rain season and show high interannual variability at this district.

Table 4. 3: Coefficient of variation of rainfall for belg, kiremet

Season	N	Minimum	Maximum	Mean	SD	CV%
Kiremt	31	340.7	804.5	574.1	122.9	21.4
Belg	31	49.4	418.9	169.9	84.9	49.9

The impacts of rainfall on crop production can be related to its total seasonal amount or its intra-seasonal distribution. Hence, for a better insight into the impacts on crop production, analysis of seasonal variation is very significant since variation in all seasons of the year is not equally important from a crop production point of view. Like most parts of Ethiopia, minjar shenkora district has two cropping seasons and experiences a bimodal rainfall pattern receiving small spring rains from February/March to May known as belg; a short rainy season, and The main rains from June to September; known as kiremet; the main rainy season (Aynalem, 2020). Kiremt is generally the main cropping season that accounts for the overpowering proportion of the total area cultivated and annual crop production in Minjar Shenkora District.

The seasonal variability of rainfall is strongly associated with late-onset and early offset of the rainy season. Analysis of belg rainfall had shown a decreasing trend by 0.83 mm/year and, kiremt rainfall had also shown a decreasing trend by 3.44 mm /year during the past over three decades (Figure 4.2). This result is in line with Amogne *et al.*, (2018) reported that annual, belg and kiremt rainfall have decreased trends in woleka sub-basin. This reduction in the amount and variability of seasonal rainfall makes predicts the situation difficult which in turn affects the farming activities of farmers especially those whose livelihoods depend on rain-fed agriculture. This result is in line with Yimer *et al*., (2018). reported that summer rainfall in the central highlands of Ethiopia declined in the second half of the 20th century, while they found a decline in annual and summer rainfall in eastern, southern, and south western Ethiopia since 1982.

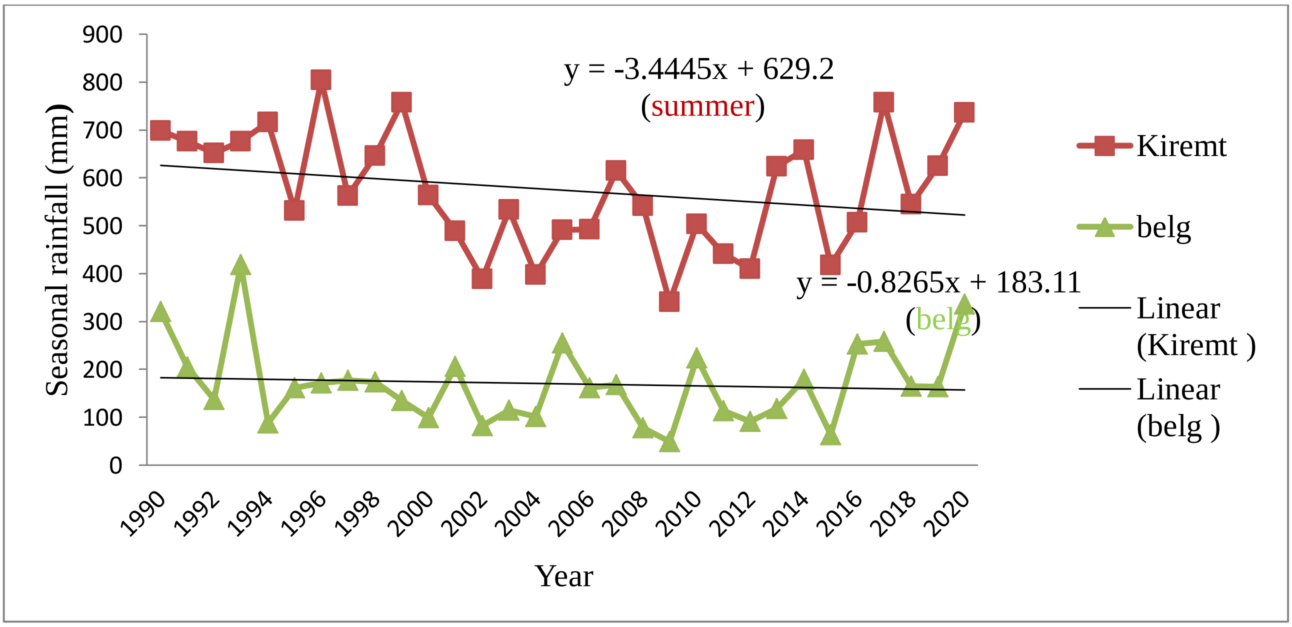


Figure 4. 2: Trend of seasonal rainfall

4.2.2. Rainfall anomaly index

The rainfall anomaly index values for Arerti was calculated range from the highest value of 1.78 in the year 1993 to −1.65 in 2002. drought years were used as evidence to show the years that drought occurred (Figure 4.3). In the figure mentioned the years 2004, 2009, 2011, 2012, and 2015 were moderate drought classes .whereas the remaining years were no drought years. The heavy rainfall occurred in 1990 resulted in rainfall which caused damage on crop of Minjar Shenkora district and low rainfall in years 1994,1996,2001,2007 which cause decrease in crop production.The frequently experienced climatic shocks identified by the respondents that have a significant impact on crop production are prolonged drought including late-onset/early offset of rain, drought, and unseasonal rainfall. Therefore, the survey conducted by the respondents was supported by meteorological data.

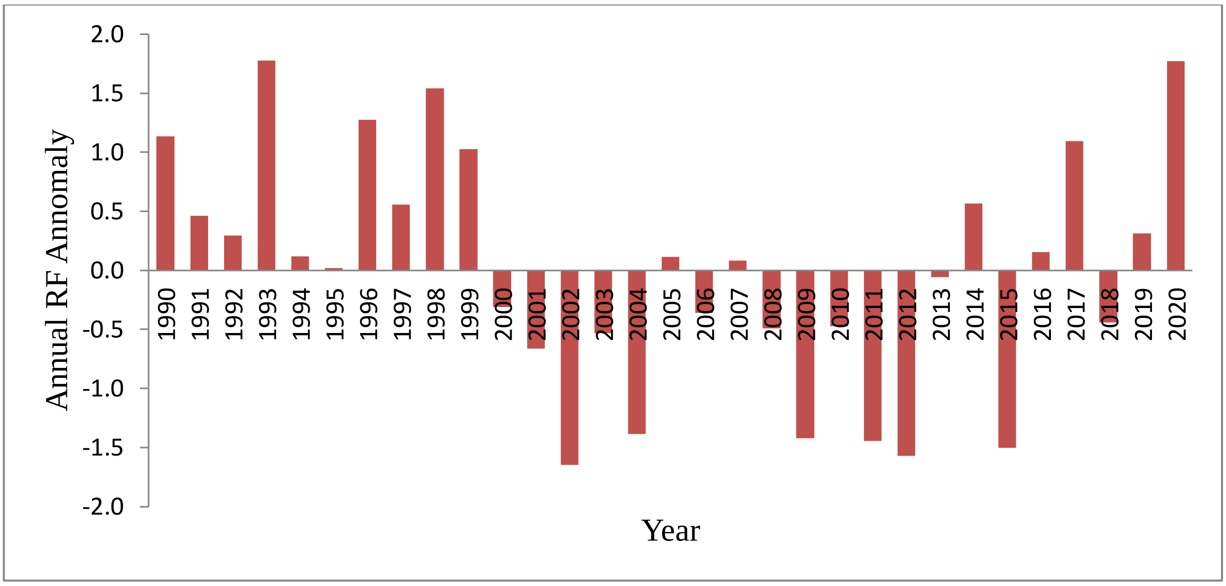


Figure 4. 3: Trends of rainfall anomalies

4.2.3. Precipitation concentration index

According to Oliver (1980), Precipitation concentration index value classification, this districts precipitation concentration index value were 16 and it greater than 15, there for the annual rainfall distribution of the district was irregular precipitation distribution over the past 31 years. A previous study in the highlands of Ethiopia by variability Ademe *et al.*, (2020), confirmed that the precipitation concentration index values range from moderate to strong irregular or significantly irregular precipitation and concluded that rainfall in Ethiopia is heterogeneous.

The seasonal precipitation concentration index showed that the Kiremt, belg and bega season precipitation concentration was uniformly distributed because the value of PCI was less than 10 in (Figure 4.4) . This indicated that seasonal precipitation concentration index was variability in this district . This result is in line with Belay *et al.*, *(*2021), reported that precipitation concentration index of rainfall showed variability in that area. The results in line with Ademe *et al.*, (2020), reported that precipitation concentration index (PCI) analysis for seasonal rainfall showed that small rain seasons experienced moderate to strong irregular rainfall distribution that dominates the Ethiopian Highlands.

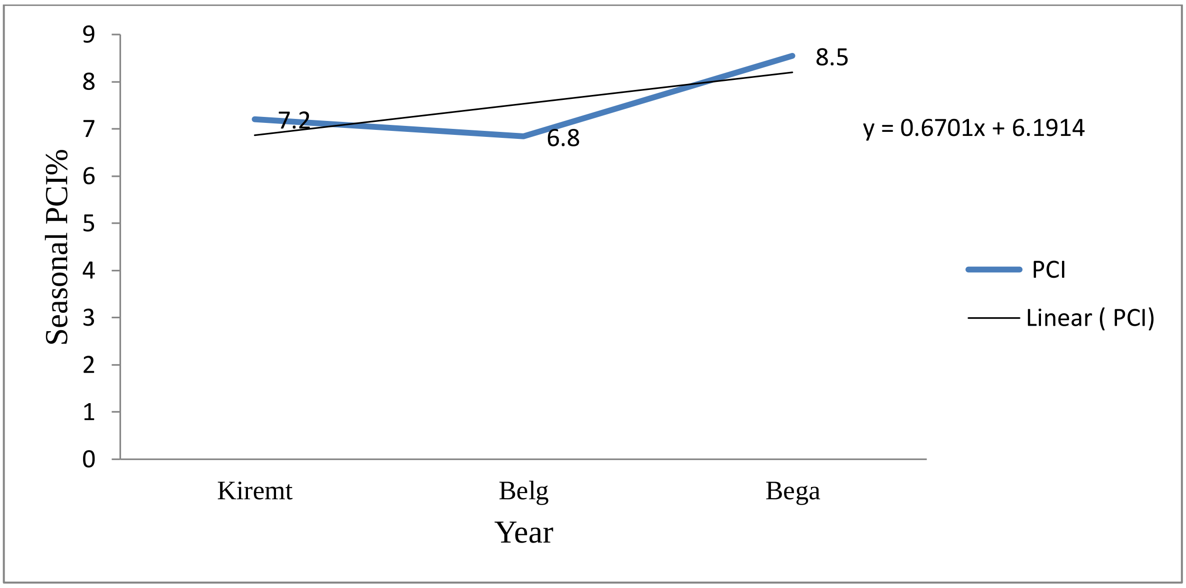


Figure 4. 4: Seasonal precipitation concentration index

4.2.4. Trend and Variability of Temperature in Minjar Shenkora Districts.

Annual maximum temperature of this district was observed from 1990 to 2020 showed that annual maximum temperature was between 26.2^{o}c and 29.8^{o}c during the last 31 years in (Figure 4.5) . The annual maximum temperatures have shown an increase of 0.028 ^{o}c. and its standard deviation over the period was 0.9 ^{o}c. This result similar with the finding of Gemeda et al.,(2021), reported that the maximum temperature has increasing trends in the wettest parts of southwest Ethiopia.

