IMPACT OF CLIMATE CHANGE AND VARIABILITY ON MAIZE (*ZEA MAYS L*) PRODUCTION AND ADAPTATION STRATEGIES OF THE FARMING COMMUNITY IN HAWASSA ZURIA WOREDA, SIDAMA REGION

MSc. THESIS

TIMOTIWOS MICHAEL DIDISO

HAWASSA UNIVERSITY
COLLEGE OF AGRICULTURE

HAWASSA, ETHIOPIA
FEBRUARY, 2021

IMPACT OF CLIMATE CHANGE AND VARIABILITY ON MAIZE (*Zea Mays L*) PRODUCTION AND ADAPTATION STRATEGIES OF THE FARMING COMMUNITY IN HAWASSA ZURIA WOREDA, SIDAMA REGION

M.SC. THESIS

TIMOTIWOS MICHAEL DIDISO

MAJOR ADVISOR: DEMELASH KEFALE (PhD)

CO-ADVISOR: WORKALEMAHU TASEW (Ass. Prof)

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

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CLIMATE CHANGE AND SUSTAINABLE AGRICULTURE

HAWASSA, ETHIOPIA

FEBRUARY, 2021

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY ADVISORS' APPROVAL SHEET

(Submission Sheet-1)

This is to certify that the thesis entitled **"Impact of Climate Change and Variability on Maize (*Zea Mays L*) Production and Adaptation Strategies of the Farming Community: The case of Hawassa Zuria Woreda, Sidama Region"** Submitted in partial fulfillment 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 **Timotiwos Michael Id. No CCSA/0012/11,** under our supervision. Therefore, we recommended that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Approved by advisors: _

Name of major advisor	Signature	Date
Name of co- advisor	Signature	Date
Head of department	Signature	Date
SGS Approval	Signature	Date

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY EXAMINERS' APPROVAL SHEET-1

(Submission Sheet-2)

We, the undersigned, members of the Board of Examiners of the final open defense by Timotiwos Michael Didiso have read and evaluated his thesis entitled "**Impact of Climate change and variability on Maize (*Zea Mays L*) production and adaptation strategies of the farming community in Hawassa Zuria Woreda, Sidama Region**", examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

___________________________	___________	___________
Name of Major Advisor	Signature	Date
___________________________	___________	___________
Name of Internal Examiner-I	Signature	Date
___________________________	___________	___________
Name of the External Examiner-II	Signature	Date
___________________________	___________	___________
SGS Approval	Signature	Date

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 fulfillment 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.

Brief quotations from this thesis are allowable without special permission, provided that an accurate acknowledgement of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the Head of the Program of climate change and sustainable agriculture or the Dean of the School of Graduate Studies when the proposed use of material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

Name: Timotiwos Michael

Place: Hawassa University College of Agriculture, Hawassa, Ethiopia

Date of Submission: ________________

Signature: _______________

DEDICATION

I dedicated this thesis to my lord Jesus Christ, my mother Shungare Ondamo and my father Michael Didiso as well as my sister Mimi, Nebiyat, Bizunesh and Ayelech and my brothers Wonsha for their support and encouragement.

ACKNOWLEDGEMENT

First of all, I thank the Almighty God for giving me endless strength in every side of my life. My heartfelt thanks are extended to my major advisor, Demelash Kefale (PhD) and co-advisor Workalemahu Tasew (Ass.Prof), throughout the time of my studies; I would like to thank them for their constant support, guidance, invaluable advice and unfailing encouragement, all of which gave me a lot of inspiration.

I thank all those who made my data collection possible in the field. While I cannot mention all of them, indeed, it is valuable to recognize village leaders, extension experts, selected elders and household heads from Hawassa Zuria Woreda who volunteered to take part in my research.

Thanks to the Ethiopian National Meteorological Agency (NMA) and Hawassa Zuria Woreda Agriculture and Natural Resource Office for their valuable support in data provision. Finally, but with a very exceptional note, I express my special gratitude to all my beloved family, for supporting me throughout my MSc Programme for their continued love, unwavering support, patience, and encouragement.

LIST OF ACRONYMS

ASI	Adaptation Strategy Index
AEZs	Agro-ecological zones
CSA	Central Statistical Authority (Ethiopia)
DAs	Development agents
DFID	Department for International Development (UK)
FDRE	Federal Democratic Republic of Ethiopia
FDREMOWR	Federal Democratic Republic Ministry of Ethiopia Water Resource
FGD	Focus Group Discussion
GHGs	Green House Gases
GOs	Government Organizations
HZWANO	Hawassa Zuria Woreda Agriculture and Natural Resource Office
HZWFaED	Hawassa Zuria Woreda Finance and Economic Development
IPCC	Inter Governmental Panel on Climate Change
KII	Key Informant Interviewees
MK	Man Kendall trend test
NGOs	Non-Governmental Organizations
NMA	National Meteorological Agency
OECD	Organization for Economic Co-operation and Development
PPb	Parts Per billion
Ppm	Parts per million
SPI	Standardized Precipitation Index
UNISD	United Nations International Strategy for Disaster Reduction

TABLE OF CONTENTS

Contents **Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDESES

Impact of Climate Change and Variability on Maize (*Zea Mays L*) Production and Adaptation Strategies of the Farming Community in Hawassa Zuria Woreda, Sidama Region

By: Timotiwos Michael
Major advisor: - Demelash Kefale (PhD)
Co-advisor:- Workalemahu Tasow (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 impacts of climate change and variability on Maize production and adaptation strategies of the farming community in Hawassa Zuria Woreda. The study used multi stage sampling procedure. Purposive sampling procedure was used to select study area. Primary data were collected using key informant interviews, focus group discussions and household surveys with 184 households. Similarly, secondary data were collected from NMA and HZWANO. Descriptive statistics, correlation coefficient, Mann Kendall trend test, MNL, ASI and SPI were used to analyze the collected data. According to the survey results, about 81% 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 2.216 mm annually over the past 33 years despite statistically non-significant. 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 NMA 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 HZWANO and NMA also showed that, the rainfall of the spring (Belg) season was 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, mixed crop livestock system, use of irrigation, soil and water conservation, adjusting planting date and income diversification activities. The marginal effects of MNL model results also indicated that, the adaptation strategies used by farmers were significantly ($p< 0.05$) influenced by age, family size, farm land size, monthly income and livestock ownership, whereas; sex, access to extension service, access to credit service and farming experience 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: Adaptation strategies, climate change, climate variability, MNL and maize.

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Climate change includes major changes in temperature, rainfall, wind pattern and other climate variables that occur over decades or longer (IPCC, 2015), whereas, Climate variability is the way climate fluctuates monthly, seasonally and yearly as above or below a long-term average value (NOAA, 2009). Both change and variability could affect agriculture by influencing emergence and distribution of crop pests and weeds as well as increasing the occurrence and frequency of extreme weather events, reducing water supplies for irrigation and enhancing severity of soil erosion (Bates *et al*., 2008).

Community's dependent on rain-fed crop production is particularly vulnerable to climate change and variability due to the climate-sensitive nature of the sector. Hence, the agricultural sector and smallholder farmers in developing countries tend to be among the most climate change exposed communities (Pettengell, 2010). Countries with limited economic resources, low levels of technology development, poor information and skills, poor infrastructure, unstable or weak institutions, along with inequitable empowerment and access to resources have little capacity to adapt to climate change. However, rain-fed agriculture is yet the dominant source of food production and the livelihood foundation of the majority of the rural poor in sub-Saharan Africa (Cooper *et al*., 2009).

Similarly, Ethiopia's agricultural sector, which is dominated by small scale, mixed crop and livestock farming, is the mainstay of the country's economy. It constitutes more than half of the nation's gross domestic product (GDP), generates more than 85% of the foreign exchange earnings, and employed about 80% of the working population (Yesuf *et al.,* 2008). Its dependence on rain fed agriculture makes the country particularly vulnerable to the adverse impacts of climate variability. Generally, increased frequency of droughts, floods, rising carbon dioxide (CO_2) concentration, causing increased temperature and reduced rainfall negatively affect crop production, demonstrating its sensitivity to climate variability (Deressa *et al.,* 2009).

1.2. Statement of the problems

Hawassa Zuria Woreda, specially, lowlands of the woreda which are the major *Maize* production areas in Sidama region have been experiencing crop yield reduction. However, historical, social and economic impacts of all natural hazards are not systematically well documented as well as quantitative climate change impact assessments are not properly conducted so far on various socio-economic sectors in Hawassa Zuria Woreda. Therefore, it was found to be vital to provide site specific information, to address knowledge gap in skills and practice of climate change and variability impacts on *Maize* production of small holder farmers in Woreda by studying their major adaptation strategies.

This study was conducted with the aim to investigate the trend of climate variables specially temperature and rainfall along with their impacts on rain fed *Maize* production and identify climate change adaptation strategies used by the farming community in Sidama Region, Hawassa Zuria Woreda.

1.3. Objective

General objective

The overall objective of this study was to investigate the impact of climate change and variability on *Maize* production and assess its adaptation strategies in Hawassa Zuria Woreda, Sidama Region.

Specific Objectives

- To assess for 33 years climatic change and variability specially rainfall and temperature in the study area
- To evaluate the impacts of climate change and variability on *Maize* production
- To identify climate change adaptation strategies and mechanisms used by the farming community in study area
- To assess the major factor that influence farmers' adaptation strategies for climate change.

1.4. Research questions

The study attempted to answer the following research questions:

1. What are the trends of rainfall and temperature in Hawassa Zuria?
2. Is does *Maize* production decrease due to climate change and variability?
3. What are the climate change adaptation strategies and mechanisms used by the farming community in study area?
4. What are the major factors that influence farmers' adaptation strategies climate change?

1.5. Scope and Limitation of the study

The scope of this study was limited in terms of both its spatial coverage as well as number of variables treated. Regarding spatial coverage, the study was conducted in Hawassa Zuria Woreda, Sidama Region. The study was clearly stated to assess the impacts of climate change and variability on *Maize* production and adaptation strategies used by smallholder farmers of the woreda. However, due to time and financial limitations, the study focused only on the three selected kebeles out of 26 kebeles.

1.6. Significance of the study

The study investigated impacts of climate change on *Maize* production mainly focusing on the changes in rainfall and temperature, farmer's perception on climate change as well as identifying adaptation strategies used by the farming community in study areas. The study would provide site information that could help the farmers to adopt the best adaptation strategies for sustainable *Maize* production and boost up existing indigenous knowledge on climate change adaptation strategies as well as helps to generate idea for further researcher.

1.7 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 and variability impact 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

2. LITRATURE REVIEW

2.1. Definition of key terms

Vulnerability to climate change refers to the degree to which a system is likely to experience harm as the result of exposure to climatic hazard. It depends on the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 20015). In other words, it is a function of exposure, sensitivity and adaptability. Exposure relates to the nature and degree to which a system is exposed to climate change, while sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate related stimuli (Brooks, 2003).

Adaptability refers to the degree to which adjustments are possible in practices, processes, or structures of systems to climate change (Martin, 2012).

Adaptation to climate change refers to the process of responding and adjusting to actual or potential impacts of changing climate conditions in ways that moderate harm or take advantage of any positive opportunities from climate change. In other words, adaptation represents a process through which people reduce the adverse effects of climate variability on their health and wellbeing, and take advantage of the opportunities that their climatic environment provide. Adaptation takes different forms: reactive versus anticipatory (timing), autonomous versus planned (spontaneity) and private versus public (scale) (Fankhauser *et al.*, 2008). Reactive or spontaneous adaptation takes place in response to climate change while anticipatory adaptation is undertaken in anticipation or in reaction to climate change (IPCC, 2017). Autonomous adaptation is triggered by ecological changes in natural systems and by market or welfare changes in human systems (IPCC, 2007a). Another term often used as opposed to adaptation is maladaptation, which refers a situation where a strategy inadvertently increases vulnerability.

Adaptive capacity refers to the ability of a system to adjust to climate change to moderate potential damage, to take advantage of opportunities, or to cope with the consequences (McCarthy *et al.,* 2001). It is the ability of people or a system to modify or change its characteristics to cope better with existing or anticipated external stresses (Smit and Wandell, 2006). A system or a community is said to have enhanced adaptive capacity if it is able to modify its characteristics or behaviors so as to cope better with changes in external conditions. A related term, resilience represents 'the capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure (UNISDR, 2005).

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).

Sustainable livelihood pertains to livelihood that can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, without undermining the natural resource base (Thennakoon, 2012).

Sustainable livelihood framework is a tool for analysis of livelihoods. It consists of the vulnerability context, livelihood assets, and transforming structures that in combination influence livelihood strategies, which in turn generate outcomes related to income, wellbeing, vulnerability, food security, and sustainability (Hameso, 2013).

Smallholder farmers are farmers who own less than one hectare plots of land on which they grow subsistence crops and one or two cash crops relying largely on family labor. In different countries, they are variously described as family farmers, subsistence farmers, poor farmers and peasant farmers (Lowder *et al.,* 2014).

Agro ecological zones (AEZs) are areas with relatively homogenous agricultural land use options that are primarily determined by geographic elevation which in turn influences temperature and rainfall. There are three zones such as: a) highland or Dega, b) midland or Woyna Degaand, c) lowland or Kolla. Terms like zones, sites and areas are interchangeably used to express the above mentioned physical agro ecological locations (Dereje, 2011).

Kebele is the lowest administrative unit in Ethiopia similar toward, a neighborhood or a localized group of people. In terms of administration, a Kebele is part of a Woreda which in turn is part of a Zone. Zones are group of woredas under Region. There are 10 regions that comprise the Federal Democratic Republic of Ethiopia (FDRE, 2020).

2.2. Climate change

Climate change is defined as "the changes in long-term trends in the average climate, such as changes in average temperatures" (IPCC, 2017) or "any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC, 2007b). The United Nations Framework Convention on Climate Change (UNFCCC) puts more emphasis on the human activities and therefore defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

Causes of climate change

Climate change is caused by directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. Succinctly put, this effect of the pursuit of livelihood and comfort leads to emission of Greenhouse gases (GHG). These gases are mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (NO_2) (IPCC 2015). The major environmental concern regarding increased concentration of CO_2 and other trace gases is their global warming potential that is ability to trap solar energy in the atmosphere. This trapped solar energy causes global warming and other changes in the world's climate (Smith, 2013).

2.3. Climate variability

Climate variability: variation in the mean state and other statistics (such as standard deviations, occurrence of extremes, etc.) of climate on temporal and spatial scales beyond that of individual weather events. Variability may be due to natural processes within the climate system (internal variability), or due to anthropogenic forcing (external variability). The term climate variability refers to short-term fluctuation of weather that can occur without interference from human activities. For example, some of the drivers of climate variability include the El Niño, Southern Oscillation (IPCC, 2007b).

2.4. Climate Change and Ethiopian Agriculture

Agriculture remains one of the most important sectors in the Ethiopian economy for the following reasons: (i) it directly supports about 83% of the population in terms of employment and livelihood; (ii) it contributes over 40% of the country's gross domestic product (GDP); (iii) it generates about 85% of export earnings; and (iv) it supplies around 73% of the raw material requirements of agro based domestic industries, such as biofuels (AfDB 2011). It is also the major source of food for the population and hence the most important sector for food security. In addition, agriculture is expected to play a key role in generating surplus capital to speed up the country's overall socioeconomic development (Diao *et al.,* 2007).

Ethiopia has a population of over 100 million, with a population growth rate of about 2.6 % (AfDB, 2011). The country has a total land area of about 112.3 million hectares. Of this, about 16.4 million hectares are suitable for producing annual and perennial crops. Of the estimated arable land, about eight million hectares are used annually for rain fed crops. Small-scale farmers who are dependent on rain fed mixed farming dominate the agricultural sector; they use traditional technologies with low inputs and get low output. The present government of Ethiopia has given top priority to this sector and has taken steps to increase its productivity. However, various problems are holding this back. The causes of poor crop production include declining farm size; subsistence farming, partly due to population growth; land degradation due to inappropriate land use such as cultivation of steep slopes; over-cultivation and overgrazing; and inappropriate policies. Other causes are tenure insecurity; weak agricultural research and extension services; lack of appropriate agricultural marketing; an inadequate transport network; low use of fertilizers, improved seeds and pesticides; and the use of traditional farm implements. However, the major causes of low levels of production are drought, which often causes famine, and floods. These climate-related disasters make the nation dependent on food aid. With agriculture almost completely dependent on rainfall, rain rules the lives and well-being of many rural Ethiopians. It determines whether they will have enough to eat and whether they will be able to provide basic necessities and earn a living. Indeed, the dependence on rainfall and its erratic pattern has contributed greatly to the food shortages and crop crises that farmers constantly face. Even in good years, the one-time harvest or crop may be too little to meet the yearly household needs; as a result, the majority of Ethiopia's rural people remain food insecure (Devereux and Maxwell, 2001).

2.5. The Impact of climate change and variability on crop production

Climate change and variability affects crop production through direct impacts on the biophysical factors such as plant and animal growth and the physical infrastructure associated with food processing and distribution (Schmidhuber and Tubiello, 2007). Some impacts of climate change are occurring more rapidly than previously anticipated (Parry *et al.,* 2007). Crop production is directly affected by many aspects of climate change, stemming primarily from average temperature increase, change in rainfall amount and patterns, rising atmospheric concentrations of CO_2, change in climatic variability and extreme events and sea water rise.

