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BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF NATURAL RESOURCE MANAGEMENT

EFFECT OF CLIMATE VARIABILITY ON MAIZE (*Zea mays L.*) YIELD AND ADAPTATION STRATEGIES; IN CASE OF ALEFA DISTRICT, AMHARA REGIONAL STATE, ETHIOPIA

By

Yemikir Ayanaw

June, 2023

Bahir Dar, Ethiopia

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By

Yemikir Ayanaw

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FORTHE DEGREE OF MASTER OF SCIENCE (MSc) IN ENVIRONMENT AND CLIMATE CHANGE

Advisor: Gashaw Bimrew (Ph.D.)

June, 2023

Bahir Dar, Ethiopia

APPROVAL SHEET

As members of the board of examiners, we examined this thesis entitled **"Effect of Climate Variability on Maize (*Zea mays L.*) Yield and Adaptation Strategies, in Alefa District Central Gondar Zone, Amhara Regional State of Ethiopia"** by **Yemikir Ayanaw** 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.

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DECLARATION

This is to certify that the thesis entitled "**Effect of Climate variability on Maize (*Zea mays L.*) Yield and Adaptation Strategies, in Alefa District, Central Gondar Zone, Amhara Regional State of Ethiopia**" by **Yemikir Ayanaw** (ID.No.BDU1300568)", 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.

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ABBREVIATIONS ANDACRONYMS

AWAOR	Alefa woreda agriculture office report
CC	climate change
CSA	Central Statistical Agency
DA	Development agents
FGD	Focus group desiccation
GDP	Growth Domestic Product
HHH	Household heads
IPCC	Intergovernmental panel on climate change
KII	key informant interview
MVP	Multivariate probit
NASA	National Aeronautics and Space Administration
NGO	Nongovernmental organization
NMA	National Metrological Agency of Ethiopia
PCI	Precipitation concentration index
RAI	Rain fall anomaly index
SWCP	Soil and water conservation practice
TLU	Total livestock unit
WB	World Bank

ABSTRACT

Climate variability and change is adversely affecting agricultural activities in many developing countries including Ethiopia. The adverse effects of climate change and variability forced them to design proper adaptation strategies. The objective of the study was to investigate effect of climate variability on maize yield and adaptation strategies. 347 sample households were selected randomly from three kebeles. Primary data were collected through key informant interview, focus group desiccation, questioners and interview; whereas, secondary data were collected the maize yield from 2000-2012 at Alefa District Agricultural and Rural Development Office (ADARDO) and climate data from National Meteorology Agency and NASA power data. The data were analyzed using STATA version 14; R-software and Microsoft excel 2010. Multiple linear regression analysis, multivariate probit model, correlation, trend analysis, Precipitation concentration index, rainfall anomaly index, and coefficient of variance were used to analyze the data. Accordingly, the results revealed that annual rainfall indicated a negative trend (0.8mm/year). The annual mean maximum temperatures increased by of 0.06^0C and in mean annual minimum temperature increase by a factor of 0.04^0C. The relationship of climate variables (rainfall and temperature) with maize yield revealed that temperature influenced crop yield variability much more rainfall. The results of Correlation indicated that duration of rainfall (r=-0.746) strong negative relation with maize and Kiremt rainfall (0.813 strongly significant positive effect on maize. Max and min temperature had negative relationship with maize yield (r=-0.659, -0.333) respectively. Regression coefficient study revealed that the maize yield is impacted by several aspects of rainfall and temperature in varying degrees. Due to climatic factors (R^2=0.829) that is 82.9% of maize yield variation was observed in the study area. This maximum value of variation on maize yield was the combination of annual rain fall, maximum and minimum temperature. Adaptation strategies implemented to combat challenges of climate variability/change in the study area includes agro-forestry (49.3%), inter-cropping system (39.8%), adjusting planting date (40.9), use drought tolerant crop varieties (55.3), soil and water conservation practices (62.8) and irrigation (29.7%). Finally, the study recommends improved and/or genetically modified crop species should be made available to farmers along with other incentives.

Key words: adaptation, climate variability, effect, rainfall, temperature,

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CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

Crop production is declining due to climate change and variability especially in developing countries that largely rely on rain-fed agriculture (Mburu, et al., 2015). Worldwide, climate variability and change accounts for a third of variation in crop production changes in surface temperature and erratic rainfall or continued drought threaten agricultural production particularly in sub-tropical regions (Kikoyo and Nobert, 2016).

Climate change affects agriculture and food production through changing agro ecological conditions (Alemu and Mengistu, 2019) .Sub-Saharan Africa is the most vulnerable region to the impact of climate change and variability due to rainfall-dependent agriculture as well as weak adaptive capacity (Matewos, 2019). There is a need to adopt adaptation strategies suitable for the current and projected climate change (Assan *et al*., 2018).

Ethiopia is among the countries in SSA that experience variation in the rainfall and temperature in east Africa. For instance, a 0.2°C to 0.28°C rise per decade in the average annual maximum temperature between1960 and 2006 was reported in recent studies whereas, a 0.37°C/ decade increase in minimum temperature was observed between 1951 and 2006 (Esayas et al., 2019). All aspects of human life, particularly agricultural economies and social activities, are influenced globally by the variability of rainfall over time and space. It is essential to identify accurately patterns in seasonal rainfall due to the high dependence on rain-fed farming in Ethiopia (Alhamshry *et al.*, 2019).

Ethiopia's climate is marked by its high annual, seasonal, and geographical variability. The temporal distribution of rainfall during the growing season is an important factor in determining crop yield, while the amount and seasonal distribution of precipitation are particularly difficult to predict annually (Evangelista *et al.*, 2013). Rains was late by several weeks or stop during critical germination periods, leading to short- and long-term droughts with crop failures, food shortages and famines. Moreover, when occurring during the dry season, rainfall can facilitate the spread of crop diseases (Evangelista *et al.*, 2013).

In the countries like Ethiopia, where agriculture is entirely dependent on rainfall, an increase in temperature coupled with rainfall variability makes Ethiopian agriculture the most susceptible to climate change (Tadesse and Alemayehu, 2017). This rain-fed and subsistence agriculture system, account for about 34% of the country's GDP and 68% of population employment (World Bank, 2018).

One of the most important cereals in the world, maize (Zea mays L.) is grown worldwide, leading in total yield, and is the third most important food crop after wheat and rice (FAOSTAT, 2010). In developed nations, only 3% of the yield of maize can be consumed directly by individuals, whereas in SSA, over 80% is used as food and provides approximately 30% of the total calorie intake of individuals (Nuss and Tanumihardjo, 2010). According to CSA (2012), Maize comes in second in terms of production area, covering more than 2.05 million hectares, and it provides food for approximately 10 million households in the nation. Maize can grow at higher temperatures than many other cereals, which are most susceptible to rainfall variation and heat stress, and it is primarily produced by smallholder farmers in Ethiopia (Shiferaw *et al.*, 2011; Abate *et al.*, 2015; CSA, 2016). High variability in rainfall is the major case of maize yield reduction (Estes *et al.*, 2014).

The majority of data and facts regarding climate change and the threats it poses to Ethiopia's economy strongly support the creation of strategies for climate change adaptation and mitigation. However, small-scale farmers' understanding of the strategies' necessity and ability to withstand climate impacts is crucial to their successful implementation of climate change adaptation strategies (Atube *et al*., 2021; Tesfaye *et al*., 2016).

There are different adaptation mechanisms that have been practiced to overcome the adverse effect of climate change such as soil and water conservation which is use-full to protect soil loss, to conserve water and to improve soil fertility; Agroforestry/Tree planting it is exercise by planting different vegetation like tree varieties, plants, grasses and bush on the farm land and other off farm land areas to improve soil fertility, to maintain the environment, to protect land degradation and to support the rain comes in seasonal; irrigation it is practices when the season is dray which is applied by controlling amount of water to plant or crops at a needed interval by using different irrigation system (Abirham, 2017).

1.2. Statement of the Problem

The most pressing environmental issues that human societies worldwide face are caused by climate change. The majority of Ethiopia's population relies on the agriculture sector , making it one of the least developed nations (Gouwens *et al.*, 2020). The rain-fed agriculture is highly affected by the negative impacts of climate variability and change in Ethiopia (Mareverwa, 2018). Changes in rainfall patterns, including decreased reliability and predictability, appear to be increasing the frequency of heavy rainfall events (Salack *et al*., 2018). As a result, the country suffers greatly from the negative effects of climate change and variability (Zhao *et al.*, 2020). Because most of society's livelihood directly or indirectly depends on nature which is more sensitive to climate variability and change (Hillier *et al*., 2021).

In Alefa district, farming patterns are gradually changing and faced with perceived climate variability and its negative consequences on the maize productivity in the location. Further, rural people are reporting famine and maize crop failures have become a recurrent feature of their life. Maize production has been quite variable and declining due to the problem of rainfall pattern and variability of temperature in the study area. Therefore adaptation is an essential strategy to enable farmers to cope with the adverse effect of climate change and variability which continuously increase the agricultural production of the poor farm households (Yesuf *et al.*, 2008). Additionally, due to the lack of information and knowledge of farmers about variation of temperature and rainfall, the farmers deforests tree for expansions of agricultural land is the major problem in study area again. So knowledge and perception of smallholder farmers about climate variability are vital to improve productivity and environmental condition.

In Alefa District the systematic assessment and documentation of adaptation strategies on climate variability and information that affect their major crops (especially on maize) yield had not been well studied. Crop variability and yield trend as well as farmers adaptation strategies on climate and crop variability had not been well studied in previous research undertakings. Therefore, this study aims to fill information gap regarding how recent changes in rainfall and temperature affect maize production. Moreover, it attempts to assess farmers' adaptation options used against climate variability in Alefa district.

1.3. Objective of the Study

1.3.1. General objective

The general objective of the study was to investigate the effect of climate variability on maize (*Zea mays L.)* yield and adaptation strategies in Alefa district Amhara Ethiopia.

1.3.2. Specific objective

- To analyses the trend and variability of temperature and rainfall in the past thirty years in the study area.
- To analyses the relationship between climate variability and maize yields in the study area.
- Assess determinants of farmers' choice of adaptation strategies to climate variability in the study area.

1.4. Research Questions

- What is the trend and variability of rainfall and temperature in the study area?
- What is the relationship between climate variability on maize yield in the study area?
- What are the factors that determine choice of adaptation strategies to climate variability in the study area?

1.5. Significance of the Study

Studying the effects of climate change and variability and its adaptation strategies may initiate academicians and researcher to carry out an in-depth investigation of its future potential in Alefa district. The study also increases the attitude and awareness of the local farmers about how to respond to a changing climate. This will help to increase the adoption of modern and an integrated farming method, founding of local market centers to open up markets for farmers' produces with the changing climatic parameters. Furthermore, this research may also be essential so as to fight food insecurity with right adaptation strategies of climate change**.**

1.6. Scope of the Study

The study was limited to the Alefa district central Gondar zone Amhara national regional state of Ethiopia in three kebeles that are found surrounding of Shahura town which are delimited to impacts of climate change and variability on maize production and adaptation strategies. As crop production is the main livelihood in the district; farmers face socio-economic problems due to the impacts of climate change and variability. Crops are highly sensitive to the impacts of climate change and variability. The study's analysis focused first on climate trends of temperature and rainfall, the impact of climate change and variability on maize crops, and adaption strategies in the study area.

1.7. Limitation of the Study

Some challenges were occurred while conducting this study. One of the main problems faced during the study was, some farmers were reluctant to give correct information on their socio economic and demographic situation during the survey time. However, efforts were made by the researcher and able to get the required information despite these challenges.

CHAPTER TWO: LITERATURE REVIEW

2.1. Concept and Definition of Climate Related Terms

Climate: Climate in a narrow sense is usually defined as the average weather, or more thoroughly, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, rainfall, and wind (IPCC, 2012).

Climate variability: refers to a variation in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events (IPCC, 2012). The variations in the current state of the climate, and is a natural modification of the climate and therefore independent of human activity e.g. the amount of rainfall received from year to year; also includes extended droughts, floods, and conditions that result from periodic El Niño and La Niña events by (Klammler *et al.*, 2020).

Adaptation: refers to adjustment in natural or human systems in response to actual or expected climatic change or their effects. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate (Field *et al.*, 2012). Adaptation is the process of improving society's ability to cope with changes in climatic conditions across time scales, from short term (e.g. seasonal to annual) to the long term (e.g. decades to centuries). Adaptations are adjustments or interventions, which take place in order to manage the losses or take advantage of the opportunities presented by a changing climate (Ndamani and Watanabe, 2015).

Climatic variability are 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 and water resources, coastal area, biodiversity, human settlement, energy, industry, and financial services (Lunyolo et al., 2021). In Ethiopia, climate variability and change is mainly manifested through the variability and decreasing trend in rainfall and increasing trend in temperature. Besides, rainfall and temperature patterns show large regional differences (Asfaw *et al.*, 2018).

Climate change is a key concern to Ethiopia in our time and need to be tackled in a state of emergency. It has brought an escalating burden to already existing environmental concerns of the country including deforestation (Ayana, 2011)

Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, in order to reduce adverse impacts and take advantage of new opportunities (Mesfin *et al*., 2020). Those societies that can respond to change quickly and successfully have a high adaptive capacity). Ethiopia is vulnerable to climatic variability due to its low adaptive capacity accountable to low level of socioeconomic development, high population growth, inadequate infrastructure, lack of institutional capacity and high dependence on climate sensitive natural resource-based activities (Gezie, 2019).

2.2. Climate variability and Agricultural production

According to FAO (2012), climate variability may affect agriculture and consequently food security, through changes in temperature and precipitation, changes in soil moisture and soil fertility, changes in the length of growing season and an increased probability of extreme climatic conditions. Climate change affects agriculture directly and indirectly. Unswervingly, it interrupts by influencing the weather elements like rainfall, temperature, solar radiation, wind speed, and humidity (Sowunmi, 2010; Arimi, 2014). Indirectly, it affects disease and pest occurrence as well as favoring the increase of climate associated diseases like malaria that disturb the workforce. As the climate is a major influencing factor on crop growth, climate change will have an impact on agricultural production.

