



**IMPACT OF CLIMATE CHANGE ON MAIZE (*Zea mays* L.) YIELD AND  
LOCAL ADAPTATION STRATEGIES IN DAMOT-WOYDE DISTRICT,  
SOUTHERN ETHIOPIA**

**MSc. THESIS**

**DAMTEW DATTA**

**HAWASSA UNIVERSITY**

**COLLEGE OF AGRICULTURE**

**DECEMBER, 2021**

**HAWASSA, ETHIOPIA**

IMPACT OF CLIMATE CHANGE ON MAIZE (*Zea mays* L.) YIELD AND  
LOCAL ADAPTATION STRATEGIES IN DAMOT- WOYDE DISTRICT,  
SOUTHERN ETHIOPIA

DAMTEW DATTA

MAJOR ADVISER: BISLAT ELIAS (PhD)

CO-ADVISOR: TEWODROS AYALEW (ASSOC. PROFESSOR)

A THESIS SUBMITTED TO FACULTY OF ENVIRONMENT, GENDER AND  
DEVELOPMENT STUDIES

HAWASSA UNIVERSITY  
COLLEGE OF AGRICULTURE

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

DECEMBER, 2021

HAWASSA, ETHIOPIA

# APPROVAL SHEET: I

## SCHOOL OF GRADUATE STUDIES

### HAWASSAUNIVERSITYADVISORS' APPROVAL SHEET

This is to certify that this thesis entitled "Impact of Climate change on Maize (*Zea mays* L.) Yield and local adaptation strategies in Damot- woyde district, southern Ethiopia" Submitted in partial fulfillment of the requirement for the degree of Master with specialization of climate change and sustainable agriculture has been carried out by **DAMTEW DATTA (Id.No GPCCSA/0005/11)** under our supervision. Therefore, we recommended that the student has fulfilled the requirements and hence hereby can submit the thesis to the school of graduate studies

#### Approved by Advisors:

_____	_____	_____
Name of Major Advisor	Signature	Date
_____	_____	_____
Name of co Advisor	Signature	Date
_____	_____	_____
<b>SGS approval</b>	Signature	Date

**APPROVAL SHEET: II**

**EXAMINER’S APPROVAL SHEET-I**

**SCHOOL OF GRADUATE STUDIES**

**HAWASSA UNIVERSITY EXAMINERS’**

We, the undersigned, members of the Board of Examiners of the final open defense by DAMTEW DATTA have read and evaluated his/her thesis entitled IMPACT OF CLIMATE CHANGE ON MAIZE (*Zea mays* L.) YIELD AND LOCAL ADAPTATION STRATEGIES IN DAMOT- WOYDE DISTRICT, SOUTHERN ETHIOPIA and 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 Internal Examiner-II	Signature	Date
_____	_____	_____
Name of External Examiner	Signature	Date
_____	_____	_____
SGS Approval	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidate's department.

**Stamp of SGS Date:** \_\_\_\_\_

**Remark**

- Use this form to submit the thesis with MINOR CORRECTION suggested by the examining board3 copies

## **DEDICATION**

The thesis dedicated to my beloved wife Ayinalem Biniyam, my children and parents for their constant support, encouragement and unfailing love

## **STATEMENT OF THE AUTHOR**

I declare that this thesis is my work and all sources of materials used in this thesis have been acknowledged. 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 may be made without special permission, provided that accurate and complete acknowledgement of the source is made. Requests for permission for extended quotations from, or reproduction of this thesis in whole or in part may be granted by the Head of the School or Department when in his or her judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author of the thesis.

Name: Damtew Datta

Place: Hawassa University College of Agriculture,

Hawassa

Date of Submission: \_\_\_\_\_

Signature: \_\_\_\_\_

## **ACKNOWLEDGMENT**

Above all, honors, adorations, great appreciations and thanks go to Almighty God for his everlasting love, mercy and support towards me. Next to God, my special genuine appreciation goes to my major adviser **BISRAT ELIAS** (PhD), Co-Advisor **TEWODROS AYALEW (Assoc. Professor)** for their unreserved advice, guidance, constructive and critical comments and devotion as well as provision of relevant materials all through my work. Particularly, I wish to thank them for their comments, which enabled me to complete my work on time. I would also like to express my gratitude to Mr. Elias Eshetu for his assistance in data organization. My thanks are extended to Damot -woyde administrative office, Damot-Woyde district agriculture and natural resource office, sample kebele farmers and extension agents. I owe more than I can say to my lovely wife Sr., Ayinalem Biniyam, especially for her unreserved care, amoral as well as financial support throughout my study.

## LIST OF ACRONYM

UNFCCC	United Nations Framework Conventions on Climate Change
IWW	Water Management Institute
GCM	General Circulation Model
SDMs	Statistical Down Scaling
RCM	Regional Climate Model
CMIPs	Coupled Model Inter Comparison
CV	Coefficient of Variance
AOGCM	Atmosphere-Ocean General Circulation Model
RAMO	Regional Atmosphere
RCP	Representative Concentration Pathways
SRES	Spatial Report Emission Scenarios
CSA	Central Statistical Agency
NMA	National Meteorological Agency
CPT	Climate PredicblityTool
DWDAFO	Damot-Woyde District Agriculture and Natural Resource Office
ETO	EvapoTranspiration
FAO	Food and Agricultural Organization
GDD	Growth Degree Days
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
MOA	Ministry of Agriculture
SRES	Special Report on Emission Scenarios
SNNPR	Southern Nation Nationality and People Region
TR	Crop Transpiration
USD	Us Dollar
WP	Water Productivity

## Table of Contents

Content	Page
APPROVAL SHEET: I.....	II
APPROVAL SHEET: II.....	III
DEDICATION.....	IV
STATEMENT OF THE AUTHOR.....	V
ACKNOWLEDGMENT.....	VI
LIST OF ACRONYM.....	VII
LIST OF TABLES.....	XI
LIST OF FIGURES.....	XII
<b>ABSTRACT</b> .....	<b>XIII</b>
CHAPTER ONE.....	1
INTRODUCTION.....	1
1.1. BACKGROUND OF THE STUDY.....	1
1.3. OBJECTIVES OF THE STUDY.....	4
1.3.1. General objective.....	4
1.3.2. Specific Objectives.....	4
1.4. RESEARCH QUESTIONS.....	4
1.5. SIGNIFICANCE OF THE STUDY.....	4
<b>1.6 SCOPE OF THE STUDY</b> .....	<b>5</b>
<b>1.7 LIMITATIONS OF THE STUDY</b> .....	<b>5</b>
1.8. THESIS ORGANIZATION.....	5
CHAPTER TWO.....	6
LITERATURE REVIEW.....	6
2.1. THEORETICAL BACKGROUND.....	6
2.1.1. Concepts of climate change.....	6
2.1.2. Causes of climate and its impacts.....	7
2.1.3. Climate change in Ethiopia.....	8