2.5.1 Change in average temperature on crop production

Increases in mean, maximum and minimum temperatures are forecasted for most regions of the world as a result of climate change. It is expected that countries in the low latitude (tropical and sub-tropical) regions, where water availability is low, would generally be at risk of decreased crop yield at even 1 to 2ºC of warming (Parry *et al.*, 2007). This is as a result of increased evapo-transpiration and lower soil moisture levels. Thus, the phenomenon would result in some of the agricultural lands, which is located in the tropics, becoming unsuitable for cropping and some grassland becoming unsuitable for pasture. This would result in crop yield reduction in the region. The extent of this decline is still unknown, but they could be severe (Bals *et al.*, 2008).

2.5.2 Change in rainfall amount and patterns on crop production

It is expected that as a result of climate change, the temperate regions (wet areas) could become wetter and the dry areas in the tropics could become drier (FAO, 2008). The intensity of rainstorms could increase in some areas and precipitation could become more variable and unpredictable. The change in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields. Some countries would experience decrease precipitation in 20 present (Parry *et al.*, 2007). Thus, increase in temperature along with reduced precipitation will likely result in the loss of arable land in the region due to decrease soil moisture, increased aridity, increased salinity and ground water depletion (Bals *et al.*, 2008). Water storages could lead to water rationing and higher water cost and will limit opportunities to maintain or extend these cultivated agricultural lands through the use of irrigation. The reduction in available good quality water for crop at certain times of the year will negatively affect food supplies (FAO, 2008).

2.5.3 Rising atmospheric concentrations of CO_2 on crop production

The atmospheric CO_2 concentrations are estimated to be approximately 379 ppm by 2100 under the IPCC scenario under the lowest future emissions scenario and greater than 800 ppm under the business as usual scenario (Schmidhuber and Tubiello, 2007). Increasing atmospheric CO_2 levels is beneficial to plant: it acts as a fertilizer by enhancing the growth and development of crops. Increase in the atmospheric CO_2 levels would stimulate photosynthesis and improve water use efficiency (Aranjuelo *et al.,* 2009). Thus result an increasing in the crop biomass and yield. However, the increasing atmospheric CO_2 level does not only contribute to increased crop yields, but is also a major cause of the greenhouse effect.

2.5.4 Change in extreme events on crop production

Extreme events are not new in agriculture, but they are expected to increase in the frequency, intensity and the areas subject to extreme events are likely to expand (Schmidhuber and Tubiello, 2007). Increased frequency of extreme weather events will have more serious consequences for food production and food security (Esterling *et al.,* 2007). This is becoming worrisome due to the high dependency of the region on rain-fed agriculture. Climate variability particularly severe flooding and drought have been directly linked to declines in economic activity (Brown, 2009). Some countries have experienced a series of extreme precipitation events that seem to be linked to changing climate (Wassman and Dobermann, 2007). Flood had apart from huge human losses a devastating effect on agriculture with approximately 90 percent of the countries functioning irrigation infrastructure damaged and a significant loss in agricultural land that resulted many households without food.

2.6. Agricultural adaptation strategies to climate change and variable impacts

Adapting to climate change entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes. Adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or effects, which moderates harm or exploits beneficial opportunities (IPCC, 20017). It also refers to actions that people, countries, and societies take to adjust to climate change that has occurred. Adaptation has three possible objectives: to reduce exposure to the risk of damage, to develop the capacity to cope with unavoidable damages and to take advantage of new opportunities.

2.6.1. Crop adaptation strategies to climate change

I. Planting of drought resistant varieties of crops: Emphasis on more drought resistant crops in drought prone areas could help in reducing vulnerability to climate change. For example, wheat requires significantly less irrigation water compared to dry season rice. The use of drought-resistant crop varieties is adaptation methods to climate change (Ramirez-Villegas *et al.,* 2015).

II. Crop diversification: Diversification towards high value crops is feasible in the medium to long term. Crop diversity is a high priority adaptation measure in both irrigated and non-irrigated areas. For example, land use is manipulated leading to land use conversion, such as the shift from livestock farming to game farming. (Ziervogel *et al.,* 2008). In some countries food crops have replaced cash crops, and more resilient crop varieties have been introduced (DFID, 2004).

III. Change in cropping pattern and calendar of planting: Climate change adversely affects crop production through long-term alterations in rainfall resulting in changes in cropping pattern and calendar of operations. The trend of uncertainties in extreme weather events had generally increased (Urama and Ozor, 2011). To avoid crop production risks due to rainfall variability and drought, staggered plating is very common to most farmers whereby crops are planted before rain onset (dry land) on uncultivated land. Others were planted immediately after rain, while still other plots were planted a few days after the first rains. Tilling the land commences in fields which were planted prior to cultivation on the third week after the onset of rain which also enables destroys early geminating weeds and reduces weeding. These were done purposely to distribute risk by ensuring that any rain was utilized to the maximum by the crop planted the in dry field (Liwenga, 2003).

IV. Mixed cropping: Mixed cropping involves growing two or more crops in proximity in the same field. The advantages of mixing crops with varying attributes are in terms of maturity period (e.g. maize and beans), drought tolerance (maize and sorghum), input requirements (cereals and legumes) and end users of the product (e.g. maize as food and sunflower for cash). Different planting dates of mixed crops are an important for adaptation (Mendelsohn *et al.*, 2000).

V. Improved irrigation efficiency: Success of climate change adaptation depends on availability of fresh water in drought-prone areas. It should be emphasized that most adaptation methods provide benefits even with the lower end of climate change scenarios, such as improved irrigation efficiency. As water becomes a limiting factor, improved irrigation efficiency will become an important adaptation tool, especially in dry season, because irrigation practices for dry area are water intensive. Climate change is expected to result in decreased fresh water availability (surface and groundwater) and reduced soil moisture during the dry season, while the crop water demand is expected to increase because of increased evapo-transpiration caused by climate change and the continuous introduction of high-yielding varieties and intensive agriculture (Ramirez-Villegas *et al.*, 2015).As temperature increases, farmers tend to irrigate more frequently. Irrigation is clearly an adaptation strategy to warming. When precipitation increases, they tend to irrigate less often and resort to natural rainfall more often. Farms in the deserts reduce irrigation when temperature increases. Similarly, when precipitation increases, farms close to the deserts increase irrigation.

VI. Adopting soil conservation measures that conserve soil moisture: Farmers use contour ridges to minimize soil erosion, encourage better root penetration and enhance moisture conservation (Lema and Majule, 2009).Traditional pruning and fertilizing techniques of double tree densities in semi-arid areas are important for holding soils together and reversing desertification. Conservation of carbon in soils through the use of zero tilling practices in cultivation, mulching and other soil management techniques (Nyong *et al.,* 2007). Natural mulches moderate soil temperatures and extremes, suppress diseases and harmful pests, and conserve soil moisture. Before the advent of chemical fertilizers, local farmers largely depended on organic farming, which also is capable of reducing GHG emissions.

VII. Planting of trees (afforestation) and agroforestry: Tree planting is the process of transplanting tree seedlings, generally for forestry, land reclamation, or landscaping purposes. It differs from the transplantation of larger trees in arboriculture, and from the lower cost but slower and less reliable distribution of tree seeds. In silviculture the activity is known as reforestation, or afforestation, depending on whether the area being planted has or has not recently been forested. It involves planting seedlings over an area of land where the forest has been harvested or damaged by fire or disease or insects. Rural farmers in most of the Africa countries have been planting trees as a way of adapting to the effect of climate change. Agro forestry is a rational land-use planning system that tries to find some balance in the raising of food crops and forests. Shade tolerant crops, such as Dioscorea spp, and cocoyam are essential a permanent forest setting (Adesina *et al.*, 2016). In addition to the fact that agro forestry techniques can be perfected to cope with the new conditions that are anticipated under a drier condition and a higher population density, they lead to an increase in the amount of organic matter in the soil thereby improving agricultural productivity and reducing the pressure exerted on forests. In the drier parts of the world, baobab (Adansonia digitata) and acacia (Acacia) trees are usually planted by local farmers as it realized as a valuable tree, especially during the hot and dry parts of the year (Nyong *et al.*, 2007).

2.6.2. Other adaptation strategies

A. Labour migration

Migration is a dominant mode of labour (seasonal migration), providing a critical livelihood source. The role of remittances derived from migration provides a key coping mechanism in drought and non-drought years but is one that can be dramatically affected by periods of climate shock, when adjustments to basic goods, such as food prices are impacted by food aid and other interventions (Devereux and Maxwell, 2001). Migration is (and always has been) an important mechanism to deal with climate stress. Pastoralist societies have of course habitually migrated, with their animals, from water source to grazing lands in response to drought as well as part of their normal mode of life. But it is becoming apparent that migration as a response to environmental change is not limited to nomadic societies. In western Sudan, for example, studies have shown that one adaptive response to drought is to send an older male family member to Khartoum to try and find paid labour to tide the family over until after the drought (McLeman and Smit, 2004). Temporary migration as an adaptive response to climate stress is already apparent in many areas. But the picture is nuanced; the ability to migrate is a function of mobility and resources (both financial and social). In other words, the people most vulnerable to climate change are not necessarily the ones most likely to migrate. In the West African Sahel, recent studies have cast light on the use of temporary migration as an adaptive mechanism to climate change. The region has suffered a prolonged drought for much of the past three decades and one way that households have adapted is by sending their young men and women in search of wage labour after each harvest. But how far they travel depends, in part, on the success of the harvest (Oli, 2008).

B. Income diversification

Farmers adapt to the effects of low yield by indulging in the dry season market gardening and non-farm income sources (Mertz *et al.,* 2010). This is corroborated by people focus on activities that are less dependent on climate (Nielsen and Reenberg, 2010a). An analysis of national household survey data in Africa between 1998 and 2007 showed that the average wealth increased for almost all major livelihood groups and the number of wealthy people steadily increased. These results highlight the importance of off-farm income which generates opportunities, especially in marginal rural areas, for long-term adaptation strategies to climate variability and change.

2.7 Impacts of climate change and variability in relation to biotic and abiotic stress

Due to global warming, and potential climate abnormalities associated with it, crops typically encounter an increased number of abiotic and biotic stress combinations, which severely affect their growth and yield. Concurrent occurrence of abiotic stresses such as drought and heat has been shown to be more destructive to crop production than these stresses occurring separately at different crop growth stages. Abiotic stress conditions such as drought, high and low temperature and salinity are known to influence the occurrence and spread of pathogens, insects, and weeds. They can also result in minor pests to become potential threats in future (Duveiller *et al.*, 2007). These stress conditions also directly affect plant-pest interactions by altering plant physiology and defense responses. Additionally, Abiotic stress conditions such as drought enhance competitive interactions of weeds on crops as several weeds exhibit enhanced water use efficiency than crops.

2.7.1. Abiotic stresses on *Maize* under the changing climate

Drought: Drought is the most pervasive limitation to the realization of yield potential in maize (China Meteorological Disaster Yearbook., 2015). Average annual global losses due to drought in maize range from 15% in temperate zone to 17% in tropical zone as estimated by empirical methods. A precise measurement of yield losses worldwide is not possible due to a range of occurrences of drought from individual fields to regional in extent, with severity from slight to catastrophic. Losses are greatest in parts of the world where soils and weather patterns are less favorable than US Corn Belt, which is named for its long-term suitability for growing maize at relatively low level of risk of crop failure.

Heat: By the end of this century, growing season temperatures will exceed the most extreme seasonal temperatures recorded in the past century (Battisti and Naylor, 2009). Using crop production and meteorological records, Thomson (2004) showed that a 6°C increase in temperature during the grain filling period resulted in a 10% yield loss in the US Corn Belt. Increase in temperature of 2°C would result in a greater reduction in maize yields within sub-Saharan Africa than a decrease in precipitation by 20 %. A recent analysis of more than 20,000 historical maize trial yields in Africa over an eight year period combined with weather data showed for every degree day above 30°C grain yield was reduced by 1 % and 1.7% under optimal rain fed and drought conditions, respectively (Lobell *et al.,* 2013). The temperature threshold for damage by heat stress is significantly lower in reproductive organs than in other organs (Sánchez *et al.,* 2014). Successful grain set in maize requires the production of viable pollen, interception of the pollen by receptive silks, transmission of the male gamete to the egg cell, and initiation and maintenance of the embryo and endosperm development (Ordónez ˜ *et al.,* 2015). High temperature during the reproductive phase is associated with a decrease in yield due to a decrease in the number of grains and kernel weight. Under high temperatures, the number of ovules that are fertilized and develop into grain decreases.

Water Logging: Over 18% of the total maize production area is frequently affected by floods and water logging problems, causing production losses of 25-30% annually (Zaidi and Singh, 2010). Although the area of land in sub-Saharan Africa affected by water logging is lower than in other parts of the world, it is a risk in a few areas. Water logging stress can be defined as the stress inhibiting plant growth and development when the water table of the soil is above field capacity. The diffusion rate of gases in the flooded soil could be 100 times lower than that in the air, leading to reduced gas exchange between root tissues and the atmosphere (Armstrong and Drew, 2002). As a result of the gradual decline in oxygen concentration within the rhizosphere, the plant roots suffer hypoxia (low oxygen), and during extended water logging (more than 3 days), anoxia (no oxygen) (Zaidi and Singh, 2010). Carbon dioxide, ethylene and toxic gases (hydrogen sulphide, ammonium and methane) also accumulate within the rhizosphere during periods of water logging. A secondary effect of water logging is a deficit of essential macronutrients (nitrogen, phosphorous and potassium) and an accumulation of toxic nutrients (iron and magnesium) resulting from decreased plant root uptake and changes in redox potential. Nutrient uptake is reduced as a result of several factors. Anaerobic conditions reduce ATP production per glucose molecules, thereby reducing energy available for nutrient uptake. Reduced transport of water further reduces internal nutrient transport.

2.7.2. Biotic stresses on *Maize* under the change climate and variability

Abiotic stresses account for a significant proportion of maize yield losses worldwide. The predominant insect-pests and diseases vary across environments and a major challenge in adapting crops to climate change will be the maintenance of genetic resistance to pests and diseases (Reynolds and Ortiz, 2010). Climate change will affect the diversity and responsiveness of agricultural pests and diseases.

Plant Diseases: For a disease to occur a virulent pathogen, susceptible host and favorable environment are essential (Legrève and Duveiller, 2010). All of these components are strongly coupled with environmental conditions. Global climate changes have the potential to modify host physiology and resistance, and alter both stages and rates of pathogen development. Environmental conditions controlling disease development include rainfall, relative humidity, temperature and sunlight. Changes in these factors under climate change are highly likely to have an effect on the prevalence of diseases and emergence of new diseases. For example, in Latin America tar spot complex, caused by Phyllachora maydis, Monographella maydis and Coniothyrium phyllachorae, was previously rare. However, recent epidemics of the tar spot complex have been recorded in Guatemala, Mexico, Colombia and El Salvador due to recent climate variability (Pereyda-Hernández *et al.*, 2009). Climate change may also affect gene flow, the process through which particular alleles or individuals are exchanged among separate populations. This will increase pathogen population diversity leading to variation in host resistance, variation in pathogen virulence and new specific interactions. This has the potential to result in new diseases or pathogen emergence, and the introduction of pathogens into new ecological niches. Depending on the distribution of populations and environmental conditions that are influenced by climate change, gene flow leads to an increase in population diversity or to the introduction of a new population in new ecological niches. An important example of changes in growing season conditions being linked to outbreaks of diseases, with serious human health implications, is mycotoxins and their prevalence within maize systems. Mycotoxins are toxic secondary fungal metabolites that contaminate agricultural products and threaten food safety. Different groups of mycotoxins are produced by different fungi. A. flavus and A. parasiticus produce aflatoxin, F. verticillioides produces fumonisin, and F. graminierum produces deoxynivelanol (DON) and zearalenone) (Miller, 2008).

Mycotoxin contamination is a serious problem with long-term consequences for human and animal health. Sub-lethal exposure to mycotoxins suppress the immune system, increase the incidence and severity of infectious diseases, reduce child growth and development, and reduce the efficacy of vaccination programs (Williams *et al.,* 2004). Consumption of high doses of mycotoxins causes acute illness and can prove fatal. In 2004, more than 125 people died in Kenya from eating maize with aflatoxin B1 concentrations as high as 4,400 parts per billion - 220 times the Kenyan limit for foods (Lewis *et al.,* 2005). The maize implicated in this outbreak was harvested during unseasonable early rains and stored under wet conditions conducive to mold growth and therefore aflatoxin contamination. Previous outbreaks in Kenya and India have also been attributable to unseasonable, heavy rain during harvest (Ngindu *et al.,* 2005).

Insect-Pests: The dynamics of insect-pests are also strongly coupled with environmental conditions. Insects do not use their metabolism to maintain their body temperature, and are dependent on ambient temperature to control their body temperature. Temperature is therefore the single most important environmental factor influencing insect behavior, distribution, development and survival, and reproduction. Insect life stage predictions are calculated on accumulated degree days, which is a function of both time and temperature.

Increased temperature can speed up the life cycle of insects leading to a faster increase in pest populations. It has been estimated that a 2°C increase in temperature has the potential to increase the number of insect life cycles during the crop season by one to five times (Porter *et al.,* 2014). The feeding rate of many arthropod vectors increases at higher temperatures, thus increasing exposure of crops to mycotoxigenic fungi thereby increasing the spread of mycotoxins (Bale *et al.,* 2002). The increased global warming and drought incidences will favor insect proliferation and herbivory, which will likely increase the incidence and severity of insect related damages as well as aflatoxin and fumonisin mycotoxins in maize.