Ethiopia's main economic sector is agriculture. It employs approximately 80% of the population, generates over 85% of the foreign exchange earnings, and contributes approximately 52% of the GDP (Deressa *et al.*, 2009). However, climate-related risks and variability will continue to have far-reaching effects on Africa's agricultural sector, affecting marginalized and resource-poor smallholder farming communities whose livelihoods are dependent on agriculture (Tesfaye *et al*., 2019). Climate change has been affecting the agrarian communities in different ways particularly confusion on planting dates due to unpredictable nature of the rainfall, forced to stop irrigation activities due to a shortage of water, decrease in crop yield, forced to travel along distance in search of water and reduction in the productivity of domestic Animals (Asfaw *et al.*, 2019).

One of the main factors that affect agricultural production is the climate (Ashalatha *et al.,* 2012). In the process of providing the lives and livelihoods of millions of people who rely on it for food and sustenance, agriculture is heavily dependent on the climate (Prantilla and Laureto, 2013) Climate change affects agriculture and agriculture also affects climate change (Deressa *et al.,* 2011). Agriculture is not only a fundamental human activity at risk from climate change, it is a major driver of environmental and climate change itself (Tubiello, 2012). Concerns about the effects of climate change and its variability on agricultural production are widespread (Ashalatha *et al.,* 2012).

The observed changes in the two parameters of climate namely temperature and precipitation have affected the agriculture and livelihoods of the people (Zeray and Demie, 2015). Ethiopia's economy's heavily reliance on rain-fed agriculture increased its susceptibility to the effects of climate change. Additionally, due to its low adaptive capacity and low location and topography, it is highly susceptible to the effects of climate change. Historically, the country has been prone to extreme weather variability. Rainfall is highly erratic, most rainfalls with high intensity, and there is a high degree of variability in both time and space. Since the early 1980s, the country has suffered major drought years (Masih *et al.,* 2014).

2.3. Effect of Climate variability and Crop Production

The growing of field crops, for both food and energy, is one of the human activities most influenced by climate. The progress of meteorological elements and the course of processes related to them in every year are unique and non-recurring. Year-to-year differences for example: in the length of the vegetation period, rainfall totals, rainfall distribution, or the temperature itself generate a variability which is quite natural and easily explicable. Growers can flexibly correct for moderate deviations from the average weather by timely cultural practices. But when there is clear evidence of longer-term trends in weather variability, it is necessary to investigate their causes and likely impacts (Zalud et al., 2009; Assefa *et al.,* 2015). Climate variability and change negatively affect agriculture in most parts of Africa especially the semi-arid areas in Sub-Saharan countries (Thornton et al., 2011), characterized by high rainfall variability it is expected that climate change has already and will further increase climatic variability and the frequency and severity of extreme weather events in Africa as well as elsewhere (IPCC, 2012).

Climate change is predictable to overall reduction in the yields of cereal crop in Africa through shortening growing season length, amplifying water stress and increasing incidence of diseases, pests and weeds outbreaks (Niang *et al*., 2014).

According to Welch *et al*. (2010), yields are reduced by higher minimum temperatures, while yields are increased by higher maximum temperatures. However, it is essential to keep in mind that the kind of crop under consideration determines how high and low temperatures affect it. Similarly (Datta, 2013), emphasized that crops can be significantly affected by high temperatures, which can result in a decrease in yield. Temperature is critical environment factors affecting the plant environment. It has also been thought that rainfall provides crops with soil moisture. Therefore, having knowledge on sequences of rainfall variability, events can assist acquiring specific information for agricultural planning. Within variable seasonal rainfall patterns, understanding the events of the occurrence of rain features like; onset and end date of rainy season, dry spells are crucial to decrease the adverse effects and exploit opportunities (Yemenu and Chemeda, 2013).

Several studies have conducted on impacts of climate variability in the area of crops yield in different parts of the world (Bewket, 2009; Oluwasegun and Olaniran, 2010) Some of these studies have shown that environmental changeability has a significant impact on farming practices, especially in the last 40 years. According to Traore *et al.* (2013), climate has a strong influence on agricultural production. One of the most weather-dependent human activities is sustained agriculture, which has socioeconomic effects whose severity varies from region to region.

2.3.1. Climate variability on maize production

Since agricultural production is dependent on the weather, it is vulnerable to climate change and variation (Nelson *et al.*, 2014). The maize crop is more prone to global climate change, thanks to this crop cultivated within the world more moisture stress area, rely upon this case the rainfall, and temperature have opposite effects on yield levels and variability of corn (maize) crop. Variability in the climate will have an effect on agricultural production because climate is a major factor in crop growth.

Crop production is affected both directly and indirectly by climate variability. Directly, it affects by influencing climate parameters such as rainfall, temperature, solar radiation, wind speed and humidity (Sowunmi, 2010; Arimi, 2014) Indirectly, it affects through disease and pest outbreak as well as favoring the development of climate related diseases like malaria that affect the workforce (Newton *et al.*, 2011).

According to Ayalew *et al*. (2012b) and Taye *et al.* (2013), the raising temperature is related with increased spatial and temporal variability in amount and distribution of rainfall above the long term spatial and seasonal variability. The farming system will be affected immediately and directly by a few degrees of warming, a decrease in rainfall, an increase in the frequency of extreme weather, such as drought (Tagel and Anne, 2013). A recent meta-analysis of fully fertilized maize experiments in southern and eastern Africa revealed that a 3 % decrease in maize grain production can result from an increase in temperature during the growing season (Lobell *et al.*, 2011).

Maize yield is most affected by inter-annual variation in rainfall because the best distribution of rain during the rainy season increases yield per hectare (Bewket, 2009). The most important factor in determining maize yield is the amount of rainfall it receives during the growing season. Maize yields will decline as the amount of precipitation below 200 mm and 450 mm to 600 mm is preferable; in the tropics, maize dose best with 600-900 mm (Worku, 2018). During the critical growth period, it is essential to have a good distribution and enough rain to keep crop growth stable.

2.4. Adaptation Strategies toward Climate variability

Efforts to adapt to the continued climate change should begin from tackling the current climate variability and take a climate risk management approach for adapting to the continued climate change (Alemayehu and Bewket, 2016). Important agricultural adaptation mechanisms include adjusting the crop variety (such as planting a drought-tolerant or early-maturing variety or genetically modified varieties), improving irrigation facilities to maximize water efficiency, and using a cropping calendar to synchronize crop planting and the growing period with the availability of soil moisture based on seasonal climate and rainfall forecasts (Oseni and Masarirambi, 2011).

There are also viable adaptation options that can be implemented in some sectors at low cost, and/or with high benefit-cost ratios for instance; development of systems, local warning, adjustment of planting dates and crop variety; development of a flexible mixed crop, crop relocation; grain storage arrangements, improved land management, e.g. erosion control and soil protection through tree planting (Pachauri *et al*., 2014).

Effective adaptation strategies and practices also depend on a rigorous understanding of the dimensions of exposure and vulnerability as well as a proper assessment of changes in those dimensions (Cardona *et al*., 2012). Depending on the local climate, natural resource endowments, and patterns of agricultural and livestock activities, households may adopt a variety of adaptation strategies in response to a variety of risks, including climate variability (Bandyopadhyay *et al.*, 2011).

Farmers can take a number of different approaches to reduce their vulnerability to the effects of climate variability. Farmers employ a variety of adaptation strategies in response to the various climate-related challenges they faced. This is because the impact of climate variability is unevenly distributed across various geographic areas, and as a result, the types and magnitude of the impact of climate variability also vary the adaptation mechanisms (Bosekeng *et al*., 2020).

As a result, the farmers employed a variety of adaptation strategies to reduce the impact of climate variability (Legesse *et al.*, 2013). These include: changing crop variety, Adjusting planting dates, Agroforestry, crop diversification, soil and water management, change animal breeds, seek off farm employment, planting short season crop, and irrigation/water harvesting are among some of the several strategies available to enhance social resilience in the face of climate variability (Nhemachena and Hassan, 2007).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Description of the study area

3.1.1. Location

The study is conducted in Alefa district, central Gondar Zone of Amhara Regional State. Alefa is found at 649 km from North of the capital city of Addis Ababa and 88 Km from, Bahir Dar and 142kms from central Gondar administrative zone. The district is geographically located at 11^0 $30^{'}$ $0^{''}$ to 12^0 0'0" North latitude, and 36^0 $30^{'0''}$ to 37^0 0'0'' East longitude (Fig 3.1). It is bordered by North Achefer in the south, Quara to the West Takussa in the North, and Lake Tana in the East. The district has 34 peasant associations (kebeles).

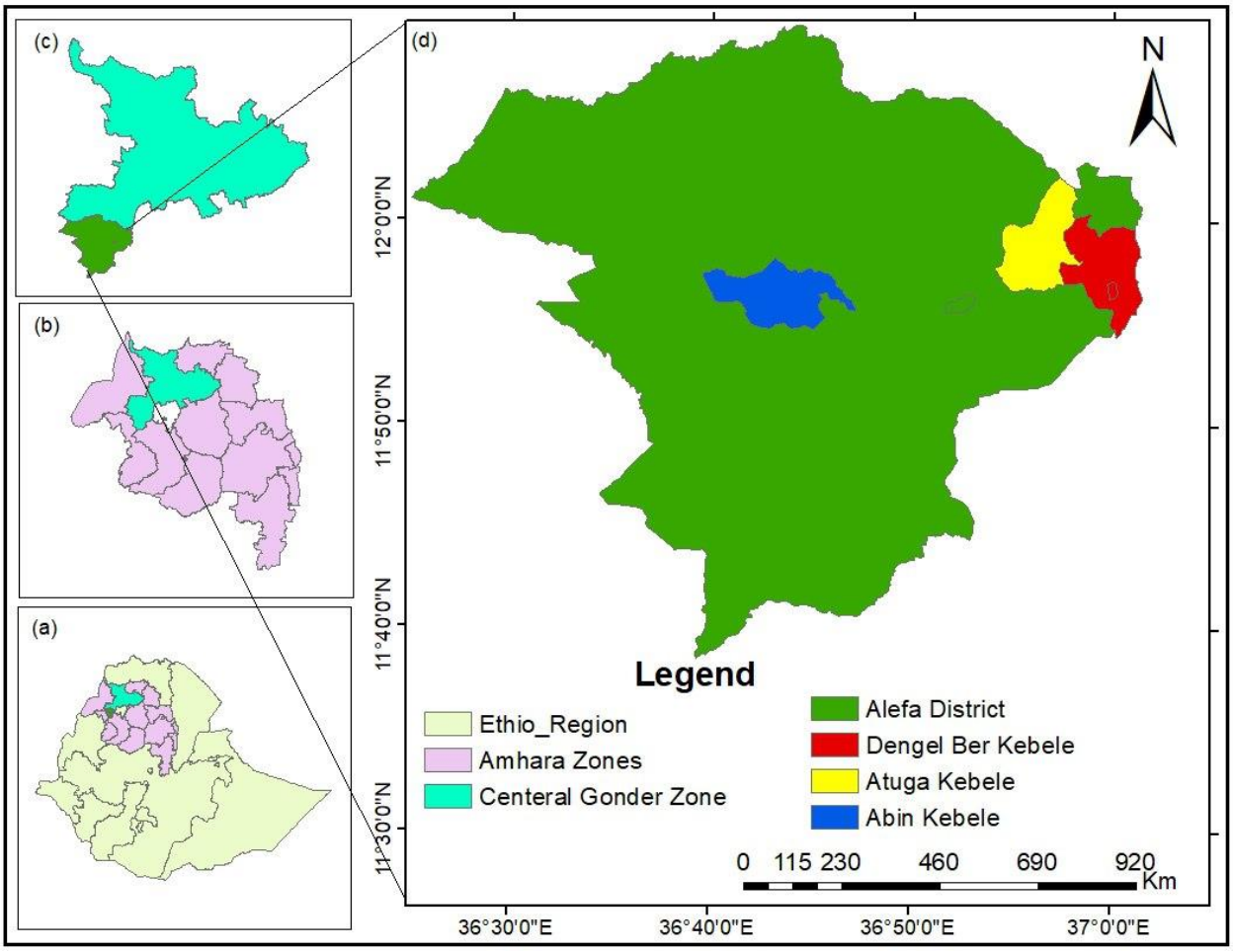

Figure3.1.Map of the study area

3.1.2. Population

According to AWAOR, (2022) the district has total population of 233, 325, of which 120,353 are males and 112,972 are females.

3.1.3. Climate and agro-ecology

The study area comprised of two major agro-climatic zones. According to the AWAO report largest area of Alefa district is found under the Woinadega agro climatic region accounting about 55%, of the total area. While the rest of the study area lies under Kolla climatic regions accounting 45% of the total area. The district receives the highest rainfall amount from June to September or locally known as *Kiremt.* The district is characterized by a unimodal rainfall distribution with along *Kiremt* rainy season. (Fig 3.2) showed that the highest rainfall occurred in August followed July in the district. The elevation of the district ranges between750m to 2250rn above sea level. The annual rainfall of the district ranges from 950 mm to 1500 mm and the average annual temperature of the study area are between 18°C and 29°C.

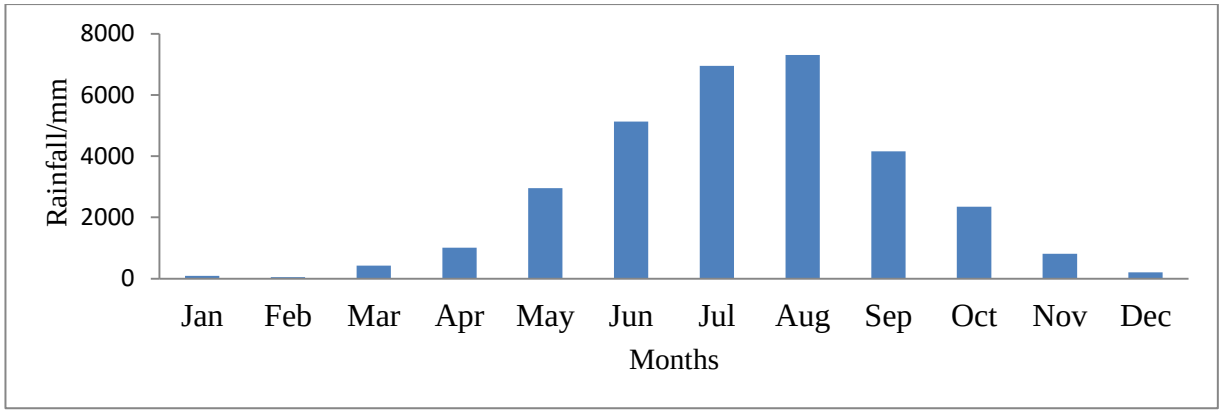

Figure 3. 2. Annual rainfall cycle of Shahura

3.1.4. Agriculture and economic activities

The subsistence agricultural production is almost entirely dependent on *Kiremt*; Most of the crops are grown by local farmers who use traditional farming methods with respect to the local agricultural zone divisions which are a function of the elevation and climate. The dominant farming system of the area is mixed farming system crop and livestock production is the dominant farming system. The main crops grow include teff (*Eragrostis sp.*), maize (*Zea mays. L*), finger millet (*eleusine coracana sp.*), barley (*Hordeum sp.*) (AWAOR, 2022).

