IMPACT OF CLIMATE CHANGE ON MAIZE (*ZEA MAYS L*) PRODUCTION AND FARMERS' ADAPTATION STRATEGIES IN HAWASSA ZURIA DISTRICT, SIDAMA REGIONAL STATE, ETHIOPIA

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HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

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A THESIS SUBMITTED TO THE FACULTY OF ENVIRONMENT, GENDER AND DEVELOPMENT STUDIES, COLLEGE OF AGRICULTURE, HAWASSA UNIVERSITY

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SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY ADVISORS' APPROVAL SHEET

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This is to certify that the thesis entitled **"Impact of Climate Change on Maize (*Zea Mays L*) Production and Farmers Adaptation Strategies in Hawassa Zuria District, Sidama Regional State, Ethiopia"** Submitted in partial fulfilment of the requirement for the degree of **Master's** with specialization of **Climate Change and Sustainable Agriculture,** the Graduate Program of the **Climate Change and Sustainable Agriculture,** and has been carried out by **Korma Gidessa Id. No GPCCSA/0006/13,** under our supervision. Therefore, we recommended that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by Korma Gidessa have read and evaluated his thesis entitled "**Impact of Climate Change on Maize (*Zea Mays L*) Production and Farmers' Adaptation Strategies in Hawassa Zuria District, Sidama Regional State, Ethiopia**", examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfilment of the requirements for the degree.

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STATEMENT OF AUTHOR

I declare and affirm that this thesis is my work and all sources of materials used for this thesis have been fully acknowledged. This thesis has been submitted in partial fulfilment of the requirements for M.Sc. degree at the Hawassa University college of Agriculture and is deposited at the University Library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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DEDICATION

I dedicated this thesis to my lord Jesus Christ, my mother and my father as well as my sister and my brothers for their support and encouragement.

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ACRONYMS AND ABBREVIATION

ADLI	Agricultural Development Led Industrialization
CSA	Central Statistics Agency
FAO	Food and Agricultural Organization
FGDS	Focus Group Discussions
GDP	Gross Domestic Product
HZDOA	Hawassa Zuria District office of Agriculture
KII	Key Informant Interview
MNL	Multi-Nomial Logistic
MoFED	Ministry of Finance and Economic Development
SSA	Sub-Saharan Africa
UNDP	United Nation Development Program

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Impact of Climate Change on Maize (*Zea Mays L*) Production and Adaptation Strategies of the Farmers' in Hawassa Zuria District, Sidama Regional State, Ethiopia

By: Korma Gidessa

Major advisor: - Zerihun Ganewo (Ass.Prof)

ABSTRACT

Climate change which is one of the challenges facing the world and is increasingly affecting peoples' food security and livelihood specially in developing countries including Ethiopia. This research assessed the impact of climate change on Maize production and adaptation strategies of the farmers in Hawassa Zuria district, Sidama regional state of Ethiopia. The study used multi stage sampling procedure. Purposive and random sampling procedures were used to select study area and respondents respectively. Primary data were collected using key informant interviews, focus group discussions and household surveys. Similarly, secondary data were collected from National Metrology Agency and District agriculture office. Descriptive statistics, correlation, Multinomial logit model, Adaptation Strategy Index and Standardized Precipitation Index were used to analyse the collected data. According to the survey results, about 66.1% of the respondents perceive that, the rainfall amount in the study area is decreasing. However, long-term recorded rainfall data showed that the annual rainfall is increasing by the rate of 3.65 mm annually over the past 30 years. The mean annual rainfall was 968.5mm with 14% of coefficient of variation which is less variable based on degree of variability. Similarly, 85.30% of interviewed farmers said that temperature is in increasing trend, which confirms the results from the analysis of long-term recorded data by National Metrology Agency that indicated the mean average minimum and maximum temperatures are increasing by 0.062 ^oC and 0.028 ^oC per annum respectively. The data obtained from National Metrology Agency and Woreda agriculture office also showed that, the rainfall of the annual and summer (Kremit) season were positive and significantly correlated with Maize production. However, negative relationship was observed between long-term maximum temperature and Maize production. The study had also shown that farmer's adaptation measures include; using improved crop variety and livestock species, use of irrigation, soil and water conservation, change date planting, use agroforestry and income source diversification activities. The marginal effects of Multinomial logit model results also indicated that, the adaptation strategies used by farmers were significantly ($p< 0.05$) influenced by age, family size, farm land size, yearly income, access to extension service, access to credit service and farming experience , whereas; sex, did not have significant impact. Therefore, to increase and sustain farmers Maize productivity under changing climatic conditions; improving the agricultural production policy measures like: developing drought resistant crop varieties, improving farmers' perception of climate information, and promoting farm-level adaptation measures such as the use of new agricultural technologies and adjusting planting date must be strengthened in the study area.

Key words: Climate Change, Adaptation Strategies, Maize, Multinomial logit, and Hawassa Zuria.

CHAPTER ONE: - INTRODUCTION

1.1. Background of Study

Climate change has been and continues to be, the principal source of fluctuations in global food production in countries of the developing world where agricultural production is highly dependent on traditional practices (Oseni and Masarirambi, 2011). The fact that climate has been changing in the past and will continues to change in the future implies the need to understand how farmers perceive climate change and adapt in order to guide strategies for adaptation in the future. Some studies indicated that farmers do perceive on climate change and adapt to reduce its negative impacts. However, there are also other studies which indicated that both the perception and awareness of climate change and taking adaptive measures are influenced by different socio-economic as well as environmental factors (Hassan and Nhemachena, 2008).

Currently, among the scientific communities there are wider communications and concrete facts in regard to climate changes. Such a climate changes and its impact are also expected to exist over the 21st century; which will affect ecosystems and access to natural resources such as: reduce access to drinking water, affect the health of poor people, and pose a real threat to food security in many countries in Africa, Asia, and Latin America (Müller *et al.*, 2009). Similarly, it is also expected to have adverse impacts on socio-economic development of all nations. However, the degree of its impacts will vary across nations depending on different countries situation (Somorin, 2010).

In Africa, where agriculture is considered as the main stay of the national economy, climate change is expected to adversely affect this sector Hans *et al.* (2006). Besides the impacts from abrupt climatic events, there is the possibility of imperceptible changes accumulating until thresholds are crossed that could cause entire thresholds to collapse. This perceived or potential risk is greatest where much of the livelihoods and socio-economic systems depend on natural resources (Limantol *et al.*, 2016).

Ethiopia is a country with a very diverse climate. In general, climate patterns are highly variable and unpredictable. The country also has a history of experiencing climate extremes, such as droughts and floods, increasing temperature, and unreliable rainfall NMA (2007 cited in FDRE MoWR). Rain fed agriculture remains the dominant means of production for the national economy (Cooper, 2008). Although agriculture has such a great role in Ethiopia, it is basically dominated by small-scale farmers engaged in subsistence production.

Cereal crops are particularly important to the country's food security as they are a principal dietary staple for most of the population. They comprises about two-third of the agricultural GDP and one-third of the national GDP and are a source of income for a majority of the people (CSA, 2019).

From the country's total cereal production, Maize shares 82.5% area coverage and more than 27% of its production (CSA, 2014/15). The crop is increasingly grown to the highlands of Ethiopia where it has been a minor crop in the past because of its wider adaptation (Abakemal, 2013). In Ethiopia, the high altitude of sub-humid agro-ecology is estimated to cover 20% of the land devoted to annual maize cultivation. More than 30% of small-scale farmers in this agro-ecology depend on maize production for their livelihoods (Twumasi *et al.*, 2002). However, climate change is expected to adversely affect the productivity of this and other crops in those and other similar areas.

The rural population, for whom agriculture is the primary source of food, direct and/or indirect employment and income, will be most affected due to agriculture's vulnerability to climate changes (IFPRI, 2009). The factors that make up the vulnerability more important is that they have a direct impact upon people's asset status and the options that are open to them in pursuit of beneficial livelihood outcomes (Tao and Wall, 2009).

The capacity to adapt both seasonal and yearly climate variability provides an existing set of experiences and mechanisms that can be built upon to help farmers, communities and governments to prepare for climate change. Adaptation to climate change and variability is widely acknowledged as a vital component of any policy response **(**Bryan *et al.,* 2010). Studies showed that low input farming systems, such as subsistence agriculture in marginal areas is not only unsustainably depleting the natural resource base; it is also demonstrably ineffective at alleviating rural poverty (Milder *et al.,* 2011).

Thus, without adaptation, climate change will push poor rural farmers on a razor's edge of survival, but with adaptation, vulnerability can largely be reduced (FAO, 2008). Understanding the level of farmer's perception to climate change and variability effect currently employed adaptation strategies and is important for policy making. It is instrumental in promoting successful adaptation of the agricultural sector, fighting food insecurity and improving livelihood of smallholder farmers. Accordingly, this study would try to effects of climate change on maize (zea mays L) production and farmers adaptation strategies in Hawassa Zuria District, Sidama region, Ethiopia.

1.2. Statement of the Problem

Climate change have direct impact on agricultural productivity and indirect impact through by pests on crops, reducing water availability and increasing natural resources degradation (IPPC, 2017). It threatens agricultural production through rising temperature and erratic rainfall is a critical problem, which changes in precipitation patterns, dries spells and early cessation of rains during critical for crops (Temesgen *et al.*, 2009).

According to Ababe (2007), the climate of Ethiopia is characterized high variability annually, seasonally and geographically. Especially the amount and seasonal distribution of rain are varying annually and difficult to predict while the temporal distribution of rainfall during the growing season is an important factor influencing crop yield.

According to the Hawassa Zuria District Agriculture and Natural Resource Office (2020), farming patterns are gradually changing and faced with perceived climate change and its negative consequences on the *Maize* productivity in the district. 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. Additionally, due to the lack of information and knowledge of farmers about change 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 change are vital to improve productivity and environmental condition.

In Hawassa zuria district, the systematic assessment and documentation of adaptation strategies on climate change 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 perception on climate and crop variability had not been well studied in previous research undertakings. To fill this information gap, the researcher was interested to assess the impacts of climate change on the *Maize* production and their adaptation strategies of farmers used in Hawassa zuria district. Taking in to account the severity of climate related problems in the study area, this study was conducted with overall objective of assessing the impacts of climate change on *Maize* production among smallholder farmer's and their adaptation strategies in Hawassa zuria district.

1.3. Objectives of the Study

1.3.1. General objective of the study

The overall objective of this study was to investigate effects of climate change on maize (*Zea mays L*) production and farmer's adaptation strategies in Hawassa zuria district

1.3.2. Specific objectives of the study

The specific objectives are:

- To assess long term climate trends specially rainfall and temperature in the study area
- To identify the effects of climate change on Maize production
- To identify climate change adaptation strategies used by the farming community and major factor that influenced households' adaptation strategies in the study area.

1.4. Research Questions

1. What are the major climatic elements (rainfall and temperature) trends in the study area?
2. What were climate changes induced effects on Maize production? And
3. What were climate change adaptation strategies applied and the major factors that influenced households adaptation strategies to climate change in the study area

1.5. Delimitation (Scope) of the Study

The study has focused to investigate effects of climate change on maize (*Zea mays L*) production and farmer's adaptation strategies in Hawassa zuria District. In order to meet this objective it is delimited by geographical, conceptual and methodological scope and discussed these scopes as follows.

1.5.1. Geographical scope

Even districts in Sidama region have reached 34, this study focus only on the Hawassa Ziria district. Therefore, the geographical scope of the study will be Hawassa Ziria district and sampled rural kebele administration such as Jara dado, Jara galalicha, Labu koromo and Udo wotate.

1.5.2. Conceptual scope

The conceptual scope of the research is the effects of climate change on maize (*Zea mays L*) production and farmer's adaptation strategies. As result the independent variables to be studied includes; Age of the households, gender of the household, marital status of the households, education level of the households, family size of the households, farm land size of the households, annual income of the households, access to agricultural extension and access to credit services. Whereas, dependent variables of the study includes; using improved crop variety and livestock species, use of soil and water conservation structures, agroforestry, changing planting date and income source diversification.

1.5.3. Methodological scope

To examine the effects of climate change on maize (*Zea mays L*) production and farmer's adaptation strategies, the study use both qualitative and quantitative data and also to analyze this data the study employed explanatory research design. To examine the effects and relationships between the dependent and independent variable the study used Multinomial Logit model with using SPSS 22.

1.6. Limitation of the Study

It is obvious that research work cannot totally free from limitations. Thus, some limitations were observed in this study. The major limitation of this study was the inclusion of only six climate change adaptation strategies in the model and the sample size was also not large because of financial and time constraint. During the course of field surveying, some households could not really provide accurate answers to the questions while some others lack patience and were not willing to spend their time to respond the questionnaire and participate in FGDs. Shortage of adequate secondary data particularly, reluctance of some concerned government officials in providing the available data needed and absence of well-organized metrological data at the nearby to the study area. In spite of these shortcomings, however, it was attempted to make the study as complete as possible by further gathering adequate gridded data from National Metrological Services Agency.

1.7. Significance of the Study

This study will be conduct on the basis of samples households in Hawassa Zuria district, and can be applicable to the adjacent districts, and expanded to other districts of similar agro ecological conditions that are under the impact of climate change and play decisive roles on farmers livelihood and adaptation strategies. The study will also help to understand the impact of climate change on vulnerability of the rural farming communities and provide opportunities for effective policy responses. Similarly, it intends to make some contribution for the on-going effort of combating the recurrent food insecurity problem due to drought, crop failure and other related issues in the district.

1.8. Organization of the study

This study was contained five chapters. The introductory part deals with background, statement of the problem, research questions, objective of the study, significance of the study, scope and limitation of the study. The second chapter contains a brief review of related literature regarding the issue of climate change effect on *Maize* production and adaptation strategies. The third chapter deals with research methodology. The fourth chapter discusses the results, data presentation and analysis of the study under different sections. Finally, the last chapter presents conclusion and recommendation.

CHAPTER TWO: - LITRATURE REVIEW

2.1. Theoretical Review

2.1.1. Definition and concepts of key terminologies

Climate change: Climate is the long-term average of the weather in a given place. While the weather can change in minutes or hours, a change in climate is something that develops over longer periods or decades to centuries, regardless of its causes (Hulme, 2016). It is caused by factors such as biotic processes, variations in solar radiation received by earth, plate tectonics, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as "global warming" (Smith, 2013). Thus, its projected consequences include the warming of the earth's global mean surface temperature, leading to changes in precipitation patterns, shifts in vegetation cover, rising sea levels and increased frequency of some extreme weather events (Seneviratne *et al.*, 2012). Also climate change is very likely to increase the frequency and magnitude of extreme weather events such as droughts, floods and storms (Woodruff *et al*., 2013).

Livelihood: it comprises the capabilities, assets, and activities required for a means of living. It is deemed sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities, assets, and activities both now and in the future, while not undermining the natural resource base (Serrat, 2017).

Vulnerability: is characterized as insecurity in the well-being of individuals, households, and communities in the face of changes in their external environment (Serrat, 2017). Vulnerability to food insecurity is a forward looking concept related to people's proneness to future acute loss in their capability to acquire food. The degree of vulnerability depends on the characteristics of the risk and a household's ability to respond to risk (Heltberg, 2009).

Adaptation: is about tackling the effects of climate change, mainly through increasing the resilience and capacity to cope with its physical impacts (Prowse and Scott, 2008). It has been also defined as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001). Adaptation to climate change includes all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system. Adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation of change in conditions (Lelonkiewicz and Gambi, 2017).