Higher average temperatures have the potential to change the geographical distribution of crops. This may in turn result in an expansion of the geographical distribution of insect-pests and their associated pathogens (e.g. maize streak virus, corn stunt complex that are vectored by different species of leaf hoppers), resulting in a change in the geographical distribution of diseases.

2.8. 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).

Green House Gases (GHGs) are gasses that trap long-wave radiation in the upper atmosphere, raise atmospheric temperatures and produce other changes in the climate system. And it is the main driving cause of climate change and variability. Climate change includes major changes in temperature, rainfall, wind pattern and other climate variables that occur over decades or longer (IPCC, 2015), whereas, Climate variability is the way climate fluctuates monthly, seasonally and yearly as above or below a long-term average value (NOAA, 2009). Change and variability affects agriculture by influencing emergence and distribution of crop pests, weeds and crop parasites, increasing the occurrence and frequency of extreme weather events, reducing water supplies and irrigation and enhancing severity of soil erosion (Bates *et al.*, 2008).

Climate change would severely compromise crop production (IPCC, 2007). An increase in temperature will speed up plant growth. In the case of an annual crop, the duration between sowing and harvesting will shorten. The shortening of such a cycle could have an adverse effect on productivity. Finally agricultural practice will be challenged by greater seasonal weather variability and change in the start and end of growing seasons. And climate related risks like flood and heavy rain in the harvesting seasons result post-harvest crop failure special cereal crops.

Exposure to climate impact, low adaptive capacity and high sensitivity of socio economic systems affect level of households‟ vulnerability. Adaptation greatly reduce vulnerability by enabling farmers adjust to change, by moderating potential damage and helping them cope with adverse consequences. The capacity to cope with extreme event is highly dependent on geographic location, time, socio-economic and environmental conditions.

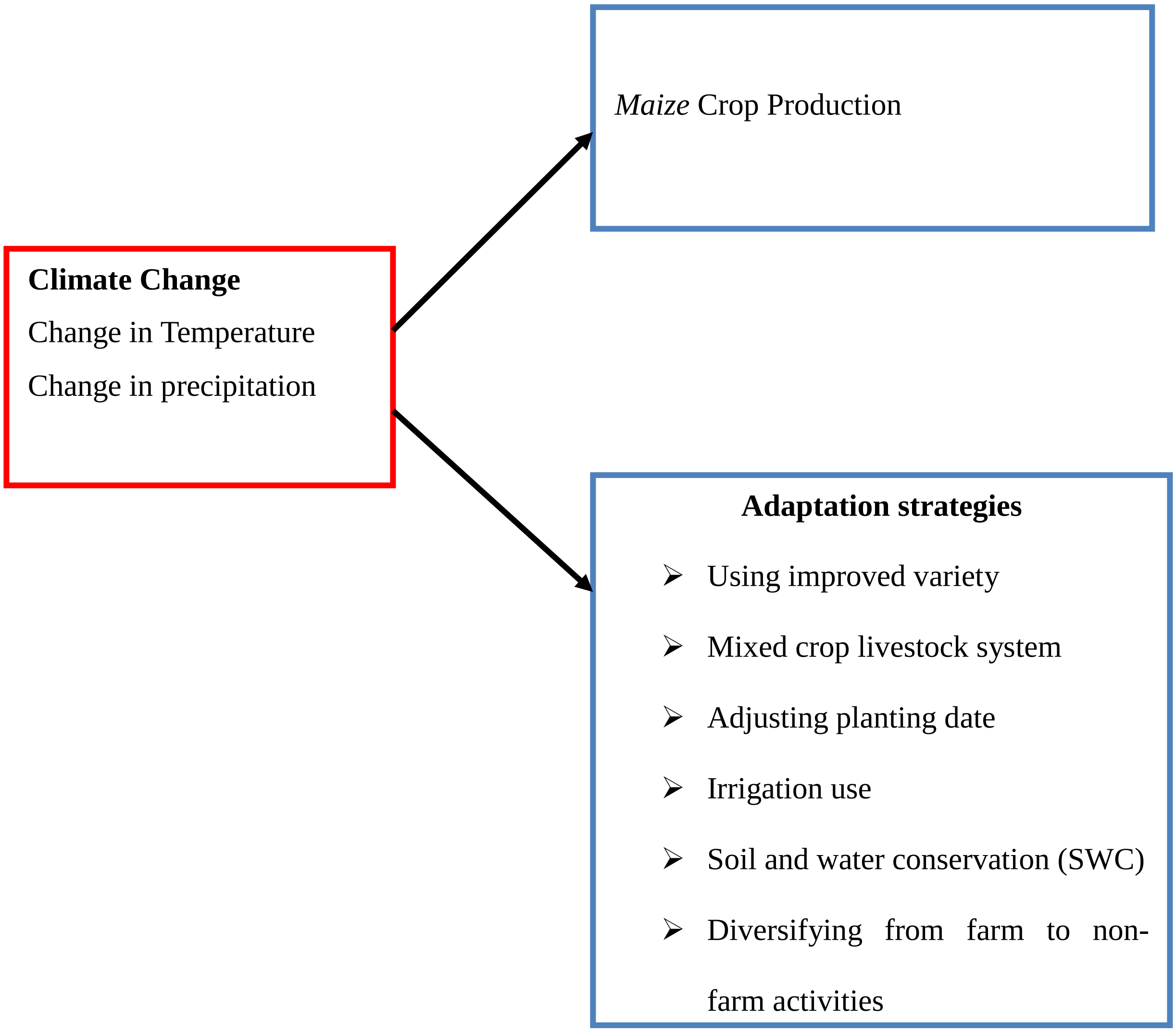

Figure 1.Conceptual framework of the study

Source: Developed by review of different literature

CHAPTER THREE

3. METHEDOLOGY

3.1. Description of the study area

The study was conducted in Hawassa Zuria Woreda, Sidama region. The Woreda is located 302 km south of Addis Ababa along the Addis Ababa- Moyale high way and the out skirts of Hawassa town. It is located at an altitude ranging from 1600 to 1800m above sea level and roughly lies between 6°83' to 7°17'N and 38°24' to 38°72'E.

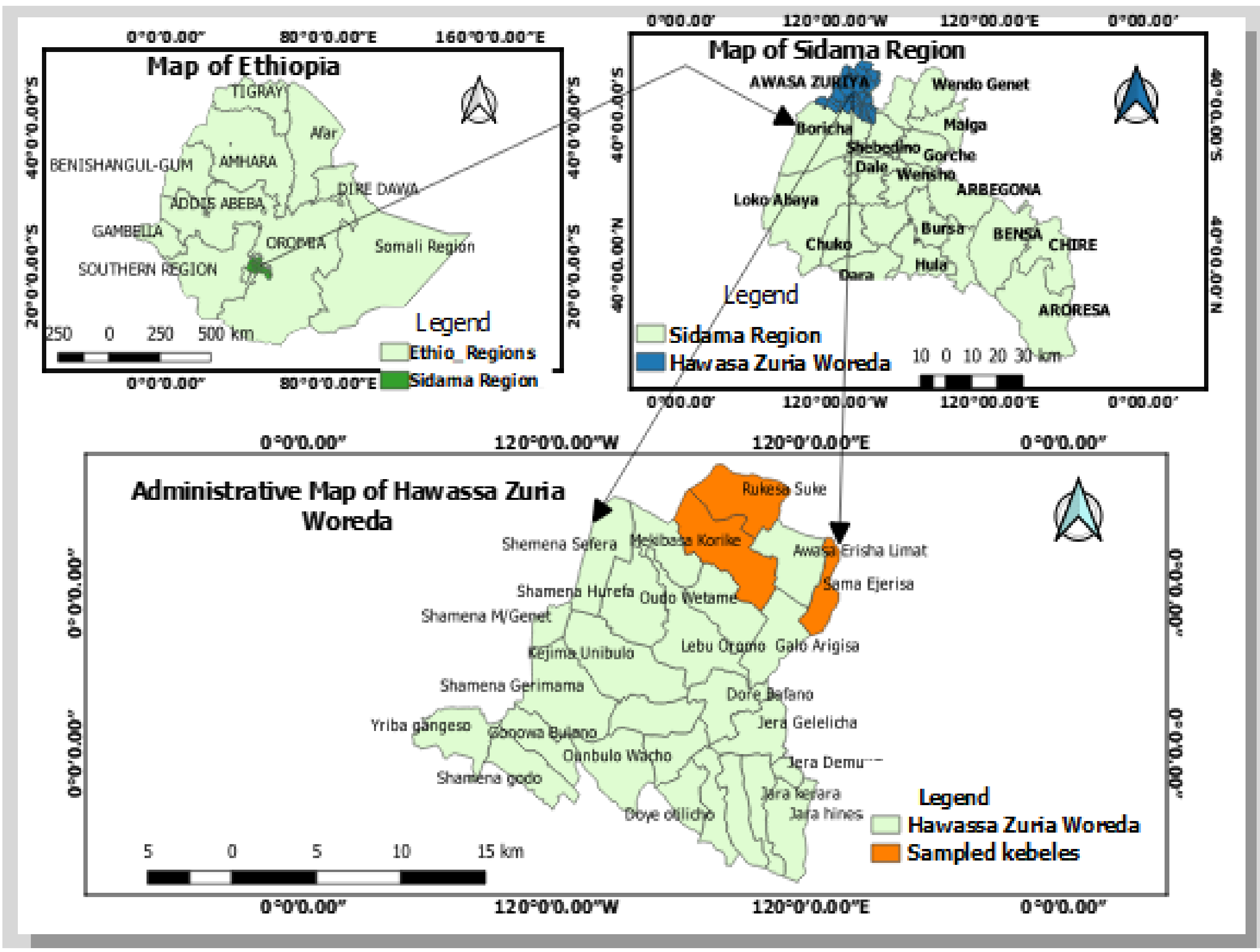

Figure 2.Map of the study area

According to the National Meteorological Agency (NMA), Hawassa Zuria Woreda receives an average annual rainfall of 900 to 1200mm with annual mean temperature of 20^{o}C (SNNPR-CSA, 2006). It is bordered by Shebedino and Boricha Woredas to the West and North by the Oromia Region and to the East by Hawassa town. 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). Based on the Hawassa Zuria Woreda Finance and Economic Development of (HZWFaED, 2015/16) report, about 136,938 and 11,284 people were estimated to live in rural and urban areas, respectively.

Besides the available land data, Lake Hawassa is the main water resource for fishing and vegetable production. The land use data shows about 8545 hectares are cultivated (for both annual and perennials crops), 21850 hectares allotted for grazing, 730 hectares covered by shrubs, 107.5 hectares cultivable, 75 hectares un cultivable, 593.2 hectares irrigated, 2374 can be irrigated respectively (WOA, 2015/2016). Tef, Maize, Haricot bean, Chat, Vegetables and livestock are the main components of the farming system in Hawassa Zuria Woreda.

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, 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 Size Determination

The study used a multi stage sampling procedure. First Hawassa Zuria woreda was purposely selected since; it is one of the lowland areas and susceptible to problems related to climate change in the Sidama Region (NMA, 2018 and WAO, 2020). Second, 3 *kebeles* which have potential of *Maize* production were also purposely selected out of the 23 rural *kebeles* based on information from Woreda Agricultural Office. Then, 184 households were selected by using systematic random sampling technique with probability proportional size for the reason that it has advantage in providing information on large group of people, within limited time and a cost effective manner (Geofrey *et al.*, 2005). In order to reduce sampling error and determine the required sample size, the researcher was used Yamane's (1967) simplified formula at 95% confidence level and 7% level of precision as shown below.

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

Where n is the sample size, N is the population size (total household heads), and e is the level of precision. $n = \frac{1917}{1+1917(0.0049)} = 184$

Table 1 Sample household size used for the study from each kebeles

No	Name of sampled kebeles	Household Size	Sample Size
1	Makibassa Korqe	683	66
2	Rukessa Suke	607	58
3	Sama Ejerssa	627	60
Total		1917	184

3.4. Data Types and Sources

The study used both primary and secondary data comprising of qualitative and quantitative variables. Primary data were collected from sample households, focusing on socio- economic & demographic characteristics of households in the study area and other essential information related to the research objectives. Additional data were also collected using household survey, FGDS and Key Informant Interviews.

Whereas, secondary data were collected from; office reports and documents of Governmental organizations (GO) and Non-Governmental organizations (NGO), from National Meteorology agency (NMA), Hawassa Zuria Agriculture and Natural Resource Office, published and unpublished materials to supplement analysis of the impacts of climate change and variability on *Maize* production and adaptation strategies of the farmers in the study area.

3.5. Methods of Data collection

The primary data were collected through various way including:-

Household survey: It is the commonly used approach in various data collection activities and it was the major source of data collection for this study. Structured questions were also prepared to collect data to achieve the major research objective areas. Socio-economic and demographic characteristics of respondents were also included in the questionnaire. In order to reduce time and communicate easily with the respondents the questionnaires were translated in to Sidaamu Afoo. The respondent sample farmers were then characterized by socioeconomic and demographic profile for the study such as; sex, age, education level, farm-land size, family size, monthly income, farm experience, livestock ownership,….etc.

Focus group discussion: 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 man 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.

Key Informant Interview: Includes Woreda Agricultural and Natural Resource Management officer, Woreda disaster prevention and preparedness officer, kebele administrators and development agents. A total 12 key informant interviews were participated 3 in each *kebeles* in order to gain more understanding on the impacts of climate change on agriculture.

Secondary data: 33 years rainfall and temperature data were obtained from National Meteorological Agency (NMA), while 15 years *Maize* production data from Woreda Agricultural and Natural Resource Office (WANRO). The temperature and rainfall trends were, thus, compared with the *Maize* data and the respondents' perception of climate change trends and with its effect.

3.6. Data entry and 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 STATA version 14.1 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. STATA version 14.1 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. Specification Empirical model

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,

$$P\ (i\ j) = \beta o + \beta 1X1 + \beta kXk + e \text{..} 2$$

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,

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

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) = α + β1X1 +β2X2 +... +βk Xk +e...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: -

VIF or CC (X_i) =$(1 - R_i^{\,2})^{-1}$…………………………………………….......................... (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).

Description and operationalization of key model variables

1. Dependent variables

Dependent variable of the model: in the findings there were some common adaptation strategies, which are all, explained by similar explanatory variables, and were identified:

I. 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.

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

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

IV. 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.

V. 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.

VI. Income Source diversification: diversifying source of income like on farm and off farm systems to increase the income of the household.

2. Independent variables

The independent variables are those variables which are expected to have influence on the dependent variable. The independent variables that are hypothesized to affect the farmers‟ adaptation decision of various factors, such as:

I. Sex household head (SEXHH): is the femaleness or maleness of household head. It is dummy variable (0 for female and 1 for male). It was hypothesized that male headed households are more adapted to climate change than female headed households.

II. Age of household head (AGEHH): 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.

III. Level of Education of the Household head (LEDUC): 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.

IV. Family size (FAMSIZE): family size is the total family number of the household.

The existence of large number of children under age of 15 and above 65 in the family could affect adaptation measure of the farm household. Hence, it was hypothesized that the family size are positively or negatively affect household adaptation measures to climate change and variability.

V. Farm land size (FMLSIZE): Farm land size is the total landholding of the household that uses for the farming activities. The farm households with holding large farm land are positively affect the use of adaptation measures to the climate change and it measures in hectare. Therefore, the variable is continuous and its expected was a positive sign for the farmer's adaptation measures to climate change and variability.

VI. Livestock Ownership (LVSOWSH): 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.

VII. 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 farmer's adaptation strategies to climate change.

VIII. Farm experience (FRMEXP): The farming experience of the household head is 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.

IX. Access to credit service (ACREDIT): The availability of credit is important for the farmers in order to make adaptation strategies. It is dummy variable indicating 0 if the farmers have access to credit 1 otherwise. Credit can be used as for the farmers to introduce new technology, to buy modernize crop, fertilizers and oxen. Therefore, thus was expected a positive sign for the farmers who are used adaptation strategies to climate change and variability.

X. Agricultural extension service (AGEXS): This is a formal service and plays a great role that affect for farmers' adaptation measures to climate change and variability. This variable is also a dummy which represent 1 if farmers get agricultural extension service 0 otherwise and the expecting sign was a positive.

Table 2.Expected signs on how the 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	+

3.6.3 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)

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

Where,

ASI = Adaptation Strategy Index

ASn = 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

3.6.4 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:

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

Where; SPI refers to rainfall anomaly (irregularity) on multiple time scales; x represents annual rainfall in the year t; x^{-} “represents the long-term mean rainfall; and $\boldsymbol{\sigma}$represents the standard deviation over the period of observation (Woldeamlak, 2009). 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).

Intra seasonal rainfall variability was analyzed using the coefficient of variation (CV).

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

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

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

Where, CV is Coefficient of Variation, SD is Standard Deviation and X^{-} is mean

3.6.5. Mann-Kendall trend analysis

Mann-Kendall trend test such as Mann-Kendall Stat (S), Kendall's tau and P-value were computed to detect the trends of temperature and rainfall. In general, the non-parametric Mann-Kendall test (Mann 1945, Kendall 1975) was used to assess the presence of significant trends in precipitation and temperature data. The Mann-Kendall statistic S of the series x is given by test (Mann, 1945; Kendall, 1975)

$$s = \sum_{i=1}^{n-1} \sum_{j=i=1}^{n} sng(x_j - x_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where, xj and x_i are the annual values in years j and i, j>i, respectively and

$$sng(x_j - x_i)\begin{cases} 1\ if\ x_j - x_i\ > 0 \\ 0\ if\ x_j - x_i = 0 \\ -1\ if\ x_j - x_i < 0 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

A positive value of S connotes and "upward trend or increasing trends", while a negative value of S indicates a "downward trend or decreasing trends".