3.2. Research Design

This study employed both longitudinal and cross-sectional research design to assess the overall activities of impact of climate change and variability on maize yield and adaptation strategies in Alefa 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.

3.3. Sampling Techniques and Sample Size Determination

3.3.1. Sampling techniques

Two stage sampling technique was used to draw sample households. In the first stage the study area is stratified in to two agro climatic zones, that is low land (kola) & midland (Woina Dega). In the second stage based on AWAOR from 34 kebeles three kebeles were selected purposively from the two agro climatic zones proportionally, which are more vulnerable to climate change (Atuga dibanti, Dengelber kebeles from mid land and Abin kebeles from low land). Finally, 347 farm households were selected by using simple randomly from 3126 total households using the formula adapted from Yamane (1967) at a 95 % confidence level and 5 % level of precision. The formula is as follows.

$$\boldsymbol{n} = \frac{\boldsymbol{N}}{\boldsymbol{1+N(e)2}} \qquad \text{Equ (1)}$$

Where; n =number of sample size,

N= total household size

e= is precision degree/ error (5%=0.05).

n = $\frac{N}{1+N(e)^2}$ the total household size is 3126, therefore the sample size is

$\boldsymbol{n} = \frac{\boldsymbol{N}}{\boldsymbol{1+N(e)2}}$ $n = \frac{\boldsymbol{3126}}{\boldsymbol{1+3126(0.05)2}}$ =347

Table 3.1. Distributions of sample households

District	Kebeles	Agro ecological zone	Household	Male	Female	Sample
Alefa	*Atuga dibanti*	*Woina dega*	944	85	18	103
	Dengel ber	*Woina dega*	1158	105	24	129
	Abin	*Kola*	1024	96	19	115
Total			3126	286	61	347

3.3.2. Sources of data and data collection

3.3.3. Sources of data

The required input data of this study was generated from both primary and secondary sources. Primary data were generated from the farmers. The primary data was obtained through field survey, questionnaire, and focus group discussions (FGD). The secondary data was obtained from governmental offices of the district. Maize yields for the past 12 years (2000-2012) from the district agricultural offices and time series rainfall and temperature data spanning a period of 30 years (1990-2020) from knmi climate explorer.

3.3.4. Methods of data collection

A closed-ended questionnaire was administered face to face with the heads of the households within selected kebeles of the district. The collected data has been coded and to complement the household questionnaire data and focused group discussions was formed by selecting some individuals from sampled kebeles in order to understand adaptation strategies used by farmers to minimize rainfall and temperature variability impacts, some climate variability induced observed change in the maize yield and remembered climate risks in the study area.

3.3.5. Household questionnaire

Questionnaire was used to generate quantitative and qualitative information at household level using a structured questionnaire. The study used closed-ended questionnaires which were thought to be helpful in achieving the objectives of the study. To avoid misunderstanding, the preparation of questionnaires and household interviews were undertaken in the enumerators' local language Amharic to easily understand it and coordinate clear communication and discussion with respondents.

3.3.6. 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 discussions (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 (FGD) were held one FGD in each kebele). The numbers of focus group participants in one group ranges from 6-12 members the participants in FGD include men and women farmers of various age levels.

3.3.7. 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. The interviews were used to better understanding of some climate variability in the district, responses used by farmers and climate risk in study area.

3.4. Method of Data Analysis

3.4.1. Descriptive analysis

The qualitative information gathered using; focus group discussion and key informant interviews were analyzed and interpreted using qualitative techniques. Microsoft excels analysis methods such as descriptive statistical methods, correlation. Descriptive statistics such as mean, standard deviation, frequency, and percentage are used to explain and describe the final result of the study and multiple linear Regression were used for maize with rainfall, maximum temperature and minimum temperature by STATA. The processed results of the study are summarized and presented by various tables, graphs, and pie charts. Z- (Mk), 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 employed with the help of Microsoft Excel and R software to analyze climate variability and trend in study area.

3.4.2. Analysis of rainfall variability

Coefficient of variation: is a statistical measure of the dispersion of data points in a data series around the mean. The Coefficient of Variability is a unit-less normalized measure of dispersion of a probability distribution. It expresses the standard deviation as a fraction of the mean and is useful when interest is in the size of variation relative to the size of the observation (Bekele *et al.*, 2016). The coefficient of variation computed as the following formula:

$$CV = \frac{\delta}{\mu} \times 100 \qquad \text{Equ (2)}$$

Where, CV is coefficient of variation, δ is standard deviation while μ is the long-term mean annual (rainfall or temperature) over the period of observation. This is used to compare the variability of any two distributions which may be measured in different units. According to (Hare, 1983; Araya and Stroosnijder, 2011; Getahun *et al.*, 2021) CV (%) values are classified as follows: < 20% as less variable, 20- 30% as moderately variable, and > 30% as highly variable.

On the other hand, standard deviation was computed as the square root of variance. Using the classification of (Reddy 1990), the stability of rainfall is examined as follows: Where SD can be computed as:

$$SD = \sqrt{\sum_{i=1}^{n} 1(\frac{xi-x)2}{n}} \quad \text{Equ (3)}$$

Precipitation concentration index: is 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. Precipitation Concentration Index (PCI) was analyzed using (De Luis *et al.*, 2000) which are the modified version of (Oliver, 1980; Bewket, 2009), it was computed as follows:

$$\text{Annual PCI} = \frac{\sum_{i=1}^{12} P^2{}_i}{[\sum_{i=1}^{12} P_i]^2} * 100 \quad \text{Equ (4)}$$

$$\text{Seasonal PCI} = 25 * \frac{\sum_{i=1}^{4} P^2{}_i}{[\sum_{i=1}^{4} P_i]^2} \quad \text{Equ (5)}$$

Where: Pi = the rainfall amount of the ith month, pi^2 = square root of ith months of rainfall and $\Sigma\ Pi^2$ = summation square root of ith months. PCI $\leq$ 10 indicate low precipitation distribution, PCI 10 - 21 moderate precipitation distribution, PCI value above 21 very high precipitation distributions.

Rainfall anomaly: Standardized anomaly index, precipitation concentration index and coefficient of variation were used as descriptors of rainfall variability (Bewket and Conway, 2007 ; Ayalew *et al.*, 2012b). The rainfall anomaly index was used to calculate the negative and positive anomalies of rainfall fluctuations in a certain region. This was calculated as:

$$SRA = \frac{PT-PM}{\sigma} \quad \text{Equ (6)}$$

Where SRA = standardized rainfall anomaly, Pt = annual rainfall in year t, Pm = is long-term mean annual rainfall over a period of observation and σ = standard deviation of annual rainfall over the period of observation. The drought severity classes based on SRA are, extreme drought (SRA < -1.65), severe drought (-1.28 > SRA > -1.65), moderate drought (-0.84 > SRA > -1.28) and no drought (SRA > -0.84).

3.4.3. Trend analysis

Trend analysis of a time series consists of the magnitude of the trend and its statistical significance (Pal *et al.,* 2017). Mann-Kendall method, a nonparametric test used to test trends in rainfall and temperature of an area (Shi *et al*., 2013; Amirabadizadeh *et al.*, 2015). It is less sensitive to outliers and tests for a trend in a time series without specifying whether the trend is linear or nonlinear (Yenigün *et al*., 2008).

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: $\mu = \mu o$ (there is no significant trend/stable trend in the data).
HA: $\mu \neq \mu o$ (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 $|Z| < Z1-\alpha/2$ at a given level of significance. The standard test statistics Z is compared as follows:

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

The presence of a statistically significant trend was evaluated using the Z value. If the Z value is positive and the computed probability is greater than the level of significance, the trend indicates increasing.

If the Z value is negative and the computed probability is greater than the level of significance, the trend indicates decreasing.

The computed probability is less than the level of significance, and there is said to be no trend. The Z values tested at 95% level of significance.

The magnitude of the trend in the seasonal and annual series was determined by Sen's estimator (Sen, 1968). This method can be adopted if a linear trend is present in a time series and trend can be described as:

$$Ti = \frac{xj - xk}{j - k} \text{ for } i = 1, 2, 3 \ldots N \qquad \text{Equ (8)}$$

Where x_j and x_k are data values at time j and k (j > k), respectively. The median of these N values of Ti is represented as Sen's estimator of slope which is computed as:

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

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

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. Analysis of temperature and rainfall with maize yield

The statistical correlation coefficients between maize yield and climatic variables namely rainfall and temperature was used to assess the strength and the direction of the relationship, and significance of the relationship between maize yield production and the climate variables.

Correlation Analysis: This method provides the degree of relationship between two variables. Pearson Correlation coefficient (r) analyses were used to analyze the correlation between crop yields (Maize yield expressed in qt/ha) with maximum temperature, minimum temperature, mean annual temperature and rainfall characteristics, value of r ranges between -1 to +1, a correlation coefficient close to +1 indicates a strong positive correlation, a correlation coefficient close to -1 indicates a strong negative correlation similarly a correlation coefficient of 0 indicates no correlation (Odekunle *et al.,* 2007). For this study, the value of r was calculated using the Pearson correlation coefficient equation.

Pearson correlation coefficient (r) analyze was used to analyze the correlation between maize yields (qt/ha) with rainfall characteristics and temperature components.

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[\sum xi^2 - (\sum xi)^2]\,[n\sum yi^2 - (\sum yi)^2]}} \quad \text{Equ (11)}$$

Where: coefficient (r) ranges from -1 to +1. A correlation coefficient (r) close to +1 indicates strong positive relationship, -1 indicates strong negative relationship and 0 indicates no relation.

Regression analysis: multiple linear regression methods were computed to establish the relation, case and effects of rainfall and temperature on maize yields. The equation is provided in the form of the following:

$$Y = a + b1x1 + b2x2 + b3x3 \ldots bnxn + e \quad \text{Equ (12)}$$

Where; Y= the value of the dependent variable (maize yield in qt or qt/ha); a= Y intercept and b1, b2, b3… bn= regression coefficients, x1, x2, x3….xn= the independent variables, e= the error of estimate or residuals of the regression. Coefficient of multiple determinations (R2) was used to determine the percentage of climatic parameters impacts together (Brien and Scott, 2012).

3.5. Econometric Analysis

The study applied multivariate probit model to examine factors affecting farmers' choices of climate change adaptation strategy. Therefore, the dependent variable, choice of climate change adaptation strategy, is a multiple variable. Thus, when households can be choose more than one adaptation strategy, multivariate probit model employed best fit model with the data generation process. (MVP) model is a binary response regression model to estimate both observed and unobserved disturbance on dependent variables by several explanatory variables simultaneously which permit error terms to correlate freely. It is used to estimate many correlated binary outcomes jointly (Huguenin *et al.*, 2009). The MVP is one form of a correlated binary response regression model that can simultaneously estimate the influence of the set of explanatory variables on each of the different practices, while allowing for the potential correlation between unobserved disturbances as well as the relationship between the adoptions of different practices (Belderbos *et al.*, 2004). The model is based on the multivariate normal distribution and is recommended in cases of interdependence among the irrelevant alternatives (Greene, 2003).

3.5.1. Specification of multivariate probit model

This study modeled climate change adaptation behavior of farmers using discrete dependent variables with multiple choices. Any adaptation option could fall under the general framework of utility and profit maximization (Gbetibouo *et al.,* 2010). A rational farmer then seeks to maximize his profit over a specified time horizon, and must choose among a set of j adaptation options. The íth farmer will choose to use jth adaptation option if it has a greater perceived net benefit than the utility from other adaptation options (say, k) stated as

$$U_{ij}\ \beta_j{}'\ X_i + \varepsilon_j > U_{ik}\ \beta_k{}'\ X_i + \varepsilon_k\ ,\ k \neq j \qquad \text{Equ (13)}$$

Where

U_{ij} And U_{ik} are perceived values by farmer to response climate change í of adaptation options j and k respectively

X_i A vector of explanatory variables that influence the choice of the adaptation option β_j and β_k are parameters to be estimated and ε j and ε k are the error terms. Under consideration of the revealed preference assumption, the farmer practice adaptation options that generates net benefit and does not practices an adaptation option otherwise;

the researcher can relate the observable discrete choice of practice to the un observable continuous net gain variable as Y_{ij} =1 if U_{ij}> 0 and Y_{ij} = 0 if U_{ij} < 0 in this formulation Y is a dichotomous dependent variable taking the value of 1 when households select an adaptation option 0 otherwise.

This econometric approach will be used for this study is characterized by a set of 6 binary dependent variables those are soil and water conservation practice, improved variety, tree planting, adjusting of planting period, intercropping and irrigation. Such that:

$$Y_{ij}^{*} = X_{ij}'\ \beta_j + \varepsilon_{ij},\ j = 1, 2,3,4,5 \text{ and } 6$$

And

$$Y_{ij} = \begin{cases} 1 = if Y_{ij}^{*} > 0 \\ 0\ other\ wise \end{cases}$$

It is possible to assign as Y1= soil and water conservation practice, Y2 = drought tolerant crop variety, Y3 = agro forestry, Y4 = adjusting of planting date, Y5 = irrigation Y6 = inter cropping practices.