2.1.4. Climate models .....	9
2.1.5 General Circulation Models (GCMs).....	10
2.1.6 Regional Climate Models (RCMs) .....	10
2.1.7. Downscaling of general circulation models.....	11
2.1.8. Dynamical downscaling.....	11
2.1.9. Statistical downscaling.....	12
2.1.10. Climate Scenarios .....	13
2.1.11. The Representative concentration pathway (RCPs) .....	14
2.1.13 CORDEX Project.....	16
2.2. EMPIRICAL LITERATURE ON ADAPTATIONS TO CLIMATE CHANGE AND VARIABILITY .....	17
2.2.1 Modeling and Types of Models .....	19
2.2.2 Crop models .....	19
2.2.3 Aqua Crop .....	20
2.2.4 Field management for effective development of yield .....	22
2.3 CONCEPTUAL FRAMEWORK OF THE STUDY .....	22
CHAPTER THREE .....	25
MATERIALS AND METHODS.....	25
3.1. DESCRIPTION OF THE STUDY AREA .....	25
3.2. CLIMATE, TOPOGRAPHY AND SOIL TYPE.....	27
3.3. VEGETATION .....	27
3.4. AGRICULTURAL PRODUCTION .....	27
3.5. AQUA CROP MODEL SETUP .....	28
3.5.1. Aqua crop model equations .....	30
3.5.2 Dataset for Aqua Crop model .....	30
3.5.3 Aqua Crop model calibration and simulation .....	31
3.5.4 Aqua Crop model evaluation criteria .....	32
3.6. TARGET AREA AND SAMPLE SIZE.....	33
3.6.1. Sampling technique.....	33
3.6.2. Data collection procedure .....	35
3.6.3. Climate Data Analysis .....	35
CHAPTER FOUR.....	37
RESULT AND DISCUSSIONS .....	37

4.1. DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS OF THE FARMING HOUSEHOLDS	37
4.2. RESULT AND DISCUSSION OF SMALLER HOLDER PERCEPTION ABOUT CLIMATE CHANGE	46
4.3. RESULT AND DISCUSSION OF SMALLER HOLDER FARMER HOUSEHOLD HEADS IMPLEMENTATION OF LOCAL CLIMATE ADAPTATION STRATEGIES	46
4.4. COMPARISON BETWEEN MODEL OUTPUT WITH OBSERVED DATA SETS	50
4.5 EVALUATION OF FUTURE CLIMATE CHANGE UNDER RCP SCENARIOS	51
4.5.1 Temperaturechange	52
4.5.2. Rainfall change	59
4.5.3. Evaluation of Rainfall Variability	62
4.6 EVALUATION OF CLIMATE CHANGE IMPACT ON MAIZE YIELD UNDER RCP SCENARIOS	64
CHAPTER FIVE	70
CONCLUSSIONS AND RECOMMENDATIONS	70
5.1. CONCLUSIONS	70
5.2. RECOMMENDATIONS	74
REFERENCES	75
APPENDICES	82
BIOGRAPHY	92

## List of Tables

<b>Table</b>	<b>Page</b>
Table 1. History of scenarios .....	14
Table 2: Total population, households and maize field of sample kebele .....	34
Table 3: Demographic and socio-economic characteristics of respondents .....	39
Table 4: Multinomial logit model result of demographic and socioeconomic characters source, own survey data 2020.....	45
Table 5: Multinomial logit model result of farmer perception .....	46
Table 6: Multinomial logit model result of farmer perception .....	48
Table 7: Mann-Kendall test for average annual maximum temperature under RCP scenarios....	54
Table 8: Seasonal average maximum temperature change from baseline over in the study area under both RCP scenarios in (O c) .....	55
Table 9: Seasonal average maximum temperature change from baseline over in the study area under both RCP scenarios in (O c) shows that the minimum temperature is expected to increase in all seasons in future.....	57
Table 10: Seasonal average minimum temperature change from baseline in the study area under both RCP scenarios in (O- <sup>c</sup> ).....	58
Table 11: Seasonal average rainfall change from baseline period in the study area under both RCP scenarios in (%).....	61
Table 12: Mann-Kendall test results for annual rainfall in the study area under RCP scenarios .	62
Table 13: Observed yearly rainfall variability over the study area during (1987-2008) .....	63
Table 14: Aqua crop model validation results with observed available maize yield data from (2002-2019).....	65
Table 15: Yield sensitivity Comparison from Aqua crop model outputs .....	69

## List of Figures

<b>Figure</b>	<b>page</b>
Figure 1 Sequence of conceptual framework.....	24
Figure 2 Map of study area .....	26
Figure 3: Flow chart of aqua crop, Source (Raes <i>et al.</i> , 2009) .....	29
Figure 4: Average monthly rainfall 1987-2014 .....	49
Figure 5: Average monthly maximum and minimum temperature of study area during 1980-2008 .....	49
Figure 6: Comparison of average monthly rainfall (A), maximum (B) and minimum temperature (C) of observed data with bias uncorrected and bias-corrected RCP datasets from (1980-2008)	51
Figure 7 : Projected monthly maximum temperature change for near-term (A) and mid-term (B) from baseline period in the study area. ....	53
Figure 8: The Projected average monthly minimum temperature change .....	56
Figure 9: Projected change of average rainfall distribution for near-term (A) and mid-term (B) from baseline period in the study area .....	60
Figure 10: Observed annual rainfall anomaly index over the study area during 1980-2007.....	64
Figure 11: Aqua model simulated versus observed maize yield data for the period the (2009- 2019) .....	65
Figure 12: Observed /A/and projected/B/ average yield for grain and biomass of Maize. (2009- 2018) .....	66
Figure 13: Projected grain yields versus biomass for near-term (A) and mid-term (B) of maize crop under both RCP scenarios in the study area .....	67

# **Impact of climate change on maize (*Zea mays L.*) yield and local adaptation strategies the case of Damot - Woyde district Wolayta zone SNNPR, ETHIOPIA**