2.1.2. Role of agriculture in development and food security

A majority of sub-Saharan Africa's population, 62.6%, live in rural areas where poverty and deprivation are the most severe (FAOSTAT, 2012). Of these, more than 70% of the poor depend on agriculture as their sole means of livelihood and depend directly or indirectly on agriculture, and given the sector's large contribution to the overall economy (IFAD, 2012). Thus, it might seem obvious that agriculture should be a key sector for development in these regions. Improving agricultural productivity, while conserving and enhancing natural resources is an essential requirement for farmers to increase global food supplies on a sustainable basis (Holden *et al*., 2017). The role of smallholder farmers and their families in increasing agricultural productivity growth sustainably will be crucial. Half a billion small family farms produce most of the food consumed in developing countries and farm over 80% of the land in countries like Asia and Africa. The success of developing countries in increasing agricultural productivity will have global implications in strengthening the resilience of food markets, enhancing food security, improving well-being and promoting sustainability (FAO, 2012).

The development of the agricultural sector and the improvement of the food security situation are seen as essential components to sustainable development in Africa (Godfray *et al.*, 2010). However, continuing population growth, impacts of climate change and environmental degradation add to an unprecedented combination of pressures that threaten existing efforts and solutions. Therefore, there is an urgent need to avert the current food security situation in Africa (FAO, 2012). Some of the strategies include adaptation to climate change, using better technology or expanding cultivated land or compensate through increasing food imports. This solution would target the use of plants that can adapt to new climate conditions and the adjustment of agricultural methods, such as the timing of sowing and the use of organic agricultural practices. Additionally, agro-forestry has the potential to mitigate the effects of climate change.

2.1.3. Maize production in Ethiopia

Maize is a strategic food crop grown in 13 agro-ecological zones covering 90% of Ethiopia cultivated land. In one year, smallholder farmers produce over 95% and maize constitutes more than 60% of the caloric intake of a typical household food's (2012). This indicates the clear signs of the crop in the livelihood of most Ethiopians smallholder farmers. Nevertheless, despite its prominence, its productivity is still at a low profile, the national maize yield average is of 3.6 t/ha this is far below the world's average which is about 5.66 t/ha FAO (2017). This low productivity is attributed to several factors amongst which frequent droughts, declining soil fertility, poor agronomic practices, limited use of inputs, insufficient access to technology, lack of credit facilities, poor seed quality, incidence of diseases, pests and weeds. Also, changes in soil moisture, increases in temperature and shifts in patterns of plant diseases and pests could lead to decreases in agriculture productivity.

2.1.4. Climatic requirement of maize *(Zea Mays.L)*

Maize production has many climates and weather constraints. The crop is very sensitive to moisture stress at emergence, flowering and grain feeling stages. Hence, to avoid coincidences of moisture stress at these critical stages need a thorough analysis of most important climatic parameters such as onset, cessation, total amount and distribution of rainfall, the probability of the prevalence of the prolonged dry spell and total length of growing period are among many very crucial climatic elements that influence production and should be considered to reduce risk. Maize yields will reduce as a result of climate change in the semi-arid areas of Ethiopia by 2080s up to 46%, but could result an increase up to 59% result in sub-humid and humid areas (Camberlin, P. and Okoola, R. E 2003).

Temperature: Maize is a warm weather crop and is not grown in areas where the mean daily temperature is less than 19 ºC or where the mean of the summer months is less than 23 ºC. Although the minimum temperature for germination is 10 ºC, germination was being faster and less variable at soil temperatures of 16 to 18 ºC. At 20 ºC, maize should emerge within five to six days. The critical temperature detrimentally affecting yield is approximately 32 ºC. Frost can damage maize at all growth stages and a frost-free period of 120 to 140 days is required to prevent damage. While the growth point is below the soil surface, new leaves were from and frost damage was not being too serious. Leaves of mature plants are easily damaged by frost and grain filling can be adversely affected (Plessis, 2003 and Young, 2012).

Rainfall: Maize (corn) requires considerable amount of moisture 500-750 mm of well distributed rain is conducive to proper growth; expends water economically and relatively drought-resisting crop; after germination and up to tasseling stage crop stands less moisture; requires more moisture during the reproductive period; requires less moisture when developing towards maturity (Kumar, 2012). Approximately 10 to 16 kg of grain are produced for every millimetre of water used. A yield of 3152 kg/ha requires between 350 and 450 mm of rain per year. At maturity, each plant was using 250 litters of water in the absence of moisture stress Plessis (2003).

Agricultural development needs timely and adequate supplies of essential farm inputs. However, the investment capacity of majority of Ethiopian farmers is low, the poor farm household cannot afford to meet increased demand for the purchase of improved seeds, recommended quantity of fertilizer and buying or hiring of farm machinery (Quisumbing *et al*., 2010), thus, lack of finance is one of the main reasons for low productivity in our agriculture. A number of studies show that farmers' yields of various crops were higher when they get an access of credit to by agricultural inputs (Olomola and Gyimah-Brempong, 2014).

On the other hands, Ethiopian agriculture is characterized by the use of inadequate production technologies which results in fluctuations in crop yields, uncertainties, and food insecurities due to climatic variability (Shiferaw *et al*., 2014). In addition to the above, access and availability to improved production technologies including seed, fertilizers, mechanization and markets are limited. The Ethiopian Central Statistical Agency (CSA, 2009) indicates that, from a total cultivable area of 12.8 million ha, only about 8 million ha is under cereal crops. The improved seeds are used in less than 3% of the total cultivated area. Therefore, it is widely argued that, achieving agricultural productivity growth will not be possible without developing and disseminating improved agricultural technologies that can increase productivity to smallholder agriculture farm (Asfaw*et al.*, 2012).

2.1.5. Impact of climate change on agriculture in Ethiopia

Agriculture is highly dependent on climatic conditions, and being one of the most sensitive activities to the negative effects of climate change i.e. its performance depends directly on climate variability (Olesen *et al.*, 2002). The effect of climate change is considered to be a global phenomenon; however, its impacts are more widely felt in the developing countries, due to their greater vulnerabilities and lesser ability to mitigate the effects of climate change. Because most developing nations including Ethiopia are agriculture-based economies, their agricultural sector is affected mostly due to its direct exposure to nature. Therefore, the major impact of climate change on agricultural production is due to changes in rainfall duration and pattern, temperature, floods, droughts, and negative effects on water and land resources.

The occurrence of droughts and floods, have a negative impact both on the plants and the soil. The frequent droughts that have been observed over the past decades reduce soil moisture and water resources for plants, thus resulting in severe water stress adaptation to climate change (Gan, 2000). Reduced soil moisture decreases available water for irrigation and hinder plant growth in non-irrigated plants (Aydinalp and Cresser, 2008). Water stress also reported to affects plant growth, productivity, caused an increase in the concentration of soluble sugar and proline content in the leaves of legume (Nazarli *et al*., 2011). Furthermore, it reduces soil fertility by reducing the organic component of the soil as the amount of crop residues is reduced (Pareek, 2017). This tends to increase the costs of farming as households need to apply fertilizer to avoid reduction of crop yields. Floods affect crop production through water logging and soil erosion, where such conditions interfere with soil fertility and therefore reduce crop yields.

On the other hands, extremely high and low distribution and intensity of rain fall during crop growth periods may results in total crop failure even if the crop has been performing well during the early stages of development. Rainfall intensity has changed in such a way that the total rainfall received does not balance the water demand for most crops (Knapp, 2008). Similarly long dry periods have been observed during the planting season as a result of changed rainfall intensity which affect plant growth and eventually crop yield.

Furthermore, the temperature has great impacts on climate change (Henson, 2011). For instance, higher temperatures during the germination stage of above 35°C cause seedling death while saturated soils with temperatures of about 32°C increase the risk of seedling diseases. Temperatures above 30°C for more than eight hours can reverse verbalizations in wheat. At the reproductive stage, air temperatures ranging from 35°C to 36°C or higher can cause maize pollen to lose its viability, affecting post-blooming in soybean, result in groundnuts producing less yield and rice pollen becoming sterile after only an hour of 35°C. Soil temperatures higher than 20°C depress potato bulking while moisture deficit is very detrimental to crop yields in this growth stage, especially for maize.

2.1.6. Adaptation Strategies for the Changing Climate

The terms “coping” and “adaptation” are often used interchangeably to reflect strategies for adjustments to changing climatic and environmental conditions (Jones, 2010). Responding to a changing climate exploring how disaster risks reduction, social protection and livelihoods approaches promote features of adaptive capacity). However, the two are associated with different time scales and represent different processes (Eriksen and Kelly, 2007). Coping is a short term reactive response to climate variability. Whereas, adaptation is associated with longer time scales and points at adjustments as fundamental changes of the systems practices, processes or structures to changes in mean conditions. Nonetheless, coping strategies may become adaptive strategies when people are forced to use them over a run of bad years and across seasons rather than just at the worst time of the year. Besides, the way households cope with crises either may enhance or constrain the future coping strategies, as well as their possibilities to adapt in the longer term (Smit and Wandel, 2006).

Adaptation strategies to climate change can be grouped into autonomous or private and planned or public sector adaptation strategies (Smit and Pilifosova, 2003). Private adaptation strategies involve action taken by non-state agencies such as farmers, communities or organizations and or firms in response to climate change (Smit and Pilifosova, 2003). According to Crane (2011), adaptation strategies include switching crops, shifting crop calendar, engaging new management practices for a specific climate regime, changing irrigation system and selecting different cropping technologies. Public adaptation involves actions taken by local, regional and or national government to provide infrastructure and institutions to reduce the negative impact of climate change. Public adaptation strategies include development of new irrigation infrastructure, transport or storage infrastructure, land use arrangements and property rights, water shed management institutions (World Bank, 2010).

According to Bruin (2011) adaptation strategies can be either proactive or anticipatory depending whether it takes place before or after climate change. Reactive adaptation strategies addresses effects of climate change after they have been experienced, while proactive adaptation strategies are engaged in anticipation of climate change. In crop production**,** reactive adaptation strategies include control of soil erosion, construction of irrigation dams, improving soil fertility, development of new varieties, shifting planting and harvesting time. Anticipatory adaptation strategies on the other hand involve the development of tolerant cultivars, research development, policy measures on taxation and incentives. Gbetibouo (2009) suggested that smallholder farmers can adapt to climate change by changing planting dates and diversifying crops. This can be possible if government provides them with the necessary support. Smallholder farmers can also adapt to climate change by practicing soil and water conservation measures and planting trees (Yesuf *et al.*, 2008).

In Ethiopia traditional and contemporary coping mechanisms to climate variability and extremes at different level includes changes in cropping and planting practices, reduction of consumption levels, collection of wild foods, use of inter-household transfers and loans, increased petty commodity production, temporary and permanent migration in search of employment, grain storage, sale of assets such as livestock and agricultural tools, mortgaging of land, credit from merchants and money lenders, use of early warning system, food appeal or aid (NAPA, 2007).

The study conducted by Mengistu, (2011) revealed that the existence of common as well as different coping mechanisms for male and female respondents. Male respondents rated credit and migration as effective coping strategies while female respondents preferred petty work and daily meal reduction. However, female respondents argued that credit, food for work and migration are not the right type of coping strategies even though they are preference of male respondents. The difference in preference of the strategies by the two categories of respondents indicates variation in level of satisfaction even though both use the strategy to escape the hazard. The level of satisfaction varies for different coping strategies. Male respondents are 100% satisfied with credit as a coping strategy while female respondents get full satisfaction from daily meal intake reduction. Level of satisfaction gained (50%) from labor and livestock selling is equal for both male and female respondents (Mengistu, 2011).

2.2. Empirical study

2.2.1. Impact of climate change on crop production

Climate variability can affect agricultural production in a variety of ways. Temperature and precipitation patterns, extreme climate conditions, surface water runoff, soil moisture and CO2 concentration are some of the variables which can considerably affect agricultural development (IPCC, 2007; Zhai and Zhuang, 2009). However, Ethiopian agriculture is heavily dependent on rainfall with irrigation agriculture accounting for less than 1% of the country's total cultivated land. Thus, the amount and temporal distribution of rainfall and other climatic factors during the growing season are critical to crop yields and can induce food shortages and famine (CSA, 2008). During drought and delay in the onset of rain land becomes dry and difficult to plough, forage deficit leads to weakness and oxen mortality and lack of precipitation hinders seed cultivation and germination of cultivated seeds. Even weeks delay in the onset of rain was found to have significant difference on the harvest and has deprivation of households‟ livelihood (Abate, 2009).

2.2.2. Impact of climate change on maize productivity

The world is experiencing rising demand for crops such as maize. It has been estimated that; global agricultural production may needed to increase by 60 percent or more by 2050 (World Bank, 2010). The IPCC projections suggest a particularly high demand for maize over other cereal crops. To meet this increasing demand will require around a 2.4 percent per year increase in yield. However, based on current performance, estimates suggest annual global yield increases for maize as low as 1.6 percent, well below the rate required. This average also conceals significant variations between regions. Whilst maize yield increases in Asia are generally high, in South America they vary between 1.7 and 4 percent (IFRPI, 2013). Variations in maize yield increases are most dramatic in Africa where some countries are facing decreases in annual yields of over 7 percent. Currently yields in SSA can be as low as 1.5 tons per hectare, a fifth of what achieved by leading maize producers. A recent foresight report suggests a gap between potential and actual maize yields of over 60 percent for SSA (EC, 2008). Therefore, a need to improve yields by making agriculture more efficient, profitable and sustainable, particularly for smallholders in SSA, which combine a high reliance on maize for food with low levels of production and vulnerable agricultural system (NAAS, 2013).

According to Kim et al. (2007), leaves of maize grown at 23 °C photosynthesized faster than the leaves of maize grown at 13 °C and 28 °C so that most maize cultivation in developing world is dependent on temperature. This makes crop particularly vulnerable to drought, heat and pests. Current estimates suggest that 25 percent of maize production affected, and threaten by frequent drought (FAO, 2010). It is widely accepted that these stresses would be more serious because of climate change, resulting in a potential loss of up to 10 percent in maize production in Africa by 2055 (IFRPI, 2009). The lack of access to improved varieties and good quality seed, limited access to often-expensive fertilizers or low fertilizer rates, decreasing size of farms and pesticides, poor dissemination of good agricultural strategies, need for affordable, small-scale mechanization to replace manual labor and significant post-harvest losses due to poor storage, pest attack and spoilage affects smallholders (NAAS, 2013). The other important thing in area is the presence of opportunity for better agricultural production. One of such opportunities is current better emphasis of government to Climate-Resilient Green Economy Strategy (Ayelach, 2015).

This strategy gives emphasis to more agricultural production through environmentally and friendly techniques and wise use of natural resources. As a result, currently one can observe larger public movement to protect environment through reforestation, soil protection, rehabilitation of water bodies, and integrated watershed management.