It is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend. The variance associated with S is calculated from (Mann 1945; Kendall, 1975):

$$Var(s) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{m} t_k(t_k - 1(2t_k + 5)}{18} \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Where m is the number of tied groups and t k is the number of data points in group k. In cases where the sample size n > 10, the test statistic Z(S) is calculated from (Mann 1945, Kendall 1975):

$$Z = \frac{s-1}{\sqrt{var(s)}}\ if\ S > 0$$

Z=0 if S=0……………………………………………………………………… (12)

$$Z = \frac{s+1}{\sqrt{var(s)}} if\ s < 0$$

The trend is said to be decreasing if Z is negative and the absolute value is greater than the level of significance, while it is increasing if Z is positive and greater than the level of significance. If the absolute value of Z is less than the level of significance, there is no trend. The desired value of α (taken as 0.05 in this study) (Birhan, 2017).

3.6.6. 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.

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

3.7. Analytical framework

Table 4 provides a summary of analytical methods (models) used for each objective, types of data required for specific variables employed in the data analysis and suitable analytical software for each model.

Table 3.Analytical framework

Objectives	Type of data and data requirements	Analytical models, tests	Analytical Software
To assess long-term climatic change and variability trend specially rainfall and temperature in the study area	Time series data of rainfall (annual and seasonal) and temperature (maximum and minimum) Type of data: Time series (1987-2019)	***Mann-Kendall trend test***	Man- Kendall trend test program
To evaluate the impacts of climate change and variability on production of *Maize* in study area	*Dependent variables: Maize* yield data. *Independent variables:* Rainfall and temperature. Type of data: Time series (1987-2019)	***Correlation analysis***	STATA
Identify the climate change adaptation strategies and mechanisms used by the farming community in study areas.	*Dependent variables:* Adaptation strategies *Independent variables:* Socio-economic and demographic characteristics of household	**Adaptation Strategy Index (ASI)**	Microsoft Excel
To assess the major factor that influence farmers' climate change adaptation strategies.	*Dependent variable:* adaptation strategies. *Independent variables:* Sex, age, household size, education, household land size, farming experience, monthly income, access to credit service, access to extension services and livestock ownership. *Type of data:* Household survey data	***Multinomial Logit Model***	STATA

CHAPTER FOUR

4. 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 farming households

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

Gender of the household head: _

During the survey 80.4 % were male while 19.6 % were female in sampled *kebeles* (Table 4). 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.

Age of the household head: _

The highest proportion of the respondents (34.2%) was lies between 46 and 65 years, while only13% was between 18-25 years (Table 4). This implies that both young and old people were involved in farming activities. 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).

Family size: _

The family size of respondents was higher in which about 46.2% of the sampled farmers had 6-9 family members, 44.0% have more than 9 (Table 4). 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.

Marital status of the household head: _

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 4). 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).

Educational status of the household heads: _

The educational status of the sampled households result revealed that 51.1% were (cannot read and write), 23.9% have primary level education (1 – 4), 8.7% secondary education level (5 – 8), 5.4% high school level and 10.9% have attended college level education (Table 4). 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).

Household land size: _

Data collected on possession of land revealed that out of the total 184 respondents 40.6% acquired 0.5-1 hectares, 39.1% acquired 1.5-2 hectares, 17.4% acquired 2.5-3 hectares and 2.7% acquired >3hectares (Table 4). This indicates about 80% of the farmers acquired < 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 variability. For instance, Ehiakpor *et al*., (2016) noted that farmers with larger farm sizes are more likely to perceive climate variability than their counterparts with smaller farm sizes.

Table 4.Socio-economic and demographic characteristics of the respondents**.**

No	Characteristics	Frequency	Percentage (%)
1	**Sex of respondents**		
	Male	148	80.4
	Female	36	19.6
2	**Marital status**		
	Married	150	81.5
	Single	26	14.1
	Widowed	8	4.3
3	**Family size**		
	1-2	4	2.2
	3-5	14	7.6
	6-9	85	46.2
	>9	81	44
4	**Age category**		
	18-25	24	13.0
	26-35	32	17.4
	36-45	51	27.7
	46-65	63	34.2
	>65	14	7.6
5	**Educational status**		
	Cannot read and write	94	51.1
	Primary(1-4)	44	23.9
	Secondary(5-8)	16	8.7
	High school(9-12)	10	5.4
	College	20	10.9
6	**Household land size (hectare)**		
	0.5-1	75	40.6
	1.5-2	72	39.1
	2.5-3	32	17.4
	>4	5	2.7

Source: household survey result in the study area, 2020

Farming experience

The household survey result shows that, 40.2% of the respondents have got farming experience of more than 30 years, while 26.6% are with 21-30 years of experience (Table 5). This result indicates that more than two-third of the respondent farmers is more experienced (more than 20 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).

Table 5 Farm experience of respondents

Years	**Frequency**	**Percent (%)**
0	8	4.3
1-5	7	3.8
6-10	19	10.3
11-20	27	14.7
21-30	49	26.6
>30	74	40.2

Source: household survey result in the study area, 2020

Source of income

The household survey results revealed that, income sources for the majority 63.6% of the sample households are from on-farm activities (Figure 3). However, non-farm activities and off farm activities are not significantly adopted in the sample areas.

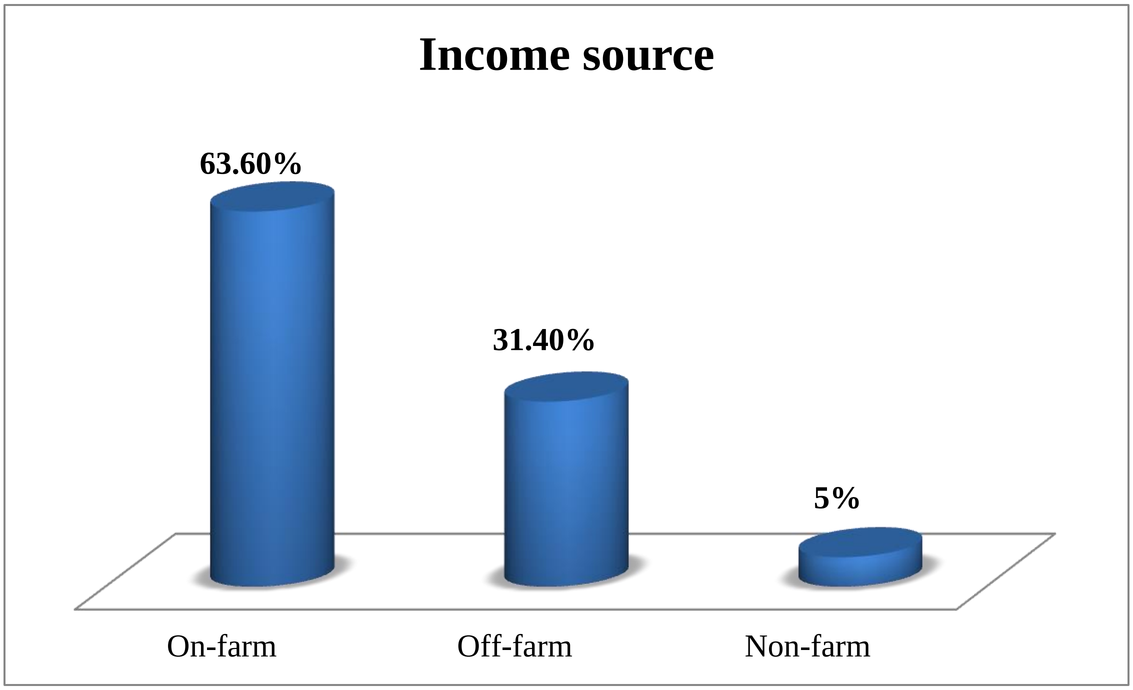

Figure 3.*Income source of the respondents*

Source: Household survey result in the study area, 2019

4.2 Perceptions of Farmers on Climate Change Indicators and Variables

4.2.1 Indicators of climate change

In this study, the sample respondents were asked to identify the intensity of different climate-related problems in the study area. The result showed that, 20.10 % of the respondents labeled crop failure as the primary indicator of climate change in the study area (Fig 4). According to household survey results, 31.50% and 24.40% of the respondents reported that shortage of rainfall and increment of temperature are the main causes for the crop failure, respectively. Poor livestock productivity, decreased income of agriculture and loss of some plant and animal species are also the other climate change-related problems reported by the respondents. On the other hand, the increase of flood incidence and severe soil erosion were chosen by the respondents as the least two indicators of climate change.

According to FGDs climate change and variability observed in terms of temperature rise, high frequency of recurrent drought and shortage of rainfalls were among the indicators of climate change in the study area (Figure 4). Unexpected rain during harvesting time and sometimes heavy rainfall accompanied with strong wind was also stated as an indication for climate change.

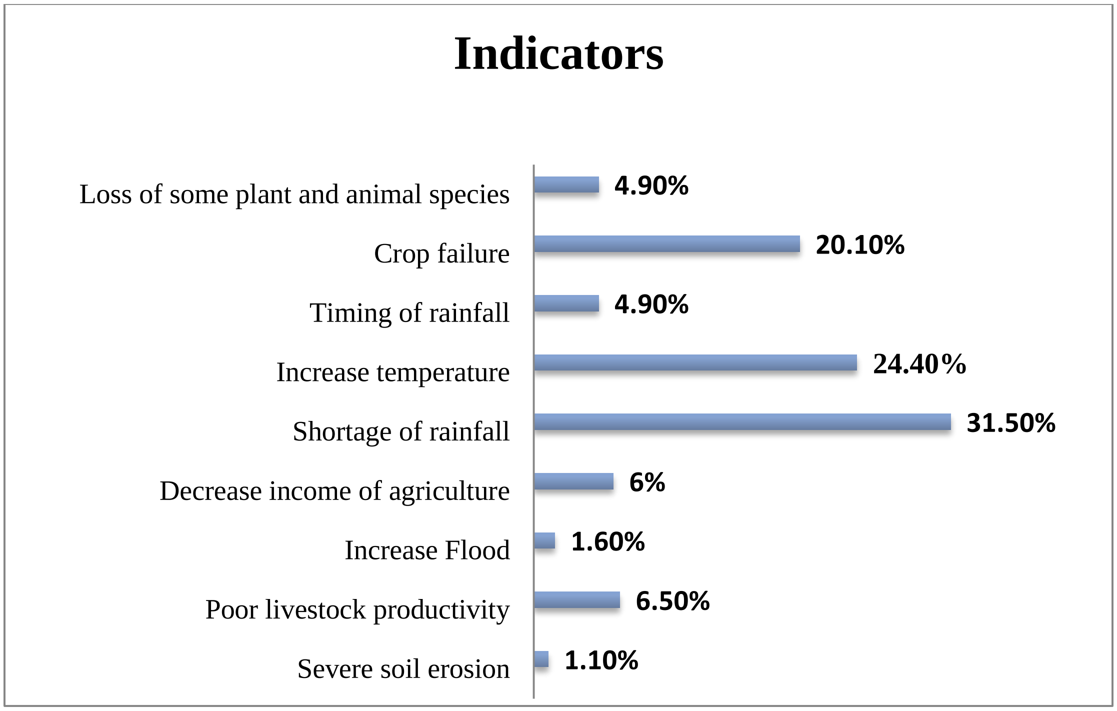

Figure 4.Indicators of climate change.

Source: Household survey result in the study area, 2020

4.2.2 Perceptions of Farmers on Climate Variables

I. 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 (Figure 5). Of the interviewed respondents, 81%

felt a decrease in the amount of rainfall. However, 11%, and 8% respondents felt an increase and no change respectively. 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).

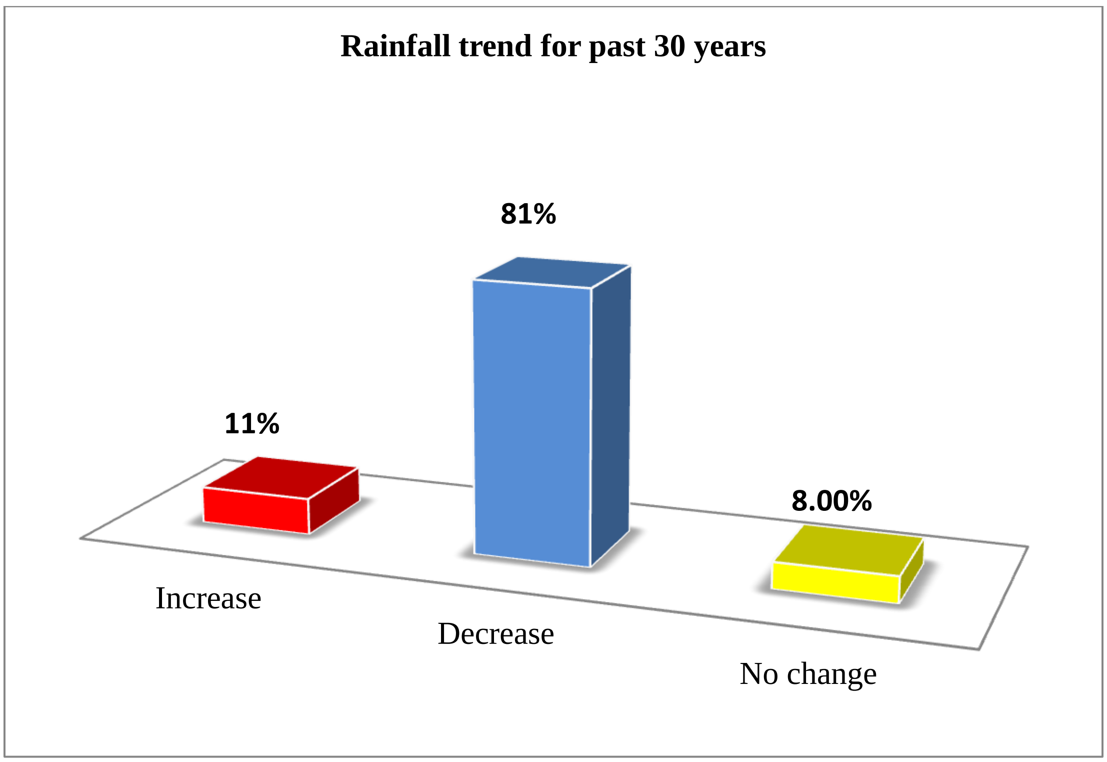

Figure 5.Trend of rainfall in Hawassa Zuria Woreda for past 30 years

Source: household survey result in the study area, 2020

II. Farmers perception on temperature

The majority of respondents (85.30%) perceived an increase in temperature over the past

33 years (Figure 6). About 11.40% perceived a decreasing in temperature, and 3.30% 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.

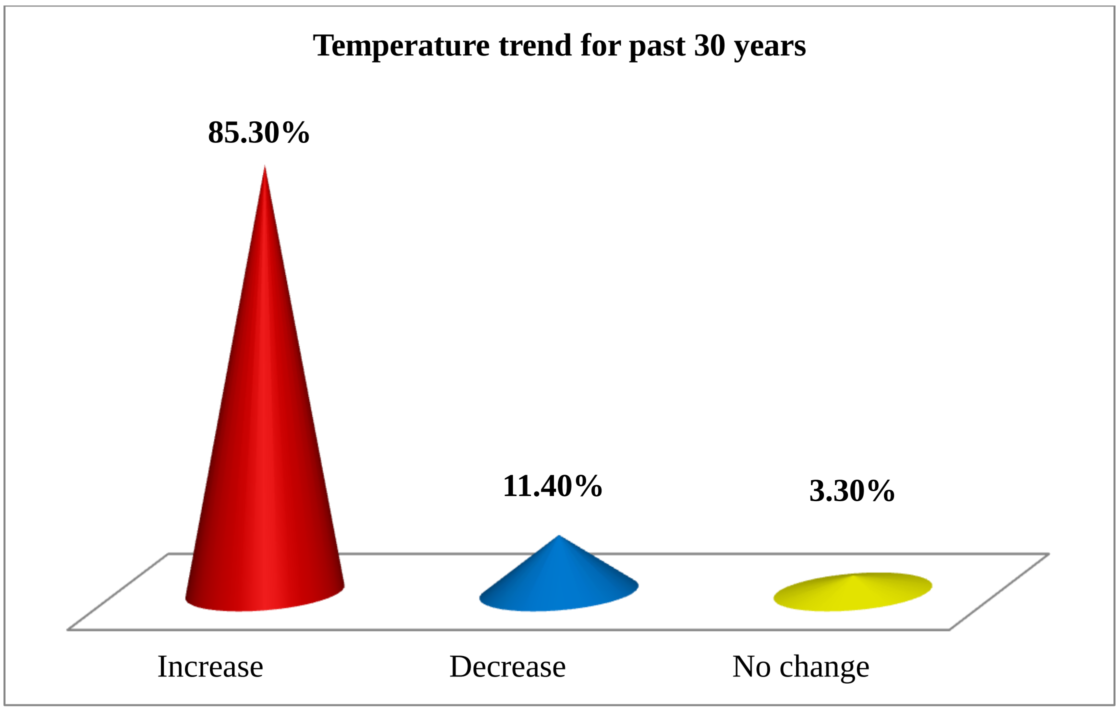

Figure 6.Trends of temperature for the past 30 years

Source: Household survey result in the study area, 2020

4.3. Climate Variables Trend Analysis

4.3.1. Rainfall trends

Mann-Kendall trend analysis, results indicated increasing rainfall trend in Hawassa Zuria

Woreda (Table 6). Hence, significance test for the trend is of paramount importance in order to predict the occurrence of extreme weather events and their likely impacts. However, the trend test at 0.05 levels was not statistically significant.