Damtew Datta, Bisrat Elias, Tewdros Ayalew

## **ABSTRACT**

*The main objective of this research was to evaluate climate change impacts on maize productivity in Damot-woyde district of Wolayta Zone, Southern Ethiopia. The study investigates and addresses the likely occurrences of climate change on maize productivity. It was explained by future pattern of rainfall and temperature and its impact on maize yield. The existing knowledge and perception of farmers about climate change and adaptation used was assessed. The research methodology was used by employing CORDEX-Africa for RCP 4.5 and RCP 8.5 scenarios of climate model projected data, Aqua Crop model simulation and yield projection using projected rainfall and temperature data and questionnaire based assessment of community perception and adaptations used. The climate data used was near-term (2019-2048) and mid-term (2049-2078) projection for rainfall and temperature. The data was quality checked, biased corrected and evaluated with real data and statistical significances. Aqua Crop model maize simulation was verified by Central Statistical Agency yield data. The projected rainfall pattern shows a decrease by 3.7 mm/annual and increase by 4.6 mm/annual under RCP 4.5 for near and mid-term respectively projected to increase by 2.6 mm/annual and decrease by 2 mm/annual under RCP 8.5 for near and mid-term, respectively. Maximum temperature projected to increase by 0.004 and 0.017°C/ annual for near and mid-term under RCP4.5 respectively. It is projected to increase by 0.024 and 0.026°C/annual in near and mid-term under RCP 8.5 respectively. Future projected biomass and grain yield of maize is expected to decrease by 0.07 biomass and by 0.05 tone ha<sup>-1</sup> grain yield under RCP 4.5 from near to mid-term while, it is projected to decrease by 0.1 biomass and 0.15 tone ha<sup>-1</sup> grain yield under RCP 8.5 from near to mid-term. The community adaptation used to combat climate change effects shows that, the smaller holder farmers have somehow good knowledge of existing climate condition and climate change. In addition, some smaller holder farmers has been engaged in practice of climate change adaptation strategies but being come across with different challenges. Therefore, the study recommended the capacity building and supporting smaller holder farmers in regard to climate change adaptation strategies to enables them to cope-up the possible challenges.*

**Keywords:** *Climate change, Aqua crop model, maize yield, adaptation strategies*

# CHAPTER ONE

## INTRODUCTION

### 1.1. Background of the study

Agriculture is the most vulnerable economic sector to climate change due to its reliance on local environmental conditions and all agriculture depends on acceptable temperature ranges and patterns of rainfall for raising crops and livestock (Huntingford *et al.*, 2005; van Dervelde *et al.*, 2012). In comparison to developed countries, agriculture in developing countries is more vulnerable to climate change mainly due to dependent on rain fed agriculture, lack of improved technology, resource limitation, inadequate infrastructure and institutional capacity to adaptation Jones, (2003). Agriculture is the most important sector, particularly in Sub-Saharan Africa (SSA) which employs more than 60% of the population and contributes on average about 40% to the GDPs of the region. IPCC (2007) climate prediction shows that, the large areas of Sub-Sahara Africa are likely to be in the most vulnerable condition to climate change by 2100. The role of agricultural sector and its impact on the different aspects of socioeconomic life in Ethiopia by its contribution to GDP (46%), livelihood source for the majority of the population (80%), food supply, and export trade and foreign exchange earnings (84%). Ethiopian agriculture is dominated by smallholder farms that produce the bulk (over 90 %) of outputs for consumption and the market (Zenebe *et al.*, 2005).

The Intergovernmental panel on climate change (IPCC,1997,2001) report shows the existence of increasing frequency and severity of droughts and floods, shift in onset of the rains, and increasing intensity of mid- season dry spells in the past 50 years as major impact resulted due to climate change. According to IPCC(2016) climate change scenarios, global mean temperature is expected to increase by 1.0 to 3.0 C average in 2100 (relative to 1900-2000 average level), and

East Africa particularly Ethiopia has an annual minimum temperature rise of 0.25°C every 10 years. Accordingly, it will be evident that, the climate change explained by temperature would be resulted to immediate loss of the precipitation that can be used by crops and so high chance of inability to have enough number of agricultural products.

As described by IPCC (2007), for the reason of climate change over time could be related to either natural phenomena or/and adverse human activities in emission of greenhouse gases. The effects of climate change in globe could be evidenced by the rise in global mean temperature, increase/decrease of amount of rainfall, increasing frequencies of extreme events like floods and droughts and heat waves IPCC, (2007). Many Africa regions were recognized for climate variability in the world on seasonal and decadal time scales that resulted in repeated drought, flood, and occurrence of famine and widespread disruption of socio-economic well-being in UNFCCC agreement Möhner, (2018). Among all the developing countries, Ethiopia is found to be most vulnerable countries to climate variability, particularly, in agricultural sector.

Moreover, according to World Bank report put it, as a 90% nation Ethiopia has the largest population being engaged on agricultural production activities that 40% of the national GDP. According to (Zou and Zhou, 2016), the small-scale household farmers in rural part of the nation have been vulnerable to declining agricultural product both in quantity and quality and not able to feed their family accordingly and being exposed to food insecurity and aggravating poverty.

Agriculture strength of Ethiopian economy, which contributes more than 45% of gross domestic production (GDP), 80% to labor force and takes 85% to earn foreign exchange is highly disposed to climate change (Deressa *et al.*, 2008) smallholder and subsistence farmers in particular. For instance, the GDP of Ethiopia is very low during the years of severe drought, crop failure and famine (1984-1985 and 2000-2001), as compared to better periods (1982-83 and 1990-91).

Damot-Woyde district is located in Wolayta zone of Southern Ethiopia is one the area exposed to rainfall variability and temperature variation results into shortage of water during cropping season and consequently to frequent food insecurity and malnutrition occurrence in hotspots and drought-prone area. Southern Nation Nationality and Regional (SNNPR) are associated with drought and lack of better production employment opportunities, 90% of export earnings CSA, (2017).

Therefore, this study evaluates the climate change and trends from regional climate model (RCM) and its implication on maize productivity by developing simulation using crop models. The crop coefficients for this study adopted from previous MSc study by Elias Sorsa and Bisrat Elias (2018) for Mirab Abaya in consideration of similarity in climate pattern.

## **1.2. Statement of the problem**

Damot –Woydedistrict especially low lands of districts which are major maize production areas in SNNPRS have been experiencing crop yield reduction. However, historical, social and economic impacts of all natural hazards are not systematically well documented as quantitative climate change impact assessments are not properly conducted so far on various socio-economic sectors in Damot-Woyde district. Therefore, it was found to be vital to provide site specific information to address knowledge gap in skills and practice of climate change impacts on maize yield for smaller holder farmers in district by studying their major adaptation strategies.

This study was conducted with the aim to investigate the trends of climate variables specially temperature and rainfall with their impact on rain-fed maize yield and identify climate change adaptation strategies practiced by farming community in the study area.

### **1.3. Objectives of the study**

#### **1.3.1. General objective**

The general objective of the study was to evaluate the climate change impact in Damot-woyde district of Wolayta Zone, Southern Ethiopia.