2.3. Conceptual Framework

The study uses the following framework to conceptualize and understand climate change and variability impact on Maize production in the study area. Figure 1 below show that, the household maize was affected by different factors. According to their nature, these variables are categorized under three categories. The demographic and socio-economic characteristics of the household include age, sex, and educational level of the household head, family labor and dependency ratio. Institutional factors category includes access to credit, health status, market distance, and contact with development agent and food aid. Socio-economic factors involves, farm size, livestock size and non-farm income activity

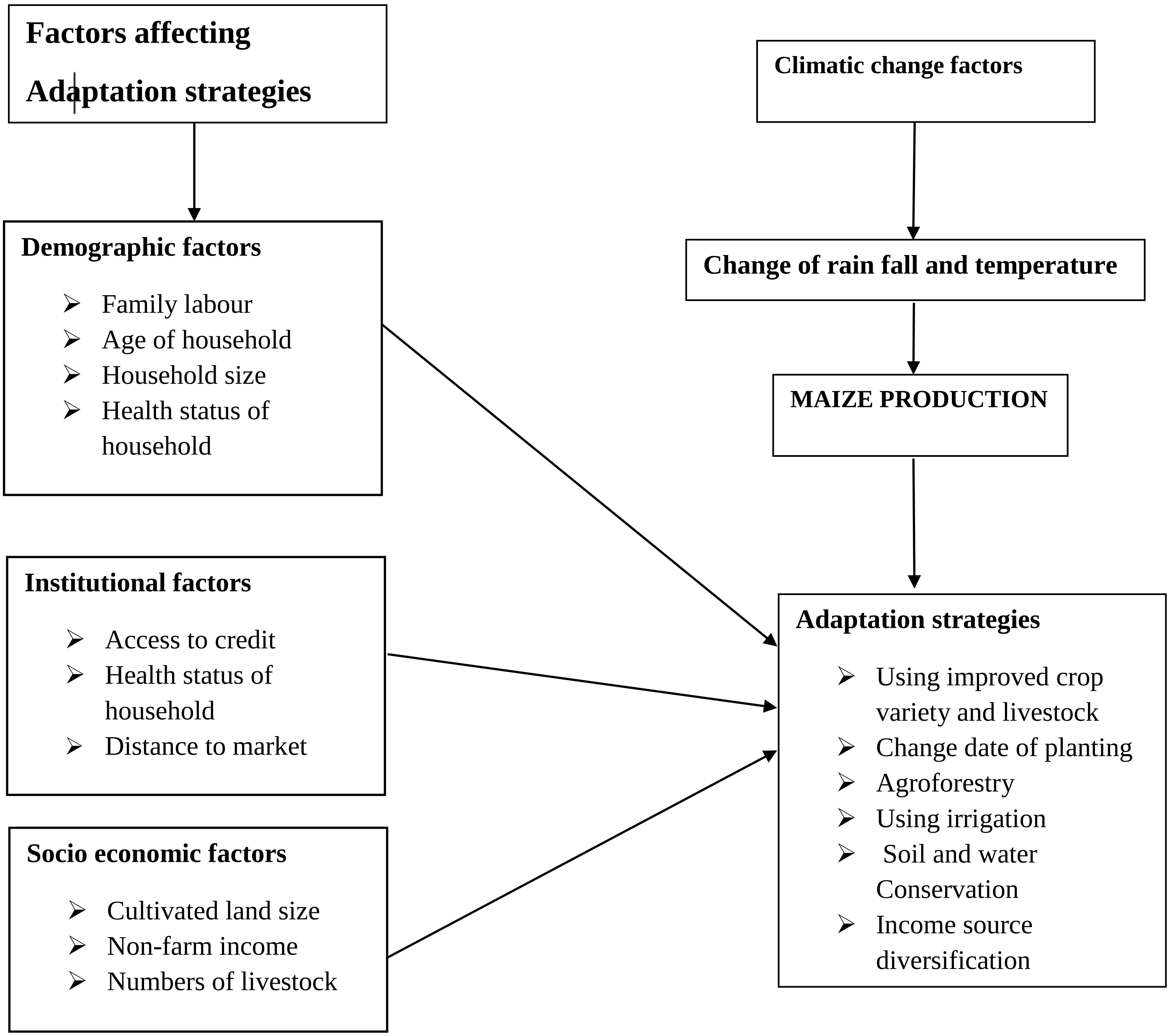

Figure1**:** Conceptual framework of the study

Source: Modified after (Korma, 2023, Timotiwos M., 2022) and review of different literature

CHAPTER THREE: - RESEARCH METHODOLOGY

3.1. Description of the Study Area

This study was conducted at Hawassa Zuria district in Sidama Regional State of Ethiopia. It is one of the 36 districts of Sidama regional state. It is located at an altitude ranging from 1700 to 1850 m above sea level and roughly lies between 6^0 83 'to $7^0$17'N and $38^0$24'to $38^0$72 E.The Hawassa Zuria district shares boundaries with the Oromia region to the North and West, Lake Hawassa to the East and Boricha district to the South. Hawassa Zuria district is located 290Km south of Addis Ababa. The District town, Dore-Bafano is located approximately 20 km west of Hawassa, the capital of Sidama National Regional State. Hawassa Zuria district has 23Kebele administrations (HZDOA 2021).

The district has a total population of 124,472, composed of which 62,774 are male and 61,698 female. The annual mean maximum and minimum temperatures are 27 °C and 12 °C respectively, and the mean annual rainfall is 1015 mm. In terms of traditional agro-ecology classification, categorized under Dry Woina-Dega (Sub-humid weather) and the area is characterized by bimodal rainfall pattern, i.e. belg (small rainy season that extends from March to May) and kiremt (main rainy season, extends from June to the end of September) (HZDOA 2021).

The size of the district is 22,643 ha. Lake Hawassa is the main water resource for fishing and vegetable production. Agriculture in the study area largely depends on rain-fed and crop-

Livestock mixed farming systems are commonly practiced. Maize, Haricot bean and Enset are the main staple crops mainly grown for multipurpose uses such as for food, animal feed, to construct traditional houses (HZDOA, 2022).

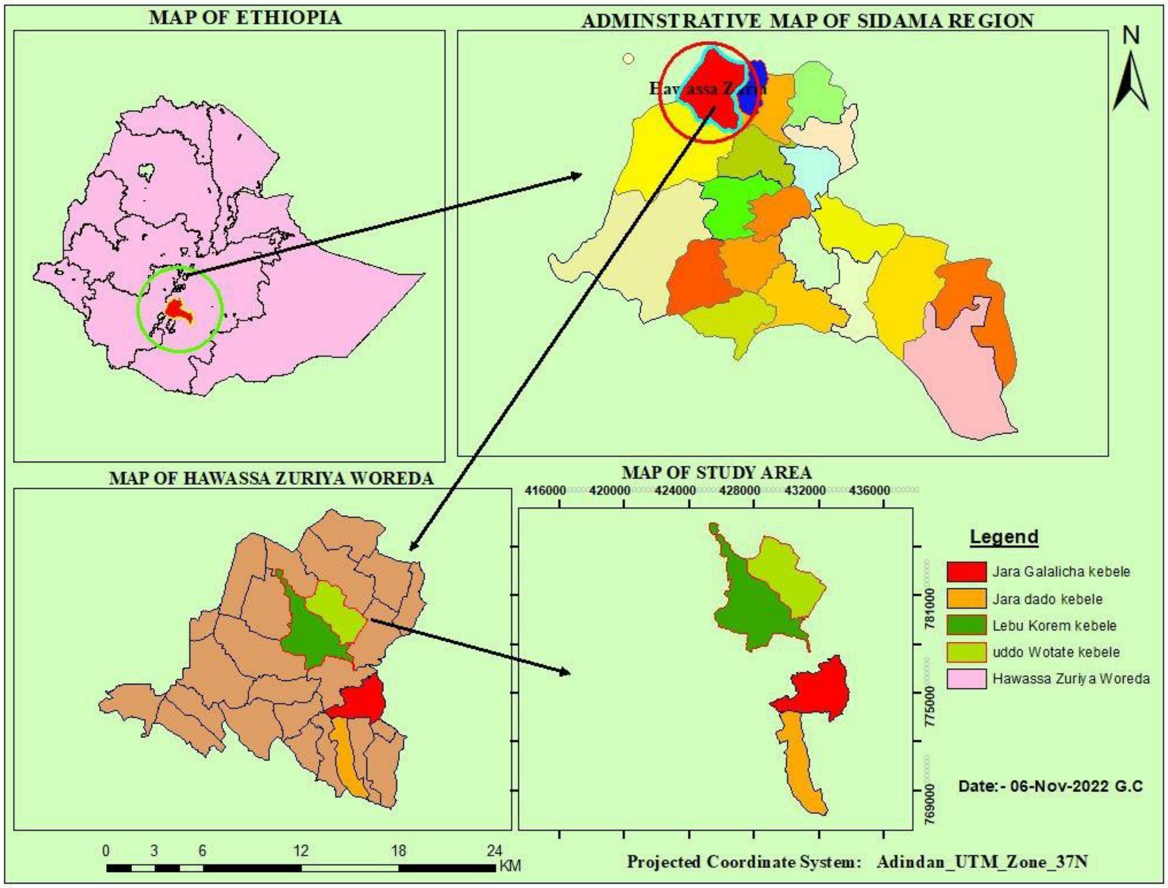

Figure 2**:** Location Map of the study area

Source Arc GIS, 2023

3.2. Research Design

The study used a cross-sectional survey design with both qualitative and quantitative approaches. In this research, mixed methods were used because it helps to have better understanding of the situation in the villages than what could have been made with the use of only one method. In cross sectional survey design, information on all variables was collected at specific point in time, and association between explanatory variables and response variables was done.

3.3. Sampling Techniques and Sample Size Determination

3.3.1. Sampling techniques

The study used a multi stage sampling procedure. First, Hawassa Zuria woreda was purposely selected since; it is one of the Maize production areas and susceptible to problems related to climate change in the Sidama Region (NMA, 2018 and WARO, 2020). Second, due to its potential for maize production and experience with farmers' tribulations with climate concerns, From the 23 *Maize* producing kebeles of the district, four *kebeles* (Jara Dado, Jara Galalcha, Labu Koromo and Udo Wotate) were purposively selected. Households were selected randomly from the four *kebeles* for survey data collection.

3.3.2. Sample size determination

Simplified formula provided by Yamane (1967) was used to determine the required sample size at 93% confidence level and 7% level of precision as shown below

$$\mathbf{n} = \frac{\mathrm{N}}{1 + \mathrm{N}(\mathrm{e})^2} = \frac{2492}{1 + 2492(0.07)^2} = 188$$

Where,

n is the number of sample size,

N is the total number of households in study kebeles and

e- is the level of precision

Table1: Distribution of Sample household in each kebeles

Name of Maize production kebeles	Total number of HHs	Number of Sample households
1. Jara- Dado	761	57
2. Jara- Galalcha	486	37
3. Labu- Koromo	615	46
4. Udo - Wotate	630	48
Total	**2492**	**188**

3.4. Data type and Source

3.4.1. Data types

The study used both primary and secondary data comprising of qualitative and quantitative variables.

3.3.2. Data Sources

Primary and secondary data sources were used to collect data for this study. Primary data were acquired through a structured questionnaires survey, key informant interviews, focus group discussions (FGD), and field observations. Secondary data were obtained from the National Meteorological Agency (NMA) of Ethiopia, various published research papers and reports, documents in agricultural offices of the district.

3.5. Methods of Data Collection

3.5.1. Primary data collection methods

The primary data were collected through various way including:-

i. Household questionnaire survey

The main primary data source for this study was the preparation of a questionnaire for the household respondents. For the four rural *kebeles*, structured open-ended and closed-ended questionnaires were constructed to acquire information on climate change, particularly the impact of rainfall and temperature change on maize production and adaptation methods. The questionnaires were intended to collect data on the household head's socioeconomic characteristics, the area of land and agricultural production, the farming system, and other related topics such as climate change and adaptation strategies. Before conducting survey, the data enumerators are trained and questionnaires were written in the local language to make it easier to converse, comprehend, and ask and respond to the enumerators.

ii. Focus Group Discussions

Focus group discussions were organized at community level with a group of small holder farmers between 5-8 with 18 years and above (man and woman) randomly selected to discuss on the existing and persistent impacts of climate change and variability on *Maize* production and actual adaptation measures used as response to the impacts of extreme weather events. With the help of village leaders, a sample of farmers able to answer the questions listed in the FGDs check list were identified. These FGDs included both men and women as well as aged and young farmers. During the field survey 21 FGDs were conducted 7 of each selected 3 *kebeles* for the study.

Figure 3 Focus Group Discussions During Survey, 2022

Source: photo by Desaleng Mustafa in study area, 2023

iii. Key informant interview

Key informant interview as one of the data collection methods was carried out with experienced experts from the district's agricultural office and development agent (DA). For each selected kebele a group of people consisting of four elders, three religious leaders, and one development agents was formed. This enabled extraction of sufficient information on climate change and variability in maize production and adaptation strategies of the farmers in the study area.

3.5.2 Secondary data collection methods

Long-term observed daily rainfall (mm) and temperature of maximum and minimum (0C) for time series of (1989-2019) was obtained from (NMA), Hawassa. The secondary data of maize yield and harvested area data were obtained from the Agricultural office of Hawassa Zuria district.

3.6. Methods of data analysis

Household level data were entered and compiled in one file comprising all sections of the questionnaire after which data cleaning was followed to ensure the removal of all mistakes and errors in order to have a clear data set ready to be used in the analysis. The cleaned data set were then exported first to Microsoft Excel and to the SPSS version 22 to come up with graphs and tables indicating the results to discuss on.

3.6.1. Descriptive statistic

Descriptive statistics such as mean, frequency and percentage were used to characterize demographic and socio-economic profile of the farmers, farmer perceptions on changes in long-term temperature and rainfall changes as well as various adaptation measures being used by farmers, and the main challenges which prevent the practicing of adaptation strategies. SPSS version 22 and Microsoft-excel were used for the analysis of quantitative data. The temperature and rainfall trends were, compared with the *Maize* data and the respondents‟ perception of climate change trends and its effect''. Data which were obtained from key informant and FGDs were analyzed using narration.

3.6.2. Standardized precipitation index (SPI)

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

$$SPI = \frac{Xi - \bar{X}}{\sigma} \text{...} 7$$

Where;

SPI refers to rainfall anomaly (irregularity) on multiple time scales;

xi is the annual rainfall in the year t;

x^{-} is the long-term mean rainfall; and

is the standard deviation over the period of observation.

Hence, the drought severity classes are: extremely dry (SPI < -2); moderately dry (-1 > SPI >-1); severe drought (-2 > SPI > 1.5); near normal -1 < SPI> 1; moderately wet (1 < SPI >1.5); very wet (1.5 <SPI <2) and extremely wet (SPI >2) (Woldeamlak, 2009).

3.6.3. Coefficient of variation (CV)

The impact of climate change on variables such as rainfall and temperature was studied using descriptive statistical approaches such as coefficient of variation (CV), standard deviation (SD), mean, and median. The coefficient of variation computed as the following formula:

$$CV= \frac{SD}{\bar{X}} * 100 \text{..} 8$$

Where, CV is Coefficient of Variation, SD is Standard Deviation and $\bar{X}$ is mean

According to (Abate, 2009) CV % values are classified as follows:

- <20% as less variable,
- 20-30% as moderately variable and
- >30% as highly variable.