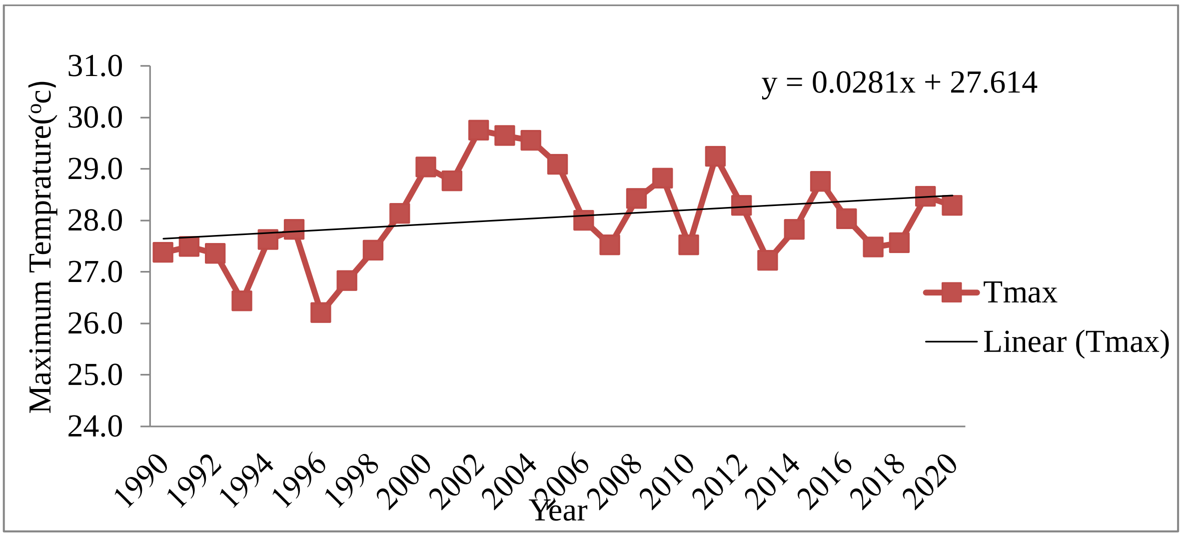


Figure 4. 5: Trend of annual maximum temperature

Figure 4.6 showed that the annual minimum temperature of the study area observed for years 1990 to 2020. It is observed that annual minimum temperature of Minjar Shenkora district was between 6.43^{o}c and 10.92^{o}c during the last 31 years. The annual minimum temperature had shown increase trends by 0.03^{o}c. It implies that there was a year-to-year variation in temperature in this district. This result is in line with the finding of (Asfaw, 2020), that temperature was a slightly variable from year to year. In addition Gemeda et al.,(2021), reported that the minimum temperature rainfall has increasing trends in the wettest parts of southwest Ethiopia.

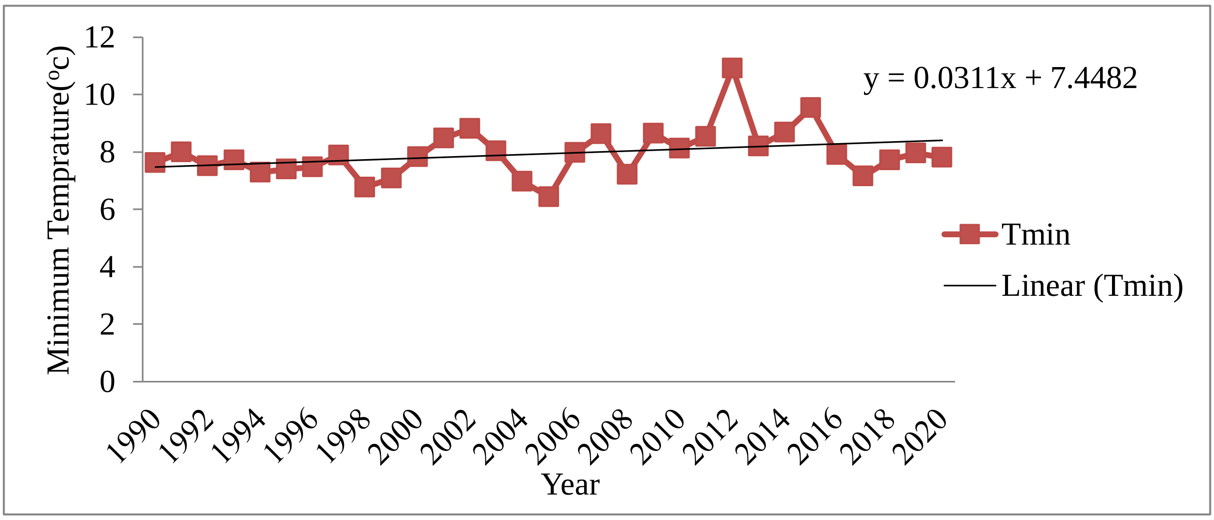


Figure 4. 6: Trend in annual minimum temperature

Table 4.4, showed that the maximum temperature, minimum temperature, and mean temperature mean value of minjar shenkora district was 28.1, 7.94, and 18, respectively.

Table 4. 4: varaibility value of Tmax, Tmin, Tmean

Station	Temperature	N	Max	Min	Mean	SD
Arerti	T max	31	29.8	26.2	28.1	0.9
	T min	31	10.9	6.4	7.94	0.86
	T mean	31	19.4	16.8	18	0.7

The mean values of the annual temperature of Minjar Shenkora district trend were 0.029 ^{o}c and its standard deviation over the period was 0.86 ^{o}c and its standard deviation over the period was 0.7 ^{o}c (Figure 4.7) .

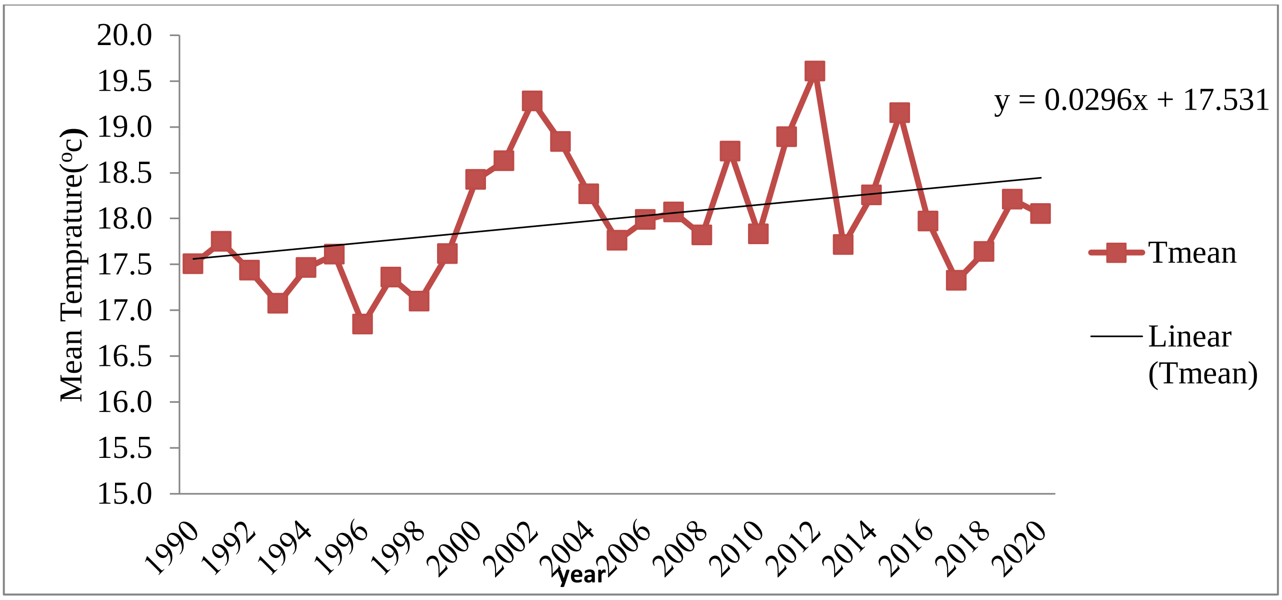


Figure 4. 7: Trend of annual mean temperature

This result was similar with , NMSA, (2007), the average annual minimum temperature over the country has increased by about 0.37℃, whereas, the average annual maximum temperature has increased by about 0.1℃ every decade. average minimum and maximum temperatures indicate have been increasing by about 0·25 °C and 0·1 °C, respectively (Deressa *et al.*, 2011). Farmers participating in focus group discussion and key informant interview also explained that temperature becomes warmer every year, which is consistent with the statistical result.

4.2.5. Trend Test of (Mann-Kendall)

The annual , seasonal rainfall and temperature trends analysis for the period of 1990-2020 exhibited different trends is showed significant increasing and decreasing trends (Table

4.5). Mann-Kendall (Z) and Sen's slope(Q) test showed that the decreasing trend in rainfall during the annual and seasonal rainfall which showed that the trends satisfied because z statistical is less than z critical value at 5%significance level. The annual rainfall decreased significantly whereas the rainy season (belg and kiremt) rainfall decreased non-significantly. The sen's slope rate of annual rainfall decreased by-6.12 mm/year annually and it decreased by -4.31mm/year and -0.44mm/year in belg and kiremit respectively.

Maximum and minimum temperature had showed significantly increasing trend at 5% z statistical value (Table 4.5). The annual and seasonal average maximum and minimum temperature had showed that non-significant increasing trend except in kiremt and bega maximum temprature. The sen's slope rate on annual, kiremt, belg and bega increased by 0.02, 0.01, 0.03 and 0.02 in T max and 0.02 ^{o}C, 0.01 ^{o}C, 0.01 ^{o}C and respectively 0.03^{o}C in T min.

Table 4. 5: Annual and seasonal rainfall and temperature of mann–kendall and sen's slope

Station	Rainfall			T max			T min		
	Zs	Q	P-value	Zs	Q	P-value	Zs	Q	P-value
Annual	-1.495	-6.12	0.13	1.47	0.02	0.13	1.69	0.02	0.08*
Kiremt	-1.22	-4.31	0.22	0.76	0.01	0.44	0.79	0.01	0.42
Belg	-0.27	-0.44	0.78	1.41	0.03	0.15	0.44	0.01	0.65
Bega	-0.4	-0.42	0.64	1.29	0.02	0.19	1.85	0.03	0.06**

*statistically significant at Z=± 1.96 (α = 0.05) at 5% significance level.

Mann -Kendall (Z -test) and Sen's slope(Q) showed the increasing and decreasing trend in monthly rainfall (Table 4.6). The monthly rainfall showed significantly decreasing trend in Jan, Feb, Mar, June, July and August whereas the monthly rainfall in Feb and Mar showed non significantly increasing trend. The monthly rain fall in were Apr, May, Sep, Oct, Nov, Dece showed significantly increasing trends. This result showed that the trends were not satisfied in month rainfall because Z stastical is less than Z critical value at 5% significance level except may.

Mann -Kendall (Z -test) and Sen's slope (Q) showed the increasing and decreasing trend in monthly maximum and minimum temperature (Table 4.6) while monthly maximum and minimum temperature decreased in January, June and July in maximum temperature February, Apr, May in minimum temperature respectively.

Table 4.6: Monthly Mann–Kendall (Z) and Sen's Slope test for rainfall, maximum and minimum temperature.