In multivariate model, where the choice of different adaptation strategy is possible, the error terms jointly follow a multivariate normal distribution (MVN) with a mean of zero and variance–covariance matrix V has values of 1 on the leading diagonal and correlation $\boldsymbol{\rho}_{jk} = \boldsymbol{\rho}_{kj}$ as off- diagonal element where ($\mu_{y1,}$ $\mu_{y2,}$ $\mu_{y3,}$ $\mu_{y4,}$ $\mu_{y5,}$ μ_{y6}) MVN ~ (0, Ω) (Belderbos *et al.*, 2004).

The 6×6 matrices of Off-diagonal elements in the variance - covariance matrix represent the unobserved correlation between the stochastic components of the different types of climate change adaptation strategies. This assumption means that equation will generate MVP models that jointly represent a decision to choose a particular climate change adaptation choice. This specification with non-zero off-diagonal elements allows for correlation across error terms of several latent equations, which represents unobserved characteristics that affect the choice of alternative adaptation strategies. The likelihood that contributes for an observation is six variant standard normal probabilities.

$\Pr(y_1, y2 \ldots y_6 / x) \int_{-\infty}^{(2y1-1)\times\beta1} * \int_{-\infty}^{(2y1-1)\times\beta6} \Phi (\varepsilon 1, \varepsilon 2 \ldots E5; ZRZ)\, d\varepsilon 6 \ldots d\varepsilon 2, d\varepsilon 1$

Where, Z=*diag* (2Y1-1….2Y6-1).

3.5.2. Statistical tests

Before running the model, it is useful to look into account the problem of multicollinearity among the independent variables. To this effect, all the ten explanatory variables were checked for multicollinearity using Variance Inflation Factor (VIF). VIF for all variables were less than 10 (1.1–2.13). Which indicate that multicollinearity is not a serious problem in model estimation. All the hypothesized explanatory variables were included in the model. Therefore, in this study, only those variables, whose coefficients were statistically significant at less than or equal to 10% probability levels were discussed.
(Gujarati, 2004; O'brien, 2007). (Appendix Table A and B)

3.5.3. Definition of the model variable for multivariate probit model

Dependent variables: The dependent variable is a variable that is said to be affected or explained by another variable/ variables. The dependent variables of this study is the choice of adaptation options that the farmers' employ in response to cope climate change.

Adjusting planting dates: this implies that making of adjustment depends on the rain comes and planting of short duration crops like drought tolerant crops and change the date of planting crop with respect to the change in climate that is either early or late planting (Gebru *et al.*, 2014).

Agro-forestry: In order to protect land degradation and reduction of soil fertility farmers planting different vegetation like tree varieties, plants, grass and bush are the more valuable because roots are protect from erosion .Includes growing eucalyptus tree, coffee, rosemary, avocado, mango, papaya and other fruits and trees used for timber production and has a multi-purpose (as a sources of income and means of keeping climate balance). It also constitutes trees used for energy consumption and prevents deforestation (Temesgen *et al.*, 2014).

Use of drought tolerant variety: It involves cultivating crops that are better suited to the new climate, such as stress-tolerant varieties, shorter-growing varieties, and pest- and disease-resistant cultivars. It additionally incorporates developing harvests which are appropriate to the new climate and growing conditions (Hadgu *et al.*, 2015).

Soil and water conservation practice: : Include soil erosion preservation, management and care of soil in order to make it appropriate for their crops, dam construction, conservation of rain water for watering the crops in times of lacking rain, ground water harvesting. The adoption of soil and water conservation practices such as soil/stone bending, terracing, mulching, and runoff diversion to prevent erosion, improve soil fertility, and conserve soil moisture (Hassan and Nhemachena, 2008; Adisu *et al.*, 2016) used this measure as one adaptation strategies to climate change.

Use of irrigation: It involves farmers building water systems, harvesting schemes like shallow open wells or traditional hand-dug wells to take groundwater for irrigation, and diverting and pumping spring water for irrigation (Deressa *et al.*, 2008; Adisu *et al.*, 2016) identified use of irrigation as one strategy for climate change adaptation.

Intercropping: is a sustainable farming practice in which two or more crops are grown side by side in the same field during the same or overlapping growing season (not necessarily at the same time). It can improve land-use competence by reducing the amount of land needed for intercropped systems to produce the same amount of monoculture crop grains (Li *et al*., 2013; Wang *et al.*, 2014).

Independent variable: Independent variables are factors that influence the use of adaptation strategies either positively (+) or negatively (-). Independent variables for the study were identified and listed based on previous, theoretical and empirical, findings. These variables were assumed as a factor influencing on farmers adaption strategies. The following major explanatory variables were hypothesized to influence farmer's adaptation strategies.

Age of the household head (agehhh): It is a continuous variable that is defined as the age in years of the household heads. Due to their relative strength, households with younger members participate in a variety of climate change adaptation activities. While the older household head has developed the experience necessary to diversify their adaptation strategies, their physical capacity to engage in a variety of activities is somewhat diminished (Obayelu *et al.*, 2014).

Sex of household head (sexhhh): This is a dummy variable that assumes a value of "1" in the event that the household head is male and a value of "0" in the other case. A person who financially supports or manages the household is the household head. It has been discovered that male-headed households are more likely than female-headed households to adapt to climate change (T. Deressa *et al.*, 2008). According to (P. Asrat & Simane, 2018) male headed households have better adopt to climate change whereas female head households have less adapt to climate change. Therefore, in this study sex of the household or being female headed household expected to have negative relation with activities of climate change adaptation strategies and have been predicted that male household head positively influence activities of climate change adaptation strategies.

Educational level of household head (educhhh): It is a dummy variable that takes a value of 1 if literate and 0 for illiterate. Evidence from various sources indicates that there is a positive relationship between the education level of the household head and adaptation to climate change (Adeoti *et al.* 2016). When household level of education increase or when they are more educated, they can more adopt climate change.

Family size (famsiz): This refers to the total number of family members of the household who live in together and they may be to participate in different activities of climate change adaptation strategies. It is a continuous variable measured by the number of family members in a household. A one person increases in the family can increase the chance of adapt the adaptation measures (Atinkut & Mebrat, 2016).

Land holding size (sizefarm): Farm size is the total landholding of the farm household that used for the farming activities. The bigger the farm size, the more likely the farmer is to adopt suitable strategies. In this study a positive or negative relationship is expected between farm holding size and climate change adaptation (Lemma, 2016).

Accesses to weather information (getwathinfo): It is a dummy variable taking 1 if the household head gets information (from radio, television, friends, Mobil phone and etc.) and 0 other wise. Household who access more information from radio, television and telephone are highly participant in diversifying adaptation strategy. According to (Sorhaug, 2011), farmers who have more information about climate change; they adopt or implement different climate change adaptation measures.

Thus, this dummy variable is predicted to possess direct relationship between access of weather information and the choice climate change adaptation strategies.

Farmer-to-Farmer extension (FFEXT): This variable indicates the access to informal extension services. It involves sharing information and inputs from nearby farmers. It is a dummy variable taking the value of 1 if there is access and 0 otherwise. (Deressa *et al.*, 2009) it also enhances the chances for farmers‟ decision to adapt to climate change and influence their preferences for different adaptation strategies. Hence, it serves as a source of information and experience sharing among farmers and expected to positively affect choice of adaptation strategies.

Access to credit (acces2cred): It is a dummy variable taking the value of 1 if the household head who take credit and 0 other wise. It provides the farmer to improve introduce new technology, to buy improved seed variety, fertilizer and other necessary imputes. As result in this study this dummy variable is predicted to possess positive relation with the availability of credit and farmers who were used adaptation strategy (Gbetibouo *et al*., 2010).

Distances from market (DMKT): it is continuous variable measured in the total distance from their residential to the nearest market in minute. It shows access to the market to buy input and/or to sell output. Thus, the variable is predicted to possess negatively or positively related with climate change adaptation strategy. As the farmer is nearer (closer) to a market, the higher will be the chance of adaptation to climate change. Market may also serve as information sources of various issues including climate change and its adaptation options. Therefore, in this research as distance from market is increased it is hypothesized that adoption of an adaptation option is decreased (Tesfaye and Seifu, 2016).

Amount of livestock holding: is defined as the total numbers of livestock owned by a household and were measured in Tropical Livestock Unit (TLU). Livestock is good instrument to adapt climate change. This is due to the actual fact that livestock is crucial for farm household to use as for harvesting, transportation and also for financial purpose by selling them. Therefor, the variable is predicted to possess posetive or negatively inflounce on farmers choice of climate change adaptation strategy. It is a continuous variable and expect a positive sign for the farmers' who are use adaptation method to climate change (Kide, 2014).

Table3. 2. Description of the independent variables

Explanatory variables	Hypothesized signs	Description
Agehhh	+ve/-ve	Continuous
Sexhhh	+ve/-ve	Dummy: take the value of 1 if the house hold head is male, 0 otherwise
Educhhh	+ve	Dummy take 1illitrate 0 otherwise
Famsize	+ve	Continuous
land Size	+ve	Continuous
Getweathinfo	+ve	Dummy: take the value of 1 if the house hold get weather information, 0 otherwise
farmer to faEx	+ve	Dummy: take 1household get farmer to farmer extension 0 other wise
acces2cred	+ve	Dummy: take the value of 1 if the house hold get access to credit, 0 otherwise
TLU	+ve/-ve	Continuous
Dist2nearmkt	+ve/-ve	Continuous

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1. Demographic and Socio-Economic Characteristics of the Respondents

As shown from Table 4.1 out of the total 347 respondents, 11.24% respondents were female-headed whereas, the remaining88.76% was male-headed household respondents. Similarly the average age of the respondents in the given area was 48.49 years.

According to the survey data showed that regarding their educational status, 19.60% and 80.40% of respondents were literate and illiterate respectively. Education is an important characteristic that determines a farmer's ability to communicate, acquire information and adapt new technologies. This implies that among the household respondents, more than half of the respondents were illiterate.

Moreover, the survey result shows that marital status of respondent households were about 2.02%, 1.15%, 96.54% and 0.29% was stay on single, divorced, married and widowed respectively. In countries like Ethiopia where agriculture is labor intensive and family size is the main source of agriculture labor; households with large family size can easily undertake their farm operations. From (Table 4.1) the average family size of the respondent was 5.82. And also indicated in (Table 4.1) the average farm land size of the respondent was 1.18 hectares.

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

Variables		Mean	
Age		48.49	
Family size		5.82	
Farmland size		1.18	
		Frequency	Percent%
Sex	Male	308	88.76
	Female	39	11.24
Marital status	Single	7	2.02
	Married	335	96.54
	Divorced	4	1.15
	Widowed	1	0.29
Education level	Illiterate	279	80.40
	Literate	68	19.60
Total		347	100

4.2. Trends and Variability of Rainfall in Alefa District

The annual rainfall of Alefa district in the years 1990 -2020, ranged from 951 mm to 1294.1mm in1991 the wettest year. The mean rainfall of the district was 1079.6mm in the past three decades. *Kiremt* rainfall shows a 12.3%, 102.9mm coefficient of variation and standard deviation respectively. Which means 102.9mm amount of rainfall, was deviated in plus or minus from the mean rainfall 785.1mm.

The standard deviation and coefficient of variation of annual rainfall (CV) were 75.8mm, and 7.0%, respectively. That means in the last 30 years 75.8mm amount of rain fall deviate in a plus or minus from the mean rainfall and erratic over the past years.

This variability has also been indicated as a major problem to crop production and as indicated from CV the annual total rainfall variability is less variability category which is consistent with the work of (Gebremichael *et al.*, 2014; Weldegerima *et al.*, 2018).

Table4. 2. Annual and *Kiremt* rainfall variability of Alefa district (1990-2020)

Season	No years	Min	Max	Mean	SD	CV
Annual	30	951.3	1294.1	1079.6	75.8	7.0
Kiremt	30	683.1	1603.4	835.1	102.9	12.3

According to linear trend in (Fig 4.1) below annual rainfall indicates a decreasing trend in the station. The amount of rainfall was decreased by about 1.33mm every year between 1990 and 2020.

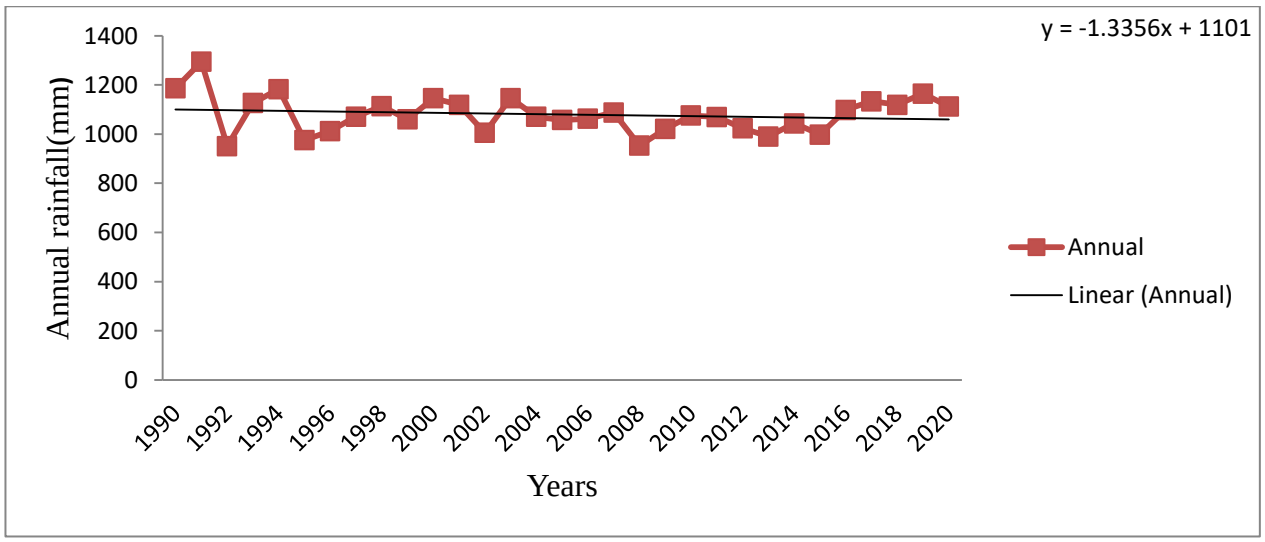

Figure 4.1.Trend of annual rainfall total from 1990 -2020

According to linear trend in (Fig 4.2) Kiremt rain fall has shown decline trend. It has decreased by about 4.5mm every year during the past three decades. This finding was in line with (Kefelegn, 2020).