3.6.4. Adaptation Strategy Index (ASI)

To identify those adaptive strategies which held relative importance over others an adaptation index procedure was implemented, as measured by the formula presented below (6). Farmers were asked to assess different adaptation strategies by using the same four-point rating scale described in Section 2 to rate the importance of each strategy to their agricultural enterprises. The relative importance of adaptation strategies to climate change was calculated based on the following index formula (Uddin, and Takeya, 2005)

$$ASI = ASn \times 0 + ASl \times 1 + ASm \times 2 + ASh \times 3 \quad (6)$$

Where,

ASI = Adaptation Strategy Index

AS*n* = Frequency of farmers rating adaptation strategy as having no importance

ASl = Frequency of farmers rating adaptation strategy as having low importance

AS*m* = Frequency of farmers rating adaptation strategy as having moderate importance

AS*h* = Frequency of farmers rating adaptation strategy as having high importance

3.6.5. Correlation analyses

Correlation coefficient analyses have been performed to determine the climate elements and yield of *Maize* relationship using STATA 14.1. The correlation coefficient was used to measure the strength of the association between *Maize* yield and climatic variables. The range of correlation coefficients is -1 to +1. The complete dependency between two variables is expressed by either -1 or +1, and 0 represents the complete independency of the variables. The calculation of the correlation coefficient is performed using equation (13), in which x represents the independent variable and y represents the dependent variable.

$$r = \frac{\sum(x-x)(y-y)}{\sqrt{\sum(x-x)^2}\,(y-y)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 13$$

3.6.6. Multinomial Logit Models (MNL)

Multinomial Logit Models (MNL) was used to identify the major factors determining adaptation strategies to climate change and variability. The MNL model was used by many researchers to model climate change adaptation strategies of smallholder farmers (Temesgen *et al.,* 2010). Therefore, the multinomial legit model is appropriate to model of climate change adaptation strategies of smallholder farmers in the study area. The choice of a given adaptation option is discrete because it is chosen among other alternative option. Let P_{ij} represent the probability of choice of any given adaptation option by small farm households, then equation representing this will be,

$$P\,(i\,j) = \beta o + \beta 1X1 + \beta kXk + e \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where *i* takes values (0, 1, 2, 3, 4, 5, 6), each representing the choice of adaptation option (no adaptation =0, using mixed crop livestock system =1, use improved crops variety=2, use of irrigation =3, soil and water conservation=4, adjusting planting date=5, and diversifying income sources =6). X1 are factors affecting choice of an adaptation option, β are parameters to be estimated and e is randomized error. With j alternative choices, the probability of choosing adaptation option j is given by,

$$P(yi = j) = \left(\frac{ezj}{\sum_{k}^{j}=oezj}\right) = \cdots \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where Z_j is a choice and Z_k is alternative choice that could be chosen (Greene, 2000). The model estimates are used to determine the probability of choice of an adaptation option given j factors that affect the choice X_i.

$$\ln(Pi\,j/Pi\,k) = \alpha + \beta 1X1 + \beta 2X2 + \ldots + \beta k\,Xk + e \ldots\ldots\ldots\ldots\ldots\ldots 4$$

P_{ij} and P_{ik} are probabilities that a farmer will choose a given adaptation option and alternative adaptation option respectively. ln (P_{ij}/P_{ik}) is a natural log of probability of choice j relative to probability choice k,α is a constant, β is a matrix of parameters that reflect the impact of changes in X on probability of choosing a given adaptation option , e is the error term that is independent and normally distributed with a mean zero.

Before running the model, it is useful to look into account the problem of multi-co linearity among the independent variables. The existence of multi-co linearity problem between explanatory variables of the study was tested by using Variance Inflation factor (VIF) for continuous explanatory variables and Contingency Coefficient (CC) for discrete explanatory variables. Thus, it can be defined as: -

$$\text{VIF or CC } (X_i) = (1 - R_i^{\,2})^{-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where, R^2 is the multiple correlation coefficients between explanatory variables.

The larger value of R^2, the higher the value of VIF or VCC (Xi), causes multi co linearity in the variable (Xi).

3.7. Variable Definition and their Descriptions

3.7.1. Dependent variables

The dependent variable of the model is the common adaptation strategies, which are all, explained by here below:-

Mixed crop livestock system: A mixed crop-livestock farming system consists of integrated crop and livestock activities. Field crop production depends on the supply of draught animals and animal manure. Draught animals play a key role in tillage of land while animal manure fertilizes field crops. Livestock in this system depend on extensive grazing of natural and crop residues during the dry season. This is a closed system in which waste products of crops are used by livestock, which in turn return its own waste (manure) back to the crop field

Use of improved variety: This includes planting of short duration and drought tolerant, pest and disease resistant variety.

Agroforestry: include growing very important tree, spice trees, incense trees, coffee, rosemary, avocado, mango, papaya and other fruits and trees used for timber production and has a multi-purpose (as a source of income and means of keeping climate balance). It also constitutes trees used for energy consumption and prevents deforestation. Temesgen *et al.*, (2009) also used planting trees as a common climate change adaptation strategy

Using irrigation: Includes irrigation development from rivers or lakes in order to cope up with the challenges of climate change and variability.

Soil and water Conservation: Includes soil erosion preservation, management and care of soil in order to make it suitable for their crops, dam construction, conservation of rain water for watering the crops in times too little rain, ground water harvesting and agro forestry.

Changing date of planting: This means that farmers could change the date of planting and harvesting crop with respect to the change in the climate (early or late planting and harvesting) that survive in adverse climatic conditions.

Growing Drought tolerant crops: It involves using varieties better fitting to the new climate such as the use of stress tolerant crops or varieties that have a shorter growing period and pest and disease resistance crops. It also includes cultivating crops which are suitable to the new climate and growing conditions. Elasha *et al.,* (2006) mentioned planting of drought resistant varieties of crops as one of adaptation to climate change

3.7.2. Independent (Explanatory Variables)

Description of explanatory Variables Based on the review of the literatures and practical experiences, explanatory variables which have logical and justifiable rational in determining climate change adaptation status are identified. These are presented as follows:

Age of a Household Head (HHAGE): This is continuous variable defined as the number of years of the farm households starting from the year of birth. Older people have relatively richer experiences of the social and physical environments as well as greater experience of farming activities (Haile *et al.,* 2005). Hence, it was hypothesized that age positively or negatively affects adaptation measure to climate change and variability of the farm households.

Education Level of a Household Head (**HHEDUC):** number of years spent by the heads of the household for acquiring education. As the level of education of the household head increase, the farmers‟ proximity for new information and the probability of accepting new technology also increase. Hence, it was hypothesized that levels of education positively affect adaptation measure to climate change and variability of farm households.

Household size (HSIZE): It is measured in the number of peoples living in the household converted in to adult equivalent.

Monthly income (MATHLINC): is an income return to the household from different activities. This is a continuous variable and expected a positive sign for the farmers' adaptation strategies to climate change.

Health Status of the Household Head (HSHH): To work farming activity, physical wellbeing of the farmer was mandatory. The farmer was able to involve in farming work and management aspect of the farm if he/she is healthy.

Contact with development agent (CONDAGE): Refers to the frequency of contact that respondents made with development agent per month. It was the continuous variable. Farmers' contacts more with development agent have better knowledge about extension packages including irrigation technology than the others.

Access to Credit (ACREDIT) was a dummy variable that takes the value 1 when the household takes loan and 0 otherwise. Credit is very much useful to purchase inputs such as improved seeds, other important inputs including staple food. Hence, farmers who have access to credit would have positive effect on crop production due to use of agricultural inputs which enhance food production

Total Livestock Holdings /TLU/: livestock are the major source of income in rural area where mixed farming is practice. Particularly the ownership of farm oxen forms the cornerstone of farm economy in the rural households. It determines the household's level of vulnerability to climate change impacts. This is due to the fact that livestock is essential for farm household to use as for harvesting, transportation and also for financial purpose by selling them. This implies that farmers with more numbers of the livestock is the richer and can respond to the adverse effect of climate change through adaptation method. This is a continuous variable and expected a positive sign for the farmers who used adaptation measures to climate change.

Distance to District Market (DISMKT): This is a continuous variable measured in kilo meter. It refers to the distance between the households‟ home and the nearest market". As the farmer is nearer to a market, the higher will be the chance of increasing the household's income, access to purchase food from market and to sell his/her outputs. It is, therefore, expected that households nearer to market will incur lower transaction cost and can easily access the market the required food.

Cultivated Land size (CULTLAND): this refers to total cropping land cultivated by a household in the past one year production period. It has a direct relation with crop production. A larger size of cultivated land implies more production and availability of food grains. According to Haile *et al.,* (2005) and Babatunde *et al.,* (2007) and other literatures, food production can be increased extensively through expansion of areas under cultivation. Hence, size of cultivated land was expected to have positive effect on household food security status.

Participation in Non-farm activity (NONFARM): It is a measure of any household member participated in non-farming activities and generated an income in USDA Dollar. It was assumed that non-farm income earned by a household is primarily spent on food items such as on food grains, and non-food items required for household members.

Farm experience (FRMEXP): The farming experience of the household head is 36 expected to be positively related to undertaking adaptation. A farmer with more experience would know when climate change is occurring in the area and which methods work well in that specific agro-ecological zone.

Table 2**:** Expected signs on explanatory variables will influence adaptation to climate change

Explanatory Variables	**Definition**	**Measure**	**Expected Sign**
SEX	Sex	Dummy, takes the value of 1 if male and 0 otherwise	±
AGE	Age	Continuous	±
FAMSIZE	Family size	Continuous	±
LEDUC	Educational level of respondent	Continuous	+
FRMEXP	Farm experience of respondent	Continuous	+
FLDSIZE	Farm land size(ha)	Continuous	+
MATHLINC	Monthly income	Continuous	+
EXTSERV	Access to Extension services	Dummy	+
ACCRSRV	Access to credit service	Dummy	+
LVTKOWSHP	Livestock ownership	Continuous	+

CHAPTER FOUR: - RESULTS AND DISCUSSIONS

This chapter provides detailed information on each section here in. The chapter has sub-sections such as demographic and socio-economic characteristics of the farming households, farms characteristics and level of maize production of smallholder farmers under climate change and variability etc.

4.1. Demographic and Socio-economic Characteristics of the Respondents

This sub-section emphasizes demographic and socio-economic characteristics of the household, that play important role in *Maize* production such as gender, age, household size, marital status, education level, farming experience, household income etc.

4.1.1. Gender of the household head

During the survey 79.9 % were male while 20.1 % were female in sampled *kebeles* (Table 3). This implies that majority of the respondents were men, which indicates that women participation in agricultural activities is very low due to either having high number of children or being engaged in different non-agricultural activities. This result agrees with the reports of Deressa *et al.,* (2009) which states that, male headed households are more likely to get information about new technologies and undertake risky businesses than female-headed households.

4.1.2. Age of the household head

The highest proportion of the respondents (32.8%) was lies above 55 years, while only 7.9% was between 15-25 years (Table 3). This implies that both young and old people were involved in farming activities in the study area. The older farmer, the more experienced he/she is in farming and more exposure he/she has had to the past and present climatic conditions over longer periods of time. The age of household head can be used to capture farming experience (Deressa *et al.*, 2009).

4.1.3. Family size of the household head

The family size of respondents were higher in which about 46.6% of the sampled farmers had 9-10 family members, 22.6% have more than 11 (Table 3). This that means about 90.2% family sizes was greater than 6 persons per household. The studies of Mugula and Mkuna, (2016) showed that large household size might have positive impact in the improvement of the productivity especially if members fully participate in farming activities and those households are more likely to adapt to climate change.

4.1.4. Marital status of the household heads

Majority (81.5 %) of the of household heads are married in the study area, while only 14.1% and 4.3% are single and widowed respectively (Table 3). As the majority of the household heads are married, there is advantage for these households to increase their levels of crop production and come up with efficient adaptation measures to climate change and variability than other household heads (single, divorced, and widowed), because they share their ideas on how to improve their main economic activity which is mainly agriculture (Tenge *et al.*, 2004).

4.1.5. Educational status of the household heads

The educational status of the sampled households result revealed that 51.9% were (cannot read and write), 27.5% have primary level education (1 – 4), 10.6% secondary education level (5 – 8), 3.7% high school level, 2.1% preparatory level (11-12), 2.6 % and 1.6% have attended diploma and degree level education respectively (Table 3). This result implies that, the adaptation opportunities to climate change was very low in study area, because of lower education level of the household heads decreases the probability of adapting to climate change (Deressa *et al.*, 2009). Farmers with better education are more likely to pursue adaptation strategies related to climate change than those farmers with lower education levels (Komba and Muchapondwa 2015).

4.1.6. Household land size

Data collected on possession of land revealed that out of the total 188 respondents 52.4% acquired 0.5-1 hectares, 30.2% acquired 1-2 hectares, 12.2% acquired 3-4 hectares and 5.3% acquired greater than 5 hectares (Table 3). This indicates about 80% of the farmers acquired less than 2 hectares and unable to cop up with climate change impacts. Some studies found farm size to have positive influence on farmers' perception on climate change. For instance, Ehiakpor *et al.*, (2016) noted that farmers with larger farm sizes are more likely to perceive climate change than their counterparts with smaller farm sizes.

Table 3: Socio-economic and demographic characteristics of the respondents.

No	Characteristics	Frequency	Percentage (%)
1	**Gender of respondents**		
	Male	151	79.9
	Female	37	20.1
2	**Marital status**		
	Married	152	81.5
	Single	27	14.1
	Widowed	9	4.4
3	**Household size**		
	2-4	22	11.6
	5-8	36	19
	9-10	88	46.6
	11-12	42	22.8
4	**Age category**		
	15-25	15	7.9
	26-35	26	13.8
	36-45	39	20.6
	46-55	46	24.8
	>55	62	32.8
5	**Level of Educational**		
	Cannot read and write	98	51.9
	Primary(1-4)	52	27.5
	Secondary(5-8)	19	10.6
	High school(9-10)	7	3.7
	Preparatory (11-12)	4	2.1
	Diploma	5	2.6
	Degree	3	1.6
6	**Household land size**		
	0.5-1 hectare	99	52.4
	1-2 hectare	56	30.2
	3-4 hectare	23	12.2
	5-7 hectare	10	5.3

Source: household survey result in the study area, 2022

4.1.7. Farming experience

The household survey result shows that, 52.9% of the respondents have got farming experience of more than 35 years, while 25.6% are with greater than 55 years of experience (Figure 3). This result indicates that more than two-third of the respondent farmers is more experienced (more than 30 years) in farming practice in the sample *kebeles* so more ability to adapt climate change. Generally, educated and experienced farmers are more likely to notice the climate change and more likely to respond to the climate change events by using various adaptation measures (Maddison, 2007).

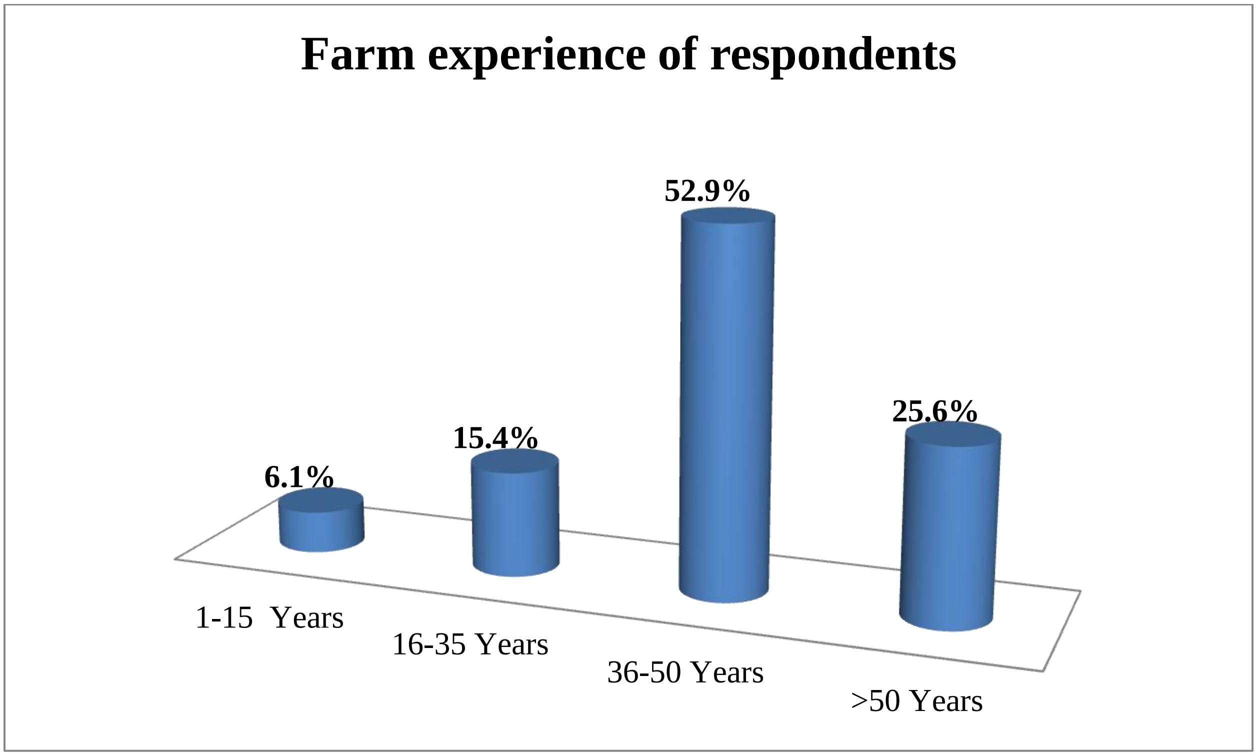

Figure 4: Farm experience of respondents

Source: household survey result in the study area, 2022

4.1.8. Source of income

The household survey results revealed that, income sources for the majority 74% of the sample households are from on-farm activities (Figure 4). However, non-farm activities and off farm activities are not significantly adopted in the sample areas.