RF												
Test	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Zs	-1.57	-1.75	-1.81	0.64	2.51	-0.88	-1.22	-1.22	0.54	0	0.83	-0.72
Q	-0.09	-0.33	-1.5	0.63	1.63	-0.97	-2.10	-1.71	0.48	0	0.22	0.0
p-value	0.11	0.07	0.06	0.51	0.01	0.37	0.22	0.22	0.58	0	0.40	0.46
Tmax												
Test	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Zs	-0.86	0.42	1.54	1.36	0.085	-0.02	-0.64	0.91	1.64	1.68	0.66	0.52
Q	0.02	0.01	0.04	0.05	0.00	-0.00	-0.02	0.02	0.06	0.05	0.03	0.01
P-value	0.39	0.67	0.12	0.17	0.93	0.98	0.51	0.35	0.09	0.09	0.50	0.59
Tmin												
Test	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Zs	0.74	-0.19	0.64	-0.10	-0.08	0.64	0.39	0.59	0.22	0.57	1.83	0.57
Q	0.02	-0.01	0.03	0.0	0.0	0.02	0.01	0.02	0.01	0.02	0.07	0.01
P –value	0.45	0.85	0.51	0.91	0.93	0.51	0.69	0.55	0.82	0.56	0.06	0.56

*statistically significant at Zs > 1.96 (α = 0.05) at 5% significance level.

4.5. Trend Analysis of Extreme Rainfall and Temperature Indices

Extreme rainfall indices

Analysis of the weather indices showed that the maximum precipitation total was 1370.7.whereas the minimum total precipitation was 455.1with a yearly change of -7.7. The maximum continuous dry days were 139 whereas the minimum continuous dry days were 14 with a yearly change of 0.9. The maximum continuous wet days were 103 whereas the minimum continuous wet days were 11. Consecutive dry days show an increasing trend, and this phenomenon is conducive to drought occurrence, while consecutive wet days show a decreasing trend over Ethiopia. In contrast, the number of heavy precipitation days at R10 shows variability and a decreasing trend in most recent years. This is similar to that reported in previous studies (Teshome and Zhang, 2019). Climate extremes such as drought and flood affect various socioeconomic activities, and understanding the intensity and frequency of extreme climate is very important.

The rainfall extreme indices table 4.7, showed that increasing trend in Max. 1- Day rainfall amount (Rx1day), Max. 5- day rainfall amount(Rx5day), Simple daily intensity index (SDII), Number of very heavy rainfall days (R20mm), Consecutive dry days (CDD), and Extremely wet days(R99p) and decreasing trend in the Number of heavy rainfall days(R10mm), Consecutive wet days (CWD), Very wet days (R95p)and Annual total wet-day rainfall(PRCPTOT). Consecutive dry days (CDD), the index indicated an increasing trend at all rainfall indices ($P>0.05$), and Consecutive wet days (CWD) and Annual total wet-day rainfall (PRCPTOT) index indicated a decreasing trend at all rainfall indices ($p=0.05$ and 0.1). Similarly, Teshome and Zhang, (2019), reported that precipitation extreme of annual total precipitation (PRCPTOT), consecutive wet days (CWD), and the number of heavy precipitation days (R10) show a decreasing trend and consecutive dry days (CDD) shows an increasing trend. Mohammed *et al.,* (2018) reported that the frequency of total drought was the highest in the central and northern parts of the Amhara Region in all study seasons.

Extreme temprature indices

The temperature extreme indices showd that in Table 4.7, increasing trend in summer days (SU25), Max. T max (TXx), Min. T max (TXn), Max. T min (TNx), Min. T min (TNn), warm days (TX90p) and warm nights (TN90p) and significance decreasing trend in Cool days (TX10p), Cool nights (TN10p), warm spell duration indicator (WSDI), Cold Spell Duration Indicator (CSDI), The trend of the summer days (SU25), Cool days (TX10p), and Warm nights (TN90p), index indicated an increasing trend at all temperature indices ($p < 0.05$) and Max. T max (TXx), Min. T max (TXn) is ($p>0.05$). Similarly, Teshome and Zhang, (2019) reported that temperature extremes summer days (SU25), Max. T max (TXx), Max. T min (TNx) shows an increasing trend, changes in temperature and precipitation extremes are likely to have significant negative impacts on various socioeconomic activities in Ethiopia. conclude that these results need for planning and developing effective adaptation strategies for disaster prevention.

Table 4. 7: Trend of annual rainfall and temperature extremes index

Temperature indices			Rainfall indices		
Indices	Slope	p-value	Indices	Slope	p-value
SU25	2.33	0.038**	Rx1day	0.318	0.378
TXx	0.03	0.1*	Rx5day	0.029	0.952
TXn	0.039	0.089*	SDII	0.001	0.952
TNx	0.014	0.286	R10mm	-0.117	0.525
TNn	0.012	0.492	R20mm	0.032	0.462
TX10p	-0.296	0.041**	CDD	0.903	0.062*
TX90p	0.198	0.309	CWD	-1.04	0.05**
TN10p	-0.338	0***	R95p	-0.582	0.8
TN90p	0.232	0.034**	R99p	0.932	0.436
WSDI	-0.04	0.83	PRCPTOT	-7.724	0.1*
CSDI	-0.09	0.404			

***significance at 0.001=1%, **significance at 0.05=5%,*significance at 10%=0.1

4.3. Impacts of Climate Change and Variability on Crop Production

Crop production in the study area is dependent on the onset of the rainy season, any changes in the amount and temporal distribution of rainfall and other climatic factors affect crop production. The late onset of the rainfall hinders agricultural operations such as land preparation and sowing time while early offset of the rain when most of the crops are at flowering stage also directly affects fruit setting of crops. The results in line with Ademe *et al.*,(2020), reported that change in temperature and rainfall patterns have serious implications for food security. The results in line with IPCC, (2007), reported that Climate change and weather variable conditions have serious impact on crop production productivity directly through changes in the growing environment and but also indirectly through shifts in the geography and prevalence of agricultural pests and diseases, associated impacts on soil fertility and biological function, and associated agricultural biodiversity.

According to the sample respondents, the trend on the crop production on the scenarios of increase in crop yield, decrease in crop yield, a decrease of long cycle crops and no change in crop yield‟; 62.6 % of respondents responded that decrease in crop yield; 28.4 % responded decrease of long cycle crops; 8.2% responded there was no change and only 0.9 % responded that there was an increase in crop yield.

Figure, 4.8 showed that wheat and sorghum yields were increasing trend and Teff, lentil and chickpea were decreasing trend. The result of this study indicated that the area of cereal crop production for wheat, sourghum showed a significant increasing trend and teff production area indicated a non-significant decresing trend. The pulse crop production lentil and chickpea showed that significant decreasing trends. This result is in line with Getachew,(2017), reported that the trend of wheat and sorghum yield show an increasing trend at Nefas Mewcha in South Gonder Zone, Ethiopia.

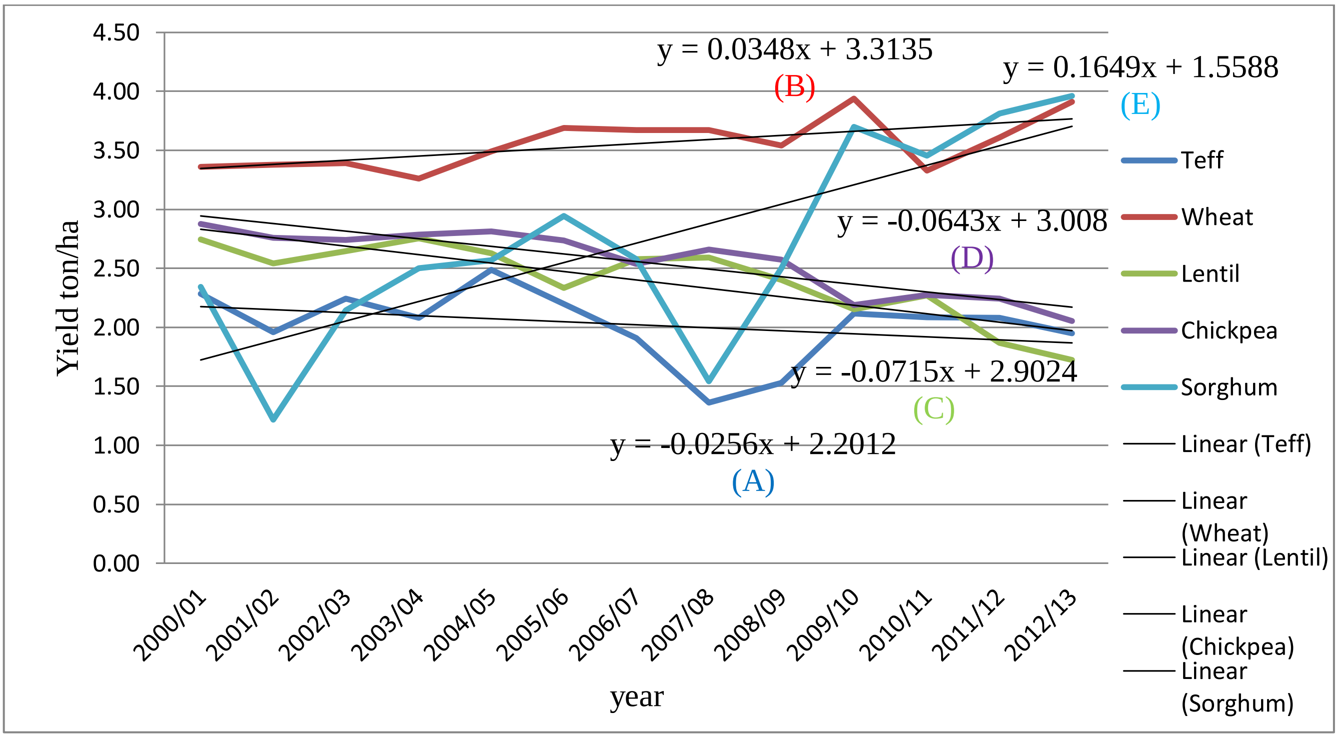


Figure 4. 8: Trends of major crops (Teff (a),Wheat (b),Lentil (c),Chickpea (d) and sorghum (e).

Trend of Rainfall were decreasing in table (4.1) , Wheat and sorghum crop production was increasing because currently different wheat crop variaties and according to survey data farmers to used different adaptation strategies such as fertilizer , add mulching. Soughum is C4 crops and drought resistance crops. Teff is C4 crops and moisture leaves . Moreover, Farmers added that wrongdoings in main rain season rainfall challenged teff planting, as planting that crop requires regular and sufficient moisture for land preparation and planting decreasing yield , lentil and chickpea were decreasing trend,chickpea is to sowing in residual crop so to want effective moisture for germination and grow. Increased temperature, changed precipitation conditions and increased CO_2 content in the atmosphere are the major climatic factors affecting crop production. Rise in atmospheric temperature will lead to loss of soil moisture and will increase the crop demand for water.

Baye, (2018), reported that the productivity of lentil in Ethiopia varies from region to region due to variation in environment and biotic factors. Currently, lentil is considered as a cash crop that realizes higher price compared to most of the cereals and pulses grown in Ethiopia.

4.3.1. Regression analysis for the climatic variables and major crops

The results of the multivariate regression analysis used to estimate the influence of rainfall and maximum and minimum temperature on crop output are shown. The results show that the adjusted R^2 of this model -20, 59, 47, 50, and 43% with the coefficient of determination (R^2)= 0.09, 0.69,0.60, 0.62,0.57 of the results also showed that the climatic variable explained roughly 9, 69, 60,62, and 57 percent of the variation in the log of teff, wheat, lentil, chickpea, and sorghum respectively in the study area (Table 4.9). Climatic variables have an impact on selected crop yield over the years under study except for teff with low percentage**.**

The F-ratio, which determines the overall significance of regression, is statistically significant at the 1% and 5% level of probability as the F-calculated values (6.82, 4.67, 5.0, and 4.02) for wheat, lentil, chickpea, and sorghum, respectively, are greater than the F-tabulated values. Therefore, it can be concluded that climate change does not significantly affect teff yield. On the other hand, the F-ratio, which determines the overall significance of the regression, is not statistically significant even at the 1% level, and at 5%, the F-calculated value (0.32) is less than the F-tabulated value. To this effect, it will be concluded that there is no significant relationship between climate variables with teff yield.