#### **1.3.2. Specific Objectives**

- To assess long term climatic trends especially rainfall and temperature in the Damot-Woyde district
- To evaluate Aqua crop maize yield simulation using long term data
- To identify farmers' perception towards climate change impact on their maize production practice in the study area.
- To indicate farmers' practice of climate adaptation strategies in the study area.

### **1.4. Research questions**

The above objectives were investigated to answer the following questions.

- What are the likely occurrences of future climate change explained by rainfall and temperature?
- What is the future pattern of maize productivity under changing climate?
- How are the farmers perceiving climate change impact and reacting for adaptation?
- What are the adaptation strategies farmers implementing to cope with climate change?

### **1.5. Significance of the study**

This study presented the assessment of climate change on maize crop productivity and to evaluate the future trend of important climate variables. The study provided evidence on agricultural production problems and clues to advise in need of prior adaptation strategies in the area to overcome the emerging problems. The study was believed to bring meaningful attention

for different stakeholders. Accordingly, it could enable farmers to get ready and act properly during good rainfall season as well as best manager for climate related challenges. Moreover, it also gave shade light on the existing maize yield and so would enable policy and decision makers to have informed decision making. In addition, academically it could serve by both initiating others to conduct a study on similar or related topics and serving as a reference.

### **1.6 Scope of the Study**

The area of the study is in Damot-woyde district of Wolayta Zone of Southern Nation, Nationality and Peoples Regions (SNNPR) of Ethiopia. Data sources Dynamical downscaled Hadley Global Environmental Model Version 2

### **1.7 Limitations of the study**

This study has been conducted in Damot Woyde district of limited area due to lack of finance and time. Consequently, the study was conducted in a small area for maize crop productivity by smaller holder farmer household heads. Accordingly, in order to accomplish the established general and specific objectives of the study, the study has gathered up-to date, precise and comprehensive data from the selected sample kebele inhabitants of smaller holder farmer households and with that it had compensate the deviation.

### **1.8. Thesis organization**

The study is organized into five chapters. The first chapter consist introduction, statement of the Problem, objective, significance, scope and limitation and this section too, of the study. Chapter two review different important literatures related to the impact of climate change and variability on modeling maize production and adaptation option. Chapter three present descriptions of the study area, the type of research design and methods employed for data collection and analysis. Chapter four presents the finding of the v study along the discussion and the conclusions and recommendations are presented in chapter five

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1. Theoretical background

##### 2.1.1. Concepts of climate change

Climate change refers to a change in the state of the climate that can be identified (example by using statistical tests) by changes in the mean and or the variability of its properties and that persists for an extended period, typically decades or longer, may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use IPCC (2014).

Climate change is caused due to external forcing or natural processes, to persistent anthropogenic changes in the composition of the atmosphere or in land use. In the past few years, climate change has become a core issue in various developmental and political forums at the national, regional and international level. Many regional conferences have discussion sessions on climate change based on the recognition that global climate change is increasing and this has become more evident in recent years (Aklilu and Alebachew, 2009). Man-made influence on the climate system is strong, and recent anthropogenic emissions of greenhouse gases are the highest compared with the past. It is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. Anthropogenic GHG emissions have greatly increased since the pre-industrial age, caused largely by population and economic growth, and are now higher than ever. The effects together with those of other human activities and anthropogenic drivers have been identified throughout the climate system and are enormously likely to have been the main cause of the observed warming since the mid-20<sup>th</sup>C (Edenhofer *et al.*, 2014).

Greenhouse gases like carbon dioxide, methane, chlorofluorocarbon and nitrous oxide have been identified as a main factor of global warming (Singh *et al.*, 2014). It is thus apparent that global warming is due to anthropogenic emission of greenhouse gases. The major sources of greenhouse gases are electric power stations due to burning of fossil fuels, numerous factories spread all over the world, the transport sector and deforestation. According to the finding, the relative share of carbon dioxide, chlorofluorocarbons, methane and nitrous oxides were 51%, 20% 16% and 16% respectively up to 1990. The increased concentrations of these gases affect agricultural productivity. (Elliset *et al.*, 2010) argued that the increased carbon dioxide concentrations in the atmosphere are a key element of climate change that could affect food security.

### **2.1.2. Causes of climate and its impacts**

Climate change refers to long term fluctuations of temperature, precipitation, wind and other elements of Earth's climate system. It is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global and/or regional atmosphere. Natural climate variability observed over comparable time periods in the types of changes of temperature and rainfall. It occurs because of internal variability within the climate system and external factors. The external causes may be natural or human induced activity. Human activities cause climate change mainly due to fossil fuel burning and removal of forests. Changes in temperature and precipitation patterns as a consequence of increased greenhouse gases (GHG) concentration may affect the hydrological processes and availability of water resources for various purposes IPCC (2014). According to the IPCC fifth assessment report, AR5 there are many indicators of climate change. These include physical responses such as changes in the surface temperature, atmospheric water vapor, precipitation, severe events, glaciers, ocean and land ice, and sea level rise.

### 2.1.3. Climate change in Ethiopia

Ethiopia's contribution to GHG emissions is very low on a global scale. The emissions of greenhouse gases are predominantly from high-income countries while the negative effects of climate change are predominantly in low income countries. This means climate change is generally expected to hit developing countries harder than industrialized countries. Developing countries are less capable of mitigating or adapting to the changes due to their poverty and high dependence on the environment for subsistence. It has brought an escalating burden to already existing environmental concerns of the country mainly by anthropogenic factors. The mainstay of the Ethiopian economy is rain-fed agriculture, which is heavily sensitive to climate variability and change. Over the last few decades, the temperature in Ethiopia increased at about  $0.2^{\circ}\text{C}$  per decade. The increase in minimum temperatures is more pronounced with roughly  $0.4^{\circ}\text{C}$  per decade. Precipitation, on the other hand, remained stable over the last 50 years when averaged over the country. However, the spatial and temporal variability of precipitation is high.

Most of the global climate models discern an increase in precipitation in both the dry and wet seasons. Studies with more detailed regional climate models, however, indicate that the sign of the expected precipitation change is uncertain. The temperature is very likely continued to increase for the next few decades with the rate of change IPCC, (2014). Detrimental and beneficial impacts of the ongoing and projected climate change and variability are widespread in both socioeconomic and natural systems. These impacts include: Agriculture, Food Security: The increasing year-to-year variability and increases in both droughts and heavy precipitation events lowers agricultural production with corresponding negative effects on food security.

**Water:** The availability of clean drinking water is likely to decrease due to the increasing evaporation and the increasing variability of rainfall events.