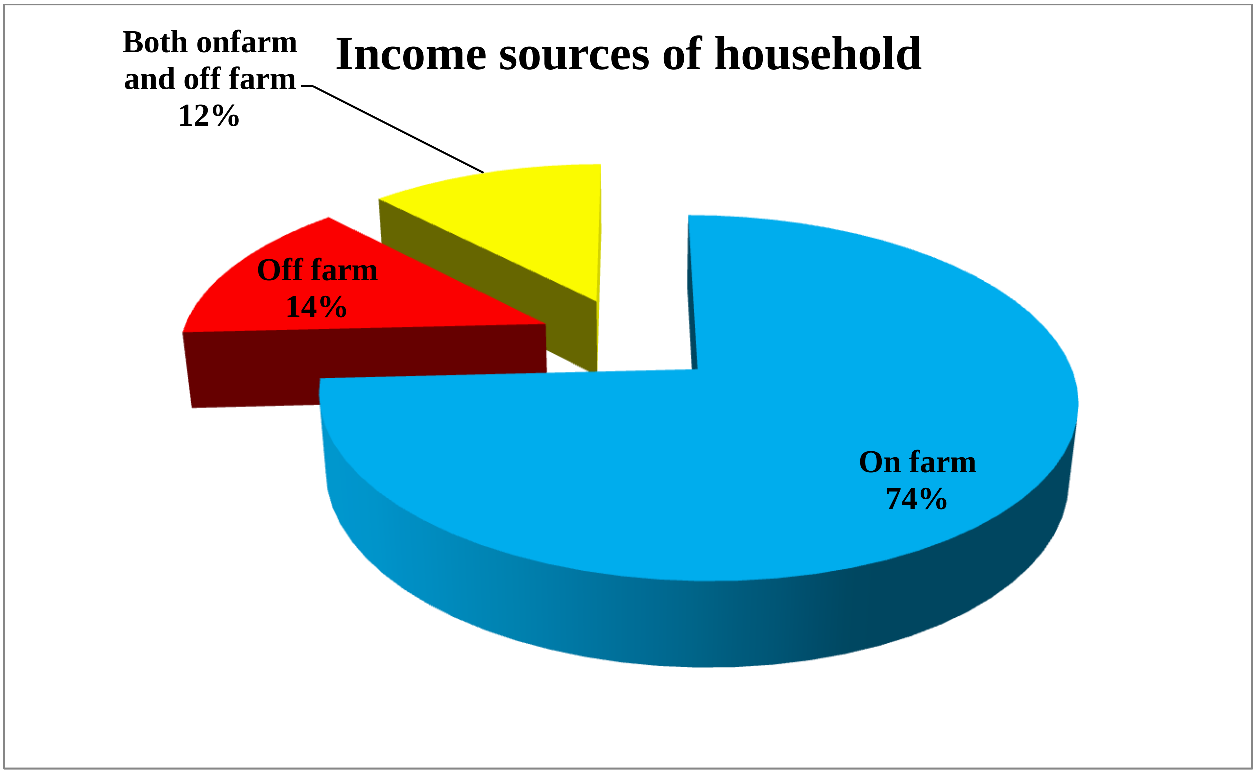

Figure 5: Income sources of farmers in the study area

Source: household survey result in the study area, 2022

4.2. Perceptions of Farmers on Long-term Climate Change Variables

4.2.1. Farmers perception on rainfall

Changes in rainfall amount and pattern, affect rate of soil erosion and soil moisture content, both of which are significant for crop yields (IPCC, 2015). Most of the interviewed farmers perceived the existence of rainfall changes in terms of both the amount and distribution over the years. Of the interviewed respondents, 66.1% and 5.8% felt a decrease and increase in the amount of rainfall in Hawassa zuria district respectively. However, 8.5%, and 19% respondents felt fluctuate and no change respectively (Figure 5). Similar to this finding the study conducted in seven districts of Kenya showed that 88 % of the farm households perceived that, the amount of rainfall decreased over the last 20 years. Similarly, 91% of farmers reported a long-term increase in rainfall variability, across all districts and agro-ecological zones (Bryan *et al.*, 2010). The other study conducted in Ghana indicated that the rain was better in previous times (1960s) compared to the contemporary times (2000s) (Codjoe and Wusu, 2011).

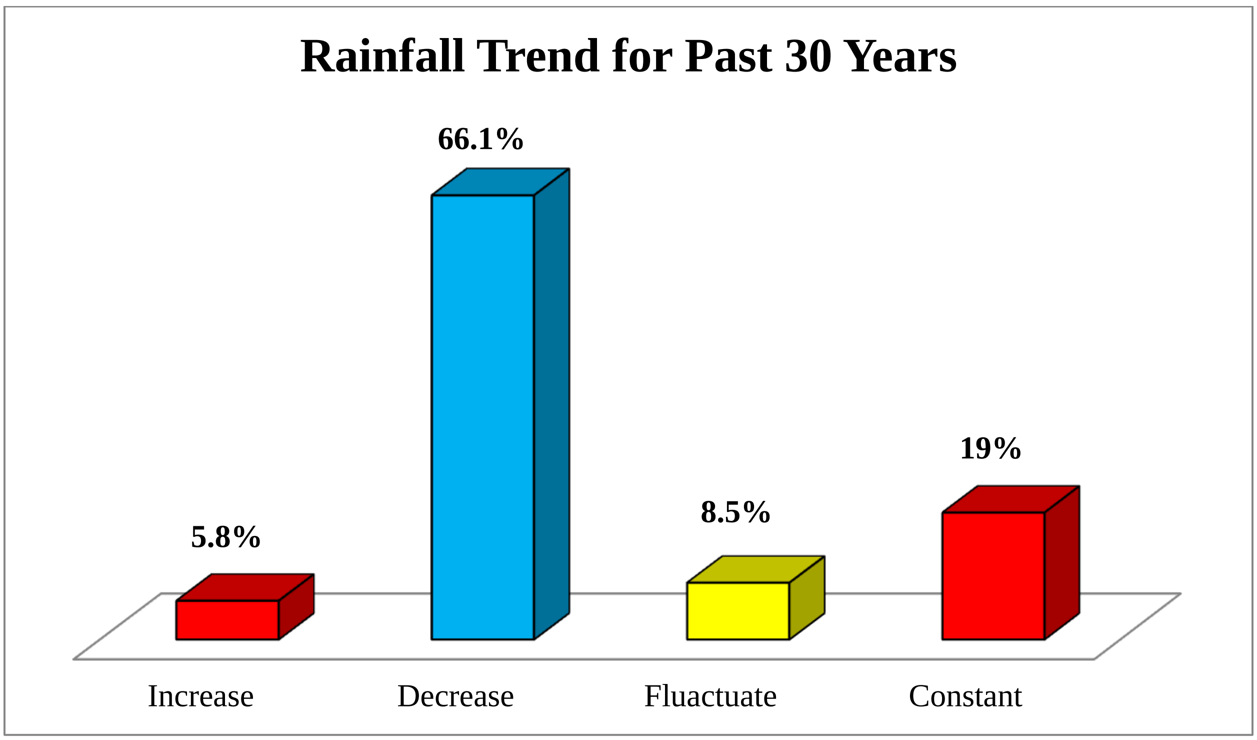

Figure 6.Trend of rainfall in Hawassa Zuria Woreda for last 30 years

Source: Household survey result in the study area, 2022

4.2.2. Farmers perception on long-term temperature in the study area

The majority of respondents (81.6%) perceived an increase in temperature over the past 30 years in the study area (Table 4). About 3.2% perceived a decreasing in temperature, 12.7% perceived that fluctuate and 3.3% no long-term change in temperature. Similar results were obtained from the focus group discussion. Generally, farmers believe that the increasing temperature trend was associated with the decreasing changes in rainfall. Similarly to this finding the research work conducted by (Anbesu, 2013) at Dodota Woreda revealed that 97.5% of respondents feel that temperature of the study area was increasing in the last three decades.

Table 4: Trends of temperature for the past 30 years

No.	Temperature trend for 30 years	Respondents response	
		Frequency	Precept (%)
1.	Increase	153	81.6
2.	Decrease	6	3.2
3.	Fluctuate	23	12.7
4.	Constant	6	3.2

Source: Household survey result, 2022

4.3. Long-term Climate Variables Trend Analysis

4.3.1. Rainfall trend of study area

The trend equation of the annual rainfall of Hawassa zuria district shows an increased trend with 3.6 mm per year over the past 30 years with large inter-annual fluctuation (Figure 6). This result is in line with the findings of (Nicholson *et al.,* 2000) that reported variability in annual rainfall in the semi-arid and sub humid zones of West Africa.

The summer (kremit) and spring-(belg) rainfalls have shown an increasing trend per year in the period noted. The summer rainfall in this study has shown a decreasing trend with 1.0036 mm per year in the 1991-2020. The spring/belg season rainfall has shown an increasing trend from1991-2020 by 3.977 mm per year in the study area (Figure 6).

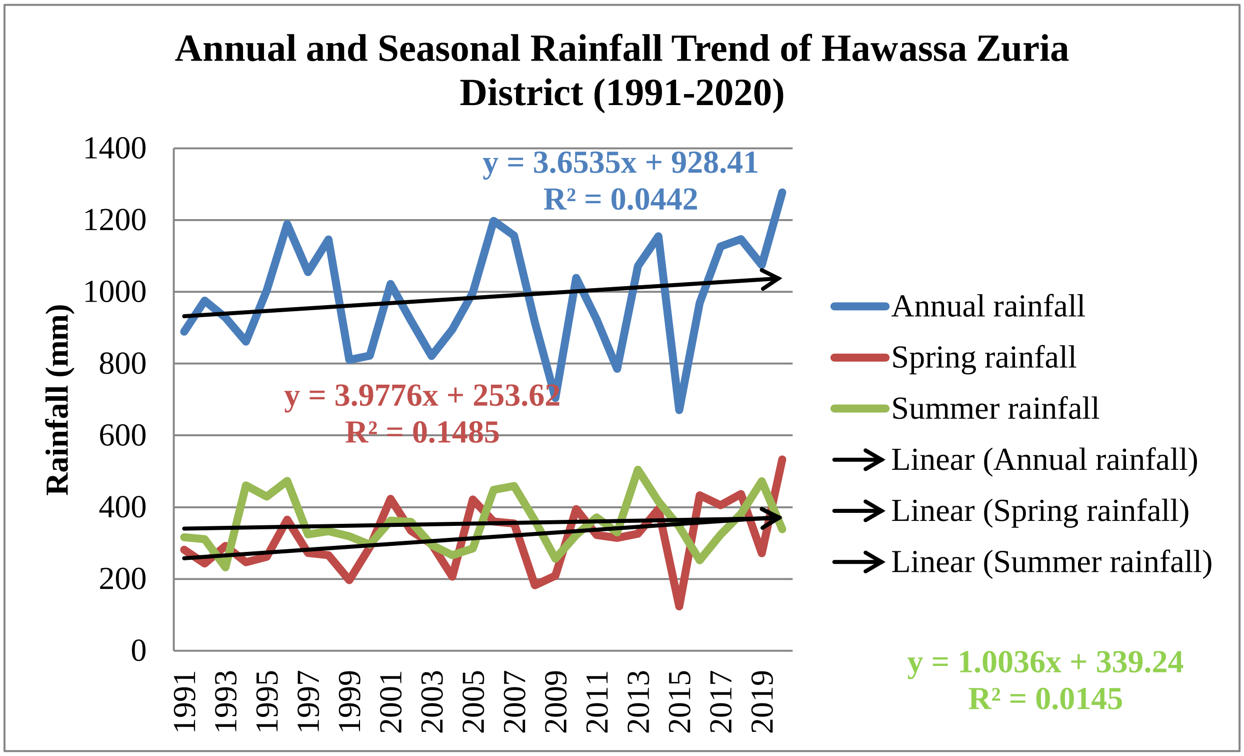

Figure 7: Annual and seasonal rainfall trend for the last 30 years (1991-2020)

Source: National Meteorological Agency (NMA, 2022)

The data obtained from Ethiopia Metrological Agency revealed that the coefficient of variation of study area were 32.4% and 31.2% for summer (Kiremt) and spring- (Belg) respectively, which indicates that there was very high variability of rainfall especially during the summer season, while the Belg rainfall variability was less variable than that of Summer between 1991-2020 (Table 5). A study made by (Abate 2009) in which, CV is used to classify the degree of rainfall variability indicated that, CV<20 it is less variable, CV <30 moderate and high CV>30. Various studies indicated that the trends in inter-annual and inter-seasonal rainfall variability was decline in amount and increase in intensity along with increasing temperature which would aggravate the rate of erosion, and consequently reflecting negative implication on crop productivity.

The impact of rainfall on crop production can be related to its total seasonal amount or its intra seasonal distribution. In the extreme case of droughts, with very low total seasonal amounts of rainfall, crop production suffers the most. But more subtle intra-seasonal variations in rainfall distribution during crop growing periods, without a change in total seasonal amount, can also cause substantial reductions in yields. This means that the number of rainy days during the growing period is as important, if not more, as that of the seasonal total (Woldemlak, 2006).

Table 5**:** Annual and seasonal rainfall analysis (1991-2020)

Rainfall (mm)	**Minimum (mm)**	**Maximum (mm)**	**Mean**	**Stdv (mm)**	**CV (%)**
Annual	701.9	1459.5	968.5	199	17.7
Summer (Kiremt)	175	721	392.5	127	32.4
Spring (Belg)	135. 8	595.9	355.1	111	31.2

Source: National Meteorological Agency (NMA, 2022)

According to National Meteorological Agency of Ethiopia (NMA), in the Sidama Region Hawassa zuria district, the seasonal rainfall shows lower inter-annual variability than the summer (main rain season, June-end of September) and belg (small rainy season, March-May) rainfall (Table 5). Summer is the main rainy season in the study area on which farmers are engaged to produce their crop. However, according to NMA data, the seasonal total amount of rainfall during the summer (June to end of September) showed higher variability especially during the years 1993, 1994, 1996, 2000, 2005, 2007, 2009, 2011, and 2019 which were below the average of rainfall in the study area. This has to be shown by SPI values.