The multivariate regression analysis showed that an increase in maximum temperature is associated with an increase in yield of wheat, whereas an increase in maximum temperature were a decrease in yield of lentil, chickpea, teff, and sorghum (Table 4.9). On the other hand, an increase in minimum temperature will increase the yield of teff, wheat, and sorghum, whereas an increase in minimum temperature will decrease the yield of lentils and chickpeas. an increase in rainfall will increase the yield of wheat, and sorghum,whereas an increase rainfall will decrease the yield of teff, lentil, and chickpea yields (Table 4.9).

Crop yield is nonlinearly affected by variations in rainfall and temperature, according to the findings of multivariate regression research. Crop yield is reduced by rainfall and temperature variability, but the impacts differ by crop. The findings also revealed that rainfall and temperature variations have a major impact on crop production in the study area.

Table 4.9 :Multivariate regression analysis of the climatic variables with major crops

Variable	Teff	Wheat	Lentil	Chick pea	Sorghum
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Rainfall	-0.0003314	0.0011706	-0.0015662	-0.0012712	1.024053
Maximum temprature	-0.1769959	0.0023376	-0.0969692	-0.0693180	-0.045130
Minimum temprature	0.0005971	0.1076697	-0.0446442	-0.0184815	0.042878
R^2	0.09	0.69	0.60	0.62	0.57
Adjusted R^2	-0.20	0.59	0.47	0.50	0.43
F-statistic	0.322	6.82	4.67	5.0	4.02
P-value	0.808	0.01	0.03	0.02	0.04

4.4. Correlation Analysis for the Climatic Elements and Major Crops

The Pearson correlation analysis on the yields of major crops and climate variability indicated that Kiremt rainfall had positive significantly correlated with wheat (r = 0.742**) and sorghum (r = 0.823**) and had a significant negative correlation with chickpea (r = -0.731**) and lentil (r = -0.683*). Sorghum had a significant positive correlation with belg rainfall (r = 0.663*). Annual rainfall had a significant positive correlation with yields of wheat (r = 0.735**) and of sorghum (r = 0.755**) whereas it had a negative Significant correlation with chickpea (r = -0.779**) and that lentil (r = -0.755**). Moreover, the correlation of major crops with minimum temperature showed a (positive) relationship for teff , chickpea and lentil and it had a (negative) correlation with wheat, and sorghum. The negative sign in wheat, and sorghum indicated that temperature highly afects their production or it means that teff, chickpea and lentil require adequate minimum temperature to survive while wheat and sorghum do not require much of minimum temperature to grow. This means that increase in minimum temperature will lead to reduction in the major crops. And the correlation of major crops with maximum temperature showed a (positive) relationship for chickpea and lentil and it had a (negative) correlation with teff, wheat, and sorghum (Table 4.10). It means that these crops do not need maximum temperature to grow. This result is in line with Kebede *et al.,* (2019) reported that the production of wheat shows stronger correlations with kiremet rainfall while sorghum production is more strongly correlated with belg and kiremt rainfall. The negative sign in temperature with teff, wheat, and sorghum indicated that temperature highly affects their production. This result in line with Kushabo *et al*., (2019), who reported that the negative sign in teff, wheat indicated that temperature highly affects their production. Suggesting rainfall is the major yield-limiting factor as the use of chemical fertilizers and other agricultural inputs is limited and farmers are vulnerable to food insecurity due to rainfall variability there is a need for water resources development including household-level rainwater harvesting for crop production.

Table 4. 10: Pearson correlation between major crop and climate variable.

Weather Element	Teff	Wheat	Chickpea	Lentil	Sorghum
Kiremt Rainfall	0.107	0.742**	-0.731**	-0.683*	0.823**
Belg rainfall					0.663*
Annual RF	-0.038	0.735**	-0.779**	-0.755**	0.755**
Tmax	-0.250	-0.351	0.265	0.234	-0.396
Tmin	0.022	-0.147	0.435	0.381	-0.438

** = Significant correlation at 0.01 level(2- tailed); * = Significant correlation at 0.05 level(2- tailed).

4.5. Adaptation Strategies to Climate Change

Adaptation to climate change is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (Yibekal et al., 2013). Adapting to climate change refers to adjustments and changes at every level from community to national and international. Communities must build their resilience, including adopting appropriate technologies while making the most of traditional knowledge and diversifying their livelihoods to cope with current and future climate stress.

Major adaptation measures identified were adjusting planting dates, diversification of crop types or using improved seed varieties, intercropping, recommended mineral fertilizers, use of irrigation, and soil and water conservation measures, plantation of trees, crop rotation (Abid *et al.*, 2014; Mekonnen, 2018; Helen *et al.*, 2021). Legesse *et al*., (2012), reported that crop diversification together with soil and water conservation and water harvesting practices were commonly used climate change adaptation strategies in Ethiopia

According to household survey methods, the researcher revealed that different adaptation strategies such as improving seed varieties, crop diversification, planting trees, soil and water conservation, changing planting dates, irrigation, water harvesting, and Growing short-maturing crops are the most local adaptation strategies in the study area.

According to respondents, they are using different adaptation options to reduce the negative effect of climate change. So adaptation strategies used in this district include Soil and water conservation, Improve seed variety, Changing plant date, Crop diversification , Irrigation and Rainwater harvesting, Tree planting, and Growing short mature crops table 4.11. According to the household survey (90.35%) used soil and water conservation as an adaptation measure. The reasons for the majority of farmers to practice these strategies were cheap practice relative to others, and soil and water conservation measures are largely practiced by the intervention of the government.

4.5.1. Improve seed variety

From the total household survey, 70.47 % of respondents followed by Improve seed variety. As the information gained from sample household head respondents, FGD and key informants interviewed reported that Diversifying crop varieties they grow to avoid the effect of climate change and variability. Producing crop species with enhanced nutrients and health‐ promoting compounds is one of the main aims of current breeding programs. However, breeders traditionally focused on characteristics such as yield or pest resistance, while breeding for crop quality, improving seed quality of main crops is a major target of breeding programs, to ensure human nutrition, as they provide a significant percentage (around 20%) of the consumed energy, protein and dietary fiber (Pott *et al.*, 2021).

4.5.2. Crop diversification

According to the sample, household survey 64.62 % of respondents followed by Crop diversification. Crop-based approaches include growing improved crop varieties and using different crop varieties that survive in adverse climatic conditions. Crop diversification is one of the promising adaptation strategies. Legesse *et al*.,(2012), reported that crop diversification together with soil and water conservation and water harvesting practices were commonly used climate change adaptation strategies in Ethiopia. Smallholder farmers take advantage of the different maturing times of crops, to strengthen their resilience to impacts associated with climate change and variability (Kihupi *et al.*, 2015). The use of different crop varieties is the most commonly used adaptation strategy whereby a variety of crops are grown on the same plot or different plots, thus reducing the risk of complete crop failure since different crops are affected differently by climate events (Leta, 2011). Crop diversification can be implemented in a variety of forms and at a variety of scales, allowing farmers to choose a strategy that both increases resilience and provides economic benefits. Farmers may be able to assist in creating biotic barriers against new pests by increasing the plant diversity of their farms in ways that promote natural enemy abundance. The composition of the plant community, as determined by a farmer, may be described as the planned diversity of the system (Lin, 2011). Improves tolerance to drought and water- logging, a Key adaptation strategy for smallholder farmers under climate change; Increases yield stability, Can serve as insurance against rainfall variability as different crops are affected differently by climate events, Relative differences in productivity Feliciano, 2019 cited Lin, 2011.

4.5.3. Changing plant dates

This adaptation strategy includes early and late planting options as a strategy for the changing climate. This strategy helps to protect sensitive growth stages by managing the crops to ensure that these critical stages do not coincide with very harsh climatic conditions such as mid-season droughts (Gebrehiwot and Veen, 2013). From the sample household survey result, 55.85 % of the respondents indicate that change in cropping pattern is dominantly practiced. Recently; rainfall in the study area has shown variability. The focus group discussion (FGD) reported that changing the sowing of lentils, and chickpea the reason was a pest and disease. Change to teff, farmers could not be certain about rainfall conditions, even after the onset of rain. According to them, even after the onset, rainfall could be heavy or light or it may stop earlier than the expected time. Through experience, farmers are aware of the type of crops planted following the characteristic of the rain.

From focus group discussion (FGD) belg rainfall are important not only for the Belg season production but also for land preparation for the main season crops. The declining trend in belg rains affects both belg and summer season crops, particularly in long-cycle crops such as maize and sorghum. Although soil fertility decrement, government policies, land scarcity, and market situation are the cause of cropping pattern change, most of the respondents have had the opinion that the contribution of climate variability was considerable in the past practice in this district.

4.5.4 . Soil and water conservation

From household surveys, 90.35% of respondents followed soil and water conservation. In Ethiopia, they have often used different kinds of soil and water conservation strategies. To reduce soil erosion, soil and water conservation structures have been constructed in the study area including physical measures (terracing, check dams, eyebrow basin, and area closure (Yimer *et al.,* 2021). The adoption of practices and technologies that enhance vegetative soil coverage and control soil erosion are crucial to ensuring greater resilience of production systems to increased rainfall events, extended intervals between rainfall events, and potential soil loss from extreme climate events. Improving soil management and conservation techniques assists to restore the soil while also capturing soil carbon and limiting the oxidation of organic matter in the soil (Gebrehiwot and Veen, 2013)

4.5.5. Tree Planting

From the sample household survey, 66.37 % of respondents followed soil and water conservation. Tree planting is a common adaptation strategy in the study area and elsewhere in Ethiopia. Planting trees or afforestation in general provides a particular example of a set of adaptation practices that are intended to enhance productivity in a way that often contributes to climate change mitigation through enhanced carbon sequestration. It also has a role to play in strengthening the system's ability to cope with the adverse impacts of changing climate conditions (Gebrehiwot and Veen, 2013).

4.5.6. Irrigation and Water harvesting

From household survey 55.85% of respondents followed by Irrigation and Water harvesting**.** Irrigation was the major adaptation strategy (Kihupi *et al.*, 2015). Irrigation can be a valuable strategy for making agriculture more stable and safe. The use of irrigation is one of the least practiced adaptation strategies among the major adaptation methods identified in Ethiopia (Temesgen *et al.*, 2014). The use of irrigation is one of the least practiced adaptation strategies among the major adaptation methods identified in Ethiopia. The sample of the household that use irrigation at kesem river and burka produce vegetables like tomato, paper, onion, and cabbage for household consumption and to sell at the market.

Community water harvesting was also challenged by less precipitation, water seepage, and quality deterioration. In some places, plastic cover was tried to prevent seepage, and spit irrigation was used in case of less precipitation (Abate, 2009).

4.5.7. Growing short-maturing crops

From the total household survey, 41.81% of the respondent use short maturing crops, in kebele level kola and of woina dega kebeles used growing short maturing crop types as a response to climate change. Types of short maturing crops masho, teff, and the other major finding from the respondent is that households are using drought-tolerant crops to adapt to climate change but most of them lack the financial resources to access such varieties. Gebrehiwet and van dar veen, (2013) stated that growing early maturing crop varieties and increasing diversification by planting crops that are drought tolerant and/or resistant to temperature stresses serves as an important form of insurance against rainfall fluctuations.