Table 6.Rainfall Mann-Kendall's trend test results (1987-2019)

Rainfall (mm)	**Mann-Kendall Trend(S)**	**Significant (α)**	**Sen's Slope**	**Trend**
Annual	1.01	-	3.539	No significant trend
Summer (Kiremt)	1.56	-	2.226	No significant trend
Spring (Belg)	0.9	-	1.471	No significant trend

Source: National Meteorological Agency (NMA, 2020)

The same time, the trend equation of the annual rainfall shows an increased trend with 2.22 mm per year over the past 33 years (1987-2019) (Figure 7). The statistical analysis also revealed an increase in annual rainfall was insignificant with large inter-annual fluctuation. This result is in line with the findings of (Nicholson *et al.*, 2000) who reported variability in annual rainfall in the semi-arid and sub humid zones of West Africa.

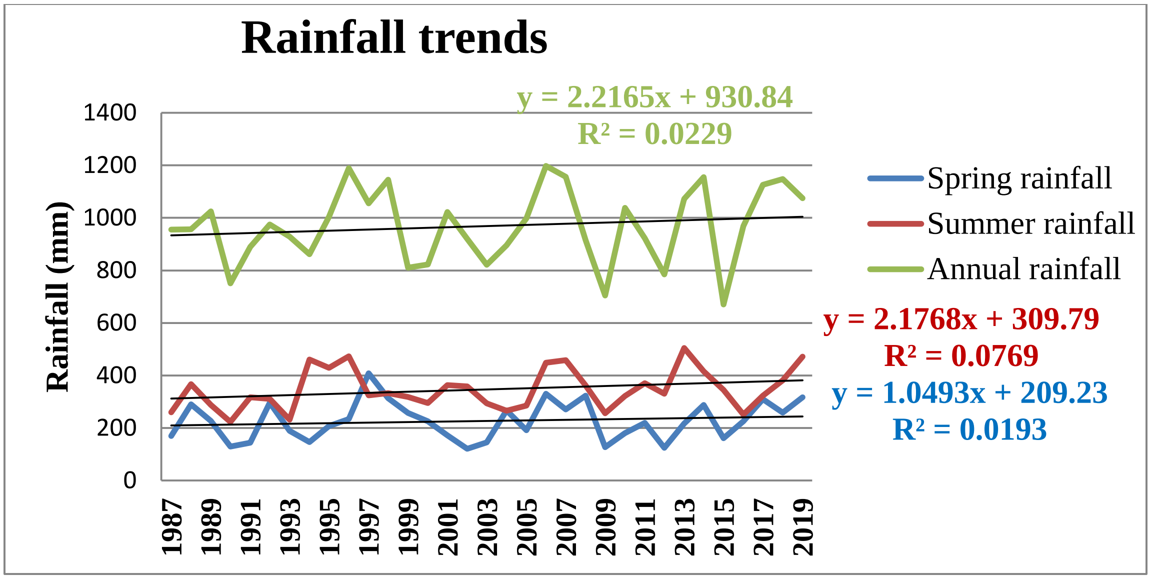

Figure 7.Annual and seasonal rainfall trend for past 33 years (1987-2019)

Source: National Meteorological Agency (NMA, 2020)

The data obtained from Ethiopia Metrological Agency revealed that the coefficient of variation of study area were 21.9% and 32.2% for summer (Kiremt) and spring- (Belg) respectively, which indicates that there was very high variability of rainfall especially during the belg season, while the kiremt rainfall variability was moderate between 1987-2019 (Table 7). 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 7.Annual and seasonal rainfall analysis (1987-2019)

Rainfall (mm)	**Minimum (mm)**	**Maximum (mm)**	**Mean**	**Stdv (mm)**	**CV (%)**
Annual	670.9	1197.9	968.5	142	14.7
Summer (Kiremt)	223	505.9	346.8	76	21.9
Spring (Belg)	120.5	408.8	227	73	32.2

Source: National Meteorological Agency (NMA, 2020)

According to National Meteorological Agency of Ethiopia (NMA), in the Sidama Region Hawassa Zuria Woreda, 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. The summer (kremit) and spring-(belg) rainfalls have shown an increasing trend per year in the period noted.

The summer rain in this study has shown an increasing trend with 2.17 mm per year in the period noted but not stastically significant (Table 6). 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 1987, 1988, 1990, 1993, 1994, 1995, 1996, 2004, 2006, 2007, 2010, 2013, 2016 and 2019 which were below the average of rainfall in the study area. This has to be shown by SPI values.

The spring/belg season rainfall has shown an increasing trend from1987-2019 by 1.05 mm per year in the study area despite not significant (Table 6). Generally, seasonal time series rainfall data did not show statically significant trend similar to the annual time series data.

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 17 years and below average rainfall for 16 years. Based on standard precipitation index procedure, the rainfall period of study area approximately categorized in to three decades (Figure 8). First decade (1987-1996) was relatively drier, while the second (1997-2006) decade and third decades (2007-2019) were wet, confirming the slightly increasing trend already observed in the trend analysis of this study

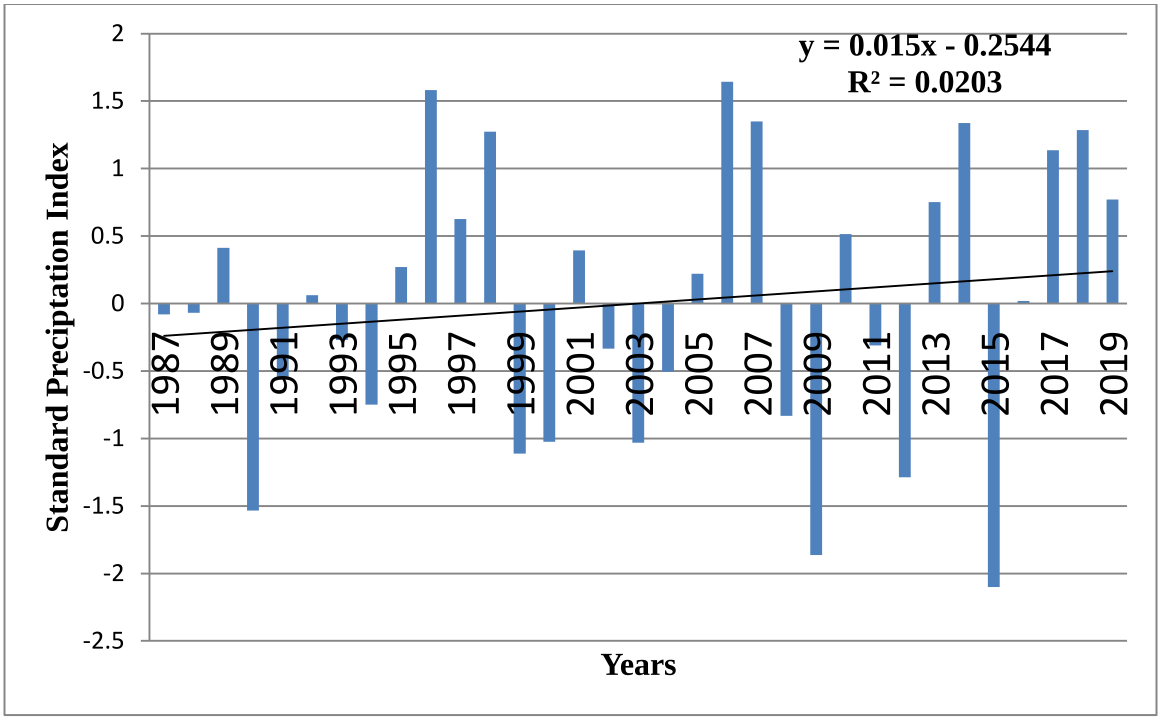

Figure 8 Annual SPI of Hawassa Zuria Woreda

Source: National Meteorological Agency (NMA, 2020)

4.3.3. Temperature trends

The trend analysis of annual temperature (minimum and maximum) in the current study shows significant increase in the Hawassa Zuria Woreda during the past 33 years (Table 8).

Table 8.Average annual and seasonal temperature trend and variability (1987-2019)

Temperature (^{o}C)		Mean	Stdv (^{o}C)	CV (%)	Mann-Kendall Trend	Significant (α)	Sen's Slope
Annual	Minimum	13.15	0.70	5.39	5.53	***	0.061
	Maximum	27.48	0.46	1.69	2.93	**	0.026

Source: National Meteorological Agency (NMA, 2020)

The mean minimum temperature increased by 0.063^{o}C per annum during 1987-2019 (Figure 9). The Mann- Kendall trend test also showed that, the mean maximum temperature significantly increasing by 0.028^{o}C per annum. (UNDP, 2008) report also revealed an increasing trend of mean annual temperature of Ethiopia by 0.37°Cper decade. Similarly, according to (NMA, 2007), the average annual maximum temperature in the country has increased by 0.1°C per decade. 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.

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).

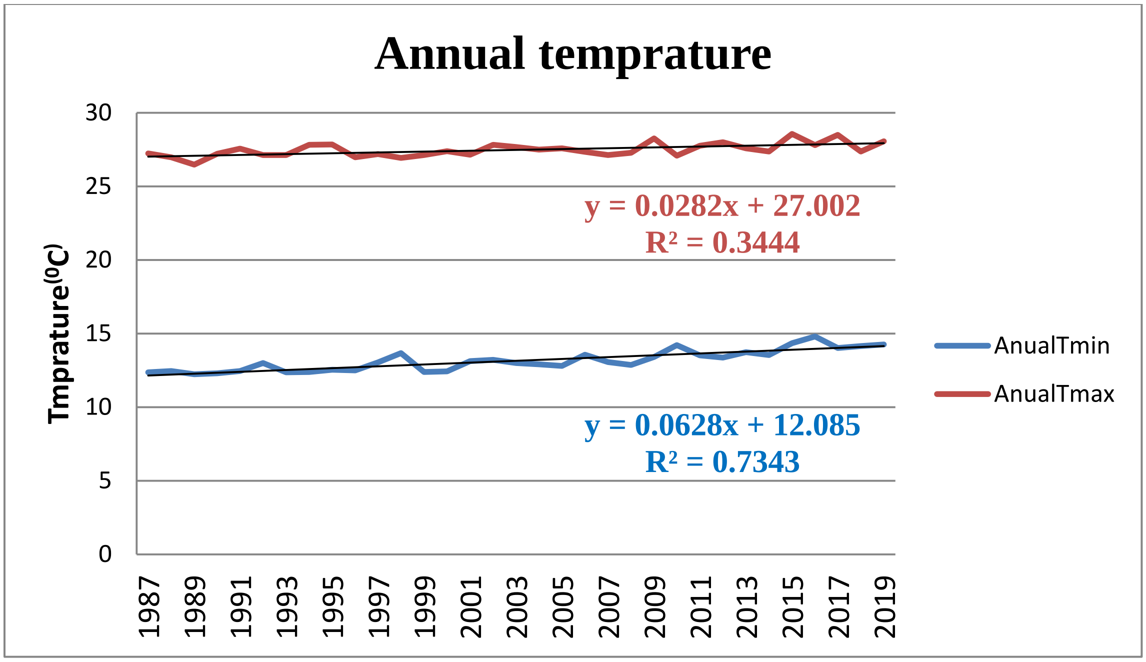

Figure 9.Annual minimum and maximum temperature trend for 33 years (1987-2019)

Source: National Meteorological Agency (NMA, 2020)

4.4 Trend in *Maize* productivity

Time series yield data of the period from 2004 to 2018 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 0.04qt/ha per annum (Figure 10). Coefficient of determination value also indicated that, about 0.22% of the decline in *Maize* productivity in the study area accounted for the time series of 2004-2018. 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.

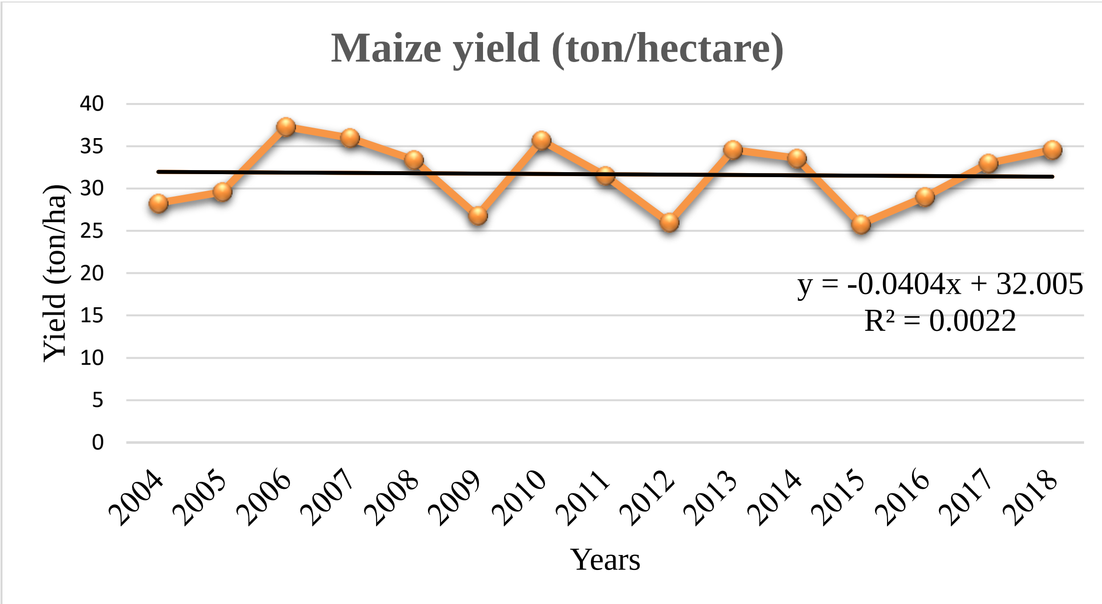

Figure 10. Maize productivity trend for 12 years (2008-2019)

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 variability and change.

4.5 Relationship between *Maize* productivity and climate variables

The correlation between *Maize* productivity and annual rainfall is 0.88 which indicates that there is strong positive linear relationship between them, when the other independent variables remain constant (Table 9). Similarly, the correlation between *Maize* productivity and summer (keremt) as well as Belg rainfalls are 0.69 and 0.68 showing the existence of strong positive linear relationship between the trend of maize productivity and both seasonal rainfalls respectively. On the other hand, the Correlation between yield of *Maize* productivity and annual maximum temperature is -0.69 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 9.Correlations between maize yield, rainfall and temperature at study area

Correlation between maize yield and Rainfall (Annual, Belg and Kiremt RF)		
Variable	**correlation(r)**	**Sig(p-value)**
Annual RF	0.883***	0.0000
Summer(keremt) RF	0.690***	0.0044
Spring(Belge) RF	0.679***	0.0054
Correlation between maize yield and	**Annual temperature (Min T^O and Max T^O)**	
Annual Min T^O	-0.006	0.9825
Annual Max T^O	-0.690***	0.0044

***, **, * Correlation is significant at the1%, 5% and 10% level 2-tailed
Source: National Meteorological Agency (NMA) and Hawassa Zuria Agriculture and Natural Resource Office (2020)

4.6. Farmers' Adaptation Strategies and Mechanisms to Climate Change and variability

Based on the data from the farm households survey, the results indicated that 89.1% of farmers are using various adaptation strategies and mechanisms to avert the effects of climate change and variability on their farm, while, 11.9% of the farmers are not using any of the adaptation strategies being adopted by their partners. 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 impact of climate change thus combination of several strategies is likely to be more effective than a single strategy. The adaptation mechanisms of the studied households who have been using various livelihood strategies in study area is presented below based on rank (Table 10).

Out of six adaptation strategies, being adopted by the farmers, using improved crop varieties 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 was taken as the common climate change adaptation strategy of farmers in Southern Ethiopia.

Mixed crop livestock system was also identified as the second in adaptation strategy in the current study. These results indicated that, farmers use mixed crop livestock farming as adaptation strategy to reduce the associated risks of climate change in the Woreda. In line with this, previous studies by (Lemma, 2016) also demonstrated that mixed crop livestock farming adaptation practice was the dominant adaptation strategy to reduce climate change-related problems in the drier areas of Ethiopia.

The third most important adaptation strategy was the “Soil and water conservation (SWC)”. Construction of physical soil and water conservation structures is also being practiced by the farmers as one of the most important adaptation strategies in the study area.

The other climate change adaptation strategies include; adjusting planting date (early and late planting), enhancing traditional irrigation schemes (including water harvesting) and income source diversification were practiced among others across the study kebeles.

Table 10.Ranked order of the adaptation strategies to climate change in study area.