4.3.2. Annual standard precipitation index (SPI)

The standardized anomaly of total annual rainfall revealed that, above average rainfall in the area was recorded for 16 years and below average rainfall for 14 years. Based on standard precipitation index procedure, the rainfall period of study area approximately categorized in to three decades (Figure 7). First decade (1991-2000) was relatively wet, while the second (2001-2010) decade and third decades (2011-2020) were wet, confirming the slightly increasing trend already observed in the trend analysis of this study

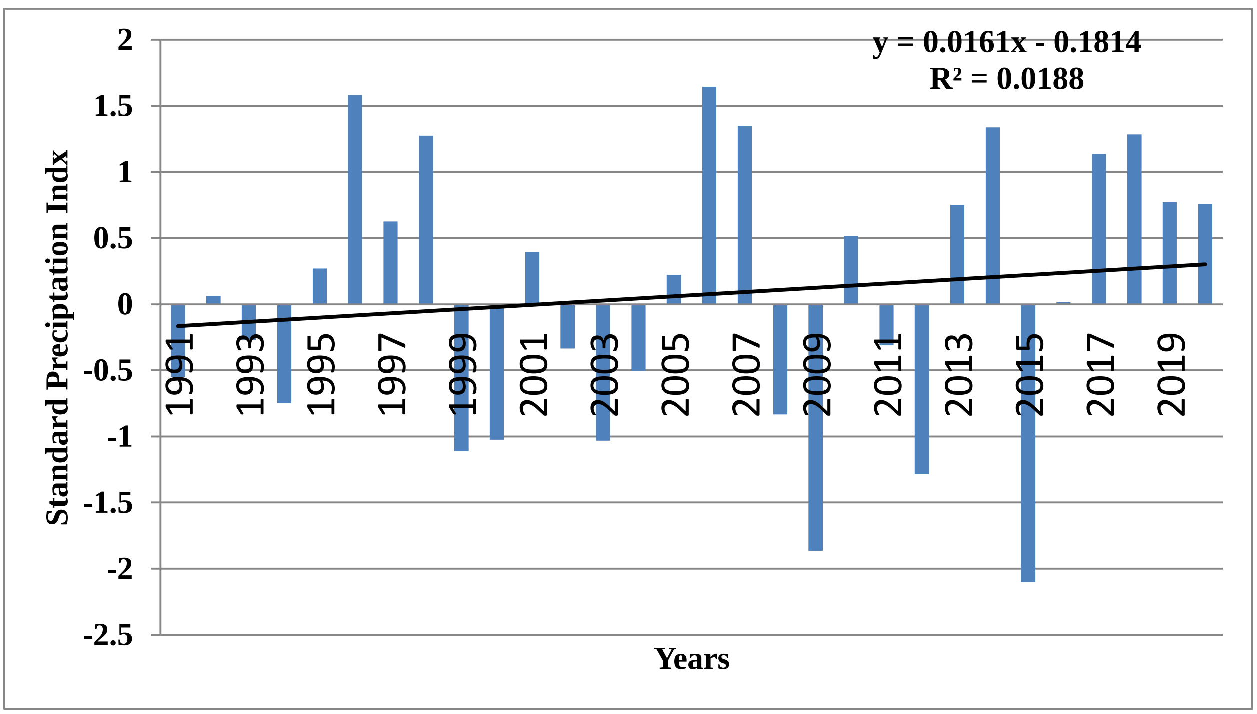

Figure 8: Standardized precipitation index of the study area

Source: National Meteorological Agency (NMA, 2022)

4.3.3. Temperature trend of study area

The trend analysis of annual temperature (minimum and maximum) in the current study shows increasing trend in the Hawassa zuria district during the past 30 years. This result is in line with (Conway and Schipper, 2011), who reported that an increase in minimum and maximum temperature in Ethiopia in the coming decades will affect crop production. According to the data from NMA of Hawassa zuria district, the mean annual maximum temperature s increased by 0.0228°C between (1991-2020, Figure 8). Similarly, according to (NMA, 2007), the average annual maximum temperature in the country has increased by 0.1°C per decade.

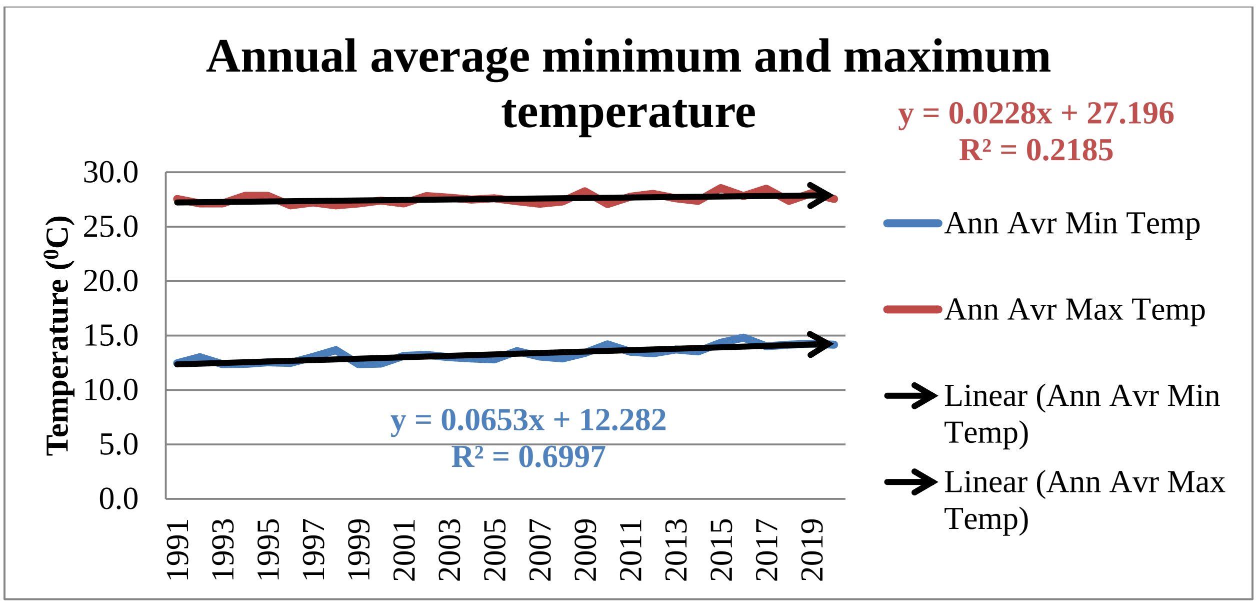

Figure 9: Annual minimum and maximum temperature trend for 30 years (1991-2020)

Source: National Meteorological Agency (NMA, 2022)

The annual mean minimum temperature increased by 0.0653°C per annum during 1991-2020 in the study area (Figure 8). (UNDP, 2008) report also revealed an increasing trend of mean annual temperature of Ethiopia by 0.37°Cper decade.

The present result was in line with that of (Kassie *et al.,* 2013), where in the climate of Central Rift Valley of Ethiopia will get warmer in the coming decades and the increasing rate in minimum temperature will be higher than the maximum temperature, particularly under the current emission scenarios. If the temperature shows an increasing trend, then it becomes essential to understand how this may also affect the ecosystems and human life if such a trend continues. Accordingly, change in a temperature pattern can lead to shift in species habitat of forests and insects. The rise in temperature can also result in intense heat waves that could be challenging for aging and other vulnerable populations (Evans A., and Perschel R., 2009).

Table 6**:** Average annual minimum and maximum temperature variability (1991-2020)

Temperature (^{o}C)		**Mean**	**Stdv**	**CV (%)**
Annual	Minimum	13.15	0.69	5.14
	Maximum	27.6	0.46	1.66

Source: National Meteorological Agency (NMA, 2022)

4.4. Trend in *Maize* productivity

Time series yield data of the period from 2004 to 2020 which were obtained from Hawassa Zuria Agriculture and Natural Resource office showed that the trend of *Maize* productivity in the past 14 years decreased by the rate of 0.0502qt/ha per annum (Figure 9). Coefficient of determination value also indicated that, about 0.0049% of the decline in *Maize* productivity in the study area accounted for the time series of 2004-2020. The declining trend of *Maize* productivity in Hawassa Zuria Woreda is mainly due to variability's in the onset of seasonal rainfall and increasing temperature which causes higher potential evapo-transpiration. Generally increased temperature accelerates the loss of water from the soil and the plant there by affects *Maize* productivity from vegetative to final grain yield.

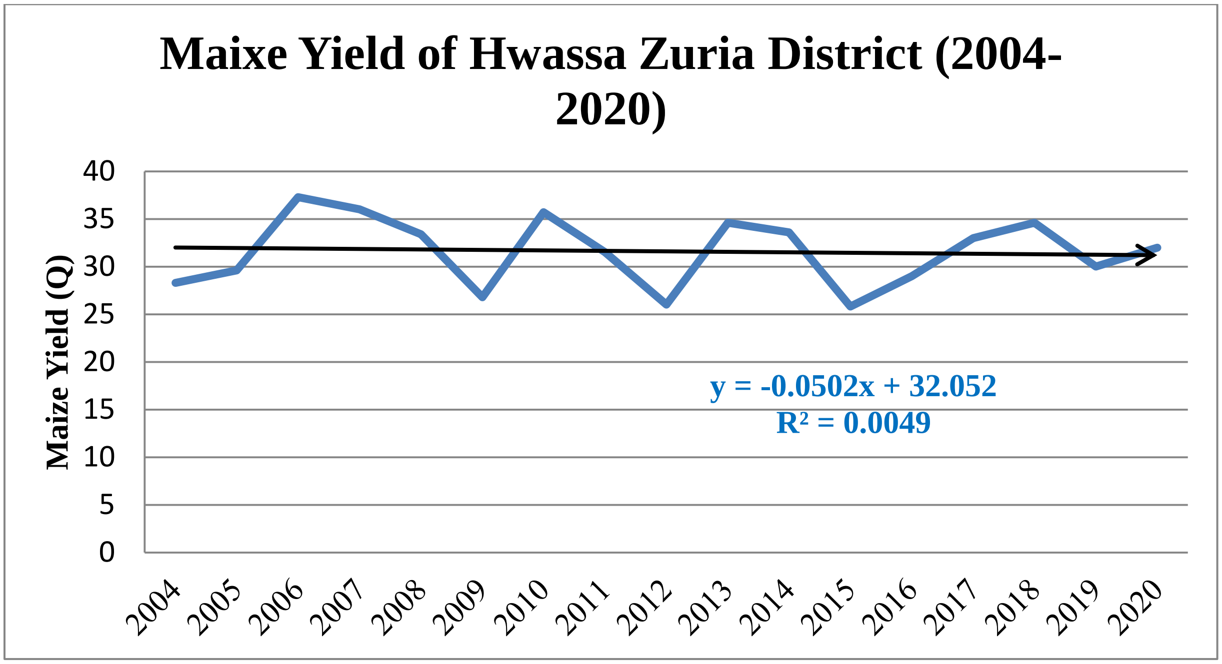

Figure 10: Maize productivity trend for 17 years (2004-2020)

Source: Hawassa Zuria Agriculture and Natural Resource Office (2020)

Although the impacts of climate variability and change on crop production are more of negative, they substantially vary between crops (IPCC, 2015). According to the experts from the focus group discussion and key informant interviews in the study area, *Maize* production is the main source of livelihoods, and has been significantly affected by climate change.

4.5. Relationship between *Maize* productivity and climate variables

The correlation between *Maize* productivity and annual rainfall is 0.812 which indicates that there is significant strong positive linear relationship between them, when the other independent variables remain constant (Table 7). Similarly, the correlation between *Maize* productivity and summer (keremt) rainfall is 0.704 showing the existence of significant strong positive linear relationship between the trend of maize productivity and summer rainfalls respectively.

On the other hand, the Correlation between yield of *Maize* productivity and annual maximum temperature is -0.609 which shows the presence of strong negative relationship between *Maize* productivity and annual maximum temperature, as the other independent variables remain constant. The present study implies that an increase in temperature imposes stress on *Maize* crop, which affects its productivity in many ways. For instance, increased temperature leads to intensive evapo-transpiration resulting in drying soil moisture and ultimate crop failure.

Table 7: Correlations between maize yield, rainfall and temperature at study area

Maize Yield		
Variables	**Correlation(r)**	**Significant (P-Value)**
Annual Rainfall	0.812	**0.000****
Spring Rainfall	0.396	0.116
Summer Rainfall	0.704	**0.002****
Average Annual Minimum Temperature	0.052	0.842
Average Annual Maximum Temperature	-0.609	**0.009****

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

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

Source: (NMA) and Hawassa Zuria Agriculture and Natural Resource Office (2022)

4.6. Climate Change Effect on Farming Activities in Study Area

The finding verified that climate change has harmed farming activities negatively in Hawassa zuria district, Sidama region. The majority of farmers indicated that climate change has resulted in increased crop failure (31.1%), low crop productivity (26.3%), increased reduction of livestock productivity (16.7%), less pasture/grass for livestock (14.2%) and crop failure

(23.1%). Furthermore, the farmers from their farming and life experience indicated that due to climate change: increasing scarcity of natural resources (change in forest and biodiversity) (5.3%), loss of income (3.7%) and increase rural-urban migration 2.8% (Table 8).

Similarly, (Tesso *et al.* 2012) documented perceived impacts of climate change among AEZs in North Shewa, Ethiopia. Hence, farmer's perception of the climate- induced impacts over years is indicative of Ethiopia's vulnerability to climate change and variability. Thus, studies recognized that Ethiopia suffers from problems associated with high rainfall variability (Degefu *et al.*, 2017). Specifically, (Amsalu and Adem, 2009) showed that climate change has both direct and indirect impacts on the occurrence and spread of pests and diseases.

The impacts of climate change on smallholder agriculture are likely to intensify in future years, as climate models project rising temperatures, more erratic rainfall, and a potential increase in the intensity and/or frequency of extreme weather events (Magrin *et al.*,2007; Imbach *et al.*, 2017). Moreover, extracts from qualitative information supports the changes in the climate parameters and the corresponding impacts over the last two decades as follows:

"Before 2000s, the area was very green and we had adequate pasture for the cattle. Now, there is no grass for grazing, and there is a movement in search of grass. Since 2000s, we have witnessed a decrease in rainfall and an increase in temperature warming. The rivers have decreased flow potential, and the vegetation cover has been declining. Where there is irrigation, production of crops is good." (Focus Group Discussion December 2022). The key informant interview as verifies that there were also agro ecology-based differences in the percent of farmers reporting different climate change impacts and the severity of these impacts.

In line with this (IPCC, 2014, Megersa *et al*., 2014; Ogalleh *et al.*, 2012; UNFPA *et al*., 2011 and WFP, 2012) indicated that climate change impact on production affects intra and inter-household social networks and arrangements, which are vital forms of food security practices. These includes high temperatures are often associated with drought while increase in temperature is expected to reduce crop yields and increase levels of food insecurity. Similarly, the traditional animal sharing is affected due to a climate change impact on livestock production. Moreover, the farmer's participation in social activities is affected because of climate change impacts on production and incomes. A study shows that climate change affects health, food security, employment, incomes and livelihoods, education, housing, poverty and mobility–either directly or indirectly.

Table 8: Farmer's response of climate change impact on farming activities

No.	**Climate change impacts**	**Frequency**	**Percentage**
1.	Crop failure	58/188	31.1
2.	Low crop productivity	41/188	26.3
3.	Increased reduction of livestock productivity	29/188	16.7
4.	Less pasture/grass for livestock	27/188	14.2
5.	Increasing scarcity of natural resources	17/188	5.3
6.	Loss of income	9/188	3.7
7.	Increase rural-urban migration	7/188	2.8
Total		**18**8	**100**

Source: Household survey result in the study area, 2022

4.7. Farmers' Adaptation Strategies to Climate Change in the Study Area

Based on the data from the farm households' survey, the results indicated that 81.5% of farmers are using various adaptation strategies to avert the effects of climate change on their farm, while, 18.5% of the farmers are not using any of the adaptation strategies being adopted by their partners in study area. Moreover, those farmers who are exercising climate change adaptation practice are even using more than one type of strategies. This implies that a single strategy is not adequate in adapting to the effects of climate change thus combination of several strategies is likely to be more effective than a single strategy.