Table 4. 11: local adaptation strategies

Adaptation strategies	Kebeles			Total
	Woldegiorgies (Dega)	BoloSelassie (Woyina-dega)	Korma (Kola)	
	Percent(%)			
Improve seed variety	15.02	30.45	25	70.47%
Changing plant date	10.35	19.5	26	55.85%
Soil and water conservation	19.3	30.05	41	90.35%
Crop diversification	15.2	18.92	30.5	64.62%
Irrigation and Rainwater harvesting	21.05	20.1	14.7	55.85%
Tree planting	22.5	26	17.85	66.37%
Growing short mature crops	5.81	11	25	41.81%

CHAPTER FIVE. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

The results indicated that the yearly rainfall was declining, while average mean, maximum, and minimum temperatures in the study area were increasing. Increase in temperature and decrease in amount of rainfall may have a negative impact on crop production.

The rainfall anomaly index and precipitation concentration index revealed that rainfall distribution in Minjar Shenkora district is highly variable. The results of the rainfall indices and temperature indices suggested that long-term rainfall trends were declining, while temperature trends were increasing.

Crop yields have both a negative and positive relationship with climate variables. In general, this research findings indicate that rainfall, as well as maximum and minimum temperature variability has both a positive and negative impact on crop yields in this district.

They have used different adaptation mechanisms to overcome the impact of climate change. The most frequently adopted response mechanisms are growing early mature crops, soil and water conservation, changing planting dates, growing short mature crops, crop diversification, tree planting, irrigationand rainwater harvesting and improve seed. further studies should be investigated on the impact of climate change and variability impacts on major crops production and adaptation strategies.

5.2. Recommendation

Based on these results of the study, the following recommendations have been made:

- ✓ Improved crop varieties to user farmers and Promote the use of early maturing seeds that can resist the impact of climate change and variability. However, the rural people who live in Minjar Shenkora District are facing a declining trend in crop productivity, the problem shall continue in the future except suitable measures are taken. Hence, selecting an appropriate variety of crops such that diseases are resistant and early maturing and improving the method of cultivation and agricultural technologies.
- ✓ To improve farmers‟ adaptive strategies, the government should contribute and enforce the community to use new agricultural technologies, such as improved new seeds, drought tolerant crops, expanding markets, establishing crop insurance institutes, and expanding education (farmers training centers, formal education).
- ✓ To minimize the impacts of climate change and variability by Empowering peoples with education and information , helping train for farmers on utilization of inputs, use environmentally sound agricultural production system, use integrated adaptation and mitigation measures, solve the constraint and expand correct adaptation strategies.
- ✓ Farmers living at different agro ecological settings used different adaptation methods. Thus, future policy has to aim at providing adaptation technologies through agro ecology based research.
- ✓ Based on the resulting, this study recommends that further studies investigating the impact of climate change and variability on major crops production should be considering the seasonal variation of climate elements in the study area and diversifying household income sources.

REFERENCES

Abadi Berhane. (2018). Climate Change and Variability Impacts on Agricultural Productivity and Food Security. *Climatology and Weather Forecasting*, *6*(3). https://doi.org/10.4172/2332-2594.1000240.

Abate, F. S. (2009). *Climate Change Impact on Livelihood, Vulnerability and Coping Mechanisms: A Case Study of West-Arsi Zone, Ethiopia*. Lund University.

Abayineh, Amare and Belay, S. (2017). Determinants of smallholder farmers ' decision to adopt adaptation options to climate change and variability in the Muger Sub-basin of the Upper Blue Nile basin of Ethiopia. *Agriculture and Food Security*, 1–20. https://doi.org/10.1186/s40066-017-0144-2.

Abdi, H. (2011). Coefficient of Variation. In *Encyclopedia of Research Design* (pp. 267–267). https://doi.org/10.1007/978-3-642-04898-2_177.

Abid, M., Scheffra, J., Schneider, U. A., and Ashfaq, M. (2014). Farmers ' perceptions of and adaptation strategies to climate change and their determinants ; the case of Punjab province, Pakistan. *Earth Syst. Dynam.*, *6*(1), 1359–1406. https://doi.org/10.5194/esdd-5-1359-2014.

Addisu B.C. (2018). Trends of major crop productivity to climate variability in Lay Gayint District , Northwest Ethiopia. *Research Journal of Social Science and Management*, *8*(5), 102–117.

Ademe, D., Benjamin, F. Z., KindieTesfaye, Belay, S., Getachew, A., and Enyew, A. (2020). Climate trends and variability at adaptation scale : Patterns and perceptions in an agricultural region of the Ethiopian Highlands. *Weather and Climate Extremes*, *29*, 100263. https://doi.org/10.1016/j.wace.2020.100263.

Aemro, T., Jemma, H., and Mengistu, K. (2012). Climate Change Adaptation Strategies of Smallholder Farmers: The Case of Babilie District, East Harerghe Zone of Oromia Regional State of Ethiopia. *Economics and Sustainable Development*, *3*(14).

Akinnagbe O.M and Irohibe I. J. (2014). Agricultural adaptation strategies to climate change impacts in Africa: a review a. *Bangladesh J. Agril. Res.*, *39*(3), 407–418.

Aklilu, A., and Alebachew, A. (2009). *Assessment of climate change-induced hazards, impacts, and responses in the southern lowlands of Ethiopia*.

Alemu, B., and Desale, K. A. (2015). Rainwater harvesting : An option for dryland agriculture in arid and semi-arid Ethiopia. *International Journal of Water ResourcesandEnvironmentalEngineeringFull*,*7*(2),1728.https://doi.org/10.5897/IJWREE2014.0539.

Amogne, A., Simane, B., Hassen, A., and Bantider, A. (2017). Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia : A case study in Wolekasubbasin.*WeatherandClimateExtremes*,113.https://doi.org/10.1016/j.wace.2017.12.002.

Aschalew, S. (2014). Smallholder Farmers Adaptation Strategies to Climate Change in Ethiopia: Evidence from Adola Rede District , Oromia. *Journal of Economics and Sustainable Development Cite*, *5*(7), 162–182.

Asefa E. (2020). *Climate Variability, Impacts on Maize (Zea mays L.) Yield, and Smallholder Farmers' Perception and Adaptation Strategies in West Badawacho District of Hadiya Zone, Southern Ethiopia.MSc Thesis, Haramaya University, Ethiopia.*

Ayalew, D., Tesfaye, K., ,Mamo G., , Yitaferu B. and Bayu W .(2012). *Variability of rainfall and its current trend in Amhara region, Ethiopia*. African Journal of Agricultural Research, Vol. 7(10), pp. 1475-1486.

Aynalem Getye. (2020). *Farmer s' Responses to Climate Variability and Change in Minjar Shenkora District of North Shewa Zone of the Amhara Region, Ethiopia.MSc thesis,Debre Berhan University*, *Ethiopia*. Debre Berhan universty.

Baye C. A. (2018) *Trends of major crops productivity to climate variability in Lay Gayint Woreda, Northwest Ethiopia*. Research journals of social science and management Volume: 08, Number: 05.

Belay, A., Demissie, T., Recha, J. W., Oludhe, C., and Osano, P. M. (2021). *Analysis of Climate Variability and Trends in Southern Ethiopia*. *June*.

Belay, A., Demissie, T., Recha, J. W., Oludhe, C., Osano, P. M., Olaka, L. A., Solomon, D., and Berhane, Z. (2021). *Analysis of Climate Variability and Trends in Southern Ethiopia*. 1–17.

Belay Zerga, and Getaneh Gebeyehu. (2016).*Climate Change in Ethiopia Variability, Impact, Mitigation, and Adaptation*. Journal of Social Science and Humanities Research, *2*(4).

Bewick, V., Cheek, L., and Ball, J. (2003). Statistics review 7: Correlation and regression. *Critical Care*, *7*(6), 451–459. https://doi.org/10.1186/cc2401

Bewket, W., and Conway, D. (2007). A note on the temporal and spatial variability of rainfall in the drought-prone Amhara region of Ethiopia. *Int. J. Climatol.*, *27*(May), 1467–1477. https://doi.org/10.1002/joc.

Bewuketu M. (2017). *Farmers Perception and Adaptation Strategies to Climate Change : The Case of Woreillu District of Amhara Region, Northeastern Ethiopia.MSc Thesis, Haramaya University, Ethiopia*.

Birtukan, A., and Abraham, M. (2020). Determinants of farmers' choice of adaptation to climate variability in Dera district , south Gondar zone, Ethiopia. *Environmental Systems Research*, *2016*. https://doi.org/10.1186/s40068-015-0046-x.

Brien, D. O., and Scott, P. S. (2012). *Correlation and Regression*. 0–16.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., and Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *International Food PolicyResearchInstitut*,*12*(4),413–426. https://doi.org/10.1016/j.envsci.2008.11.002

Cooper, P. J. M., Dimes, J., Rao, K. P. C., and Shapiro, B. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa : An essential first step in adapting to future climate change, *Agriculture, Ecosystems and Environment*, *126*, 24–35. https://doi.org/10.1016/j.agee.2008.01.007.

CSA, (2013). Population projection value . Addiss Ababa.

Daniel, B., Tena, A., Asfaw, K., Gete, Z., and Assefa, M. M. (2017). Analysis of rainfall trend and variability for agricultural water management in Awash River Basin, Ethiopia.*WaterandClimate Change*,127–141. https://doi.org/10.2166/wcc.2016.044

Deressa, T.T., Hassan,R.M., and Ringler, C.(2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *Journal of Agricultural Science*, *149*, 23–31.

Douxchamps, S., Wijk, M. T. Van, Silvestri, S., Moussa, A. S., Quiros, C., Ndour, N. Y. B., Buah, S., Some, L., Herrero, M., Kristjanson, P., Ouedraogo, M., Thornton, P. K., Asten, P. Van, Zougmore, R., and Rufin, M. C. (2015). Linking agricultural adaptation strategies, food security, and vulnerability : evidence from West Africa. *Reg Environ Change*. https://doi.org/10.1007/s10113-015-0838-6.

Escarcha, J. F., and Zander, K. K. (2018). Livestock Under Climate Change: A Systematic Review of Impacts and Adaptation Jacquelyn. *Climate*, *6*(54), 1–17. https://doi.org/10.3390/cli6030054.

Feliciano, D. (2019). A review of the contribution of crop diversification to Sustainable Development Goal 1 “ No poverty ” in different world regions. *Sustainable*

Development Published by ERP Environment and John Wiley & Sons Ltd, 1–14. https://doi.org/10.1002/sd.1923.

Firdos, K., Jürgen, P., Muhammad, A., and Wiberg, D. A. (2015). Climate variability and its impacts on water resources in the Upper Indus Basin under IPCC climate change scenarios. *Int. J. Global Warming, 8*(1), 46–69.

Frieler, K., Schauberger, B., Arneth, A., Balkoviˇ, J., Elliott, J., Folberth, C., Deryng, D., Müller, C., Olin, S., Pugh, T. A. M., Schaphoff, S., Schewe, J., Schmid, E., Warszawski, L., and Levermann, A. (2017). Understanding the weather signal in nationalcrop-yieldvariability.*Earth'sFuture*,*5*,605–616. https://doi.org/10.1002/2016EF000525

Gebeyanesh, Z., Debela, F., Dong-Gill, K., and Bettina, E.-L. (2021). Challenges of Smallholder Farming in Ethiopia and Opportunities by Adopting Climate-Smart Agriculture. *Agriculture 2021*, *11*(192), 1–25. https://doi.org/10.3390/agriculture11030192.

Gebrehiwot, T., and Veen, A. Van Der. (2013). Farm Level Adaptation to Climate Change : The Case of Farmers' s in the Ethiopian Highlands. *Environmental Management*, *52*(1), 29–44. https://doi.org/10.1007/s00267-013-0039-3.