**Health:** Incidences of malaria in areas of the highlands where malaria was previously not endemic. The warming is further expected to cause an increase in cardio-respiratory and infectious diseases.

**Ecosystems, Biodiversity:** Human drivers such as forest fires threaten forest ecosystems. Furthermore, a large number of plant and animal species is threatened by extinction, as climate conditions are changing too quickly for them to adapt.

**Infrastructure:** Heavy rainfall events and floods cause damages to roads and buildings. Factors compounding the impact of climate change in Ethiopia are rapid population growth, land degradation, widespread poverty, depending on rain fed agriculture, lack of awareness of policy and decision-makers about climate change and lack of appropriate policies and legislation NAPA, (2007). In countries like Ethiopia, more than 85% of the people depend mainly on agriculture for their livelihoods, rendering them very vulnerable to climate variability and change. Accordingly, in recent times, a significant number of people in Ethiopia are being affected chronically by drought and/or flooding, leading to deaths and loss of assets and to an appeal for international support.

#### **2.1.4. Climate models**

Climate models are numerical tools based on mathematical equations that aim to represent processes of the climate system. These equations are based on physical laws which govern fluid mechanics, such as the laws of conservation of mass, energy, and momentum. They describe the behavior and interactions between the atmosphere, lithosphere, hydrosphere, cry sphere and biosphere, under external forcing such as solar radiation, aerosols, as well as natural and anthropogenic greenhouse gas (GHG) emissions (Grotch and MacCracken, 1991).

Climate models are divided into two main groups based on the size of their calculation grid, an area referred to as the model domain:

### **2.1.5 General Circulation Models (GCMs)**

As the name suggests, GCM calculation grids (domains) cover the entire planet. Current GCMs typically have a horizontal resolution around 200 km. GCMs are divided into three main categories. The very first GCM generations of models to be developed were referred to as atmospheric general circulation models (AGCM), and only included the atmosphere portion of the climate system and its interaction with the continental land surface. The second generation of models, termed atmosphere-ocean general circulation models (AOGCM), coupled the atmosphere and land with physical ocean models. The latest generation of models, known as Earth system models (ESM), now include the addition of biogeochemical interactions and cycles, as well as changes in land cover (such as vegetation types). Thus far, the carbon cycle has been implemented in most ESMs and research is ongoing to include other cycles (Grotch and MacCracken, 1991).

### **2.1.6 Regional Climate Models (RCMs)**

RCMs have smaller domains that cover only a portion of the planet. By focusing on a limited area of the globe, it is possible to solve the climate model equations over a finer horizontal resolution (50 km or less) within a reasonable amount of time. In order to run regional climate models, data from global climate models must be integrated at their boundaries (this can also be done using reanalysis; essentially a technique that uses computer models to combine historical data from various sources to recreate the past climate). This procedure is called driving a regional climate model.

RCMs are developed by research institutions that have sufficient computational capacity and technical expertise. Various RCMs differ in their numerical, physical, and technical aspects (Sylwia and Emilie, 2014). The most commonly used RCMs in climate change downscaling studies include the U.S. Regional Climate Model Version 3 (RegCM3); Canadian Regional

Climate Model (CRCM); UK Met Office Hadley Centre's Regional Climate Model Version 3 (HadRM3); German Regional Climate Model (REMO); Dutch Regional Atmospheric Climate Model (RACMO); and German HIRHAM, which combines the dynamics of the High Resolution Limited Area Model (HIRLAM) and European Centre-Hamburg (ECHAM) models. Although the above models have been developed primarily over North America and Europe, they can be adapted to any region of the globe by incorporating appropriate information on terrain, land-cover, hydrology, and so on; hence, several RCM can be used over a given region.

#### **2.1.7. Downscaling of general circulation models**

Global Climate Models (GCMs) are the primary tools to simulate multi-decadal climate dynamics and to generate and understand global climate change projections under different future emission scenarios. However, these models have a coarse spatial resolution (typically a few hundred kilometers) and suffer from substantial systematic biases when compared with observations. Therefore, they are unable to provide actionable information at the regional and local spatial scales required in impact and adaptation studies (Grouillet *et al.*, 2015). Hence, higher resolution simulations and if possible, bias corrected are required for the most relevant climate variables (Agumagu and Todd, 2015).

Downscaling attempts to resolve the scale discrepancy between climate change scenarios and the resolution required for impact assessment. Two main downscaling approaches have been developed since the early 1990s: Dynamical downscaling (based on Regional Climate Models, RCMs) and Statistical Downscaling Models (SDMs), which are nowadays recognized as complementary in many practical applications.

#### **2.1.8. Dynamical downscaling**

The development and use of regional climate models (RCMs) also referred to as dynamical downscaling when applied to downscale global climate model (GCM) output originated in the

late 1980s. Dynamical downscaling refers to the use of high-resolution regional simulations to dynamically extrapolate the effects of large-scale climate processes to regional or local scales of interest (Gadeke *et al.*, 2013). Such models are used to refine the horizontal resolution of the climate in a selected region of the globe. Their finer resolution (typically 10 to 50 km) means they can develop more detailed characteristics of the climate because, among other things, they benefit from a much more precise representation of land surface features (such as mountains, coastal contours, or the presence of lakes and rivers).

Dynamical downscaling has some distinctive advantages such as: (1.) accounts for sub- GCM grid scale forcing (e.g. topography); (2.) Information is derived from physically based models ;(3.) Better representation of some weather extremes as compared to GCMs. However, the disadvantages include (1.) Expensive to run RCMs to statistical downscaling over a large region; (2.)Its dependence on GCM predictors; (3.) It is a spatially smoothed product compared to station scale.

### **2.1.9. Statistical downscaling**

Statistical downscaling encompasses the use of various statistics-based techniques to determine relationships between large-scale climate patterns resolved by global climate models and observed local climate responses. These relationships are applied to GCM results to transform climate model outputs into statistically refined products (Dayon *et al.*, 2015).

The statistical downscaling of a GCM simulation relies on the hypothesis that the statistical relationships established for the recent past will remain the same for future climate. In the context of climate change, this hypothesis is problematic because climate is not stationary and the validity of the assumption is difficult to test. Moreover, downscaling several climate variables simultaneously still presents a challenge. However, statistical downscaling is a

relatively inexpensive and quick approach compared to dynamic downscaling, and easier to apply to problems that involve only a single variable (Wilby and Dawson, 2013).

Statistical downscaling has some distinctive advantages such as: (1) Comparatively cheap and computationally efficient; (2.) Can provide point-scale climatic variables from GCM scale output; (3.) Able to directly incorporate observations into method. However, the disadvantages include (1.) Does not account for non-stationary in the predictor- predict and relationship; (2) Climate system feedbacks not included; (3.) Dependent on statistical or empirical model structure and associated parameters; different models will give different results.