Adaptation measures	Importance on your farm				ASI	Rank
	High	Medium	Low	No		
Improved Maize varieties	93	56	13	-	404	1
Mixed crop-livestock system	87	16	7	52	300	3
Adjusting planting date	79	64	14	5	379	2
Small-scale irrigation	13	7	4	138	57	6
Soil and conservations practices	42	57	18	45	258	4
Income diversification	26	41	22	73	182	5

Source: Computed based on Survey result (2020)

4.7. Factors influencing farmer's adaptation strategies

The results of MNL model showed that factors influencing farmers' choice of adaptation strategies to climate change and variability adaptation and significant levels of the parameter estimates in the study area shown below in Table 11. Accordingly, the likelihood ratio statistics as indicated by ch^2 statistics (LR chi-square (54) = 218.41 are highly significant (P < 001)) suggests that the model has strongly explanatory power. In all cases, the estimated coefficients should be compared with the base category using improved *Maize* variety. Therefore, table 11 represents the MNL results along with the level of statically significance.

In this study, multi-colinearity between the independent variables was tested using VIF (Appendix, 6). It measures the degree to which the interrelatedness of the variable with other predictor variables inflates the variance of the estimated regression coefficient for that variable. That is, as the extent of co-linearity increases, the variance of an estimator increases, and in the limit it can become infinite. On the contrary, if there is no co linearity between independent variable VIF will be 1 (Gujarati, 2004).

Similarly, the contingency coefficients, which measure the association between dummy variables, were computed in order to check the degree of association among the dummy variables. The values of contingency coefficient ranges between 0 and 1, in which zero indicates no association between the variables and values close to 1 indicates a high degree of association. Accordingly, there was no serious problem of association as the contingency coefficients were not exceeding 0.07 (Appendix, 6 and 7).

The coefficients of MNL tell us about the direction of effect of the independent variables on the dependent (response) variable; despite they do not represent actual magnitude of change or probabilities.

Table 11.Parameter estimates of multinomial logit model for Climate Change and variability adaptation strategies conducted in study area.

Explanatory Variabiles	**No adaptation**	**Adjusting planting date**	**Irrigation use**	**Soil and water conservation (SWC)**	**Income source diversification**	**Mixed-crop livestock system**
	Coeff. (P-value)	Coeff. (P-value)	Coeff. (P-value)	Coeff. (P-value)	Coeff. (P-value)	Coeff. (P-value)
SEX	-1.403461 (0.214)	1.568755 (0.208)	.0364449 (0.970)	.5689739 (0.467)	.3584542 (0.714)	17.36367 (0.988)
AGE	-.7651306 (0.157)	1.410335 **(0.012)****	-2.188099 **(0.040)****	-.5648238 (0.215)	-.4846985 (0.713)	-.4480106 (0.485)
LEDUC	-1.642688 **(0.005)*****	-.3707495 (0.185)	-.7268436 **(0.051)****	-.4846384 **(0.021)****	-.3294816 (0.361)	-.3894784 (0.075)
FAMSIZE	-.0008796 (0.999)	-.0354216 (0.939)	1.153363 **(0.051)****	2.230367 **(0.000)*****	.7553343 (0.133)	.1325139 (0.864)
FRMLAND	-.6325019 (0.286)	-.2107334 (0.526)	.4628544 (0.319)	-.2392367 (0.420)	-.542865 **(0.018)****	-.2568618 (0.391)
ACEXTSERV	-6.261509 **(0.000)*****	.2536802 (0.771)	-1.606016 (0.254)	-.2261105 (0.752)	.07036 (0.998)	.3601405 (0.531)
ACCRDTSERV	18.36074 (0.989)	17.48265 (0.995)	-1.606016 (0.117)	-.866796 (0.107)	.154993 **(0.080)***	-.5406243 (0.367)
FARMEXP	-.4478875 (0.403)	-.4580128 (0.396)	.6739705 (0.460)	-.328131 (0.550)	.899735 (0.548)	-.2568618 (0.360)
LIVOWSHIP	.6512115 (0.224)	.2672747 (0.513)	.0589879 (0.912)	.2546681 (0.591)	.2815614 (0.574)	-.0008796 (0.999)
MTHLTINC	-1.140437 **(0.033)****	-1.018812 **(0.061)***	1.908943 **(0.001)*****	-.2007797 (0.552)	.2440135 (0.593)	-.6325019 (0.286)

Bases category using improved *Maize* variety

No_ of observation 184

Prob $>X^2$ 0.0000

Pseudo Rsquare0.3322

Notes: ***, **, * denote significant at 1%, 5% and 10% respectively.

Source: Computed by STATA version 14.1 based on survey result (2020)

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 improved *Maize* variety to climate extreme events. The marginal effects, along with the levels of statistical significance are also presented below (Table 12).

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 12). 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 mixed crop livestock system as an adaptation strategy to climate change is increased by 10.4%, 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 6.3% with the p-value of (<5%), 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 8.5% with the p-value of (<0.05%). Similarly, as a year increase in the age of the household head, the probability of farmers not use adaptation strategy decrease by 4.2% at less than (1%) 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 16% at less than (1%) significant, holding other variables constant (Table 12). (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 5.3% 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.

Education: The results of this study revealed significant and negative effects of education on soil and water conservation, mixed crop livestock system, irrigation and no adaptation(resistance to accept adaptation) strategies to climate change and variability. However, as the education of household head increases by one level, the probability of adopting planting date adjustment as adaptation strategy increases by 2.1% with the p-value of (<10%), keeping other variables constant. While no adaptation (resistance to accept adaptation) strategies decreases by 4.3% with the p-value of (<5%), keeping other variables constant (Table 12). On the other hand the use of mixed crop livestock system 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 diversification by using to non-farm adaptation options significantly increases at (<1%) significant level.

Livestock ownership: is significant explanatory variable in this study. It was positively influencing the farmer's adaptation decision of taking mixed crop livestock system as a climate change adaptation measures. A one unit increase in the number of livestock owned by household, the probability of using mixed crop livestock system as adaptation strategies to climate change and variability also increased by 5.3 % with the p-value of (<5%), keeping other variables constant (Table 12).

Monthly income: monthly income of the household head is also a significant explanatory variable as shown in the Table 12. The result of this analysis reveals that 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 monthly income of household, the probability of farmers to use adaptation strategies of irrigation increased by 7.9%. And also a one percent (ETB) increases monthly income of household, the probability of farmers no adaptation (resistance to accept adaptation) strategies decreasedby 3.6% with p-value of 0.024, keeping other variables constant (Table 12). This result is in line with the outcome of (Tagel, 2013).

Table 12 Marginal effects from the multinomial logit model on the Climate Change and variability adaptation strategies.

Explanatory Variables	**No adaptation**	**Mixed crop livestock system**	**Adjusting planting date**	**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 (0.104)	-.0401405 (0.513)	.0961736 (0.157)	-.0015023 (0.966)	.0492153 (0.428)	-.007133 (0.849)
AGE	-.0424385 **(0.006)*****	.1042483 **(0.003)*****	.0634295 **(0.020)****	-.0854037 **(0.028)****	-.0564898 **(0.067)***	.0121602 (0.664)
LEDUC	-.0430618 **(0.026)****	-.0979342 **(0.000)*****	.0216806 **(0.074)***	-.0147778 (0.273)	.0040355 (0.798)	.0093568 (0.392)
FAMSIZE	-.0151262 (0.455)	-.0537658 **(0.049)****	-.0215596 (0.304)	.0197537 (0.286)	.1644352 **(0.000)*****	.0446878 **(0.050)****
FRMLAND	-.0183899 (0.403)	-.0347493 (0.132)	-.0012752 (0.936)	.019889 (0.238)	-.0191701 (0.377)	.0378734 **(0.000)*****
ACEXTSERV	-.2537563 (0.527)	-.0028807 (1.000)	-.0204231 (0.998)	.0111775 (0.999)	-.1503477 (0.995)	.6196739 (0.995)
ACCRDTSERV	.6232141 (0.991)	-.476017 (0.994)	.8840636 (0.995)	-.103877 (0.968)	-.2957667 (0.985)	-.0014629 (1.000)
FARMEXP	-.0197507 (0.282)	.0265215 (0.509)	-.0279324 (0.284)	.02564 (0.460)	.0246146 (0.500)	-.0207538 (0.516)
LIVOWSHIP	.0149752 (0.437)	.0532063 **(0.031)****	-.0032614 (0.869)	-.002473 (0.900)	.0067161 (0.793)	-.0237183 (0.265)
MTHLTINC	-.0367241 **(0.024)****	-.0141428 (0.602)	-.0439451 (0.132)	.0790247 **(0.000)*****	-.0162761 (0.491)	.0150112 (0.320)

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

Source: Computed by STATA version 14.1 based on survey result (2020)

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study attempted to investigate the impact of climate change and variability on *Maize* production and adaptation strategies in Hawassa Zuria Woreda. The meteorological data confirmed that, the rainfall in the study area is characterized by insignificant 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 33 years (1987-2019). Annual temperature in the study area showed increasing trend for the last three decades. The study has also confirmed that, Hawassa Zuria Woreda 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 positively significant correlation with summer and spring rainfalls. Whereas, *Maize* productivity has shown weak and non-significant correlation with the annual minimum and also weak negative and significant correlation with annual maximum temperature.

The most common adaptation options of the farmers in response to impacts of climate change and variability on crop *Maize* production in the study area include: using improved crop varieties, mixed crop and livestock system, using irrigation, soil and water conservation, adjusting planting date 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, Poor livestock productivity, decrease income of agriculture, lapse of rainfall time and loss of plant and animal species, as well as severe soil erosion are the most common climate change-related hazards 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 logistic regression model used to analyze the relationship between the socioeconomic characteristics and farmers' choices of adaptation strategies to climate change indicated that age, education, family size, monthly income, livestock ownership and farm size had significant influence on farmers' choice of climate change adaptation strategies. On the other hand, sex, access to extension service, access to credit service and farming experience of households did not impose significant impact on farmer's adaptation measures. The Mann Kendall test, on the other hand, demonstrated on-significant increasing trend both in annual and seasonal rainfall.

5.2. Recommendations

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

1. Ministry of education and different NGOs invest more in education since educated households performed better than non-educated in using yield increasing technology packages which could increase farm income.
2. National meteorology agency install meteorological station in the Woreda 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 manage ment practice with productivity enhancing interventions including irrigation to supplement crop water requirement in Hawassa Zuria Woreda.
5. Integrate indigenous knowledge with science based technologies in order to support adaptation capacity of the farming community.

REFERENCE

Abate Fayesa (2009). Climate change impact on livelihood, vulnerability and coping mechanisms: A Case study of west arsi zone, Ethiopia. Lund University Master's Program in Environmental Studies and Sustainability Scince (LUMES)

Adesina F.O, W.O. Siyambola, F.O Oketola, D.A Pelemo, L.O Ojo, A.O. Adegbugbe. (2016). Potentials of agroforestry for climate change mitigation in Nigeria: Some preliminary estimates. Glob. Ecol. Biogeogr. vol. 8, Pp. 163–173.

AfDB.(2011). "The Cost of Adaptation to Climate Change in Africa." Tunis, Tunisia. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and Operations/Cost of Adaptation in Africa.pdf.

Anbesu, B., (2013). Farmers Perception and Adaptation to Climate Change and Variability Doctoral dissertation, Addis Ababa University, Ethiopia.

Aranjuelo, I., Irigoyen, J. J., Nogués, S. and Sánchez-Díaz, M. (2009). Elevated CO2 and water-availability effect on gas exchange and nodule development in N2-fixing alfalfa plants. Environ. Exp. Bot., 65, 18–26.

Armstrong W, Drew, M.C, (2002) Root growth and metabolism under oxygen deficiency. In Plant roots: the hidden half (3rd Edn), A Eshel and U Kafkafi (Eds.), Marcel Dekker, New York, USA, pp. 729-761.

Ayumah, R., (2017). Climate variability and food crop production in the Bawku Municipality Doctoral dissertation.

Bale, J.S, Masters GJ, Hodkinson ID, Awmack C, Bezemer TM, et al. (2002) Herbivory in global climate change research: direct effects of rising temperatures on insect herbivores. Global Change Biol 8: 1-16.

Bals, C., Harmeling, S. and Windfuhr, M. (2008).Climate change, food security and the right to adequate food.Diakonie katastrophenhilfe, Brot fuer die welt and Germanwatch. Stuttgart, Germany.

Bates, B, Kundzewicz ZW, Wu S, Palutikof J (2008). Climate Change and Water: IPCC Technical Paper VI. Geneva, Switzerland: IPCC Secretariat. Accessed July 10, 2016.https://www.ipcc.ch/pdf/ technical-papers/climate-change-water-en.pdf.

Battisti, D.S, Naylor R.L (2009) Historical warnings of future food insecurity with unprecedented seasonal heat. Science 323: 240-244.

Belay, A., Recha, J.W., Woldeamanuel, T., Morton, J.F., (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia.Agric. Food Secur.6 (1), 24.

Bikila, A., (2013). Farmers' Perception and Adaptation to Climate Change and Variability: The Case of Dodota Woreda, Arsi zone, Oromia Region, Ethiopia. Addis Ababa University.

Birhan, G. (2017). Impacts of climate change on crop yields in south Gonder zone, Ethiopia. World Journal of Agricultural Research 5 (2): 102-110.http://pubs.sciepub.com/wjar/5/2/6

Brooks, N. (2003) 'Vulnerability, risk and adaptation: a conceptual framework', Tyndall Centre for Climate Change Research Working Paper 38. November.

Brown, M.E. (2009). Markets, climate change and food security in West Africa. Environmental science and Technology, 43,p. 8016-8020.

Bryan, E., Temesgen Deressa, Gbetibouo, G.A., and Ringler, C., (2010). Adaptation to Climate change in Ethiopia and South Africa: options and constraints. Available from: http//www. Science direct.Publications. Com

China Meteorological Disaster Yearbook (CMDY)(2015). China Meteorological Disaster Yearbook; China Meteorological Press: Beijing, China.

Climate change, (2007).impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the inter-governmental panel on climate change.Eds. Parry, M., Canziani, O.F., Paluticof, J., Vander Linden, P.J., and Honson. C.E., Cambridge: Cambridge university press.

Cogent Food & Agriculture (2016), 2: 1210557. Department of Agricultural and Resource Economics, University for Development Studies, Tamale, Ghana

Conway D, Schipper ELF (2011). Adaptation to climate change in Africa: challenges and opportunities identified from Ethiopia. Global Environmental Change 21:227-237.

Cooper, P. J. M., Rao, K. P. C., Singh, P., Dimes, J., Traore, P., Dixit, P., Twomlow, S.

J.,(2009). Farming with current and future climate risk: Advancing a'Hypothesis of Hope 'for rainfed agriculture in the semi-arid tropics. Jounal of SAT Agricultural Research 7, 1-19.

CSA, (2008). FDRE CSA Agricultural Sample Survey: Report on area and production of Belg Season Crops for Private Peasant holding, Addis Ababa.

Department for Food and International Development (DFID),(2004). Adaptation to climate change: The right information can help the poor to cope. Global and local environment team, policy division.

Dereje, G, (2011). Agro-ecologies of Ethiopia and major crops grown; collaboration with EIAR.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., Yesuf, M., (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change 19, 248-255.

Devereux, S., Maxwell S. (2001). Food Security in Sub-Saharan Africa. ITDG Publishing, London.

Diao, X., Hazell, P.B., Resnick, D. and Thurlow, J., (2007). The role of agriculture in development: Implications for Sub-Saharan Africa (Vol. 153). International Food Policy Research Institute.

Duveiller, E, Singh, R, Nicol J (2007) the challenges of maintaining wheat productivity: pests, diseases, and potential epidemics. Euphytica 157(3): 417-430.

Ehiakpor, T, (2016). Cocoa farmer‟s perception on climate variability and its effects on adaptation strategies in the Suaman district of western region, Ghana.

Esterling, W.E., Aggarwal, P.K., P.Batima. p., Brander, K.M., Lin, E.D., Howden, S.M., Kirilenko, A.P., Morton, J., Soussana, J., and Tubiello, F. (2007).Food fiber and forest products.

Evans, A., Perschel R., (2009). A review of forestry mitigation and adaptation strategies in the Northeast U.S. Climatic Change 96:167–18, DOI 10.1007/s10584-009-9569-3.

Fankhauser, S., J.B. Smith, and R.S.J. Tol, (2008): Weathering Climate Change: Some

Simple Rules to Guide Adaptation Decisions. Institute for Environmental Studies, Amsterdam, The Netherlands, 12 pp. Frederick, K.D., 1997: Adapting to climate impacts in the supply and demand

FAO (Food and Agriculture Organisation) (2011) 'Organic agriculture and climate change mitigation: a report of the round table on organic agriculture and climate change.' Rome: FAO. [Online]. Available at: http://www.fao.org/docrep/ 015/i2537e/i2537e00.pdf (Accessed: 28 February 2014).

FAO.(2008). Climate change for fisheries and aquaculture: Technical background document from the expert consultation held on 7-9 April 2008, Rome.

FDREMoWR (Federal Democratic Republic Ministry of Ethiopia Water Resource) and NMA(National Meteorological Agency) (2016). Climate change national adaptation programme of action (NAPA) of Ethiopia. National Meteorological agency (NMA).

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., (2007).Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change (2007): The Physical Science Basis . Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., Climate change.

Gbetibou, O., (2009). "Understanding Farmers ‟ Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa." Washington, D.C.USA.

Geoffrey, T., Mark, P. and Spencer, J., (2005). Establishing a causal chain: why experiments are often more effective than mediational analyses in examining psychological processes. Journal of personality and social psychology, 89 (6): 845.

Greene, H. W., (2003). Econometric Analysis (5th Ed.) Pearson Education, inc., Upper Saddle River, Prentice Hall, New Jersey

Gujarati, N. D., (2004). Basic econometrics (4th ed.) McGraw-Hill

Haile, H.K; Alemu, Z.G and Kudhlande ,G (2005) Causes of household food insecurity in koredegaga peasant association, oromiya zone, ethiopia. Department of Agricultural Economics Faculty of Natural and Agricultural Sciences at the University of the Free State.