The adaptation strategies of the studied households who have been using various livelihood strategies in study area are presented below based on rank (Table 9). Out of six adaptation strategies, being adopted by the farmers, using improved crop varieties and livestock species was ranked as the first and most important adaptation strategies to climate change. Similar studies were reported by (Bikila, 2013) and (Saguye, 2016), stating that using drought resistant improved short maturing crop varieties and livestock species was taken as the common climate change adaptation strategy of farmers in Southern Ethiopia.

Chang date of planting was also identified as the second in adaptation strategy in the current study. These results indicated that, farmers use Chang date of planting as adaptation strategy to reduce the associated risks of climate change in the *district*. In line with this, previous studies by (Lemma, 2016) also demonstrated that Chang date of planting adaptation practice was the dominant adaptation strategy to reduce climate change-related problems in the rainfall fluctuate areas of Ethiopia.

The third most important adaptation strategy in the study was the using small scale irrigation. Facilitating and providing small scale irrigation material is also being practiced by the farmers as one of the most important irrigation adaptation strategies in the study area.

The other climate change adaptation strategies include; income sources diversification (on farm and off farm), soil and conservations practices (including constructing physical and biological soil and water conservation structure) and using agroforestry were practiced among others across the study *Kebeles*.

Table 9: Ranked order of the adaptation strategies to climate change in study area

Adaptation measures	**Importance on your farm**				**ASI**	**Rank**
	High	**Medium**	**Low**	**No**		
Using improved crop varieties and livestock species	89	35	29	-	366	1
Using agroforestry	-	23	37	93	83	6
Change date of planting	83	29	17	34	324	2
Using irrigation	58	22	24	49	242	3
Soil and conservations practices	33	7	67	46	180	5
Income sources diversification	61	11	29	52	234	4

Source: Computed based on Survey result (2022)

4.8. Factors Influencing Farmer's Adaptation Strategies to Climate Change

Marginal effects from the MNL, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, are reported and discussed. In all cases, the estimated coefficients should be compared with the base category of using Agroforestry to climate extreme events. The marginal effects, along with the levels of statistical significance are also presented below (Table 10).

The marginal effects of marginal probabilities are a function of probabilities and measures expected to change within the probabilities. In the following section, only the variables that were statistically significant at less than or equal to 10% probability levels are interpreted and discussed.

Age: The age of the household head was one of the statistically significant explanatory variables that have negative and positive coefficient (Table 10). The positive sign indicates that it has a positive influence on taking an adaptation strategy to climate change. As the age of the household head increases by one year, the probability of household head using improved crop and livestock species as an adaptation strategy to climate change is increased by 1.04%, at less than (1%) probability significant level, keeping other variables constant. Similarly, as a year increase in the age of the household head, the probability to use adjusting planting date as adaptation strategy increases by 34.4% with the p-value of (<1%), keeping other variables constant. The result also indicates that, as the age of the household head increases by one year the probability of using irrigation adaptation strategy to climate change decrease by 5.6% with the p-value of (<5%). Similarly, as a year increase in the age of the household head, the probability of farmers not use adaptation strategy decrease by 34.6% at less than (5%) significant level, keeping other variables constant.

Family Size: The family size of the household head was a statistically significant explanatory variable in this model, which indicates farmers' adaptation strategy to climate change is also significantly affected by the number of family size. A one-unit increase in the family member resulted in an increase of probability of farmers using soil and water conservation as adaptation strategy increased by 67% at less than (1%) significant, holding other variables constant (Table 10). (Gbetibouo, 2009) also showed that household with larger family size are more willing to choose soil conservation techniques as adaptation measures that are labor-intensive especially in small scale farming. On the other hand the current result indicated that one unit increases in the member of the family resulted in a 38% decrease in the probability of farmers implementing mixed crop livestock system as adaptation strategy with the p-value of (<5%). This is in agreement with the study reported by (Belay *et al.*, 2017) study.

Level of Education: The results of this study revealed significant and positive effects of education on soil and water conservation, using improved crop and livestock species, irrigation and negative no adaptation(resistance to accept adaptation) strategies to climate change. Therefore, as the education of household head increases by one level, the probability of adopting change date of planting as adaptation strategy increases by 3.1% with the p-value of (<10%), keeping other variables constant. If the level of education increase by one grade, the probability of the farmers soil and water conservation as a climate change adaptation strategies will increased by 5% with the p-value is <1%. While no adaptation (resistance to accept adaptation) strategies decreases by 43% with the p-value of (<5%), keeping other variables constant (Table 10). On the other hand the use of improved crop and livestock species as adaption strategy declines with an increase in education level of the household head. Although, looked this result seems in contrary to the expectation whereby higher level of education to be positively related to adaptation to climate change, it may be associated with the complex nature of the specific strategy to be practiced in modern crop production system.

Farm land size: The farmer's land size had a positive and significant impact on farmers' choice of adaptation methods to climatic change. Accordingly, the results of the current study revealed that, as farm size of household head increases by one hectare, the probability of the farmers to use income source diversification by using to non-farm adaptation options significantly increased by 17% with p-value is (<1%) significant level.

Yearly income: yearly income of the household head is also a significant explanatory variable as shown in the (Table 10). The result of this analysis reveals that yearly income of household had a negative and positive significant influence on no adaptation (resistance to accept adaptation) and using irrigation adaptation strategies in response to climate change, respectively. A one percent (ETB) increases yearly income of household, the probability of farmers to use adaptation strategies of irrigation increased by 83%. And also a one percent (ETB) increases monthly income of household, the probability of farmers no adaptation (resistance to accept adaptation) strategies decreased by 25% with p-value of <5%, keeping other variables constant (Table 10). This result is in line with the outcome of (Tagel, 2013).

Table 10: Marginal effects of factor influencing Climate Change adaptation strategies

Explanatory Variables	No adaptation	Improved crop variety and livestock	Change date of planting	Irrigation use	Soil and water conservation (SWC)	Income source diversification
	Coeff. (P-value)	Coeff. (P-value)	Coeff. (P-value)	Coeff. (P-value)	Coeff. (P-value)	Coeff. (P-value)
SEX	-.065446	-.0401405	.0961736	-.0015023 (0.966)	.0492153	-.007133
	(0.104)	(0.513)	(0.157)		(0.428)	(0.849)
AGE	-.034624	.0104248	.344195	-.054037	-.0564898	.0121602
	(0.027)*	**(0.002)*****	**(0.028)****	**(0.028)****	**(0.014)***	(0.664)
LEDUC	-.430618	-.0979342	.0316806	-.0147778	.050355	.0093568
	(0.026)**	**(0.000)*****	**(0.074)***	(0.273)	**(0.000) *****	(0.392)
FAMSIZE	-.0151262	-.0537658	-.0215596	.0197537	.1644352	.0646878
	(0.455)	**(0.049)****	(0.304)	(0.286)	**(0.000)*****	**(0.050)****
FRMLAND	-.0183899	-.0347493	-.0012752	.019889	-.0191701	.1787346
	(0.403)	(0.132)	(0.936)	(0.238)	(0.377)	**(0.000)*****
ACEXTSERV	-.2537563	-.0028807	-.0204231	.0111775	-.1503477	.6196739
	(0.052)*	(1.000)	(0.998)	(0.999)	(0.995)	(0.995)
ACCRDTSERV	-.6232141	-.476017	.8840636	-.103877	-.2957667	-.0014629
	(0.001) ***	**(0.000) *****	(0.995)	(0.968)	(0.985)	(1.000)
FARMEXP	-.0197507	.0265215	-.0279324	.02564	.0246146	-.0207538
	(0.282)	(0.509)	(0.284)	**(0.046) ***	(0.500)	(0.516)
YERL INC	-.2567241	-.0141428	-.0439451	.8302472	-.0162761	.0150112
	(0.024)**	(0.602)	(0.132)	**(0.000)*****	(0.491)	(0.320)

Notes: ***, **, * denote significant at 1%, 5% and 10% probability level respectively. The values indicate coefficient (P-value).

Source: Computed by SPSS version 22 based on survey result (2022)

CHAPTER FIVE: - CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study attempted to investigate the impact of climate change on *Maize* production and adaptation strategies in Hawassa Zuria district. The meteorological data confirmed that, the rainfall in the study area is characterized by increase and greater inter annual and seasonal variability which is in line with several empirical research findings conducted in Ethiopia. The rainfall is also described by alteration of wet and dry years in a periodic pattern over the past 30 years (1991-2020). Annual temperature in the study area showed increasing trend for the last three decades. The study has also confirmed that, Hawassa Zuria district is found to be increasingly vulnerable to the risks of climate change and associated extreme weather events including drought.

Since, *Maize* production in the study area is immensely dependent on rainfall and its variability has affected the production. The results of this study have shown that, the lesser rainfall variability, the lower maize yield anomalies. Consequently, *Maize* production showed considerably positive and strongly significant correlation with annual rainfall and summer rainfalls whereas; *Maize* productivity has shown strong significant negative relation with the annual maximum temperature.

The most common adaptation options of the farmers in response to impacts of climate change on crop *Maize* production in the study area include: using improved crop varieties and livestock species, using irrigation, soil and water conservation, change date of planting, use of agroforestry and income diversification activities. According to this study, shortage of rainfall and increment of temperature have been found to be the main causes resulting in; crop failure, Low crop productivity, increased reduction of livestock productivity, less pasture/grass for livestock, increasing scarcity of natural resources, loss of income as well as increase rural-urban migration are the most common climate change-related problems that occurred in the study area.

The key informants and household survey participants also reported that lack of climate information, lack of finance, lack of access to new technology; poor administration and poor infrastructure provision are major constraints that hinder farmer's decision to adopt climate change adaptation measures in the study area. Thus, there is a need for effective and reliable access to information on changing climate to farmers.

The multinomial logit model used to analyse the factors that influence farmers' choices of adaptation strategies to climate change indicated that age, education, family size, yearly income, extension service, access to credit service, farming experience and farm size had significant influence on farmers' choice of climate change adaptation strategies.

5.2. Recommendation

To facilitate proper adaptation options to the impacts of climate change and variability in *Maize* production, stake holders should:

1. Ministry of education, Regional Education Bureau and different NGOs invest more in education since educated households use adaptation strategies better than non-educated.
2. National meteorology agency install meteorological station in the *district* to fill the information gap on weather variability and monitoring of crop-climate relationship in the area in order to achieve better *Maize* yield
3. Ministry of Agriculture and Regional Agricultural Bureau have to provide farmers with improved agricultural inputs including improved and drought tolerant crop varieties to reduce climate related risks especially on smallholder farmers.
4. Ministry of water and irrigation integrate efficient agricultural water management practice with productivity enhancing interventions including irrigation to supplement crop water requirement in Hawassa Zuria district.
5. Integrate indigenous knowledge with science based technologies in order to support adaptation capacity of the farming community.
6. There are many factors that affect Maize production, so researchers should give attention to variables without climate change special rainfall and temperature. While, variables like soil fertility status, variety type, agro ecology, crop pests and diseases and other determinant factors should be studied by other researchers.

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APPENDICES

Appendix 1: Questionnaire for household Survey

School of graduate studies Faculty of Environment, Gender and Development Studies

Department of Climate change and Sustainable Agriculture

Please indicate your personal information in the box provided.

District (Woreda ________________ kebele ____________ Date______

Enumerator __________________________ Supervisor ______

Section 1: Demographic and Socio economic characteristics of household head.

1. Sex of the household head: 0. Female 1. Male

2. Age of the household head: ______ (years)

3. Level of education complete of household head_____________________

4. Size of your household (people living in your household) _______________

5. The number of household members whose age is between 15-64 (including husband and wife) ______________________

6. How much of farm land do you have? In hectare___________

7. Which Farming system you follow currently

1. Crop production only

2. Livestock rearing only

3. Mixed farming (both crop and livestock)

8. What kind of agriculture are you practicing?

1. Rain fed agriculture 3. Both rain fed and irrigated agriculture

2. Irrigated agriculture

9. How much income can you generate from your farming activities' during last production year (2010 E. C)? Please specify in Birr:

1. from crop production___________________

2. from selling livestock and livestock products____________________

3. Others (please specify) ___________________________

12. Please estimate the total annual on farm income (crop and livestock production) of the household head during last production year____________________

14. How long you have been farming? (Years) ________________

Section 2: Questions on Institutional factors

1. Do you have a means of transport to the market?

0. No 1. Yes

2. If your answer is yes for question number 1, what is distance between market place and your home? ________km (approximately)

3. What are the possible means of transport? __________________________________

4. In undertaking your usual farming activities have you ever faced shortage of finance? For example to pure waste agricultural inputs like fertilizer, oxen, and others

0. No 1. Yes

5. Do you have access to any formal credits' in time face shortage of money?

0. No 1. Yes

6. Do you have access to any informal credit's (from neighbors, friends, relatives etc)?

0. No 1. Yes

7. If yes to „4&5" where you look for credit to fill your financial constraints? More than one choice is possible. From: 1.Relatives 2.Friends

3. Non-formal money lenders

4. Microfinance Institutes 5. Others_________

8. Do you have access to agricultural extension services in your kebele?

0. No 1. Yes

9. Do you receive any support from agricultural extension which could help improve your farming activities?

0. No 1. Yes

10. Please specify any kind of services you get from them.

____

11. Do you have access to climate information? 0. No 1. Yes

12. If your answer is yes, for question number11 from which medium do you posses?

1. TV
2. Radio
3. DAs
4. Other farmers
5. Other (specify)

Observing Climate change

1. Have you ever heard the word climate change before past 30 yrs.? 1) Yes 2) No

2. What are climate change and variability indicators that you have ever experienced?

   1. Drought 2. Flood 3. Frost 4. Too little rain 5. Intensive rainfall 6. all

3. What has been the trend of temperature for the past 30 years to date?

   1. Fluctuating 2. Constant 3. Decreasing 4. Increasing

4. What were the trends of rainfall looks like for the past 30 years up to now?

   1. Fluctuating 2. Increasing 3. Decreasing

5. Does the rainfall come on time? 1. on time 2. Too early 3. Too late

6. Is there enough rain on your fields at the beginning of the rainy seasons?

   1. Enough 2. Too little 3. Too much

7. Is there enough rain on your fields during the growing seasons?

1. Enough 2. Too little 3. Too much

8. Does the rain stop on time on your fields? 1) On time 2) Too early 3) Too late

9. Is it raining during harvest time? 1) Yes 2) No

Section 3: Adaptation Strategies to Climate Change

1. Do you adapt by improving crop and livestock production (changing crop and livestock varieties) strategy as a coping measure of climatic variations?

0. No 1. Yes

2. Do you vary your crop planting and harvesting dates to adapt changing climate?

0. No 1. Yes

3. Do you diversify your means of earning income from farm to non–farm activIties?

0. No 1. Yes

4. If your answer for the question number 3 is yes, in what are the main non-farm revenue generating activities do you get involved?

1. Pretty trading 2.daily labour 3.small shop 4. Others (specify) _____

5. Please estimate the total annual non-farm income (pretty trading, Daily labour, small shop and others) of the household heads (2008 E.C)?