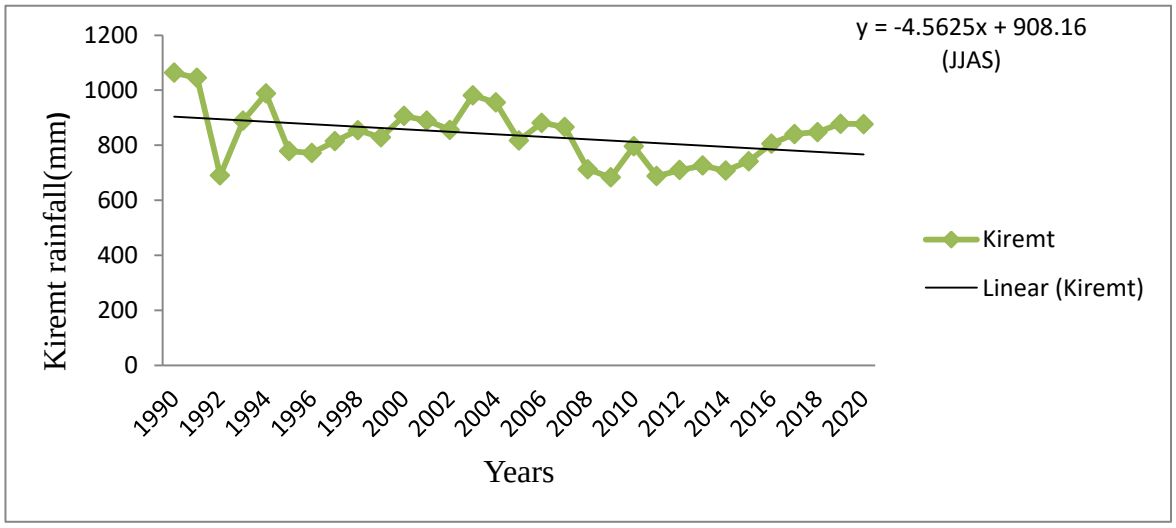

Figure 4. 2.Trends of Kiremt rainfall

4.2.1. Rainfall anomaly index

Variability in year to year variation of annual rainfall for Alefa is expressed in terms of standardized rainfall anomaly (Fig4.3). Alefa and the surrounding area is show both dry and wet years on the climatic conditions between 1990 and 2020.

Standardized rainfall anomaly index (SAI) calculated for a period of 29 years (1990 - 2020) indicated that the annual rainfall shows positive anomalies for 53.4% and dry conditions with negative anomalies for 46.6%. Based on Z values, drought severity classes obtained from the study period, extreme drought, moderate drought and no drought years were experienced. Accordingly, the years with very low values of rainfall anomaly corresponds to dry period (drought) include 1992, 1995, 2008, 2013 and 2005 while years; 1996, 2002, 2009 and 2012 were moderately drought (Fig 4). This result is in line partially with (Yilma *et al.*, 2009). On the other hands, years 1990, 1991, 1994 and 2019 are classified as years of no drought according to drought severity classes used by (Agnew and Chappell, 1999). The years 1993, 2000, 2003, 2007 and 2017 were experiencing normal or wet rainfall amount. The results of the linear trend lines for the study period clearly demonstrate that there was a slightly decreasing rainfall trend.

This result is in line with the findings of (Mideksa, 2011) whose study revealed a general decreasing rainfall in Ethiopia.

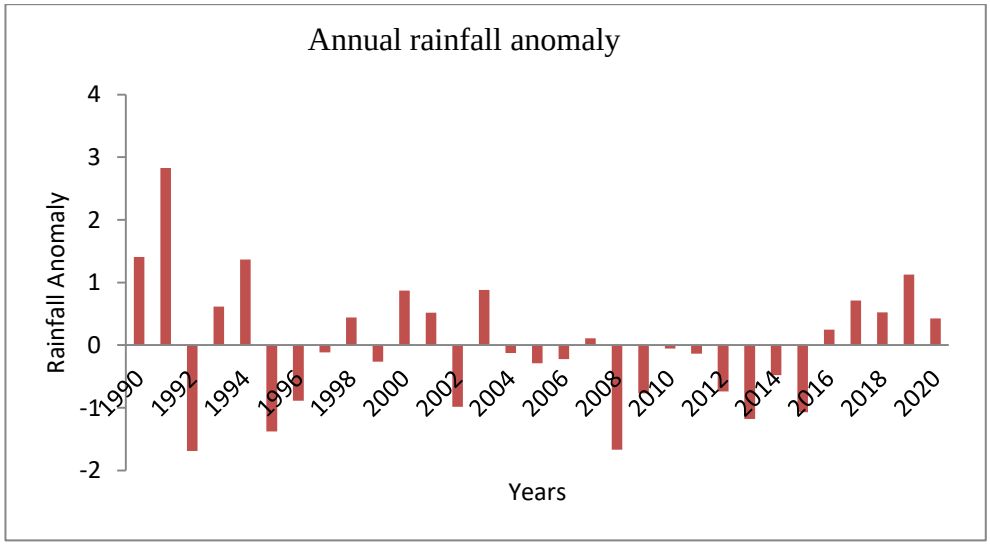

Figure 4. 3. Annual rainfall anomaly from 1990-2020 in Alefa district

4.2.2. Precipitation concentration index

The mean annual precipitation concentration index (PCI) value was 16.9 for the district, which indicates high concentrations of annual rainfall distribution. The PCI value of seasonal rainfall Kiremt was 6.4. As indicated from this Kiremt season was below 8 so they indicate uniform Kiremt rainfall distribution. Therefore, decrease in annual rainfall may be due to fact that, some years recorded very less rainfall, which might have generally influenced overall trend. This means that even though annual rainfall decreased over period, rate of decrease was uneven. The less recordings of rainfall in some periods of years may be harmful to crop production especially maize, which need excessive rainfall during fruit development stages. This result is consistent, with the finding of (Bewket, 2009).

4.2.3. Trend and variability of temperature

Temperature is one of the elements that determine whether conditions as well as the climate of an area. It is recorded as maximum and minimum, monthly, and, annual temperatures. Crop growth and development is mainly a function of temperature if water is available to the optimum satisfaction. Annual maximum temperature of the district was observed from 1990 to 2020 showed that annual maximum temperature was between 25.6^{o}c and 29.9^{o}c (Fig 4.4).

The annual maximum temperatures have shown an increase of 0.042°c and its standard deviation over the period was 0.9°c. This result is similar with (Birara *et al.*, 2018).

The positive value of slope (0.042) is indication of an increasing trend in the annual maximum temperature. Increase in temperature will poorly oppress crops and plants require more water to replenishment loss in the form of irrigation.

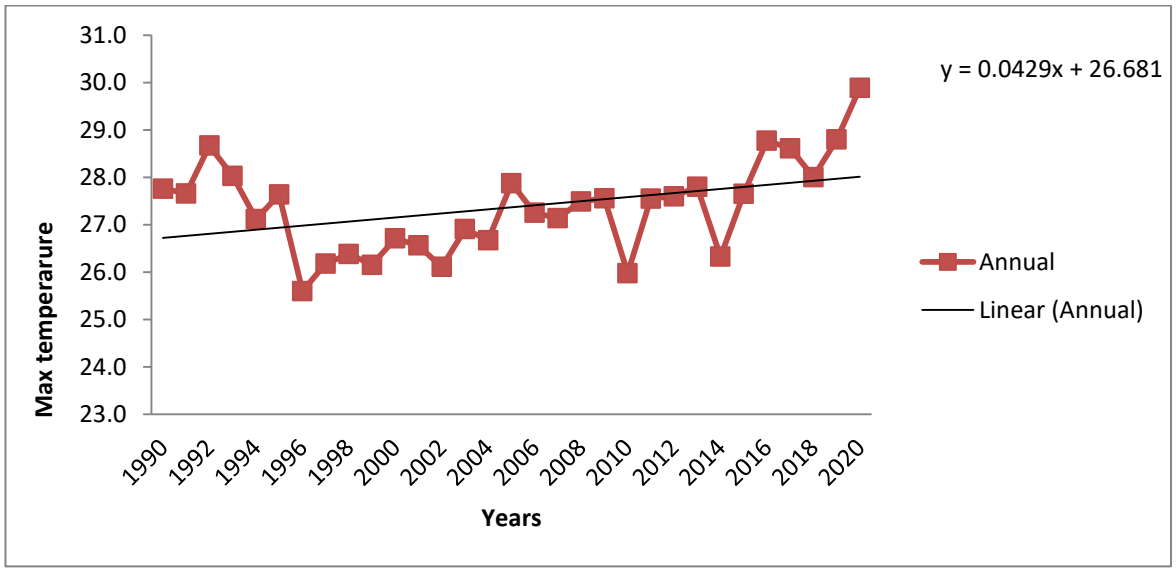

Figure 4. 4. Annual maximum temperature trend at Alefa district

The annual minimum temperature for the district ranged from 12.7°C to 15.8°C and SD 0.6°C during the study period. The average annual minimum temperature of Alefa district for the period 1990- 2020 showed a relatively increasing trend as indicated from (Fig 4.5). The trend showed that annual minimum temperature of the study area 0.041°C /year. This result is in line with (Mengistu *et al.*, 2014) at Sekota area indicated that an increased annual average minimum temperature (0.8°C).

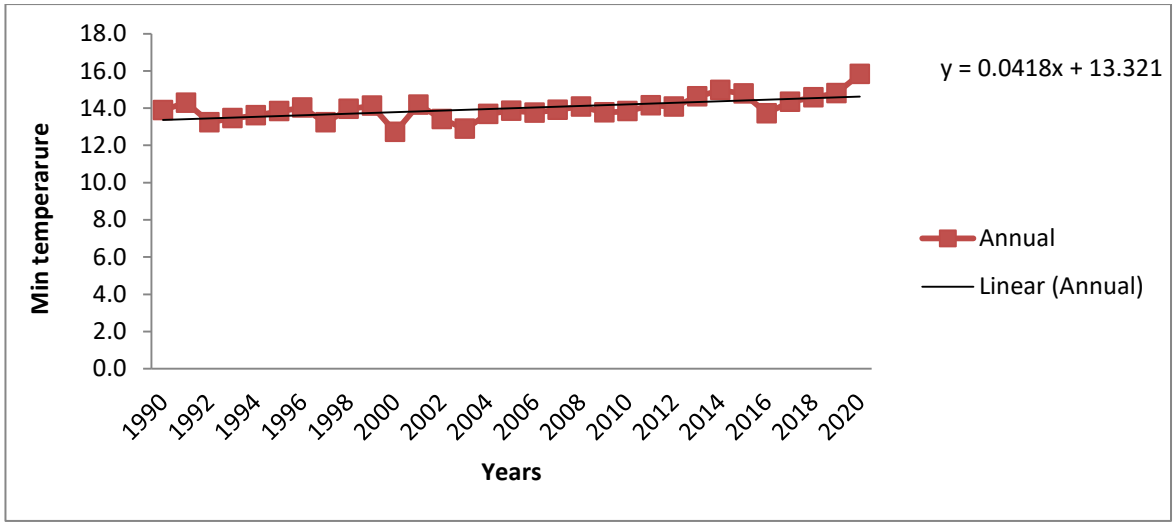

Figure 4. 5. Annual minimum temperature trend at Alefa district

(Fig 4.6) shows the mean annual maximum and minimum temperature of the study area for the study period (1990-2020) the result revealed that the average annual minimum and maximum temperature of the study area was 19.7°C and 22.9°C respectively.

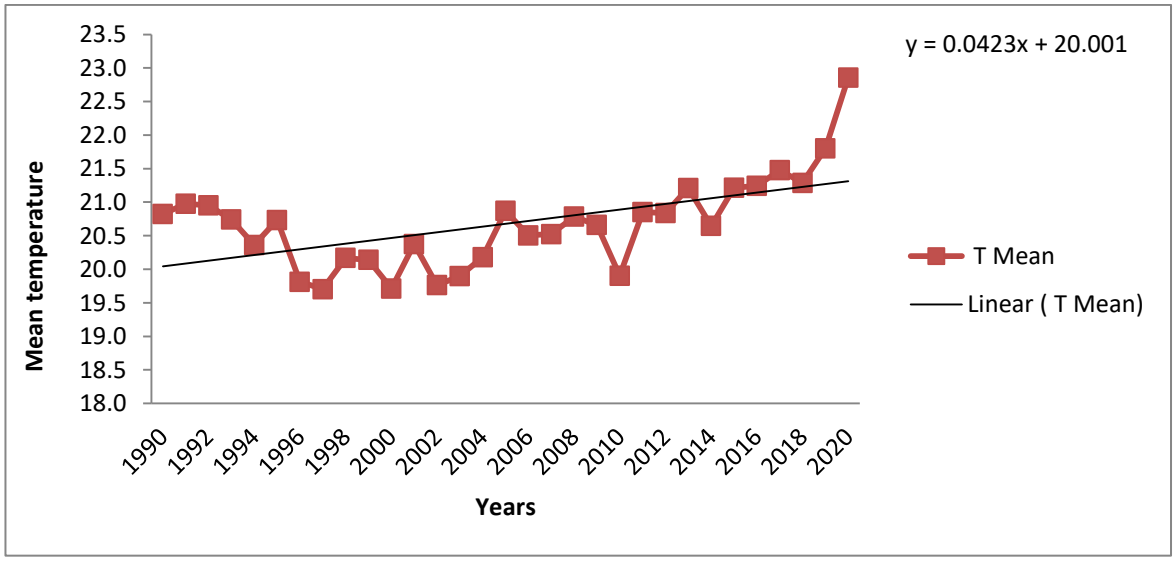

Figure 4.6. Annual mean temperature trend of Alefa district

From (Table 4.3) indicated that the variability of annual maximum, minimum and mean temperature of Alefa district.