Gemeda, D. O., Korecha, D., and Garedew, W. (2021). Evidence of climate change present inthewettestpartsofsouthwestEthiopia.*Heliyon,7*.https://doi.org/10.1016/j.heliyon.2021.e08009.

Getahun, Y. S., Li, M. H., and Pun, I.F. (2021). Trend and change-point detection analyses of rainfall and temperature over the Awash River basin of Ethiopia. *Heliyon*, *7*(9), e08024.

Getachew B. (2017).*mpacts of Climate Change on Crop Yields in South Gonder Zone, Ethiopia.* World Journal of Agricultural Research, Vol. 5(2), pp 102-110.

Grant, M. S. (2010). *Climate Variability and Climate Change*.

Haftu Brhane, G., Gelana Amente, R., Kassahun Ture, B., Gudina Legese, F., and Teshome, S. (2022). Changes in daily rainfall and temperature extremes of upper Awash Basin, Ethiopia. *Scientific African, 16,* e01173. https://doi.org/10.1016/j.sciaf.2022.e01173.

Haji , Kedir, and Solomon, T. (2016). Climate Variability and Livelihood Strategies Pursued by the Pastoral Community of the Karrayu People, Oromia Region, Central Ethiopia. *East African Journal of Sciences*, *10*(1), 61–70.

Helen, T., Kindie, T., Nigussie, D., Tamado, T., and Matthew, H. (2021). Smallholder Farmers ’ Perceptions of Climate Change and Adaptation Practices for Maize Production in Eastern Ethiopia. *Sustainability*, *13*(9622), 1–21.

https://power,larc,nasa,gov/data-access-viewer.

IPCC. (2007). *Climate Change 2007:The Fourth Assessment Report of Intergovernmental Panel on Climate Change.Cambridge University*.

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate ChangeCore Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp*.

Ishaya, S.1 and Abaje, I. B. (2008). Indigenous people’s perception on climate change and adaptation strategies in Jema ’ a local government area of Kaduna State, Nigeria. *Geography and Regional Planning*, *1*(8), 138–143.

Joseph, K. A., and Fikirte, R. B. (2013). Livelihood Impacts of Environmental Conservation Programmes in the Amhara Region of Ethiopia. *Sustainable Development*, *6*(10), 87–105. https://doi.org/10.5539/jsd.v6n10p87.

Kebede, A., Diriba, K., and Eyale, B. (2019). Impacts Of Climate Change And Variability On Major Crop Production In Ankesha Guagusa District Of Awi Zone, Northwestern Ethiopia. *Agricultural And Rural Research*, *3*(4), 158–171.

Kefelegn C. (2020). *Impacts Of Climate Change And Variability On Rural Livelihoods and Community Responses:* The Case Of Merhabete District , North Shewa Zone, Amhara National Regional State, Ethiopia.Msc Thesis, Debre Berhan University, Ethiopia.

Khan, S. A., Kumar, S., Hussain, M. Z., and Kalra, N. (2009). *Climate Change, Climate Variability, and Indian Agriculture : Impacts Vulnerability and Adaptation Strategies* (pp. 19–39). Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-540-88246-6.

Kihupi, M. L., Mahonge, C., Chingonikaya, E. E., Mwalimu, T., Memorial, N., & Dar, P. O. B. (2015). Smallholder Farmers ’ Adaptation Strategies to Impact of Climate Change in Semi-arid Areas of Iringa District Tanzania. *Biology Agriculture and Healthcare, 5*(2).

Kushabo, A., Addisu, S., and Tsegaye, D. (2019). Climate Change and Variability Impacts on Rural Livelihoods and Adaptation Strategies in Southern Ethiopia Federal Democratic Republic of Ethiopia Intergovernmental Panel on Climate Change

United Nations Environmental programs. *Earth Systems and Environment*. https://doi.org/10.1007/s41748-019-00134-9.

Legesse, B., Ayele, Y., and Bewket, W. (2012). Smallholder Farmers' Perceptions And Adaptation To Climate Variability And Climate Change In Doba District, West Hararghe, Ethiopia. *Asian Journal of Empirical Research*, *3*(3), 251–265.

Lemi, T., and Hailu, F. (2019). Effects of Climate Change Variability on Agricultural Productivity. *Int J Environ Sci Nat Res 17(1):*, *17*(1). https://doi.org/10.19080/IJESNR.2019.17.555953.

Leta Abate. (2011). *Assessment of climate change effects on rain-fed crop production and coping mechanisms: the case of smallholder farmers of west Shoa zone, Oromia, Ethiopia; Master's Thesis,* Addis Ababa University.

Lin, B. B. (2011). Resilience in Agriculture through Crop Diversification : Adaptive Management for Environmental Change. *American Institute of Biological Sciences*, *61*(3), 183–193. https://doi.org/10.1525/bio.2011.61.3.4.

Loria, N., and Bhardwaj, S. K. (2016). Farmers ' Response and Adaptation Strategies to Climate Change in Low-Hills of Himachal Pradesh in India. *Nature Environment and Pollution Technology An International Quarterly Scientific Journal*, *15*(3), 895–901.

Lyimo, James, A., and Kangalawe, R. Y. M. (2010). Vulnerability and adaptive strategies to the impact of climate change and variability. The case of rural households in semi-arid Tanzania. *Environmental Economics*, *1*(2), 89–97.

Mahoo, H., Radeny, M., Kinyangi., J., & Cramer, L. (2013). *Climate Change Vulnerability and Risk Assessment of Agriculture and Food Security in Ethiopia* (No. 59).

Mann, H. B. (1945). Nonparametric Tests Against Trend .Econometric Society Stable URL : https://www.jstor.org/stable/1907187.

Mashizha, T. M., Ncube, C., Dzvimbo, M. A., and Monga, M. (2017). Examining The Impact Of Climate Change On Rural Livelihoods And Food Security: Evidence From Sanyati District In Mashonaland West, Zimbabwe. *Asian and African Social Science and Humanities*, *3*(2), 56–68.

McGuigan, C., Rebecca, R., and Wiedmer, D. (2002). *Poverty And Climate Change: Assessing Impacts In Developing Countries And The Initiatives Of The International Community*.

Mekonen A.A., and BerlieA.B. (2021). Rural households ’ livelihood vulnerability to climate variability and extremes : a livelihood zone-based approach in the Northeastern Highlands of Ethiopia. *Ecological Process*, 5–23.

Mekonnen, H. D. (2018). Assessing Local Community Perceptions on Climate Change and Variability and its Effects on Crop Production in Selected Districts of Western Oromia, Ethiopia. *Journal of Climatology & Weather Forecasting*, *6*(1). https://doi.org/10.4172/2332-2594.1000216.

Melese Gezie. (2019). Farmer’s s response to climate change and variability in Ethiopia :A review.*CogentFood&Agriculture*,*5*(1).https://doi.org/10.1080/23311932.2019.1613770.

Michiels, E., Gabriels, D., and Hartmann, R. (1992). *Using the Seasonal and Temporal Precipitation Concentration Index for Characterizing the Monthly Rainfall Distribution in Spain*. *19*, 43–58.

Miftha, B., Menfese, T., Fantaw, Y., and Nicolas, B. (2022). Factors Affecting Adoption and Intensity of Use of Tef-Acacia decurrens-Charcoal Production Agroforestry SysteminNorthwesternEthiopia.*Sustainability*,*14*(4751).https://doi.org/10.3390/su14084751

Mitra, J. (2001). Genetics and genetic improvement of dro resistance in crop plants,. *Current Science Association*, *80*(6), 758–763.

Mkonda, M. Y. (2018). *Soil Organic Carbon Accumulation, Climate Variability and Crop Production in Tanzania’s Semi-arid Agro-Ecological Zone: A Case Study of the Kongwa District. PhD thesis, Southwest University*. Southwest University.

Mkonda, M. Y, HE, X., and Festin, E. S. (2018). Comparing Smallholder Farmers’ Perception of Climate Change with Meteorological Data: Experience from Seven Agroecological Zones of Tanzania. *American Meteorological Society*, *10*, 435–452. https://doi.org/10.1175/WCAS-D-17-0036.1.

Mohammed, Y., Yimer, F., Tadesse, M., and Kindie Tesfaye. (2018). Meteorological drought assessment in northeast highlands of Ethiopia. *International Journal of Climate Change Strategies and Management*. https://doi.org/10.1108/IJCCSM-12-2016-0179.

Moriondo, M. (n.d.). *Climate change impact assessment : the role of climate extremes in crop yield simulation*. https://doi.org/10.1007/s10584-010-9871-0.

MSDARDO. (2008). *MSDARDO (2008) Minjar Shenkora District Agriculture and Rural development office. Annual work report (Unpublished). Arerty*.

NMSA(National Meteorological Servies Agency). (2007). *Climate change: National Adaptation Program of Action (NAPA) of Ethiopia with Ministry of Water Resource, Addis Ababa.*Ethiopia.

Oliver, J. E. (1980). Monthly Precipitation Distribution : A Comparative Index. *Professional Geographer*, *32*(3), 300–309.

Panda, A., Netrananda, S., Behera, S., Sayama, T., Sahu, L., Avtar, R., Singh, R. B., and Masafumi, Y. (2019). Impact of Climate Variability on Crop Yield in Kalahandi, Bolangir, and Koraput Districts of Odisha, India. *Climate*, *7*(126). https://doi.org/10.3390/cli7110126.

Pott, D. M., Soria, S. D., Osorio, S., and Vallarino, J. G. (2021). Combining metabolomic and transcriptomic approaches to assess and improve crop quality traits. *CABI Agriculture and Bioscience*. https://doi.org/10.1186/s43170-020-00021-8.

Poudel, S., and Shaw, R. (2016). The Relationships between Climate Variability and Crop Yield in a Mountainous Environment: A Case Study in Lamjung District, Nepal. *Climate*, *4*(13). https://doi.org/10.3390/cli4010013.

Samuel, O. O., Akwasi, A. M., and Sylvia, T. S. (2019). Prioritization on cultivation and climate change adaptation techniques: a potential option in strengthening climate resilience in South Africa. *Agronomía Colombiana*, *37*(1), 62–72.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. *American Statistical Association*, *63*(324), 1379–1389.

Solomon, A., Getachew, F., Birhanu, G., and Yemane, A. (2016). Perception and adaptation models of climate change by the rural people of lake Tana Sub - Basin, Ethiopia. *Environmental Systems Research*, *5*(1), 1–10.

Solomon, B., Jones, A., and Anyango, S. (2014). Determinants of Adoption Choices of Climate Change Adaptation Strategies in Crop Production by Small Scale Farmers in Some Regions of Central Ethiopia. *Natural Sciences Research*, *4*(4).

Stone, R. J. (2015). Caribbean Workshop on Soil Physical Management Soil Management Issues Related to Food Production and Environmental Quality as a Consequence of Climate Change and Variability June.

Temesgen, G., Wondie, M., Daniel, H., and Abeba, N. (2014). Climate Change Adaptation and Mitigation Measures in Ethiopia,. *Biology, Agriculture and Healthcare*, *4*(2014.).

Temesgen, T., Hassan, R. M., and Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *Journal of agricultural Science (2011)*, *149*(1), 23–31. https://doi.org/10.1017/S0021859610000687.

Temesgen Tadesse, D. (2010). *Assessment of the vulnerability of Ethiopian agriculture to climate change and farmers' adaptation strategies*. University of Pretoria.

Teshome, A., and Zhang, J. (2019). Increase of Extreme Drought over Ethiopia under Climate Warming. *Advances in Meteorology*.