#### **2.1.10. Climate Scenarios**

Scenarios have long been used by planners and decision makers to analyse situations in which outcomes are uncertain. In climate research, emissions scenarios are used to explore how much humans could contribute to future climate change given uncertainties in factors such as population growth, economic development, and development of new technologies. Projections and scenarios of future social and environmental conditions are also used to explore how much impact lesser or greater amounts of climate change would have on different possible states of the world, for example futures with greater or lesser amounts of poverty.

The purpose of using scenarios is not to predict the future, but to explore both the scientific and real-world implications of different plausible futures (Bjornaes, 2013). These future scenarios of forcing agents (e.g., greenhouse gases and aerosols) are fed in to the climate models as input, and the output of these climate models is further used in climate change analysis and hence, the assessment of impacts, adaptation and mitigation. Several sets of scenarios including the IS92scenarios, the scenarios from the Special Report on Emission Scenarios (SRES) and, more recently, the Representative Concentration Pathways (RCP). Vuuren, (2011) are used in climate research. Scenarios previously approved by the IPCC included and illustrated in Table 1.

Table 1. History of scenarios

Year	Name	Used in
1990	SA90	First Assessment Report
1992	IS92	Second Assessment Report
2000	SRES-Special Report on Emissions and Scenarios	Third and Four Assessment Report
2009	RCP-Representative Concentration Pathways	Fifth Assessment Report

(Source; Bjornæs (2013))

### 2.1.11. The Representative concentration pathway (RCPs)

Representative Concentration Pathways (RCPs) are the new driving emission scenarios that serve as input to climate models participating in the Coupled Model Inter-comparison Project phase 5 (CMIP5), which form the basis for the Fifth Assessment report from the IPCC. Just as the SRES replaced older emission scenarios, the RCP show replace the SRES in order to be coherent with new data, new world development and new models.

RCPs form a set of greenhouse gas concentration and emissions pathways designed to support research on impacts and potential policy responses to climate change (Moss *et al.*, 2010; Vuuren *et al.*, 2011). The implications of climate change for the environment and society will depend not only on the response of the Earth system to changes in irradiative forcing, but also on how humankind responds through changes in technology, economies, lifestyle and policy.

Approximate radiative forcing level was defined as  $\pm 5\%$  of the stated level in  $\text{Wm}^{-2}$  relative to pre-industrial levels. Radiative forcing values include the net effect of all anthropogenic GHGs and other forcing agents. Note: MESSAGE, Model for Energy Supply Strategy and their General Environmental Impact, International Institute for Applied System Analysis, Austria; AIM, Asia-

Pacific Integrated Model, National Institute for Environmental Studies, Japan; GCAM, Global Change Assessment Model, Pacific Northwest National Laboratory, USA (previously referred to as MiniCam); IMAGE, Integrated Model to Assess the Global Environment Netherland Environmental Assessment Agency.

### **2.1.12. RCPs Primary Characteristics and Their Development**

Among the research community, recently there has been an increasing interest in scenarios that explicitly explore the impact of different climate-policies in addition to the no-climate-policy scenarios such as SRES Moss, (2010). The need for new scenarios prompted the IPCC to request scientific communities to develop a new set of scenarios for the assessment of future climate change. Therefore a set of new scenarios is constructed containing emission, concentration and land-use trajectories referred to as “Representative Concentration Pathways” (RCPs). In its name, the word “representative” signifies that each of the RCPs represents a larger set of scenarios in the literature. This implies that this set of RCPs should be compatible with the full range of emission scenarios (with and without climate policy) available in the current scientific literature. The word “concentration pathway” emphasizes that these RCPs are not the final new, fully integrated scenarios (i.e. they are not a complete package of socio-economic, emission and climate projections), but instead are internally consistent sets of projections of the components of radiative forcing that are used for the input to climate models. The word “concentration” also emphasizes that instead of emissions, concentrations are used as the primary product of the RCPs, designed as input to climate models (Hibbard et al., 2007). Four RCPs pathways named according to radiative forcing levels of 8.5, 6, 4.5 and 2.6 W/m<sup>2</sup>, by the end of 2100. **RCP2.6:** This scenario has also been referred to as RCP3PD representing the radiative forcing trajectory which goes to a peak level of 3 W/m<sup>2</sup>(~490 ppm CO<sub>2</sub> eq) before 2100, followed by a decline (PD=Peak-Divide). The selected pathway declines to 2.6 W/m<sup>2</sup> by 2100 (Vuuren, et al., 2007). It aims at limiting the increase of global mean temperature to 2°C above the preindustrial

period.

**RCP4.5:** This scenario describes the stabilization without overshoot pathway to 4.5 W/m<sup>2</sup> (~650 ppm CO<sub>2</sub> eq) at stabilization after 2100 (Thomson et. al., 2010). RCP4.5 corresponds to that category scenarios in AR4 which contains the far majority of the scenarios assessed.

**RCP6:** This scenario is also similar to RCP4.5, with stabilization without overshoot pathway to 6W/m<sup>2</sup> (~850 ppm CO<sub>2</sub> eq) at stabilization after 2100 (Fujino, et al., 2006). The number of mitigation scenarios leading to 6 W/m<sup>2</sup> in the literature is relatively low however, at the same time many baseline scenarios (no climate policy) correspond to this forcing level.

**RCP8.5:** This scenario corresponds to the rising radiative forcing pathway leading to 8.5 W/m<sup>2</sup> (~1370 ppm CO<sub>2</sub> eq) by 2100 (K Riahi et al., 2007). It corresponds to a scenario with no-climate policy baseline and comparatively high greenhouse gas emissions.

### **2.1.13 CORDEX Project**

The Coordinated Regional Climate Downscaling Experiment (CORDEX) program, initiated by the World Climate Research Program (WCRP; <http://www.wcrp-climate.org/>), provides an opportunity for generating high-resolution regional climate projections, which can be used for assessment of the future impacts of climate change at regional scales (Giorgi *et al.*, 2009). CORDEX is focus on the concentration pathways scenario corresponding to different radiative forcing stabilization levels by the year 2100 simulations that different from the scenario runs employed in the fourth IPCC assessment cycle, which were based on the SRES GHG emission scenarios IPCC, (2007). The CORDEX program includes twelve regions. Africa was selected as the first target region, covering the majority of the populated land areas worldwide, plus both the Arctic and Antarctic. CORDEX-Africa RCMs generate an ensemble of high resolution historical and future climate projections at regional scale by downscaling different GCMs forced by RCPs based on the Coupled model Inter comparison Project Phase

5(CMIP5). There are many different RCMs currently available, for various regions, developed at different modeling centers of the world.