Table 4. 3. Variability of max, min and mean temperature of Alefa district (1990-220)

Station	Temperature	N	Min	Max	Mean	SD
Shahura	T max	30	25.6	29.9	27.4	0.9
	T min	30	12.7	15.8	14.0	0.6
	T mean	30	19.7	22.9	20.7	0.6

4.2.4. Mann-Kendal Trend analysis of rain fall and temperature

The Mann–Kendall's and Sen's slope (Q) test on seasonally and annually rainfall data, the results presented in (Table 4.4) are obtained for Alefa district. The trend analysis has done for all months of the year, long rain season *(Kiremt*) and the whole year. The Mann-Kendall trend analysis result indicated that the annual rainfall amount in the study area showed insignificant decreasing trend by 0.8 mm/year. There are findings which are in line with results conducted by different authors Such as (Tabari *et al.*, 2015; Jury and Funk, 2013) also used the long-term gridded data and reported the decreasing trends in annual rainfall over southwestern Ethiopian in the period 1948–2006. Seasonal rainfall analysis of the Mann-Kendall trend analysis and Sen's slope (Q) indicated that there was a decreasing trend for the *Kiremt* rainfall by a factor of -3.86mm/year. The result is in line with the findings of (Wagesho *et al.*, 2013).

The result from the Mann-Kendall analysis and Sen's slope (Q) test on annual maximum temperature showed an increasing trend by 0.06°C per year (Table 4.4). It will help the planners to design appropriate strategies to minimize the impact of temperature on the livelihood of the people. The result agrees with that (Hayelom *et al.*, 2017).

The minimum temperature has shown an increasing trend with a magnitude of 0.04°C per year respectively. This result is also in line with (Kassie *et al.*, 2014). The values of Sen's slope test of Kiremt maximum temperature indicated that the trends were increased by 0.02°C, per year. On the other hand in Kiremt season minimum temperature there is no change (Table 4.4). This is supported by the investigation of (Lemma *et al.*, 2016).

Table 4.4. Mann-Kendall trend test for annual and Kiremt rainfall and temperature in Alefa district (1990-2020)

Season	Rainfall			T min			T max		
	Z_{MK}	Q	P-value	Z_{MK}	Q	P-value	Z_{MK}	Q	P-value
Annual	-0.44	-0.80	0.65	3.4	0.04	0.006	2.18	0.06	0.029
Kiremt	-1.68	-3.86	0.09	0.6	0.00	0.54	0.95	0.02	0.34

Where, Z_{MK}= Mann-Kendall trend test, Q= Sen's slope estimation '**' significant at 5% significance level.

4.3. Effect of Climate variability on Maize yield

The trends of maize productivity for 12 years in the study area are presented in (Fig 4.7) shows that there were wide fluctuations in maize productivity. From analyzed maize yields data for twelve years (2000-2012) at Alefa, the minimum and maximum maize yields were 25 qt/ha and 14.5qt/ha respectively. The recorded mean was 21.0qt/ha with SD (3.6) and CV (17.1%). The decrease in maize yields threatens food security since it is a staple food crop for the people in the study area. The results were in line with the findings of (Balcha 2009) and (Ermias, 2020) crop production capacity can be weaken because of climatic variability.

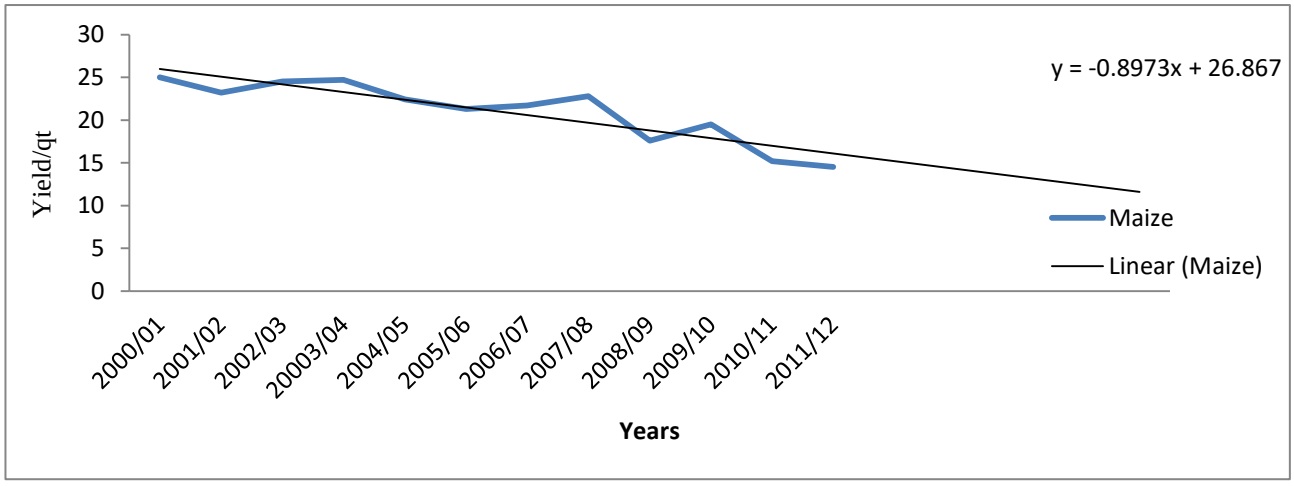

Figure 4.7.Trends of maize yield

4.3.1. Correlation analysis of rainfall, temperature and maize yield

The Pearson correlation coefficient between the climatic elements and the maize yields were computed and the result is presented in table (Table 4.6) displays the correlation coefficient calculated between maize production, rainfall characteristics and maximum and minimum temperatures. There was a negative and positive association between the yield of maize and the weather variables in the research area. The correlations between rainfall elements and maize yield shows that annual rain fall (r= -0.746**) had strong negative correlation with maize yield and Kiremt rain fall (r= 0.813*) strong (significant) positive correlation implies Kiremt season rainfall total is the most important variable that has significant impact on maize yield than annual rainfall. Kiremt rainfalls were more explain the yield of maize indicating that the yield of maize is higher when Kiremt season rainfall total is getting higher.

Maximum temperature strong (significant) negative correlation (r= -0.659*) and minimum temperature (r=-0.333) had weak negative correlations with maize yield (Table 4.6). The negative sign in maize indicated that temperature highly affects their production or it means that maize requires adequate maximum and minimum temperature to survive and grow. Increases in minimum and maximum temperature were lead to reduction in the maize yields. This result is similar with the findings (Paul and Oluwasina, 2011).

Table 4. 5.Pearson‟ Correlation between maize yield and rainfall and temperature features in the study area

	Maize yield	Annual rainfall	Kiremt rainfall	Tmax	Tmin
Maize yield	1				
Annual rainfall	-0.746**	1			
Kiremt rainfall	0.813**	0.819	1		
T max	-0.659*	0.4357	0.4897	1	
T min	-0.333	0.0771	0.1469	-0.0112	1

**= Correlation is significant at the 0.01 level (2-tailed) *= Correlation is significant at the 0.05 level (2-tailed).

4.3.2. Regression analysis of rainfall, temperature and maize yields

Regression coefficient of the study revealed that the maize yield is impacted by several aspects of rainfall and temperature in varying degrees. It is evident from regression analysis that, temperature and rainfall amount has a significant relationship with maize yield. Among the climatic elements annual rainfall total, Kiremt rainfall, maximum and minimum temperature is the most important variable that has significant and insignificant impact on maize yield indicating that the yield of maize is higher when rain rainfall total is getting higher and temperature is optimum. The multiple linear regression analysis of maize produced with rainfall and temperature parameters of climate is presented in (Table 4.7). The adjusted R of this model 0.731 with the R^2 =0.829 shows that the multiple linear regression explains 82.9 % of the variation of the maize yield as a result of the impact of rainfall, minimum and maximum temperature (Abdullahi , 2021).

Table 4. 6. Regression analysis of Annual and seasonal rainfall and temperature on maize yields

Weather element	Coefficient.	St. Error.	P-value
Annual Rainfall	-0.0135	0.015	0.408
Kiremt rainfall	0.0210	0.014	0.204
Tmax	-1.4965	0 .748	0.086
Tmin	-2.1290	1.304	0.147
Constant	123.3	27.601	0.003

Model	R^2	Adjusted R^2	F- taste	prop>F
1	0.829	0.731	8.50	0.0080

4.4. Climate Change Adaptation Strategies

Adaptation strategies are methods that the local people used to adjust themselves with the existing change. In order to this, the local people on the district made different changes and adjustments in different sectors. Thus, the result in (Table 4.8) below showed the proportion of respondents who used drought tolerant crop verities to be (55.3 %), SWCP (62.8 %), Used agro-forestry (49.3 %), Adjusting planting period (40.9), intercropping system(39.8 %) and irrigation 29.7%) were applied as the major adaptation strategies by farm households in the study area.

Drought tolerant crop varieties: Similarly, about 55.3 % of the applied drought tolerant crop varieties (improved seed and improved livestock) (Table 4.8) to tackle the adverse impact of climate change. During focus group discussion, farmers pointed that such improved crop varietal selection is depending on short growing variety, productive, disease and pest resistance crops. Farmers' report showed that, they have been using different improved crop varieties like maize, wheat and teff varieties (Anbesu, 2013).

Soil and water conservation practices: About 62.8% the respondent were applied soil and water conservation practice like stone bund, soil bund, water way, cut of drain, grass strip, and different structures like trench and micro basin to adopt climate change as indicated by distributive statistics (Table 4.8). It is implemented to reduce soil erosion, formation of gullies, losses of nutrients and improve soil productivity by controlling soil erosion (Kato *et al.,* 2011). Key informant interview and focus group discussion states that in addition to respondents' response different soil and water conservation structures like trench, micro basin and area closure were applied on highly degraded communal land in the study area to absorb the rain water.

Agro forestry (tree planting): As indicated by the distributive statistics, about 49.3% of the respondents were applied tree planting for different purpose like for building, for economic value, for fuel woods and for shading purpose (in order to collapse the increasing temperature). Grabilia, eucalyptus and other endogenous trees were planting as discussed by FGD and KII. Even if eucalyptuses have high economic returns, it has side effect on the surrounding farm land areas because of its Allelopothic and high moisture taking capacity (Magarse, 2018).

Adjusting planting period: As indicated by the distributive statistics, about 40.9% of respondents were applied adjusting planting period to tackle the impact of climate change in the study area. Farmers' crop production systems were depending on occurrence of rain fall comes. For example, if the coming of rain falls late, farmers were applied taking short duration season crops and drought tolerant crop varieties and if the coming of rain fall was early farmers were applied long time taking crop varieties on their farm land (Tesfaye and Seifu, 2016).

Intercropping system: In the study area, about 39.8 % of respondents were applied intercropping adaptation strategy in their farm land (Table 4.8). In order to minimize total failures of particular crop which is caused by climate change rural farmers were practiced mixed cultivation system under the same piece of land. Appling different crops in the same plot of land help to farmers to minimize total crop failures caused by shortage of moisture, snow, wind, disease and pests (Makate *et al.,* 2016). Different crops affected differently by climate change as indicated by or discussed by FGD and KII.

Irrigation: The distributive statistics reveals that about 29.7% of respondents were applied irrigation system to tackle the impact of climate change in the study area. As discussed by FGD irrigation system is one of the important ways used by the farmers to adopt the impact of climate change in the study area (Gashaw *et al.*, 2014).

Table 4. 7. Summary of adaptation strategies used by farmers

Adaptation strategies	Frequency(N=347)	Percentage
Soil and water conservation	218	62.8
Drought tolerant crop varieties	192	55.3
Agroforestry	171	49.3
Adjusting planting date	142	40 .9
Inter cropping	138	39.8
Irrigation	103	29.7

Based on the estimated result, the likelihood of households to adopt drought tolerant crop varieties, Agroforestry practices, adjusting planting period, soil and water conservation practices, intercropping and irrigation were about 55.3%, 49.3%, 40.9%, 62.8%, 39.8% and 29.7% respectively. It also showed that the joint probability of using all adaptation strategies was only 8.7% and the joint probability of failure to adopt all of the adaptation strategies was 7.1% (Table 4.9). These adaptation measures help farmers guard against losses due to changes in temperature and rainfall.

To use MVP model, the correlation coefficients of the error terms should be significant for any pairs of equations. The likelihood ratio test of Rhoij= 0 is significant at 5% significance level infers that the correlation coefficient of at least one pair of adaptation strategies is statistically divers from zero (Bewuketu, 2017).

Table 4. 8. Correlation matrix of adaptation strategies for the multivariate model

	Adaptation Strategies					
	Intercropping (Rho1)	Adjusting planting dates(Rh02)	Agroforestry practices (Rh03)	Soil & water conservation (Rh04)	Irrigation (Rh05)	Drought tolerant crop (Rh06)
	Coefficient (Std. error)	Coefficient (Std. error)	Coefficient (Std. error)	Coefficient (Std. error)	Coefficient (Std. error)	Coefficient (Std. error)
Rho2	0.260(0.098)**					
Rho3	-0.005(0.090)	0.030(0.096)				
Rho4	0.158(0.087)*	0.062(0.095)	-0.081(0.084)*			
Rho5	0.213(0.100)**	0.138(0.110)**	-0.051(0.100)	0.125(0.099)**		
Rho6	-0.074(0.093	-0.068(0.098)	0.010(0.086)	0.063(0.088)*	-0.044(0.102)*	
Predicted Probability	0.621	0.463	0.527	0.382	0.637	
Joint probability (Success).				0.087		
Joint probability (Failure).				0.071		
Likelihood ratio test of Rhoij = 0; chi2(15) = 18.885, P-value = 0.0219*						

** p<.05, * p<.1, Significant at 5% and 10% respectively

Accordingly, the correlation coefficients of 6 combinations are statistically different from zero which demonstrates the appropriateness of the MVP model specification and choice of climate change adaptation strategies are not mutually independent (Table 4.9). This means that positive correlations and negative correlations exist between different adaptation options being used by farmers. There is interdependence among adaptation options. There is a positive correlation between intercropping and adjusting planting date, intercropping and SWC practice, intercropping and irrigation, adjusting planting date and irrigation, SWC practices and drought tolerant verities. This implies that these combinations of adaptation strategies can be used at a time. These combinations can also supplements to each other. There is also a negative correlation between use of agro-forestry and SWC practice, use of irrigation and drought tolerant varieties. This also implies farmers may use either of the two adaptation strategies since one can be used instead of the other (Ermias, 2021).