Hameso, S. (2013) 'Crops and carbon: Paying farmers to combat climate change', [Book Review] Economic Analysis and Policy. (43)1, March: pp.109-111. [Online]. Available at: http://www.eap-journal.com/archive/v43_i1_07-Book_Reveiws.pdf (Accessed: 28 February 2014).

Hamin, E. M, Gurran, N., (2009) Urban form and climate change: balancing adaptation and mitigation in the U.S. and Australia. Habitat Int 33(3):238–245

Hoeke, R. K., K. L. McInnes, J. C. Kruger, R. J. McNaught, J. R. Hunter, and S. G. Smithers (2013), Widespread inundation of Pacific islands triggered by distant-source wind-waves, Glob. Planet.Change, 108, 128–138, doi:10.1016/j.gloplacha.2013.06.006.Lin, C.-C., C.-R.Ho, and Y.-H. Cheng (2014),

IPCC (2007a) Climate Change 2007: The physical science basis, contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

IPCC (2007b) Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, pp.273–313.

IPCC (2013) Climate Change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press.

IPCC (2015).Expert Meeting on Climate Change, Food, and Agriculture' Meeting Report.Edited by: Michael D. Mastrandrea, Katharine J. Mach, Vicente R. Barros, T. Eren Bilir, David J. Dokken, Ottmar Edenhofer, Christopher

B. Field, Taka Hiraishi, Susanne Kadner, Thelma Krug, Jan C. Minx, Ramón Pichs-Madruga, Gian-Kasper Plattner, Dahe Qin, Youba Sokona, Thomas F. Stocker, Melinda Tignor. Dublin, Ireland 27-29 May 2015.

IPCC (2017). Climate Change 2007: Climate change impacts, adaptation and vulnerability-Summary for policymakers. Contribution of Working Group II to the Fourth Assessment Report of the IPCC.

Kendall, M.G. (1975). Rank Correlation Measures; Charles Griffin: London, UK.

Komba, and Muchapondwa.(2015). "Environment for Development Adaptation to Climate Change by Smallholder Farmers in Tanzania".The Environment for Development (EfD) initiative.Swedish International Development Agency.Discussion Paper Series. EfD DP 15-12

Legrève, A, Duveiller, E, (2010) Prevailing potential disease and pest epidemics under a changing climate. In climate change and crop production, CABI press, Europe, pp. 263-283.

Lema, M.A. and A.E. Majule,(2009). Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni Woreda in Singida Region, Tanzania. African Journal of Environmental Science and Technology.**3** (8), Pp. 206-218.

Lemma, W.A., (2016). Analysis of Smallholder Farmers' Perceptions of Climate Change and Adaptation Strategies to Climate Change: the Case of Western Amhara Region, Ethiopia.

Lewis, L, Onsong, M, Njapau, H, Schurz-Rogers, H, Luber. G., (2005). And the Kenyan Aflatoxicosis Investigation Group. Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in Eastern and Central Kenya. Environ. Health Prospect 113(12): 1763- 1767.

Liwenga, E.T. (2003). Food insecurity and coping strategies in semi-arid areas: The Case of Mvumi in Central Tanzania. Ph.D Dissertation No. 11.Stockholm Studies in Human Geography, Stockholm University Stockholm, Sweden.

Lobell, D.B. Hammer, G.L. McLean, G. Messina, C. Roberts, M.J. Schlenker, W. (2013).The critical role of extreme heat for maize production in the United States. Nat. Clim. Chang., 3, 497–501.

Lowder, S.K., J. Skoet, S. Singh., (2014). What do we really know about the number of farms in the world? ESA Working Paper No. 14-02. Rome, Agricultural Development Economics Division, FAO.

Maddison.(2007). “The Perception of and Adaptation to Climate Change in Africa.” The World Bank Development Research Group, Sustainable Rural and Urban Development Team. Policy Research Working Paper Series 4308. Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria, South Africa.

Martin, A.J. (2012). Adaptability and learning. In N.M. Seel (Ed.). Encyclopedia of the Sciences of Learning. New York: Springer.

McCaffrey, M. (2012). Climate literacy hand book Availableat: http://www.eoearth.org/view/article/151183 (Accessed: 15 November 2014).

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. (eds.) (2001) Climate change 2001: Impacts, adaptation and vulnerability. Cambridge, UK: Cambridge University Press.

McLeman, R., and B. Smit.(2004). Climate change, migration and security.Canadian Security Intelligence Service, commentary no. 86, Ottawa, P. 8.

Mendelsohn, R., A. Dinar and A. Dalfelt (2000). Climate change impacts on African agriculture. Preliminary analysis prepared for the World Bank, Washington Woreda, of Columbia, Pp. 25.

Mertz O., C Mbow JØ Nielsen, A Maiga, D Diallo, A Reenberg, A Diouf, B Barbier, IB Moussa, M Zorom, I Ouattara, D. Dabi. (2010). Climate factors play a limited role for past adaptation strategies in West Africa. Ecology and Society **15**(4), Pp. 25 http://www.ecologyandsociety.org/vol15/iss4/art25/.

Miller JD (2008) Mycotoxins in small grains and maize. Food Additives Contam 25: 219-230.

Mugula and Mkuna.(2016). “Farmers‟ Perceptions on Climate Change Impacts in Different Rice Production Systems in Morogoro Tanzania.” International Journal of Scientific and Research Publications 6 (2): 334–40.

National Meteorological Agency (NMA) (2007). Climate change national adaptation program of action (NAPA) of Ethiopia. NMA, Addis Ababa.

National Meteorological Agency (NMA) (2001). Initial national communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC). NMA, Addis Ababa, Ethiopia.

Ngigi, S.N. (2009). Climate change adaptation strategies: Water resources management options for smallholder farming systems in Sub-Saharan Africa. The MDG Centre for East and Southern Africa, the Earth Institute at Columbia University, New York. Pp.189.

Ngindu A, Johnson BK, Kenya PR, Ngira JA, Ocheng DM, et al. (2005) Outbreak of acute hepatitis caused by aflatoxin poisoning in Kenya. Lancet 319(8285): 1346-134.

Nicholson SE, Some B, Kone B (2000). An Analysis of Recent Rainfall Conditions in West Africa, Including the Rainy Seasons of the 1997 El Nino and the 1998 La Nina Years. Journal of Climate 13:2628-2640.

Nielsen JØ, A. Reenberg. (2010a). Temporality and the problem with singling out climate as a current driver of change in a small West African village. Journal of Arid Environments **74**: 464–474.

NMA (2007) Climate Change National Adaptation program of Action (NAPA) of Ethiopia. Addis Ababa: NMA, Oxfam International.

NOAA (2009). Climate Literacy: The Essential Principles of Climate Sciences. U.S. Global Change Research Program. https://www.climate.noaa.gov/education/

Nyong, A., F. Adesina and O. Elasha (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitig. Adapt. Strat.Glob.Change.**12,** Pp. 787 -797.

OECD (2003) Poverty and climate change: reducing the vulnerability of the poor throughadaptation.(Online)Availableat:http://www.oecd.org/environment/cc/developmentandclimatechange.htm(Accessed: September 2014).

Oli, B. (2008). Migration and climate change. IOM migration research series no. 31, International Organization for Migration, Geneva. Pp. 1-68.

Ordónez, ˜ R.A., Savin, R., Cossani, C.M., Slafer, G.A., (2015). Yield response to heat stress as affected by nitrogen availability in maize. Field Crops Res. 183, 184–203, http://dx.doi.org/10.1016/j.fcr.2015.07.010.

Parry, M.L., Canziani, O.F., Paluticof, J., Vander Linden, P.J., and Honson. C.E.(2007). Climate change: impacts, adaptation and vulnerability. Contribution of working group II to the Thrid assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge. United Kingdom.

Pereyda, J, Hernandez, J, Sandoval, S, Aranda Ocampo, S, De León C., (2009) Etiología y manejo de la mancha de asfalto (Phyllachora maydis Maubl.) del maízen Guerrero, México. Agrociencia 43(5): 511-519.

Pettengell, C. (2010). Climate change Adaptation, Enabling people living in poverty to adapt. Oxfam research report.

Petzoldt, C, Seaman A (2005) Climate change effects on insects and pathogens. Climate Change and agriculture: promoting practical and profitable responses.

Porter, J.R, Xie, L, Challinor, AJ, Cochrane, K, Howden, M, Iqbell, MM, Lobell, DB, Travasso, MI, (2014). Chapter 7.Food security and Food production systems. Climate change 2014: Impacts, Adaptation and Vulnrability

Ramirez-Villegas J, Watson, J, Challinor, AJ. (2015). Identifying traits for genotypic adaptation using crop models. Journal of Experimental Botany in press.

Reynolds, MP, Ortiz, R., (2010) Adapting crop to climate change: A summary. In Climate change and crop production. Curr Opin Plant Biol 11: 171-179.

Saguye, T.S., (2016). Determinants of Smallholder Farmers' Adoption of Climate Change and Variability Adaptation Strategies: Evidence from Geze Gofa District, Gamo Gofa Zone, Southern Ethiopia.

Sanchez," P." A.," Palm," C." A.," Buol," S."W." (20014)." Fertility" capability" soil" classification"system:"A"tool"to"assess"soil"quality"in"the"tropics."Geoderma"114,"157Y185.

Schmidhuber, J. Tubiello, F.N., (2007). Global food security under climate change. Proceedings of the National Academy of Sciences of the United States of America.104(50).P.19703-19708.

Serrat, O., (2017). The sustainable livelihoods approach. In Knowledge solutions (pp.

21-26).Springer, Singapore.

Sidahmed, A. (2008). Livestock and climate change: Coping and risk management strategies for a sustainable future. In: Livestock and Global Climate Change Conference Proceeding, May 2008, Tunisia.

Smit, B. Wande, J. (2006) ‘Adaptation, adaptive capacity and vulnerability’, Global Environmental Change 16, pp.282-292

Smith, K., (2013). Environmental hazards: assessing risk and reducing disaster. Routledge.

Stone, P., (2001) the effects of heat stress on cereal yield and quality. In Crop Responses and Adaptations to Temperature Stress. (AS Basara, Ed.), Food Products Press, Binghamton, New York, USA, pp. 243-291.

Tang, (2013). Effects of high night temperature on yield and agronomic traits of irrigated rice under field chamber system condition. Australian Journal of Crop Science. AJCS 7(1):7-13

Temesgen, T, Hassan, R.M, Ringler C. (2010) Perception and adaptation to climate change: The case of farmers in the Nile Basin of Ethiopia, Journal of Agricultural science.

Tenge, G., (2004). “Social and Economic Factors Affecting the Adoption of Soil and Water Conservation in West Uamara Highlands, Tanzania.” Land Degradation & Development

Thennakoon, S., (2012). Rural Livelihood Strategies and the Five Capitals: A Comparative Study in the Selected Villages of Sri Lanka.

Thomson, LM. (2004) Weather variability, climate change and grain production. Science 188(4188): 535-541.

Uddin, M.T. Takeya, H., (2005). Economic analysis of integrated fish farming by agricultural enterprise in Mymensingh district of Bangladesh. Journal of Development Studies, 16(1): 40-49.

UNDP, (2008). “Adaptation to Climate Change : The New Challenge for Development in the Developing World. An Environment & Energy Group Publication. The United Nations Development Program (UNDP)”

UNISDR, (2005) Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters, A/CONF. 206/6, World Conference on 271 Disasters Reduction, 18-20 January, Kobe, Hyogo, Japan.

Urama, K. and N. Ozor.(2011). Agricultural innovations for climate change adaptation for food security in Western and Central Africa. Agro-science Journal of Tropical Agriculture, Food, Environment and Extension **10** (1): 1 – 16.

Wassman, R. Dobermann, A., (2007). Climate change adaptation through rice production in regions with high poverty levels.SAT eJournal 4(1) p.-24.

Williams, J.H, Phillips T.D, Jolly P.E, Stiles J.K, Jolly C.M,. (2004) Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences, and interventions. Am J Clin Nutr 80: 1106-1122.

Woldemlak, B. and Conway, D. (2009).A note on temporal and spatial variability of rainfall in drought prone Amhara regions of Ethiopia. International Journal of Climatology 27:1467-147

Yamane, Taro. (1967). Statistics, An Introductory Analysis, 2nd Ed., New York: Harper and Row.

Yesuf, M, Di Falco, S, Deressa T, Ringler, C, Kohlin, G (2008). The impact of climate change and adaptation on food production in low-income countries: evidence from the Nile Basin, Ethiopia. International Food Policy Research Institute. Discussion Paper No. 828.

Zaidi, PH, Singh, N.N., (2010). Effect of waterlogging on growth, biochemical compositions and reproduction in maize. J Plant Biol 28: 61-69.

Ziervogel, G., A. Cartwright, A. Tas, J. Adejuwon, F Zermoglio, M. Shale and B. Smith. (2008). Climate change and adaptation in African agriculture. Stockholm environment institute, March 2008, Pp. 17-19.

APPENDICES

HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

SCHOOL OF GRADUATE STUDIES

PROGRAM OF CLIMATE CHANGE AND SUSTAINABLE AGRICULTURE

QUESTIONNAIRE FOR HOUSEHOLD HEADS

My name is Timotiwos Michael MSc student at Hawassa University, College of Agriculture. I am conducting a research concerning Impacts of Climate Change and Variability on *Maize* Production and Adaptation Strategies of farming community in your Woreda (Hawassa Zuria Woreda). Hence, your opinion and perception will help me in this regard. Dear Respondents: The questionnaire is designed to generate data that will be used for academic purpose only. Therefore, please feel free and share us your rational views.

Appendix 1: Questionnaire

Section A. Interview:

Put(X) marks in box provided for closed ended questions and write your response on space provided for open ended questions.

General Information

Respondent's Name…….…………………………………..……………

Woreda Name……………………………………………….

Name of Kebele (village)…………………………………….…………….

Questions on Household Head Demographic and Socio-economic Characteristics

1. Sex of the respondent. Male=1 Female =0

2. Marital Status. Single=0 Married=1 Divorced=2 widowed=3

3. Age of respondents?

18-25 Years=1 | 46-64 Years=4

25-35 Years=2 | >65 Years=5

36-45 Years=3

4. Educational Level?

Cannot read and write =1 | Secondary School (grade 5-8) =4

High School (grade 9-12) =5 | College =6

Primary School (grade 1-4) =3

5. Family Size

1= 1-2 | 3= 6-9

2= 3-5 | 4= >10

6. In which status you are in the village? ___________1= Rich, 2=Medium, 3=poor, 4=very poor, 5=others.

7. What is your mean monthly household income from employment (ETB)? ________1 = 500-1000 2 = 1,001 - 30,000, 3 = 30,001 - 50,000, 4 = over 50,000, 5= other (specify)

8. What is your main source of income? 0= on farm, 1= off farm, 2= non-farm,

9. What is the size of your land? ________1=Less than one (hectare), 2= 1to 3 ha, 3= 4 to 5 ha, 4= 6 to10 ha, 5= Over 10 ha, 6 = don't know.

Questions on Household Head Farming Practice

10. What is the total area under cultivation? _______ .1= 0.5-1 ha, 2=1-2ha, 3= 3-5ha, 4= >6ha

11. What is the total area of land under pasture in your kebele? ________ (Record actual

in ha)?

12. What is the total area of land under tree cover in your kebele? ______ (Record actual in ha)?

13. How long have you been a farmer? 0= Less than 10 years, 1= 10-20 years, 2= 20-30 years, 3= over 30.

14. Agricultural system of your household before 30 years now?

1. Cop production only 3. Crop-livestock mixed agriculture
2. Livestock rearing only 4. Others (Specify)………………………….

15. Agricultural system your household currently?

1. Cop production only 3. Crop-livestock mixed agriculture
2. Livestock rearing only 4. Others (Specify)………………………

16. Cropping system 1=Mono cropping, 2= Crop rotation, 3=intercropping, 4=other (specify) ………………….

17. Number of harvest (season) per year per plot of land 1=one, 2=two, 3=three, 4=other (specify) ______________________

18. What food crops do you grow? _______________ 1 = Maize, 2 = Beans, 3 = Millet, 4 = Cassava, 5 = Others (Specify) _________________?

19. Type of your agriculture: 1=primarily rain fed agriculture, 2=primarily irrigated agriculture, 3=others (specify) _______________

Institutional Information

20. Do you have extension contact with kebeles development agents?

1= Yes 2= No

21. If your answer for question #19 is "Yes", how many contacts did you have during the last production season?

Once a week=1 Once a month=3

Twice a week=2 Twice a month=4

22. Have you got training from kebeles development agent?

1= Yes 2= No

23. If your answer for question #21 is "Yes", in which area of your activity have taken the training?

1= about adoption of new technology in farm activities

2= Information about rainfall distribution in order to give early warning

3= about climate change impact and how it can be cope up

4= about crop (variety) diversification to reduce the risk of climate change

5 =Others (Specify)…………………………………………………………

About Climate Change and Variability

24. Have you heard of the word "Climate Change and Variability" before?

1= Yes 2= No

25. If your answer for question #23 is "Yes", what are the indicators for the change or variability?

1 = Shortage of annual rainfall 3 = Rainfall variability

2 = Changing of temperature 4 = Soil acidity

5 = Disease intensification 6=others (Specify)………………...