This study uses three downscaled output of RCMs which driven by three GCMs. . For each experiment the historical runs, forced by observed natural and anthropogenic atmospheric composition, cover the period from 1971 until 2005. The future projections (2006 to 2100) are forced with two Representative Concentration Pathways (RCP), namely, RCP4.5 (mid-range emissions) and RCP8.5 (high end emissions) scenarios, which prescribe future atmospheric greenhouse gas concentrations and aerosols.

## **2.2. Empirical Literature on Adaptations to Climate Change and variability**

Large numbers of empirical studies are undertaken in the areas of farmers' adaptation and determinants of adaptation strategies to climate change and variability in different countries across the world(Khanal et. al., 2018, analyze determinants of farm-level climate adaptation measures in 11 African countries using a multinomial choice model. They use the data obtained from a cross-sectional survey of over 8000 farms. Their results reveal that specialized crop cultivation or mono-cropping is the agricultural practice most vulnerable to climate change and warming poses the highest risk especially during the summer season. Results also confirm that better access to markets, extension and credit services, technology and farm assets, particularly labor, land and capital are critical for helping African farmers adapt to climate change in Africa.

In Ethiopia, (Temesgen et al. 2008) assess determinants of farmer's choice of adaptation strategies and perceptions of climate change in the Blue Nile Basin. They indicate that the common adaptation measure employed by farmers in the area are the use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation. Using the multinomial logic model, their study finds that the level of education, gender, age, and wealth

of the head of household, access to extension and credit, information on climate, social capital, agro-ecological settings, and temperature all influence farmers a choice of adaptations. Their analysis also reveals that the age of the household head, wealth, and information on climate change, social capital, and agro-ecological settings have significant effects on climate change. Moreover, the study also reports lack of information on adaptation methods and financial constraints as key constraints to climate change adaptation.

Bethlehem (2014), assessed the adaptation to climate variability and changes in the small farming households, Dire Dawa Zuria Woreda. And the result indicated that the common adaptation measure employed by farmers in the area are use of different crop varieties, tree planting , early and late planting, soil and water conservation, shift from cattle to goat and sheep, income source diversification and growing drought tolerant crop by using multi nominal logit model, their study finds that the sex, level of education , age, active labor ,farm size ,farm experience ,farm income , access to extension and credit, information on climate, irrigation access and distance to market are all influence farmers choice of adaptation.

Similarly, Kide, (2014) assessed small holder farmer's adaptation strategies to climate change in Ethiopia. Crop varieties, improving crop and livestock farming, soil and water Conservation, irrigation and no adaptation are major adaptation strategies employed by farmers in the study area by using the multinomial logic model. The result indicates that age, family size, farm size, farm income, distance to market, access to credit, access to agricultural extension service and the number of livestock are determinants of farmer's choice of adaptation. From the brief review of previous theoretical and empirical literature, this study identifies important research gaps.

### **2.2.1 Modeling and Types of Models**

Models are used to help to solve the problems in operational and practical academic issues. Hence, by carefully and precisely following the right modeling processes, we can be able to solve academic as well as problem which happen in our practical activities. Similarly, the modeling processes; according to FAO (2015) encompasses its own steps:

Problem formulation: forming specific questions

Model choice: selecting a model from the existing one or built new one

Model calibration: finding out parameters for the selected models

Model validation: enabling the model to predict something for instance from simplified example or previous data

Model application: using the model for addressing objectives or basic research questions.

Consequently, so as to employ models, identifying and establishing basic assumptions about the problem in hand is the vital starting point. Further, based on the established problem and specific questions to be answered /being hypothesized/; selecting calibrating, validating, and finally applying the mode are parts of modeling / model applying / process. In such instances, careful problem identification and based on the result of right and appropriate model would be very decisive to be effective.

### **2.2.2 Crop models**

Crop production simulation models can be used for estimating agricultural production as a function of water and soil conditions as well as crop management. Dynamic crop prediction model systems, which can best serve as decision making support tools have been utilized by agricultural scientists very extensively for evaluating possible agricultural consequences out of inter annual climate variability /climate change. Similarly, crop modeling can provide a shell

which allows the user to organize and manipulate data, run crop models and analyze the output  
FAO, (2016).

### **2.2.3 Aqua Crop**

**Aqua crop model:** according to FAO (2009) defines it, aqua crop is a crop water productivity model developed by the land and water division of the Food and Agricultural organization of the United Nations. Further (Raes *et al.*, 2009) explained that aqua crop combines the benefit of more empirical modeling methods (low input data requirements, validity over large area) with the benefit of process-based approaches (the potential to capture variability due to different sub seasonal weather patterns and hence increased validity under future climates). It is dynamic crop water – driven prediction simulation model is recently developed tool that supports Agricultural production and people who engaged directly or indirectly in having better and informed decision making about possible production. Hence, it integrates the effect of crop phenol type, soil profile, weather data, and also management options into a crop production model. The aqua crop model uses maximum and minimum air temperature, ( $T_z$  and  $T_n$ ) rain fall and reference evapotranspiration, ( $ETO$ ) from season long weather records, computes plants growth and development processes in a specific location from planting date to maturity date For such reason, the impact of weather, soil and management decisions on a crop yield can be well examined driven

Moreover, According to Fisher (2015) stated that outcomes of decisions with aqua crop can be made at three temporal levels:

Days to week – decision of operational level and refers to these taken within a growing season on scale of day to –few weeks.

Weeks to month: tactical farming decision typically made at the start of different times during the growing season

Year to strategic or long-term decision which takes series of years.

Meanwhile, according to the same sources above FAO,(2015) briefly expresses that, the functional components of aqua crop model are: soil and its balance with water , the plant with its processes, the atmosphere and its thermal regime and rain fall, evaporative demand , carbon dioxide concentration and management practices (example : planting date, fertilizer use, irrigation). Therefore, aqua crop model can stipulate yield responses to water of herbaceous crops and so particularly suited to address conditions / phenomenon/ by which water is a key limiting factor in crop production. On the other hand, aqua crop model has main advantages in relation to crop growth simulation. Hence, as Fisher,(2015) forwarded, aqua crops main advantage is using friendly, easy to employ and above all requiring relatively low number of parameters and input data to simulate the yield response to water of most of field and crop cultivated worldwide.