4.4.1. Determinants of farmers' choice of adaptation strategies

The probability of choice of applying a variety of adaptation measures in response to climate change impact are affected by several household and institutional characteristics. The MVP model of sample farmers‟ adaptation strategies was estimated to identify explanatory variables affecting farmers‟ choice of adaptation strategies to reduce adverse effect of climate change. (Table 4.10) presented the results of estimation of MVP model along with the levels of statistical significance of factors. The wald $\chi 2\ (66)= 89.13$ and $p < 0.05$ is statistically significant at 5% significance level and the null hypothesis that the coefficient of all regresses is statistically equal to zero is rejected implying the model is fit and has a strong explanatory influence. The result implied that different household and institutional characteristics significantly affected their choice (Legesse *et al.*, 2021).

Table 4. 9. Multivariate probit results of farmers‟ climate change adaptation strategies

Independent variables	Intercropping	Adjusting planting dates	Agroforestry practices	Soil & water conservation	Irrigation	Drought tolerant crop varieties
	Coefficient (Std. error)	Coefficient (Std. error)	Coefficient (Std. error)	Coefficient (Std. error)	Coefficient (Std. error)	Coefficient (Std. error)
Sex	0.079	-0.010	0.194	-0.262	0.034	-0.37
	(0.238)	(0.260)	(0.223)	(0.234)	(0.277)	(0.270)
Age	-0.012	-0.004	0.010	0.009	-0.002	0.001
	(0.008)	(0.008)	(0.007)	(0.007)	(0.009)	(0.01)
Family size	-0.119**	-0.021	0.057	-0.008	0.106	0.040
	(0.051)	(0.055)	(0.049)	(0.049)	(0.059)	(0.052)
Land size	-0.030	-0.315**	0.025	-0.249*	0.020*	0.007
	(0.036)	(0.153)	(0.035)	(0.136)	(0.039)	(0.028)
Distance from market	0.014***	0.001	0.004	0.003	0.009**	-0.00
	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)
total Lives stokam	0.059	-0.071	-0.034	0.061	-0.137**	-0.04
	(0.045)	(0.049)	(0.044)	(0.044)	(0.05)	(0.046)
Marital status	0.694**	-0.315	-0.194	-0.184	0.432*	0.196
	(0.259)	(0.344)	(0.248)	(0.245)	(0.227)	(0.230)
Education status	-0.05	-0.297	0.047*	0.375**	-0.18	0.39**
	(0.181)	(0.192)	(0.178)	(0.183)	(0.205)	(0.205)
Credit to access	-0.235	0.126	-0.042	-0.115	0.042	0.004
	(0.155)	(0.179)	(0.154)	(0.151)	(0.187)	(0.165)
Farm to farm extension	-0.050	0.051	0.009	-0.077	0.120	-0.04
	(0.150)	(0.166)	(0.146)*	(0.146)	(0.177)	(0.157)
Acestowetrinf	0.305**	0.088	0.097	0.021	-0.204	0.019
	(0.146)	(0.161)	(0.142)	(0.140)	(0.172)	(0.152)
Constant	-1.289	2.612*	-0.453	0.725	-0.623	0.255
	(1.105)	(1.399)	(1.049)	(1.089)	(1.104)	(1.090)
Number of observation						347
Log likelihood						-1118.0985
Wald chi2(66)						89.13
P-value						0.0305**

Note: ***significant at 1%, ** significant at 5% and * significant at 10% significant level.

Family size: Family size had a negative influence on the use of intercropping of adaptation options to climate change at 5% level. This could be because households with large families may be forced to divert part of the labor force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family rather than adopting intercropping. This finding is similar with the result of (Belaineh *et al;* 2013).

Land size: Landholding size significantly and positively affected use of irrigation in response to climate change at 10% level. The bigger the landholding, the more likely the farmer is to adopt irrigation. The possible reason is that farmers who have bigger farm size have an option to divide their farm into different enterprises. This finding agrees with the result found by (Nhemachena and Hassan, 2007). And also land size is negatively correlated with planting date adjustment and soil water conservation practices at5% and10% level respectively. The probable reason for the negative relationships between adaptation and land size could be due to the fact that adaptation is plot-specific. This means that it is not the size of the farm but the specific characteristics of the farm that dictates the need for specific adaptation methods to climate change (Teshome *et al.*, 2021).

Livestock owner ship (TLU): Ownership of livestock is also statistically significant and negatively associated with irrigation practices at 5% level. Farmers who have large number of livestock in tropical livestock unit are less likely to respond to climate change using irrigation practices as an adaptation strategy. The possible conviction is that since farmers use traditional way of livestock husbandry system, it competes for land, time and labor with crop production. In addition, ownership of large livestock implies the farmer is affluent and has alternative source of income so that he or she would give less attention for crop production. This finding agrees with the result found by (Deressa *et al*., 2008).

Marital Status: This study found that marital status of the household head had positively a significant influence on adopting intercropping and irrigation as an adaptation strategy in response to the effects of climate change and household's at5%and10% significant level respectively. This particular finding is in agreement with a study conducted in southern Ethiopia (Gebre *et al.,* 2019) which indicated that marital status is highly related to household decision making. Farmers marred in the other word headed by men have the ability or probability adopting climate change adaptation than unmarried.

Education level of households head: The result of the MVP model showed that education level of the household head found to be significantly and positively related with agroforestry, using drought tolerant variety, SWC practice and irrigation. This result might emanate from the fact that education advances farmers‟ capacity of obtaining and analyzing new information about climate change and best adaptation practices that increases the probability of adapting to climate change. The result is conducted by (Gadédjisso-Tossou, 2015; Addisu *et al.,* 2016) that confirmed as the educational level of the household head increases, the level of understanding about climate change adaptation increases.

Distance to the nearest market: distance to the nearest market is positively and statically significant in influencing the choice of intercropping and irrigation at1% and 5% significant level respectively. A farmer whose residence is too far from the agricultural input as well as output market was used modern agricultural input less likely than the farmers who can get the input nearby their farm. In addition, the proximity to market is important even in helping the farmer to exchange information. On the contrary, closeness to market makes the farmer to engage in activities other than farming so that it gives less time to farming and using adaptation strategies (Nhemachena and Hassan 2007).

Farmer-to-Farmer extension: Farmer-to-farmer extension has a significant and positive effect on using of agroforestry practices as one option to climate change adaptation. Accesses of such services enhance the chances for farmers‟ decision to adapt to climate by enabling them to share experience about and collectively apply agroforestry practices keeping other variables constant. Different farmers have different skills, working habits, and experience. Therefore, sharing of experience among farmers is very important to build up the knowledge of the farmers and will help them to take the adaptation measures. This result is also similar with the finding of (Deressa *et al.,* 2010) and (Tessema *et al.,* 2013).

Access to climate information: Access to climate information significantly and positively affected intercropping at 5% level. Climate information notifies the situation of the existing climatic conditions to enable the farmers to use alternative adaptation strategies. This result is similar with the finding of (Abid *et al.*, 2015).

CHAPTER FIVE: CONCULUSION AND RECOMMENDATION

5.1. Conclusion

This study was undertaken to observe the variability of observed rainfall and temperature, as well as the impacts of climate variability (temperature and rainfall variation) on maize productivity. It also assessed farmers‟ adaptation strategies in response to climate change and variability in Alefa district. The time series trend analysis showed that there was a decreasing trend in annual rainfall. In addition, both the average max and min temperatures showed an increasing trend. Due to increasing temperature and decreasing rainfall, the area has been affected by recurrent drought. As a result of changes in current climate patterns, such as the decrease in the amount of rainfall, increasing temperatures, and shortening of rainy seasons decreasing maize yields in the district. Maize yields have both a negative and positive relationship with climate variables (rain fall and temperature).

Multivariate probit model was employed to determine the factors determining farm households choice of adaptation strategies related to climate change. The model found out those six major adaptation strategies: SWCP, tree planting, adjusting planting period, drought tolerant crop varieties, intercropping and irrigation.

MVP result also confirms that family size, distances from market and marital status have a significant impact on the use of intercropping as climate change adaptation strategy. It also showed that land size is significantly affecting the use of adjusting planting date to adapt to climate change. Moreover as obtained from the model result educational status significant in determining choice of agroforestry practices as an adaptation strategy. Education status and land size is significantly determined farmers' choices of SWCP to adapt to climate change impacts. Land size, livestock amount, distance from market, marital status and education status significantly affect use of irrigation. Finally, education status significantly affects use of drought tolerances crop varieties to adapt to climate change.

5.2. Recommendations

As per the findings of this study, the following recommendations were forwarded for reducing the impacts of climate change and variability.

- ✓ Improving their educational status, and improving their access to markets. Moreover, encouraging informal social net-works and environmental settings enhance the adaptive capacity of farmers. Educated farmers could be able to easily gathered and interpret important information about climate change and adaptation strategies. It will also use to select appropriate adaptation strategy on their farm land to manage the adverse impact of climate change. Hence, it is important to enhance farmers' level of education.
- ✓ 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.
- ✓ The farmers should be experience to mitigating the adverse effect of climate change by using and capitalize the existing adaptation strategies: use of drought tolerant varieties, intercropping, Agro-forestry, adjusting planting dates, SWC practices, and irrigation.

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APPENDIX

Appendix Table 1.Conversion factor for tropical livestock unit (TLU)

Livestock Type	Conversion Factor
Cow/Ox	1.00
Bull	0.08
Heifer	0.75
Calf	0.20
Hours/Mule	1.1
Sheep/Goat	0.06
Donkey	0.35
Chicken	0.013

Appendix Table 2. Maize yield data Qt/ha

Years	Qt/ha	years	Qt/ha
2000/01	25.02	2006/07	22.7
2001/02	23.2	2007/08	22.8
2002/03	24.5	2008/09	17.6
2003/04	24.7	2009/10	19.5
2004/05	22.4	2010/11	15.2
2005/06	21.3	2011/12	14.5

Appendix Table 3. Minimum, maximum and average temperature 5

Year	Max	min	Mean
1990	13.9	27.8	20.8
1991	14.3	27.7	21.0
1992	13.2	28.7	21.0
1993	13.5	28.0	20.7
1994	13.6	27.1	20.4
1995	13.8	27.6	20.7
1996	14.0	25.6	19.8
1997	13.2	26.2	19.7
1998	14.0	26.4	20.2
1999	14.1	26.2	20.1
2000	12.7	26.7	19.7
2001	14.2	26.6	20.4
2002	13.4	26.1	19.8
2003	12.9	26.9	19.9
2004	13.7	26.7	20.2
2005	13.9	27.9	20.9
2006	13.8	27.2	20.5
2007	13.9	27.1	20.5
2008	14.1	27.5	20.8
2009	13.8	27.6	20.7
2010	13.8	26.0	19.9
2011	14.2	27.6	20.9
2012	14.1	27.6	20.8
2013	14.6	27.8	21.2

2014	15.0	26.3	20.6
2015	14.8	27.6	21.2
2016	13.7	28.8	21.2
2017	14.3	28.6	21.5
2018	14.6	28.0	21.3
2019	14.8	28.8	21.8
2020	15.8	29.9	22.9

Appendix Table 4. Annual and monthly rainfall distribution

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual
1990	1.9	2.1	10.7	19.5	49.4	197.5	354.2	298.3	213.4	32.2	6.6	0.6	1186.4
1991	2.2	1.6	16	33	105.9	124.3	349.2	291.2	280.4	74.8	11.4	4.1	1294.1
1992	2	1.4	7.7	32.6	79.5	131	187.9	231.9	139.2	99.6	34.7	3.8	951.3
1993	1.9	3.5	11.8	49.2	49.1	187.7	221.1	304.4	176.6	99.4	20.7	0.8	1126.2
1994	1.4	1.1	6.4	13.5	114.1	237.1	275.5	320.6	154.7	41.5	15.3	2	1183.2
1995	0.4	2.2	16.3	38.6	98.4	146.4	213.2	292.3	126.7	30.2	3	7.5	975.2
1996	2.6	2.5	23.1	43.5	103.2	212.6	178.4	235.3	145.5	44.7	18.8	2.1	1012.3
1997	1.5	1.1	11.7	36.2	112.3	162.3	262.6	254.6	135.2	65.3	28.2	0	1071
1998	2.6	1.3	11	11.5	98.4	167.3	268.5	264.3	154.3	129.2	4.6	0.2	1113.2
1999	3.3	1.1	3.2	12.4	104.2	172.4	248.5	254.6	153.2	98.6	5.9	2.2	1059.6
2000	0.5	0.3	1.6	53.3	102.4	211.2	263.2	225.3	206.7	60.2	20.3	0.7	1145.7
2001	2.2	1.7	10.5	26.7	98.3	178.8	278.2	287.5	145.3	51.5	29.6	8.5	1118.8
2002	3.1	2.6	5.1	12.4	44.8	179.4	282.4	258.6	135.4	53.1	23.1	5	1005
2003	1.9	11.4	6.3	10.4	56.8	268.2	284.3	283.5	145.3	37.7	34.3	6.3	1146.4
2004	1.8	2	4.2	42.6	10.6	238.3	267.2	264.3	185.5	34.4	17.6	1.6	1070.1
2005	2	6.4	14.7	31.1	115.5	227.3	156.8	258.4	174.8	57.2	12.8	0.5	1057.5