Thomas, D. S. G., Twyman, C., Osbahr, H., and Hewitson, B. (2007). Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change*, 301–322. https://doi.org/10.1007/s10584-006-9205-4

Tsedeke, R. E., Dawud, S. M., and Tafere, S. M. (2021). Assessment of carbon stock potential of parkland agroforestry practice : the case of Minjar Shenkora ; North Shewa , Ethiopia. *Environmental Systems Research*.https://doi.org/10.1186/s40068-020-00211-3.

Twumasi Martinson Ankrah, and Jiang, Y. (2020). The impact of climate change coping and adaptation strategies on livestock farmers' technical efficiency: the case of rural Ghana. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-020-11525-1.

White, David H, and Howden S. M. (2018). *Climate and its effects on crop productivity and management: Vol. I.*

Woldeamlak, B. (2009). Rainfall variability and crop production in Ethiopia, Case study in the Amhara region. In *Proceedings of the 16th International Conference of Ethiopian Studies, ed. by Svein Ege, Harald Aspen, Birhanu Teferra and Shiferaw Bekele, Trondheim 2009*.

Yamane, T. (1967). *Statistics an introductory analysis* (S. Edition. (Ed.); p. p. 345.). Harper and Row Inc.

Yibekal A, T., Chanyalew S, A., and Getachew S, E. (2013). Understanding the process of adaptation to climate change by small-holder farmers: the case of east Hararghe Zone, Ethiopia. *Agricultural and Food Economics*, 1–17.

Yimer, M., Kindie, T., Menfese, T., and Fantaw, Y. (2021). *Analysis of smallholder farmers ' vulnerability to climate change and variability in south Wollo , north east highlands of Ethiopia : An agro-ecological system-based approach*. https://doi.org/10.21203/rs.3.rs-106882/v1.

Yimer, M., Yimer, F., MenfeseTadesse, and Tesfaye, K. (2018). Variability and trends of rainfall extreme events in north east highlands of Ethiopia. *International Journal of Hydrology*, *2*(5), 594–605. https://doi.org/10.15406/ijh.2018.02.00131.

Yohannes, A. A. (2014). *Rainwater Harvesting For Climate Change Adaptation In Ethiopia: Policy And Institutional Analysis*(Issue 488).

Zegeye, H. (2018). Climate change in Ethiopia : impacts , mitigation and adaptation. *Int. J. Res. Environ. Stud.*, *5*(1), 18–35.

Zhang, X., Yang, F., and Canada, E. (2004). *RClimDex (1.0) User Manual*. 1–23.

APPENDICES

Appendex Table 1 : Correlation of Meteorological and NASA power data for study area

Location	R value		
Minjar Shenkora	Rainfall	Maximum temprature	Minimum temprature
	0.738	0.719	0.63

Appendex Table 2: Types of major crops production(to/ha)

year	Teff(*Erogratis teff*),	Wheat *(Triticum astevium*)	Lentil (*Lens culinaris*)	Chickpea (*Cicer arietinum*)	Sorghum (*Sorghum bicolor*)
2000/01	2.28	3.36	2.75	2.88	2.35
2001/02	1.96	3.38	2.54	2.76	1.22
2002/03	2.24	3.39	2.65	2.74	2.14
2003/04	2.08	3.26	2.75	2.78	2.50
2004/05	2.49	3.49	2.63	2.81	2.57
2005/06	2.20	3.69	2.33	2.74	2.94
2006/07	1.91	3.67	2.58	2.54	2.58
2007/08	1.36	3.67	2.59	2.66	1.54
2008/09	1.53	3.54	2.40	2.57	2.50
2009/10	2.12	3.94	2.15	2.19	3.70
2010/11	2.09	3.33	2.27	2.28	3.46
2011/12	2.08	3.61	1.87	2.25	3.81
2012/13	1.95	3.91	1.72	2.05	3.96

Appendex Table 3: Regression Analysis of the Climatic Variables and teff Yield

		R value		
Variable	Coefficients:	Std. Error	t-value	Probability
Intercept	7.2551988	5.4600070	1.329	0.217
Rainfall	-0.0003314	0.0006832	-0.485	0.639
Maximum Temperature	-0.1769959	0.1812431	-0.977	0.354
Minimum Temperature	0.0005971	0.1208051	0.005	0.996

R^2 =0.09717, Adjusted R^2 = -0.2038, F-statistic=0.3229, P-value=0.8089, the regression is non-significant

Appendex Table 4:Regression Analysis of the Climatic Variables and wheat Yield

		R value		
Variable	Coefficients:	Std. Error	t-value	Probability
Intercept	1.6880232	2.2815823	0.740	0.47825

Rainfall	0.0011706	0.0002855	4.100	0.00268 **
Maximum Temperature	0.0023376	0.0757364	0.031	0.97605
Minimum Temperature	0.1076697	0.0504811	2.133	0.06173

R^2 =0.6945, Adjusted R^2 =0.5926 , F-statistic= 6.819, P-value=0.01 , the regression is significant

Appendex Table 5: Regression Analysis of the Climatic Variables and lentil Yield

R value				
Variable	Coefficients:	Std. Error	t-value	Probability
Intercept	6.7146874	3.8874838	1.727	0.1182
Rainfall	-0.0015662	0.0004864	-3.220	0.0105 *
Maximum Temperature	-0.0969692	0.1290437	-0.751	0.4716
Minimum Temperature	-0.0446442	0.0860124	-0.519	0.6163

R^2 = 0.609Adjusted R^2 = 0.4786 , F-statistic=4.672 , P-value= 0.03117, the regression is significant

Appendex Table 6: Regression Analysis of the Climatic Variables and chickpea Yield

R value				
Variable	Coefficients:	Std. Error	t-value	Probability
Intercept	5.6458973	3.2002935	1.764	0.1115
Rainfall	-0.0012712	0.0004005	-3.174	0.0113 *
Maximum Temperature	-0.0693180	0.1062327	-0.653	0.5304
Minimum Temperature	-0.0184815	0.0708080	-0.261	0.8000

R^2 = 0.627 , Adjusted R^2 = 0.5027, F-statistic= 5.043, P-value=0.02547, the regression is significant

Appendex Table 7: Regression Analysis of the Climatic Variables and shorgum Yield

R value				
Variable	Coefficients:	Std. Error	t-value	Probability
Intercept	1.024053	10.543159	0.097	0.9248
Rainfall	1.024053	0.001319	2.550	0.0312 *
Maximum Temperature	-0.045130	0.349977	-0.129	0.9002
Minimum Temperature	0.042878	0.233272	0.184	0.8582

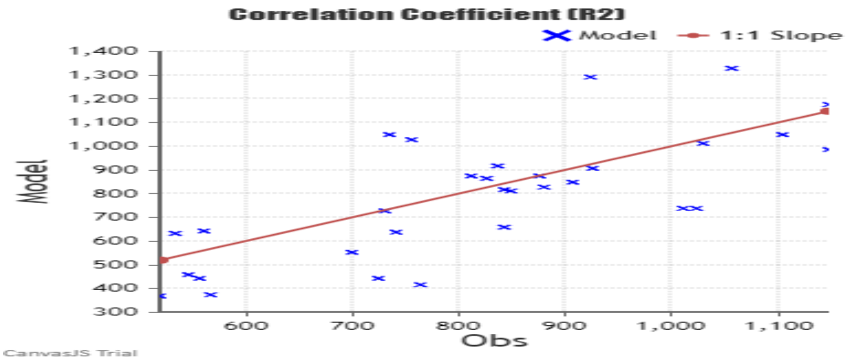
R^2 = 0.5725, Adjusted R^2 = 0.43, F-statistic=4.017 , P-value= 0.04551, the regression is significant

Appendex Table 8. Minimum, maximum and average temperature

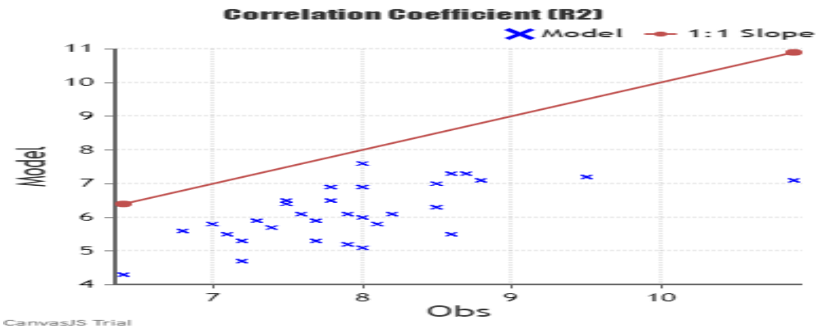
year	Minimum	Maximum	T mean
1990	7.63	27.38	17.50
1991	8.00	27.49	17.74
1992	7.52	27.35	17.43
1993	7.71	26.44	17.07
1994	7.30	27.63	17.46
1995	7.39	27.82	17.61
1996	7.48	26.21	16.85
1997	7.89	26.83	17.36
1998	6.77	27.42	17.09
1999	7.09	28.13	17.61
2000	7.82	29.03	18.42
2001	8.49	28.76	18.62
2002	8.81	29.75	19.28
2003	8.03	29.64	18.83
2004	6.97	29.56	18.26
2005	6.43	29.08	17.76
2006	7.98	28.00	17.99
2007	8.62	27.52	18.07
2008	7.21	28.42	17.81
2009	8.65	28.82	18.73
2010	8.13	27.52	17.83
2011	8.53	29.24	18.89
2012	10.92	28.29	19.60
2013	8.21	27.22	17.71
2014	8.68	27.83	18.25
2015	9.54	28.75	19.15
2016	7.90	28.03	17.97
2017	7.16	27.48	17.32
2018	7.72	27.56	17.64
2019	7.95	28.47	18.21
2020	7.81	28.28	18.05