26. Which local indicator do you use to evaluate today's rainfall pattern?

1= Loss of some plant and animal species

2= Rainfall comes early or lately

3= Increased drought and flood frequency

4 =Decline of agriculture yields

5= Decreased surface water

6= Other (Specify)……………………..

27. How was the trend of rainfall for the past 30 years to date according your perception?

Increasing=1

Decreasing=2

No change=3

28. Do you feel that timing of rainfall is a problem?

1= Yes, it starts late and ends up late

2= Yes, it starts early and ends up early

3= No, there is no problem on timing of rainfall but on its amount

4= Yes, it starts on time but ends up early

5 =Yes, it starts late and ends up early

29. How is the trend of temperature for the past 30 years according to your perception?

1= Increasing 2= Decreasing 3= No change

Information about climate change and variability impacts

30. What is the main impacts of climate changes and variability on the local community?

1 = Crop failure, 2 = Flooding 3 = Human disease outbreaks, 4 = Livestock disease outbreak,

5 = Famine, 6 = Migration to other places, 7 = don‟t know, 8 = others (specify)

31. Do you face the problems in Maize production?

1= Yes 2= No

32. If your answer for question #30 is "Yes", what is the main cause for the problem?

Changing of temperature=1 Disease infestations=3

Rainfall variability=2 Soil acidity =4

Other (Specify) =5

33. do you think your maize production system will be affected by impacts of climate change and variability?

0= No, 1 = yes

34. Have you experienced with the following types of climate change and variability indicators?

Yes=1 No=0

If your response is yes, how often (in past decade)

1 Drought

2 Flood

3 Too-much rainfall

4 Too-little rainfall

5 Higher temperature

6 Frost

7 High winds

8 Other (Specify)

35. How is the maize production per unit area of since the last 30 years?

0=Increasing 1=Decreasing 2= No change

36. How much did you harvested*Maize* yield? (Quantity) in Kg per hectar?

0= 5-15 1= 16-25 2= 26-35 3= >36

37. How maize productivity per hectare has been since the last 35 years?

0= Increasing 1= Decreasing 2= No change

38. Do you think the maize productivity is increasing or decreasing since the last 30 years? If you say decreasing what do you think the major factors?

1= Unpredictable rainfall.

2= Increased temperature

3= Increased pest and disease

4= Inadequate farm land

5= High price of farm implements

6 =Low soil fertility

7= Shortage of labor

8= Invasion of new disease

9= Lack of farm implements (fertilizer, improver seeds, and pesticides)

39. What do you think the major factors to diversify cereal crop production in this area?

1= Reduce risk of Unpredictable rainfall.

2 =Reduce risk of increased pest and disease

3 =Reduce risk of inadequate farm land

4= Reduce risk of increased temperature

5= Reduce risk of low soil fertility

6= Increase productivity

Adaptation Strategies

40. Do you Adopt adaptation strategies in order to adapt to climate change and variability?

Yes=1 No =2

41. What measures have you taken to avert the problem caused by climate change and

variability?

1. Using improved variety 3. Adjusting planting date

2. Mixed crop livestock system 4. Irrigation use

5. Temporal and permanent migration in searching job

6. Changing size of land under cultivation

7. Soil and water conservation (SWC) 8. Use of agro-forestry (Tree plantation)

9. Intercropping 10. Using traditional variety of crop

11. Using Different crop varieties 12. Crop diversification

13. Diversifying from farm to non-farm activities 14. Saving mechanism

15. Petty trading 16. Food aid 17. Grain storage

18. Mortgaging of land among the others.

42. List the main constraints to adaptation measures?

1 = Lack of capital, 2 = Lack of information, 3 = Shortage of labor, 4 = Lack of access to water, 5 = Poor health, 6= lack of access to credit, 7= irregularity of extension services

Questions on Adaptation Strategies to Climate Change

43. In response to climate change, have you taken any adaptation measures in order to buffer the effects of climate change? a) Yes b) No

44. If yes to question no.1, have you employed any of the following climate change adaptation

strategies in your farm over the past three decades? Put in ranking order

Adaptation measures	**Its importance on your farm Mark "x" on your choice**				**Rank**
	High	**Medium**	**Low**	**No**	
Use of drought tolerant varieties					

Practicing crop diversification					
Integrated farming system					
Increased use of irrigation					
Soil and conservations practices					
Practicing crop rotation					
Agroforestry					
Cultivating short duration crops					
Moved to non-farm activities					
Find off- farm jobs					
No adaptation					

Farmer's perceptions on climate change and variability before 20 years' or 30 experiences.

45. Do you perceive climate variability and change? _______________1 = yes, 2 = No

46. Is the amount of rainfall increase? 1 = yes, 2 = No, 3 = constant

47. Is the temperature increase? 1 = yes, 2 = No, 3 = constant

48. Is rain starting late than normal? 1 = yes, 2 = No, 3 = constant

49. Is the amount of precipitation sufficient for full cropping during short rainfall?

1 = yes, 2 = No, 3 = constant

50. is day and night temperatures changed? 1 = yes, 2 = No, 3 = constant

Section B. Focus Group discussions

1. What do you understand by the term climate change?

2. What climate change impacts do you face in your village?

3. How is the trend of rainfall in the past 10 years in the district?

4. How is the trend of temperature in the past 10 years in the district?

5. Which important crops have disappeared in the last 10 years in your village due to climate change?

6. How and where do you get information concerning climate change and variability?

7. How do you communicate information on climate change and variability?

8. What measures/precautions do you take to combat climate change impact in your village?

9. How can you relate climate change impacts to maize production in your village?

10. What causes the impacts of climate change in your district?

Section C. Key Informant Interview

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 1-10 years? ____

3. What can you comment on climate change and variability situation in the district for the past 1-10 years____

4. What is the situation of rainfall in the district for the last 10 years?

____

5. What is the situation of temperature in the district for the last 10 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 and variability 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 2: Monthly, annual and sesonal rainfall data of Hawassa Zuria distric

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Summer	Autumn	Winter	Spring
1987	0.1	11.8	151.4	127.8	230.8	54.4	97.3	108.1	68.8	100.1	0.4	4.1	955.1	259.8	169.3	16	510
1988	25.8	68.5	17.5	80.9	100	110.9	117.7	138.8	205	83.9	1.3	6.6	956.9	367.4	290.2	100.9	198.4
1989	38.8	49.9	62.8	211.8	95.2	123.8	78.1	86.4	164.3	40.9	22.3	50.4	1024.7	288.3	227.5	139.1	369.8
1990	10.5	94.2	115.1	89.9	85.3	44.4	139.1	39.5	94.1	27.3	7.5	3.8	750.7	223	128.9	108.5	290.3
1991	12.3	90.6	86.4	48	146.7	116.7	109.2	90.6	110	21.6	12.2	44.8	889.1	316.5	143.8	147.7	281.1
1992	23.4	83.2	73.8	109	60.5	83	104.5	123.6	74.5	142.3	80.1	17.4	975.3	311.1	296.9	124	243.3
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	928.4	232.2	189.1	214.6	292.5
1994	0	3.7	56.8	108.7	81.5	146.2	195.7	118.9	68.9	58.8	19.1	2.9	861.2	460.8	146.8	6.6	247
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	1004.4	429.1	207.4	106.4	261.5
1996	78.4	36.9	89.6	113.9	161.5	243.3	121.2	108.7	145	69.6	19.7	1.4	1189.2	473.2	234.3	116.7	365
1997	23.4	1.7	75.1	125	72.8	111.2	98.8	113.9	119.1	157.5	132.2	24	1054.7	323.9	408.8	49.1	272.9
1998	92	140	90.8	86.6	88.9	52	172.9	108.3	109.6	193.3	10.6	0.8	1145.8	333.2	313.5	232.8	266.3
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	810.2	318.7	257.9	37	196.6
2000	1.1	0	11	132	145.1	36.8	80	178.8	86.5	110.7	29	11.3	822.3	295.6	226.2	12.4	288.1
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	1022	362.9	172.5	63	423.6
2002	52.5	2.4	129.1	119.6	85.2	91.7	76.6	190.4	83.2	37.3	0	51.5	919.5	358.7	120.5	106.4	333.9
2003	30.4	2	78.2	179.1	40.4	110.5	107.8	76.1	85.5	53.4	6.2	51.8	821.4	294.4	145.1	84.2	297.7
2004	46.2	94.2	42	83.1	81.5	75.7	75.4	114.9	116	57.1	94.2	15.3	895.6	266	267.3	155.7	206.6
2005	81.1	7.7	120.9	156	144.5	73.2	150.9	61.3	117.2	28.4	46	10.4	997.6	285.4	191.6	99.2	421.4
2006	1.7	9	139.2	145.9	74.4	108	171.1	169.3	194.9	56.9	79.2	48.3	1197.9	448.4	331	59	359.5
2007	18	55	76.4	112	166.1	225.4	129.1	104.3	233.8	32.7	3.7	0	1156.5	458.8	270.2	73	354.5
2008	33.7	8.3	3.4	57.8	121	118.2	120.5	123.5	160	0	97.1	5.8	915.4	362.2	323.2	47.8	182.2
2009	32.8	9	60.3	45.6	103.1	51.6	92.6	112	81.7	41.6	4.1	69.9	704.3	256.2	127.4	111.7	209
2010	26.6	58.4	124.8	96.1	173.5	53.1	132.5	136.6	96.1	53.1	32	56	1038.8	322.2	181.2	141	394.4
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	922.8	371.2	219.2	9.6	322.8
2012	0	2.4	13	210.5	91.3	89.8	152.9	87.2	86.8	15.2	23.2	13.1	785.4	329.9	125.2	15.5	314.8
2013	23.4	1	104	78.8	143	132.4	209.4	163.1	117.7	77.5	22	0	1072.3	504.9	217.2	24.4	325.8
2014	23.4	26.3	91.5	104.5	198.7	98.4	104.6	213	164	105.3	19.1	5.8	1154.6	416	288.4	55.5	394.7
2015	0	2.5	38.2	28.9	56.1	147.2	113.1	85.3	103.6	34.1	23.3	38.6	670.9	345.6	161	41.1	123.2
2016	54.4	4.7	33.5	173.3	226.1	101	70.9	79.8	71.7	100.7	53.1	0	969.2	251.7	225.5	59.1	432.9
2017	0	88.4	91	88.5	225.6	54.7	153.6	115.1	174.4	128.8	6.4	0	1126.5	323.4	309.6	88.4	405.1
2018	4.2	59	132.1	198.6	106.4	188.2	41.7	151.6	63.7	50.4	144.7	6.7	1147.3	381.5	258.8	69.9	437.1
2019	0	13.3	17.6	128.6	125.7	81.7	207.2	183.1	167.3	88.3	62.1	0.2	1075.1	472	317.7	13.5	271.9

Source: National Meteorology Agency, 2020

Appendix 3: Monthly, Seasonal, and Annual average maximum temperature of Hawassa Zuria district

Year	Ja	Fe	Ma	Ap	Ma	Ju	Ju	Au	Se	Oc	No	De	nnual tma	summer	automn	winter	spring
1987	28.6	29.3	27.5	27.4	26.2	25.4	25.2	25.5	26.6	26.8	29.3	29.1	27.2	25.4	27.6	29.01067	27.1
1988	29.3	29.6	31.0	28.4	27.5	24.9	22.8	23.8	24.8	25.9	27.9	27.8	27.0	23.8	26.2	28.92139	29.0
1989	27.7	27.9	28.7	26.2	27.1	24.8	23.3	25.0	24.7	27.1	28.2	27.0	26.5	24.4	26.7	27.55038	27.3
1990	28.6	27.9	27.5	27.8	27.3	26.1	24.4	24.5	25.9	27.9	29.6	29.2	27.2	25.0	27.8	28.54922	27.5
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	24.8	27.6	29.12273	28.7
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	24.8	26.0	28.51353	29.2
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	24.7	27.2	28.14946	28.4
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	24.2	27.6	30.47177	29.0
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	25.3	27.6	30.08518	28.4
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	24.0	26.7	29.22532	28.0
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	25.0	26.6	28.81221	28.4
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	24.9	26.1	28.162	28.6
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	24.9	25.9	29.50902	28.2
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	25.1	26.0	29.45803	29.0
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	24.5	27.0	29.25061	27.9
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	25.8	28.1	29.10995	28.3
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	24.9	27.8	28.96755	29.0
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	25.6	26.9	28.76967	28.7
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	25.3	27.1	29.62124	28.4
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	25.1	26.5	29.62631	28.1
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	24.7	26.6	28.54155	28.7
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	24.9	26.3	28.89329	29.1
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	26.6	27.8	28.84392	29.8
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	25.2	27.2	28.36217	27.5
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	25.5	27.1	28.96939	29.5
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	25.5	27.4	29.85977	29.3
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	25.0	27.0	29.75131	28.6
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	25.7	26.4	29.0235	28.5
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	26.3	28.2	29.40469	30.3
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	25.5	27.4	29.08357	29.2
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	26.8	27.6	29.07216	30.5
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	25.2	27.4	29.23922	27.7
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	25.7	26.8	29.59128	30.2

Source: National Meteorology Agency, 2020

Appendix 4: Monthly, Seasonal and Annually Average minimum temperature of Hawassa Zuria district

Year	Jar	Fel	Ma	Ap	Ma	Jur	Ju	Au	Se	Oc	No	De	Annual	Summer	Autmn	Winter	spring Tmin
1987	9.9	11.5	14.0	13.0	14.5	14.3	13.9	13.4	12.7	12.7	9.1	9.5	12.4	13.9	11.5	10.25776	13.8
1988	11.3	13.7	12.3	14.4	13.9	13.9	14.7	14.1	13.9	12.8	6.5	7.9	12.4	14.2	11.1	10.96329	13.5
1989	9.8	10.8	13.2	13.4	12.5	13.1	14.1	13.4	12.7	11.4	9.7	13.0	12.2	13.5	11.3	11.16624	13.0
1990	9.0	14.0	12.6	14.1	13.3	13.2	14.2	13.9	12.9	10.6	10.7	9.0	12.3	13.8	11.4	10.6696	13.3
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	14.5	10.6	11.27562	13.4
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	14.1	12.1	12.34079	13.5
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	14.1	11.6	11.1674	12.6
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	14.5	11.4	10.07477	13.7
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	14.1	11.2	10.8981	13.9
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	14.4	11.1	10.75054	13.7
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	14.0	13.5	11.22369	13.4
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	15.4	12.6	11.91114	14.7
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	14.0	12.4	9.820622	13.3
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	14.0	12.7	9.987838	13.1
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	14.8	12.3	11.20879	14.2
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	14.3	12.0	12.45253	14.1
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	14.5	12.4	11.25142	13.9
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	14.1	12.2	11.98457	13.4
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	14.5	12.3	10.15081	14.2
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	14.6	13.4	12.20349	14.1
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	14.8	12.1	11.52711	13.8
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	14.6	12.8	10.80871	13.4
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	14.3	12.9	12.58896	13.9
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	15.2	13.0	13.09082	15.5
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	15.0	13.3	11.4427	14.3
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	15.1	13.0	11.09019	14.3
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	15.1	13.2	11.2904	15.3
2014	12.213	13.479	13.406	13.06	14.139	14.01	15.3	14.9	14.7	14.2	12.3	10.7	13.5	14.7	13.7	12.14447	13.5
2015	11.219	12.971	14.503	14.787	15.368	15.753	14.8	15.3	15.3	14.7	13.9	13.5	14.3	15.3	14.6	12.56252	14.9
2016	15.348	14.683	15.419	16.7	16.142	14.697	15.8	15.4	15.3	14.9	12.1	11.2	14.8	15.3	14.1	13.74372	16.1
2017	9.7484	14.493	14.49	14.78	15.819	15.487	16.0	15.5	15.6	15.1	11.7	9.4	14.0	15.7	14.1	11.2245	15.0
2018	11.287	13.275	13.929	15.627	15.584	15.4	15.0	11.3	13.3	13.9	15.6	15.6	14.2	13.9	14.3	13.38199	15.0
2019	15.4	15.164	15.194	14.52	13.865	16.233	11.6	15.1	14.9	13.3	13.3	12.6	14.3	14.3	13.8	14.37304	14.5

Source: National Meteorology Agency, 2020

Appendix 5: 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

Appendix 6: The Variance Inflation Factors of the explanatory variables

Variables	Tolerance	VIF
Age of the household head	.942	1.061
Education of household head	.935	1.061
Family size of household head	.908	1.061
Total area of farm land household head	.933	1.061
Farm experience of household head	.912	1.061
Monthly income of household head	.951	1.061
Livestock ownership	.921	1.061

Appendix 7: Contingency coefficients for dummy explanatory variables

Variables	Contingency coefficient
Sex of household heads	.0130
Access to extension service	.006
Access to criedit service	.000

BIOGRAPHY SKETCH

The author, Timotiwos Michael Didiso, was born on May 12, 1995 from his father Michael Didiso and his mother Shungare Ondamo in Hawella Woreda, Nure-dulacha, kebele, sidama Region, Ethiopia. He attended his elementary school Wondo-Tika primary school and attended his secondary school and preparatory school in Hawassa Tabour Secondary and Preparatory school. He joined Haramaya University College of Agriculture and Environmental Science in 2015/2017 and graduate with degree in Natural Resource Management. Following his graduation he was employed by Hawassa Zuria Woreda Agricultural office. He joined Hawassa University, School of graduate studies in 2018/2020 academic year. He is single.