2006	0.6	1	8.6	13.4	100.1	196.1	255.6	262.4	167.2	43.2	10.6	3.8	1062.6
2007	2.7	1.2	18.2	34.6	76.5	163.2	271.7	276.3	154.3	68.1	19.4	1.8	1088
2008	1.9	0.7	4.1	47.5	102.6	126.5	234.2	227.5	124.4	51.9	27	4.8	953.1
2009	28.6	0	35.4	23.7	68.4	112.6	231.6	216.5	122.4	122.5	57.8	1.6	1021.1
2010	4.2	4.3	12.4	35.5	84.2	132.5	223.8	232.5	207.1	96.7	37.4	4.9	1075.5
2011	2.2	0.7	4.8	56.1	135.6	123.6	236.3	225.3	102.4	123.6	39.2	19.6	1069.4
2012	3.1	0	17.4	74.3	104.6	143.1	225.4	223.8	117.6	65.3	34.4	14.4	1023.4
2013	1.6	0.7	4.6	26.9	109.3	136	202.4	213.2	174.3	110.4	10.2	0.7	990.3
2014	2.1	3.7	31.7	55	123.5	123.4	226.2	224.4	133.3	105.1	9.7	5.3	1043.4
2015	0.7	1.1	11.7	16.5	137.6	123.3	199.2	224.5	194.7	67.1	13.8	8	998.2
2016	3	1.1	11.1	24.2	160.5	122.1	168.6	316.8	198.2	83.1	8.8	0.9	1098.4
2017	0.3	2.6	7.4	22.2	176.1	165	189.2	267.8	218.9	79.1	4.4	0.6	1133.6
2018	4.6	2	25.7	9.7	135.3	273	181.6	186.5	206.8	74.7	16.1	3.3	1119.3
2019	0.4	2.7	7.2	22.2	132.4	143.1	242.3	267.3	225.2	84.2	31.8	6.2	1165
2020	2.2	2.6	6.9	26.5	121.4	125.6	297.4	289.3	164.2	56.2	17.1	2.5	1111.9
Mean	2.9	2.2	11.9	30.8	100.4	169.4	241.2	257.4	167.2	72.3	20.1	4.0	1079.7
Max	28.6	11.4	35.4	74.3	176.1	273	354.2	320.6	280.4	129.2	57.8	19.6	1294.1
Min	0.3	0	1.6	9.7	10.6	112.6	156.8	186.5	102.4	30.2	3	0	951.3



Appendix Figure 1 Photo during focus group discussion

Appendix Table 5. Assumption of the model

A. Multicollinearity test for explanatory categorical variable

Corr Sex Martialst Educstatus Creditacess Farm_farmex Acestowetrinf

(Obs=347)

	Sex	Martiast	Educstatus	Creditacess	Farm_farmex	Acestowetrif
Sex	1.000					
Martiast	-0.0273	1.0000				
Educstatus	0.0148	-0.0398	1.0000			
Creditacess	0.0442	-0.0338	0.0100	1.0000		
Farm_farmex	0.0320	-0.0129	0.0989	0.1363	1.0000	
Acestowetrif	-0.0287	0.0386	-0.0456	0.0558	0.0269	1.0000

B. Multicollinearity test for continuous variable

Variable	VIF	1/VIF
livs_stokam	1.02	0.984382
land_sz	1.01	0.986949
dist_markt	1.01	0.990935
Famliysize	1.01	0.991309
Mean VIF	1.01	

Appendix Table 6. Multivariate probit model variable results

```
Iteration 0:   log likelihood = -1127.8967
Iteration 1:   log likelihood = -1118.6398
Iteration 2:   log likelihood = -1118.1012
Iteration 3:   log likelihood = -1118.0985
Iteration 4:   log likelihood = -1118.0985

Multivariate probit (SML, # draws = 5)          Number of obs   =        347
                                                Wald chi2(66)   =      89.13
Log likelihood = -1118.0985                     Prob > chi2     =     0.0305
```

Dependent Variables	Independent variables	Coeff.	Std.Err.	z	P>z	[95%Conf.	Interval]
Drought tolerant crop	age	0.001	0.008	0.150	0.880	-0.014	0.017
	famliysize	0.040	0.052	0.760	0.450	-0.063	0.142
	land_sz	0.007	0.028	0.260	0.797	-0.048	0.063
	dist_markt	-0.000	0.004	-0.040	0.969	-0.009	0.009
	livs_stokam	-0.042	0.046	-0.900	0.369	-0.132	0.049
	Sex	-0.373	0.270	-1.380	0.167	-0.902	0.156
	Martialst	0.196	0.230	0.850	0.394	-0.255	0.647
	Educstatus	0.396	0.205	1.940	0.053	-0.005	0.797
	Creditacess	0.004	0.165	0.020	0.983	-0.319	0.327
	Farm_farmex	-0.043	0.157	-0.270	0.786	-0.350	0.265
	Acestowetrinf	0.019	0.152	0.120	0.901	-0.279	0.316
	_cons	0.255	1.090	0.230	0.815	-1.881	2.392
Adjusting planting dates	age	-0.004	0.008	-0.490	0.622	-0.020	0.012
	famliysize	-0.021	0.055	-0.380	0.706	-0.128	0.087
	land_sz	-0.315	0.153	-2.060	0.039	-0.615	-0.015
	dist_markt	0.001	0.005	0.210	0.830	-0.008	0.010
	livs_stokam	-0.071	0.049	-1.450	0.148	-0.167	0.025
	Sex	-0.010	0.260	-0.040	0.970	-0.519	0.499
	Martialst	-0.315	0.344	-0.920	0.360	-0.989	0.359
	Educstatus	-0.297	0.192	-1.540	0.122	-0.674	0.080
	Creditacess	0.126	0.179	0.700	0.481	-0.224	0.476
	Farm_farmex	0.051	0.166	0.310	0.756	-0.273	0.376
	Acestowetrinf	0.088	0.161	0.550	0.586	-0.228	0.403
	_cons	2.612	1.399	1.870	0.062	-0.130	5.355
Agroforestry practices	age	0.010	0.007	1.360	0.175	-0.004	0.024
	famliysize	0.057	0.049	1.170	0.243	-0.039	0.154
	land_sz	0.025	0.035	0.720	0.474	-0.043	0.094
	dist_markt	0.004	0.004	0.930	0.352	-0.004	0.012
	livs_stokam	-0.034	0.044	-0.780	0.436	-0.121	0.052
	Sex	0.194	0.223	0.870	0.386	-0.244	0.631
	Martialst	-0.194	0.248	-0.780	0.434	-0.680	0.292
	Educstatus	0.047	0.178	0.270	0.0791	-0.302	0.396
	Creditacess	-0.042	0.154	-0.270	0.785	-0.344	0.260
	Farm_farmex	0.009	0.146	0.060	0.0952	-0.278	0.296
	Acestowetrinf	0.097	0.142	0.680	0.496	-0.182	0.375
	_cons	-0.453	1.049	-0.430	0.666	-2.508	1.603
Soil & water	age	0.009	0.007	1.190	0.235	-0.006	0.023
	famliysize	-0.008	0.049	-0.170	0.865	-0.104	0.087
	land_sz	-0.249	0.136	-1.840	0.066	-0.515	0.017
	dist_markt	0.003	0.004	0.750	0.450	-0.005	0.011
	livs_stokam	0.061	0.044	1.380	0.167	-0.026	0.149

conservation	Sex	-0.262	0.234	-1.120	0.262	-0.720	0.196
	Martialst	-0.184	0.245	-0.750	0.452	-0.663	0.296
	Educstatus	0.375	0.183	2.060	0.040	0.017	0.734
	Creditacess	-0.115	0.151	-0.760	0.446	-0.411	0.181
	Farm_farmex	-0.077	0.146	-0.530	0.597	-0.362	0.208
	Acestowetrinf	0.021	0.140	0.150	0.879	-0.254	0.297
	_cons	0.725	1.089	0.670	0.505	-1.410	2.860
	age	-0.002	0.009	-0.180	0.858	-0.019	0.016
Irrigation	famliysize	0.106	0.059	1.800	0.072	-0.010	0.222
	land_sz	0.020	0.039	0.520	0.605	-0.057	0.097
	dist_markt	0.009	0.005	1.810	0.071	-0.001	0.019
	livs_stokam	-0.137	0.051	-2.700	0.007	-0.237	-0.038
	Sex	0.034	0.277	0.120	0.902	-0.508	0.576
	Martialst	0.432	0.227	1.910	0.057	-0.012	0.876
	Educstatus	-0.181	0.205	-0.890	0.376	-0.583	0.220
	Creditacess	0.042	0.187	0.230	0.821	-0.325	0.409
	Farm_farmex	0.120	0.177	0.680	0.499	-0.227	0.466
	Acestowetrinf	-0.204	0.172	-1.190	0.235	-0.541	0.133
	_cons	-0.623	1.104	-0.560	0.573	-2.786	1.540
	age	-0.012	0.008	-1.590	0.112	-0.027	0.003
	famliysize	-0.119	0.051	-2.360	0.018	-0.218	-0.020
	land_sz	-0.030	0.036	-0.830	0.406	-0.099	0.040
	dist_markt	0.014	0.004	3.280	0.001	0.006	0.023
	livs_stokam	0.059	0.045	1.310	0.192	-0.030	0.148
Inter	Sex	0.079	0.238	0.330	0.739	-0.387	0.546
	Martialst	0.694	0.259	2.670	0.007	0.185	1.202
cropping	Educstatus	-0.054	0.181	-0.300	0.764	-0.409	0.300
	Creditacess	-0.235	0.155	-1.510	0.131	-0.539	0.070
	Farm_farmex	-0.050	0.150	-0.330	0.741	-0.343	0.244
	Acestowetrinf	0.305	0.146	2.090	0.037	0.019	0.592
	_cons	-1.289	1.105	-1.170	0.243	-3.454	0.876

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho32 = rho42 = rho52 = rho62 = rho43 = rho53 = rho63 = rho54 = rho64 = rho65 = 0:

chi2 (15) = 18.885 Prob > chi2 = 0.01880

BAHIR DAR UNIVERSITY

SCHOOL OF GRADUATE STUDIES COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCE DEPARTMENT OF NATURAL RESOURCES MANAGEMENT QUESTIONNAIRE

Dear Respondents: My name is Yemikir Ayanaw, a graduate student of Bahir Dar University. I am conducting a research for the partial fulfillment of master degree in Environment and climate change. The main objective of this questionnaire is to understand Alefa Woreda's Farmer's toward climate change, its impact and their adaptation strategies.

N.B

1. The response you give will not have any negative impact on you.

2. No need of writing your name on the questionnaire.

1. Name of Kebele _____village _____

2. Date of interview _____

3. Name of Enumerator _____

4. Household code_____

Part 1 Household Characteristics and Institutional Related Questions

You can ask the researcher any questions if there is an ambiguity and expect to receive Satisfactory answers.

1. Sex 1=male 0 =female

2. Age

3. Marital Status 1= Married 2 =Single 3= Divorced 4= Widowed

4. Educational Status 1= Illiterate 0 = literate

6. Family size _____

7. Do you have your own farm land? If yes, what is the size of your farmland in kada (1 kada =0.25 hectare)

8. What Type of agriculture you are practicing? A. Rain fed B. Irrigated C. Both

9. Do you have access to credit from any sources? A. Yes B. No

If your answer is yes where did you get the credit? _____

10. Do you have extra income other than farming? A. Yes B. No

If yes please specify_____

11. What do you say about the main cause of climate change?

A. Natural factors B. Human factors

C. Human and natural factors

12. If your answer on question number 15 is “Human factors” which of the following are the major causes of climate change?

A. over Cultivation B. Population pressure C. Deforestation D. over cultivation

13. Is there any change in duration of rain? A. A yes B. No

14. If your answer to question number 17 is “Yes” how do you characterize it?

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

B. Comes late and goes late D. Seasonal disturbance

15. Distance of your residence from the nearest market by minutes?

16. Do you get weather information? A Yes B No

Part 2 the major adaptation practice

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

A. Yes B. No

2. Have you employed any of the following climate change impact adaptation strategies in your farm activity in past decades? (Multiple answers are possible).

	Climate change adaptation	Response		If no, please specify the reason why not?
		Yes	No	
1	Drought tolerant crop varieties			
2	Adjusting planting dates			
3	Agro-forestry/Planting trees			
4	use of soil and water conservation practices			
5	Irrigation			
6	Inter cropping practices			

3. Have you observed any change in the length of hot period in your life time? a) Yes b) No

4. Have you observed any change in the amount of rainfall? a) Yes b) No

5. If your response for Q5 is yes, how do you see it? a) Increased b) Decreased

c) Remaining the same

6. Do you observe any impact of climate change on maize production? A. Yes B. No

If your answer for question 6 is yes, what impacts did you observe?

A. Maize's are sometimes failing B. maize's are totally failing C. Production per hectare is decreasing D .different disease occurs on maize

7. How did you judge the trend of crop productivity in your life time?

A. Increased B. Decreased C. No change.

8. What are the determinant factors or barriers that hinder the adaptation of climate change/ variability?

A. Distance from market B. Lack of infrastructure

C. Poor communication with DAs D. Lack of information E. Lack of technical knowledge

F. If any other specify_____

Part 3 for Focus Group Discussion

1. Explain the condition of environment in your locality. Do you feel the pattern of weather is generally changing?

2. What is your observation on the climatic (temperature and rainfall) condition in your area?

3. What are the adaptation strategies employed by farmers to minimize the adverse impact climate change?

4. Do you sow your crops at different times or different places to avert risks of crop loss?

5. Do you switch to short maturing or drought resistance crop varieties instead of long maturing crop verities? If yes, explain the crop types and the planting/ harvesting pattern.

6. What are the main hindrances for use of adaptation options of combating climate change?

7. Do you have sufficient knowledge about adaptation options?

8. Do you receive early warning information on short term variations and/or long-term climate change from any sources?

9. What do you recommend to be done to enhance the fight towards climate change?

Part 4 key informant interview

First of all I would like to thank you to be interested for responding the question!

1. What do you think the causes of climate change?
2. What are the observed indicators of climate change?
3. How do you understand the impacts of climate change on your livelihood?
4. What are the main impacts of variability on the community, on the livestock and the environment? List down
5. Who is responsible to give response to the variability of climate?
6. What are the responsibilities of the peoples?

Thank you very much for your corporation!

BIOGRAPHY

Yemikir Ayanaw was born in January 3, 1996 GC Alefa district central Gondar Zone, Amhara National Regional State of Ethiopia. She attends her primary and secondary education in Dengel ber secondary and preparatory school. She joined Odabultum University, College of Natural Resources Management in 2017GC and obtained a Bachelor's degree in forestry on Jun 2019GC after she graduated a BSc Degree. She employed and served at Odabultum University in the department of forestry as a graduate

assistant until she joined the school of graduate studies at Bahir Dar University in 2021GC College of Agricultural and Environmental Sciences studies in Environment and climate change to pursue her MSc degree.