Nonfarm activity	Daily Income (birr)	Total (birr)
Pretty treading		
Daily labor		
Small shop		
Other (specify)		

6. What is your estimated annual income from nonfarm activities during the last harvesting year (2008 E.C)? _________________

7. Do you use soil and water conservation measures in your farm land?

0. No 1. Yes

8. If your answer is yes, for the question number 7, what water and soil conservation measures do you use?

9. Do you irrigate your farm during the season where there is no rainfall?

0. No 1. Yes

10. If your answer for question number 9is yes, what is/are the main source of water?

0. Lake 1. River 2.pipe 3 .pond 4. Others (specify)?

11. What is the most commonly used adaptation option in your household?

1. Improving crop and livestock
2. Changing date of planting and harvesting
3. Income Source diversification
4. Soil and water Conservation
5. Irrigation

6. Others (specify)?

Appendix 2: Guiding questions for Focus Group Discussion (FGD)

Kebele: ____________ Focus group size: ___________

1. Do you have access to credit, food aid, extension, agricultural inputs and technologies and water for irrigation?

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

3. Where do people sell their agricultural products (crops and livestock's)? And how far is It from your village?

4. How did the GOs and NGO‟s respond to reduce the effect of climate change your locality?

5. What should be done in order to minimize the effect and increase the adaptive capacity of the community?

Appendix 3: Guiding questions for Key Informant Interview (KII)

1. How long have you been in this village/district? _________________________ Years?

2. What are the general conditions of agricultural production in the district for the past 30 years? ____

3. What can you comment on climate change and variability situation in the district for the past 30 years____

4. What is the situation of rainfall in the district for the last 30 years?

____

5. What is the situation of temperature in the district for the last 30 years?

____ 6. Have you encountered any climate change and variable impacts to maize production in the district? (Yes/No)____

7. What measures do you take to overcome climate change and variability impacts?

____ 8.

Do you get any early warning information on the climate change in district?

____

9. Where do you get this information? ___________________________________ 10.

What is your role as a community member when climate change and variability impacts threaten maize production in the district? __________________________

Appendix 4: Hawassa zuria district monthly rain fall in mm (1991-2020)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1991	12.3	90.6	86.4	48.0	146.7	116.7	109.2	90.6	110.0	21.6	12.2	44.8
1992	23.4	83.2	73.8	109.0	60.5	83.0	104.5	123.6	74.5	142.3	80.1	17.4
1993	101.6	109.1	22.3	104.9	165.3	46.7	54.7	130.8	47.8	130.8	10.5	3.9
1994	0.0	3.7	56.8	108.7	81.5	146.2	195.7	118.9	68.9	58.8	19.1	2.9
1995	0.8	21.4	61.8	156.1	43.6	118.7	175.7	134.7	166.8	22.3	18.3	84.2
1996	78.4	36.9	89.6	113.9	161.5	243.3	121.2	108.7	145.0	69.6	19.7	1.4
1997	23.4	1.7	75.1	125.0	72.8	111.2	98.8	113.9	119.1	157.5	132.2	24.0
1998	92.0	140.0	90.8	86.6	88.9	52.0	172.9	108.3	109.6	193.3	10.6	0.8
1999	19.8	0.4	105.5	26.4	64.7	99.8	135.1	83.8	117.4	120.4	20.1	16.8
2000	1.1	0.0	11.0	132.0	145.1	36.8	80.0	178.8	86.5	110.7	29.0	11.3
2001	1.8	39.9	122.7	67.2	233.7	137.8	93.4	131.7	89.7	80.2	2.6	21.3
2002	52.5	2.4	129.1	119.6	85.2	91.7	76.6	190.4	83.2	37.3	0.0	51.5
2003	30.4	2.0	78.2	179.1	40.4	110.5	107.8	76.1	85.5	53.4	6.2	51.8
2004	46.2	94.2	42.0	83.1	81.5	75.7	75.4	114.9	116.0	57.1	94.2	15.3
2005	81.1	7.7	120.9	156.0	144.5	73.2	150.9	61.3	117.2	28.4	46.0	10.4
2006	1.7	9.0	139.2	145.9	74.4	108.0	171.1	169.3	194.9	56.9	79.2	48.3
2007	18.0	55.0	76.4	112.0	166.1	225.4	129.1	104.3	233.8	32.7	3.7	0.0
2008	33.7	8.3	3.4	57.8	121.0	118.2	120.5	123.5	160.0	66.1	97.1	5.8
2009	32.8	9.0	60.3	45.6	103.1	51.6	92.6	112.0	81.7	41.6	4.1	69.9
2010	26.6	58.4	124.8	96.1	173.5	53.1	132.5	136.6	96.1	53.1	32.0	56.0
2011	2.3	7.1	55.5	73.7	193.6	65.5	150.5	155.2	125.5	5.5	88.2	0.2
2012	0.0	2.4	13.0	210.5	91.3	89.8	152.9	87.2	86.8	15.2	23.2	13.1
2013	23.4	1.0	104.0	78.8	143.0	132.4	209.4	163.1	117.7	77.5	22.0	0.0
2014	23.4	26.3	91.5	104.5	198.7	98.4	104.6	213.0	164.0	105.3	19.1	5.8
2015	0.0	2.5	38.2	28.9	56.1	147.2	113.1	85.3	103.6	34.1	23.3	38.6
2016	54.4	4.7	33.5	173.3	226.1	101.0	70.9	79.8	71.7	100.7	53.1	0.0
2017	0.0	88.4	91.0	88.5	225.6	54.7	153.6	115.1	174.4	128.8	6.4	0.0
2018	4.2	59.0	132.1	198.6	106.4	188.2	41.7	151.6	63.7	50.4	144.7	6.7
2019	0.0	13.3	17.6	128.6	125.7	81.7	207.2	183.1	167.3	88.3	62.1	0.2
2020	24.3	61.2	118.2	215.3	199.4	104.0	104.2	130.0	133.7	169.9	17.3	0.0

Source: National Meteorology Agency, 2023

Appendix 5: Monthly and annual average minimum temperature in ℃ (1991-2020)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual avr.min
1991	11.9	12.3	13.4	12.7	14.1	15.4	14.3	13.7	13.0	9.5	9.4	9.6	12.5
1992	12.4	13.6	12.8	14.1	13.5	14.0	13.9	14.4	12.7	13.1	10.5	11.0	13.0
1993	12.1	12.3	9.6	14.1	14.1	14.2	14.3	13.7	12.8	12.8	9.3	9.1	12.4
1994	9.7	11.6	13.0	13.8	14.3	14.5	14.2	14.7	14.0	10.1	10.0	8.9	12.4
1995	9.5	12.7	13.7	14.9	13.1	13.6	14.2	14.5	13.0	12.3	8.4	10.6	12.5
1996	12.2	10.5	13.0	14.0	14.1	14.3	14.5	14.4	13.6	10.9	8.8	9.6	12.5
1997	12.4	10.0	13.3	13.9	13.1	13.6	14.1	14.2	13.2	13.6	13.8	11.3	13.0
1998	13.3	14.3	14.0	14.4	15.7	14.7	15.7	15.9	14.5	14.4	8.9	8.1	13.7
1999	10.2	9.9	13.8	12.5	13.6	14.0	14.3	13.7	13.8	14.0	9.3	9.3	12.4
2000	9.6	10.6	11.1	14.1	14.0	13.7	14.3	14.0	13.4	14.0	10.5	9.7	12.4
2001	11.6	11.1	14.0	14.4	14.2	14.6	14.8	15.0	13.1	13.7	10.3	10.9	13.1
2002	12.4	11.8	14.0	13.5	14.8	14.5	14.3	14.2	13.4	12.8	9.8	13.2	13.2
2003	11.8	11.6	13.2	14.3	14.2	14.3	14.6	14.7	14.0	11.9	11.2	10.4	13.0
2004	12.9	11.6	12.2	14.7	13.2	13.9	14.0	14.3	13.6	11.5	11.6	11.4	12.9
2005	11.3	11.4	13.8	14.0	15.0	14.6	14.2	14.7	14.4	13.1	9.5	7.8	12.8
2006	11.8	12.4	13.8	14.6	13.9	14.3	15.0	14.7	14.5	14.2	11.4	12.4	13.6
2007	12.7	12.9	12.4	14.2	14.8	15.0	14.8	14.6	14.3	11.1	10.9	9.0	13.1
2008	10.5	11.7	11.4	14.1	14.6	14.4	14.9	14.5	14.2	13.0	11.1	10.3	12.9
2009	11.8	12.4	12.9	14.3	14.4	13.9	14.2	14.7	14.8	13.2	10.7	13.6	13.4
2010	13.0	15.3	14.7	15.6	16.3	15.1	15.2	15.3	14.4	13.5	11.1	10.9	14.2
2011	12.6	11.8	13.4	14.3	15.1	15.3	14.7	14.9	14.7	12.3	13.0	10.0	13.5
2012	10.2	11.7	13.5	15.1	14.4	15.1	15.3	15.0	14.4	12.2	12.3	11.3	13.4
2013	12.2	12.2	15.6	15.1	15.1	15.4	15.1	14.9	14.2	13.5	12.0	9.4	13.7
2014	12.2	13.5	13.4	13.1	14.1	14.0	15.3	14.9	14.7	14.2	12.3	10.7	13.5
2015	11.2	13.0	14.5	14.8	15.4	15.8	14.8	15.3	15.3	14.7	13.9	13.5	14.3
2016	15.3	14.7	15.4	16.7	16.1	14.7	15.8	15.4	15.3	14.9	12.1	11.2	14.8
2017	9.7	14.5	14.5	14.8	15.8	15.5	16.0	15.5	15.6	15.1	11.7	9.4	14.0
2018	11.3	13.3	13.9	15.6	15.6	15.4	15.0	11.3	13.3	13.9	15.6	15.6	14.2
2019	15.4	15.0	15.2	14.5	13.9	16.2	11.6	15.1	14.9	13.3	13.3	12.6	14.2
2020	13.1	13.7	15.6	15.3	15.5	15.3	15.2	15.4	15.0	13.9	11.4	10.4	14.2

Source: National Meteorology Agency, 2023

Appendix 6: Monthly and annual average maximum temperature in ℃ (1991-2020)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual avr.min
1991	30.3	29.0	28.7	29.3	28.0	26.1	23.2	25.1	25.9	27.8	29.2	28.1	27.6
1992	28.5	28.5	30.5	29.6	27.5	26.3	24.5	23.7	24.9	25.9	27.1	28.5	27.1
1993	27.7	26.9	30.6	27.8	26.9	24.9	24.4	24.9	25.8	26.9	29.0	29.9	27.1
1994	30.5	31.6	30.8	29.5	26.7	24.7	23.5	24.5	26.2	28.3	28.3	29.3	27.8
1995	30.4	30.7	29.9	27.3	28.0	27.0	24.3	24.5	25.9	27.6	29.3	29.2	27.8
1996	28.2	30.8	29.5	27.6	26.7	23.8	23.8	24.3	25.0	27.1	28.1	28.6	27.0
1997	28.9	30.3	30.8	26.9	27.5	25.7	23.8	25.5	26.8	26.5	26.5	27.3	27.2
1998	27.5	28.9	29.0	29.7	27.3	26.3	24.3	24.0	25.4	25.4	27.5	28.1	26.9
1999	29.1	31.4	28.1	29.4	27.2	26.1	23.6	25.0	25.6	24.8	27.2	28.0	27.1
2000	29.5	30.7	31.8	28.9	26.1	25.7	24.9	24.8	25.1	25.8	27.2	28.1	27.4
2001	28.6	30.2	28.3	28.4	26.8	24.8	24.4	24.5	25.9	26.7	28.2	28.9	27.2
2002	28.2	30.9	28.8	28.6	27.6	25.7	26.3	25.3	26.1	28.3	29.8	28.2	27.8
2003	28.4	31.3	30.6	28.1	28.3	25.6	24.2	24.9	26.0	28.2	29.3	27.2	27.7
2004	28.9	28.8	30.2	27.3	28.6	25.9	25.3	25.5	25.5	26.7	28.6	28.6	27.5
2005	28.9	31.5	30.0	29.4	25.9	25.6	24.6	25.7	26.0	27.3	28.0	28.5	27.6
2006	30.1	31.3	29.3	27.3	27.7	26.2	24.5	24.7	25.2	26.7	27.6	27.5	27.3
2007	28.5	29.2	30.0	28.2	27.7	25.3	24.6	24.2	25.1	26.7	27.8	27.9	27.1
2008	29.5	29.4	31.5	29.4	26.3	25.6	24.4	24.8	25.7	26.6	26.6	27.8	27.3
2009	28.4	30.0	31.3	29.2	29.0	27.7	26.0	26.0	26.3	27.5	29.5	28.1	28.3
2010	28.5	28.4	27.7	28.0	26.9	26.2	24.4	25.0	25.3	27.7	28.7	28.2	27.1
2011	28.7	30.6	30.2	30.7	27.6	26.2	25.6	24.6	25.3	28.2	27.8	27.6	27.8
2012	29.7	30.8	31.8	28.0	28.3	26.6	24.9	24.9	25.1	27.8	29.1	29.1	28.0
2013	29.9	31.4	30.3	28.8	26.7	26.1	24.3	24.7	26.2	26.8	28.0	28.0	27.6
2014	29.9	29.6	29.6	28.7	27.1	26.7	25.2	25.2	25.3	26.3	27.4	27.5	27.4
2015	28.7	31.0	31.5	30.8	28.5	26.1	26.1	26.8	27.1	28.5	29.0	28.4	28.6
2016	28.8	30.7	32.3	28.7	26.7	26.0	25.3	25.3	26.6	27.4	28.1	27.8	27.8
2017	29.0	29.9	31.6	31.6	28.4	27.7	26.1	26.6	26.3	27.9	28.5	28.3	28.5
2018	29.1	30.2	28.1	27.1	27.8	25.0	24.9	25.7	26.6	28.0	27.5	28.3	27.4
2019	29.8	31.2	31.7	29.7	29.1	26.4	25.6	25.2	26.0	26.6	27.9	27.8	28.1
2020	28.6	30.1	29.8	29.0	28.0	26.1	24.3	24.7	26.0	27.4	28.1	28.3	27.5

Source: National Meteorology Agency, 2023

Appendix 7: Maize productivity data of Hawassa Zuria district

Years	Maize yield (Qu/hectare)
2004	28.3
2005	29.6
2006	37.3
2007	36
2008	33.4
2009	26.8
2010	35.7
2011	31.53
2012	26
2013	34.6
2014	33.6
2015	25.8
2016	29
2017	33
2018	34.6
2019	35
2020	32

Source: Hawassa Zuria District Agriculture and Natural Resource Office, 2023

Appendix 8: The Variance Inflation Factors of the explanatory variables

Variables	Tolerance	VIF
Age of the household head	.969	1.032
Education of household head	.961	1.040
Family size of household head	.960	1.042
Total area of farm land household head	.946	1.057
Farm experience of household head	.947	1.056
Monthly income of household head	.950	1.05

Source: Household survey Model result, 2023

Appendix 9: Contingency coefficients for dummy explanatory variables

Variables	Contingency coefficient
Sex of household heads	.001
Access to extension service	.058
Access to criedit service	.036

Source: Household survey Model result, 2023

SKETCH OF BIOGRAPHY

The author, Korma Gidessa Hakkamo, was born on august 12, 1986 from his father Gidessa Hakkamo and his mother Bohare Hanako in Boricha Woreda, Sadamo Dikicha, kebele, sidama Region, Ethiopia. He attended his elementary school Yirba Yanassie primary school and attended his secondary school and preparatory school in Leku Town. After finishing high school, he joined Ethiopian National Defence Force in 1995-2001 E.C. and marched Muqdisho of Somalia and Monrovia of Liberia as an African peacekeeper. After this mission he attended his diploma programme water technology in Hawassa technical and vocational training or TVET college 2003/2013 additionally, He joined Hawassa University Wondo Genet College of forestry and natural resources Geographical information Science (GIS) in 2007/2015 and Following his graduation he was employed by Hawassa University in main campus. He joined Hawassa University, School of graduate studies in 2021/2023 academic year. He is married and two children father.