Appendex Table . Annual and monthly rainfall distribution

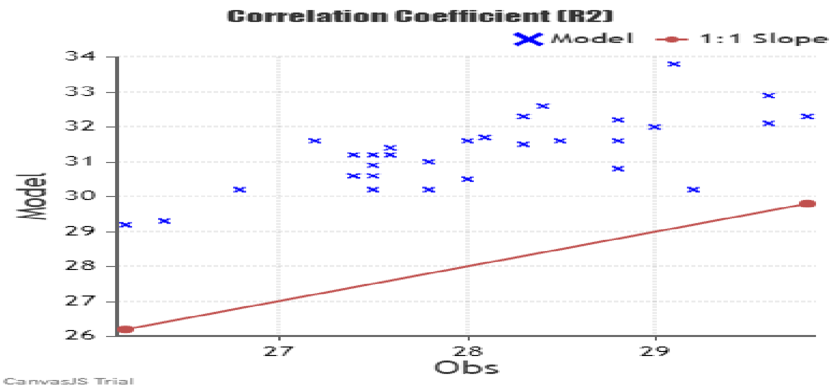
YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual RF
1990	2.1	148.1	53.5	108.1	11.3	11.5	274.5	297.7	114.7	9.3	0	0	1030.8
1991	0.4	40.6	90.7	20.7	52.7	106.7	170.5	246.6	152.7	21.0	0	4.7	907.3
1992	29.4	40.2	0.7	88.6	7.4	56.1	195.1	270.3	129.7	57.2	2.4	0	877.1
1993	14.7	112.3	97.9	176.1	32.6	81.8	247.0	203.7	143.1	26.9	0	12.2	1148.3
1994	0	0	14.9	32.6	40.7	157.8	298.9	153.7	105.4	0.5	39.8	0	844.3
1995	38.8	33.5	35.9	88.8	3.4	102.5	135.0	214.7	78.8	50.0	25.0	20.0	826.4
1996	49.9	0	82.3	26.9	62.4	263.8	180.5	197.2	163.0	10.3	20.3	0.0	1056.6
1997	19.6	2.0	85.0	65.5	24.8	103.9	200.3	219.6	38.9	108.4	56.3	0.3	924.6
1998	24.2	56.2	73.0	21.6	23.2	55.6	248.6	241.9	99.7	195.8	65.0	0.8	1105.6
1999	1.8	0	129.1	1.1	4.1	142.6	262.5	273.1	79.4	113.0	4.7	0	1011.4
2000	0	0	21.2	36.1	41.6	54.0	241.5	189.1	79.5	49.7	44.6	8.1	765.4
2001	0	24.3	125.4	15.6	40.2	40.2	248.7	167.0	33.2	1.1	0	5.6	701.3
2002	3.8	0	51.1	31.5	0	8.1	165.8	102.8	112.4	0.6	0	44.1	520.2
2003	29.5	25.7	10.0	71.2	7.5	63.3	127.0	268.6	74.7	0	0	47.5	725.0
2004	22.1	4.4	68.9	27.3	0.2	15.9	162.0	166.1	53.1	26.0	22.1	0.4	568.5
2005	44.4	0	61.2	87.4	106.2	22.0	193.3	139.8	136.0	2.1	26.6	24.8	843.8
2006	1.6	23.5	56.6	48.0	33.2	28.1	157.4	168.4	137.9	40.5	10.6	51.2	757.0
2007	14.1	9.4	50.7	51.4	57.0	21.3	151.5	296.8	145.2	27.0	13.5	0	837.9
2008	1.1	0	0	12.4	65.6	117.3	159.6	138.3	125.8	50.5	61.7	0	732.3
2009	59.6	0	21.5	21.4	6.5	23.2	73.9	186.1	57.5	92.3	9.9	9.8	561.7
2010	0	69.0	70.3	30.3	53.9	74.1	107.4	198.2	124.2	0.0	6.7	2.1	736.2
2011	0	5.2	20.4	49.6	38.7	30.8	124.9	159.5	125.6	0.0	3.5	0	558.2
2012	0	0	0	37.8	52.9	35.4	119.5	120.6	134.6	21.6	12.3	0	534.6
2013	6.2	0	34.0	25.9	57.7	40.0	213.1	247.6	123.6	43.2	21.1	0	812.4
2014	0	54.2	38.0	57.4	29.9	13.2	202.8	281.0	160.8	73.2	15.8	0	926.3
2015	0	0	5.4	0.4	57.6	106.5	91.9	141.9	77.8	41.3	24.6	0	547.4
2016	33.4	2.2	33.6	113.3	103.2	76.6	160.1	132.3	137.5	41.2	17.3	0	850.7
2017	0	0	36.8	121.4	100.0	40.3	228.3	292.0	197.2	7.4	0.0	0	1023.4
2018	1.2	0.2	49.0	56.5	59.2	80.7	193.4	200.3	70.5	3.7	27.1	0	741.8
2019	0	0.3	45.0	99.5	18.4	74.9	250.6	157.3	142.2	67.8	16.8	7.4	880.2
2020	12.0	21.8	40.9	142.6	131.1	53.6	307.8	267.0	107.7	39.7	16.3	7.4	1147.8
Mean	13.2	21.7	48.5	57.0	42.7	67.8	190.1	204.5	111.7	39.4	18.2	7.9	822.7
Min	0	0	0	0.4	0	8.1	73.9	102.8	33.2	0	0	0	520.2
Max	59.6	148.1	129.1	176.1	131.1	263.8	307.8	297.7	197.2	195.8	65.0	51.2	1148.3



Appendex figure 1: Correlation of observed and model rain fall data for study area



Appendex figure 2: correlation of observed and model minimum temprature data for study area



Appendex figure 3:Correlation of observed and model maximum temprature data for study area.

Appendex figure 4. Photo during focus group discussion

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF NATURAL RESOURCE MANAGEMENT

PROGRAM IN ENVIRONMENT AND CLIMATE CHANGE

Appendix II. Questionnaire

Dear Respondents: My name is Asinakech Welde Kinfe. I am graduate student of Bahir Dar University. I am conducting a research for the partial fulfilment of master degree (MSc) in environment and climate change. The main objective of this questionnaire is to assess the impact of climate change and variability on major crops and adaptation strategies among Minjar Shenkora district households. Therefore, the information that you give is used for the concerned bodies to analyse household's knowledge on climate change and variability impacts on major crops and adaptation strategies.

Instruction: -

1. Do not write your name.
2. Your hand writing would be clear and readable.

Thank you!

Asinakech Welde Kinfe

I. Background information of household head

Region: _________________ zone _____________ District _____________

Name of Kebele ________ Date of interview _________ Questionnaire number _____

1. Educational status of household head A. Illiterate B. can read and write C. Complete Primary School D. Complete High School E. Complete University

2. The number of families in the household Male _______female _____ total________

3. Gender of household head_________

4. Age of household head _________

5. Religion _________

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

7. The source of income for households A. Mixed agriculture (animal and crop production B. Crop production only C. Other (Specify it……….)

8. Do you have non-farm income source? A. Yes B. No

8.1) if the answer is yes place mention it _______________

10. Do you have farm land? A. Yes B. No

11. If your answer for Q, 10 ''yes'' how many hectares of land you own? ________

12. What are the major crops grown by your household?

Crop yield	Yield (quintal)	Production decrease or increase
Teff		
Chickpea		
Lentil		
Wheat		
Sorghum		

13. Trend of crop production in last year? A. Decreasing b. Increasing c. constant

14. Practice of crop production you follow A. Rain fed B. Irrigated

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

16. If your answer for Q, 15 'yes' how many hectare ________

17. Do you have access to agricultural extension services? a) Yes b) No

18. If your answer for Q.17 is "Yes", how many times the development agent/ health extension workers visit you last year ____________________

19. What types of advices did you receive from extension workers? (Multiple responses is possible)

a) Improved crop production systems

b) Improved livestock production

c) Soil and water conservation

d) Irrigation use

e) Natural resource management

f) Planting and harvesting time

g) Crop diversification

h) Using climate change tolerant variety i) others (please specify) …………………………

20. Does the extension agent provide you information on climate change? a) Yes b) No

20.1. If your answer for Q.20 is "Yes", does it help you in choosing adaptation strategy to the change in climate? If yes, in what way...................................

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

21.1. If your answer is yes, where you get the credit? ______________

22. Do you have any communication devices?

A. TV B. radio C. mobile phone D. other

23. Temperature in the past year? A. increase B. decrease

24. How far is your farm from your home? In distance.…….. Kms

25. How far is your home from the nearest market that you buy farm inputs? In distance …..…… Kms

26. How productive is your land without fertilizer?

II. Adaptation strategies to climate change/variability

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

A. Yes B. No

2. Among the following adaptation strategies, which adaptation strategies do you practice to reduce the impact of climate change and variability on your household? Mark X

No.	Adaptation strategies	Yes	No
1	Crop diversification		
2	Soil and water conservation		
3	Improve drought resistance crop		
4	Planting tree		
6	Change crop calendar		
8	Irrigation and Water harvesting		
9	Fertilizer		
10	Diversify income source		
11	Seasonal migration		
12	Reforestation		
13	Mixing farming		
14	Changing planting date		
15	No adaptation		

2. Who take the responsibility to implement adaptation strategies? A. Governmental organization B. Local community C. Non-governmental Organization

3. Do you get agricultural support from Government to practice adaptation strategies?

A. Yes B. No

3.1) If the answer is yes, list them______, _________, _________, ____________

4. Do you have local adaptation strategies? A. yes B.no

5. If you answer Q ‘’4’’ is yes mention the local adaptation strategies?

No	Adaptation strategies	Tick mark
1	Improve seed variety	
2	Crop diversification	
3	Changing plant date	
4	Soil and water conservation	
5	Planting	

6	Irrigation and water harvesting	
8	Growing short maturing crops	

III. Impact of climate change and variability on major crops.

1. What are the impact of climate change and variability on crop yield in your locality? Please Put tick mark.

No.	Impact	Put X mark
1	Drought	
2	Extreme heat	
3	Flood	
4	Disease	
5	Pests and herb infestations	
6	Shortage of water	
7	Other (specify)	

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

A. Increased B. Decreased C. No change

3. What about change in artificial forest cover in your area?

A. Increased B. Decreased C. No change

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

A. Increased B. Decreased C. No change

5. Is there change in drinking water availability?

A. Increased B. Decreased C. No change

6. What about the change in irrigation water availability?

A. Increased B. Decreased C. No change

7. How do you see about the crop yield productivity status over time?

A. Decreased B. Increased C. No change

8. Climate change and variability affect crop productivity? A. yes B. no

9. If your answer Q.8 is yes list the reason………………………………….

10. Is there a change in the timing of rain in your area? A. Yes B. No

11. If your answer is 'Yes' for Q No10, how do you characterize it?

A. comes early and goes late B. Comes and goes early C. Comes late and goes early

12. If your answer for Q No11, is comes late and goes early, what changes have you observed in crop production?

A. Decrease in crop yield B. Increase in crop yield

C. No change in production D. Decrease of long cycle crops

13. In terms of the frequency of drought, what trends have you observed?
a. Increased b. Decreased c. Not changed
14. In terms of the frequency of flood, what trends have you observed?
a. Increased b. Decreased c. Not changed
15. What do you think is the cause of climate change?
a. Human actions b. Natural process c. The act of God

Appendix III. Questions for Key Informant Interview

1. Do you think there are climate change / variability in *Minjar Shenkora* district?

2. If yes, what are the indicators of climate change and variability in the district?

3. What are the causes to climate change or variability's in this district?

4. What are the local peoples coping mechanisms used to reduce the impacts?

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

6. This kebeles is vulnerable to the impact of climate change and variability? if the answer is yes, explain it.
____

7. List down the main impacts of climate change/ variability on the crop yield, community, and the environment?
8. What are the impacts of climate change/ variability on crop yield?
9. What is your role in climate change and variability related hazards?

10. How does the government/NGO support farmers in relation to climate change and variability?

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

12. What were the main constraints/ barriers to climate change?

13. What are the local adaptation strategies on crop?

Appendix V. Questions for Focus Group Discussion

1. Is there any variability of temperature and rainfall in Minjar Shenkora District in the past year and recent year? If the answer is yes describe.

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

3. What do you think about climate change and variability?

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

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

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

7. What are the effect of climate change and variability?

8. What are the major impacts of climate change and variability?

9. Who are vulnerable to climate change?

10. Do you think climate change and variability affect your livelihood? If the answer is yes how it affect?

11. To adaptation what are the response of peoples, government and non-governmental organization?

12. What are the adapt strategies with the impact of climate change and variability on crop yield?

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

14. Do you think agriculture is the cause of climate change and variability?

15. Do you think climate change and variability affect your crop yield? If the answer is yes how it affect?

16. What are the local adaptation strategies on crop?

AUTHOR OF BIOGRAPHICAL SKETCH

The Author was born on September 22, 1990E.c in Arerti Town, Minjar Shenkora District, North Shewa Zone, Amhara Regional State, Ethiopia. She attended her elementary education at Korma Primary School from1997-2004E.c. She learned high school education and completed her preparatory school at Arerti from 2005-2008. After successful completion of her preparatory school education, She joined Oda Bultum University in September E.c and graduated with a Bachelor of Science degree in Natural Resource Management in August 2011E.c. After graduation, she worked as Graduate assistant in the Natural Resource management department at Oda Bultun University for one year. She joined the postgraduate program of Bahir Dar University in 2013E.c to pursue her MSc study in Environment and climate change.