### **The soil**

The soil component of aqua crop is configured as dispersed systems of a variable depth allowing up to five various horizons of different texture composition along the profile. As indicated by (Steduto *et al.*,2009) the hydraulic characteristics include the hydraulic conductivity at saturation, and the volumetric water content at saturation, field capacity and wilting point. Further, for the soil profile explored by the roots-system, aqua crop model performs a water balance comprising the process of runoff, infiltration, redistribution / internal drainage, deep percolation, capillary rise, uptake, evaporation and transpiration. Accordingly, daily step soil water balance keeps track of the incoming and outgoing water fluxes at root zone and stored soil water boundaries.

### **The plant**

The crop system of aqua crop comprises parts as well associated dynamic responses. Hence, as to FAO (2015) put them, they include: phenology aerial canopy, rooting depth, biomass

production and harvestable yield. The crop grows and develops over its cycle by expanding its canopy and deepening its rooting system. The canopies represent the source for actual transpiration which translated in proportional amount of biomass produce with the water productivity parameter.

### **Growing degree days**

Based on availability of data, simulation models as well as user's choice, crop growth and development can be explained dynamically either in calendar days or in thermal time. Thus, aqua crop uses growing degree day's /GDD/ to compute thermal time.

### **2.2.4 Field management for effective development of yield**

Any agricultural production activity requires appropriate resources, improved methods as well as taking care of the cultivation land in order to have best result /yield/ both in amount and quality. Further, input employment and field management of agricultural production can be very decisive in developing dynamical yield prediction using climate variables with aqua crop. Therefore, producers must employ needed inputs and should conduct best field management activities including: quality seed input employment comprising: quality seed and breed of crops and live stocks, modern as well as improved methods and techniques, organic and inorganic fertilizer, ploughing the land repeatedly, giving cautions care, and using pesticides and insecticides and other needed inputs. Field management such as: controlling soil erosion, keeping soil fertility with proper soil management practice, conducting crop rotation.

### **2.3 Conceptual Framework of the study**

The study used the following framework to conceptualize and understand climate change impact on maize yield, adaptation strategies and their determinants on \_smallholder farmers in the study area (Figure 1).Climate change is often recognized as the major challenges on \_smallholder

farmers in the 21<sup>st</sup> Century and in the developing countries where it can have negative effects on what has been developed for a long time (Chambwera and Stage, 2010).

Climate change includes major changes in temperature, rainfall, wind pattern and other climate variables that occur over decades or longer IPCC, (2007). Climate change 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).

Overall Conceptual framework of Climate change Impact Analysis on Maize Yield

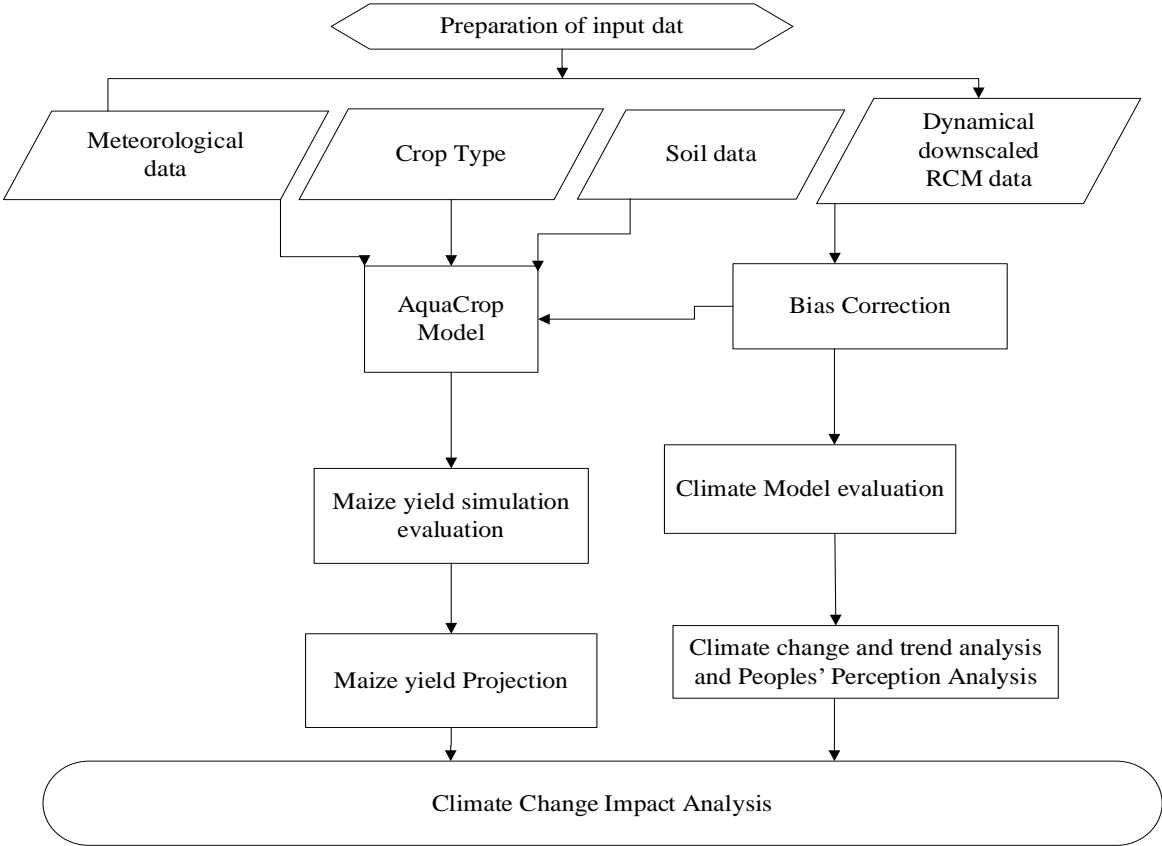


Figure 1 Sequence of conceptual framework

## CHAPTER THREE

### MATERIALS AND METHODS

#### 3.1. Description of the Study Area

The study was conducted in Damot-Woydedistrict, Southern region, Ethiopia. Damot-woyde district is one of the districts (16 rural districts and 6 town administrations) in Southern Region. Damot-Woydedistrict is located about 100\_kms west of the regional capital, Hawassa, along the HawassaWolayta-Soddo Highway as well as absolute location of  $6^{\circ}40'48''$  and  $6057'36''$  latitude and  $37^{\circ}49'48''$  East up to  $380\ 4'48''$  west longitude and with a total area of  $352\text{ km}^2$ . CSA, (2017).Moreover, the study area is located relative location of Humbo District in the south, Damot gale district in the North, Diguna-fango district in the East and Soddo-zuriya district in the west

Meanwhile, according to CSA, (2017) Damot-woyde district have a total of 128,452 populations, with 63,066 male and 65,386 female of the total population of the district. In addition as the same source above stated there are 15,637 households in the district.

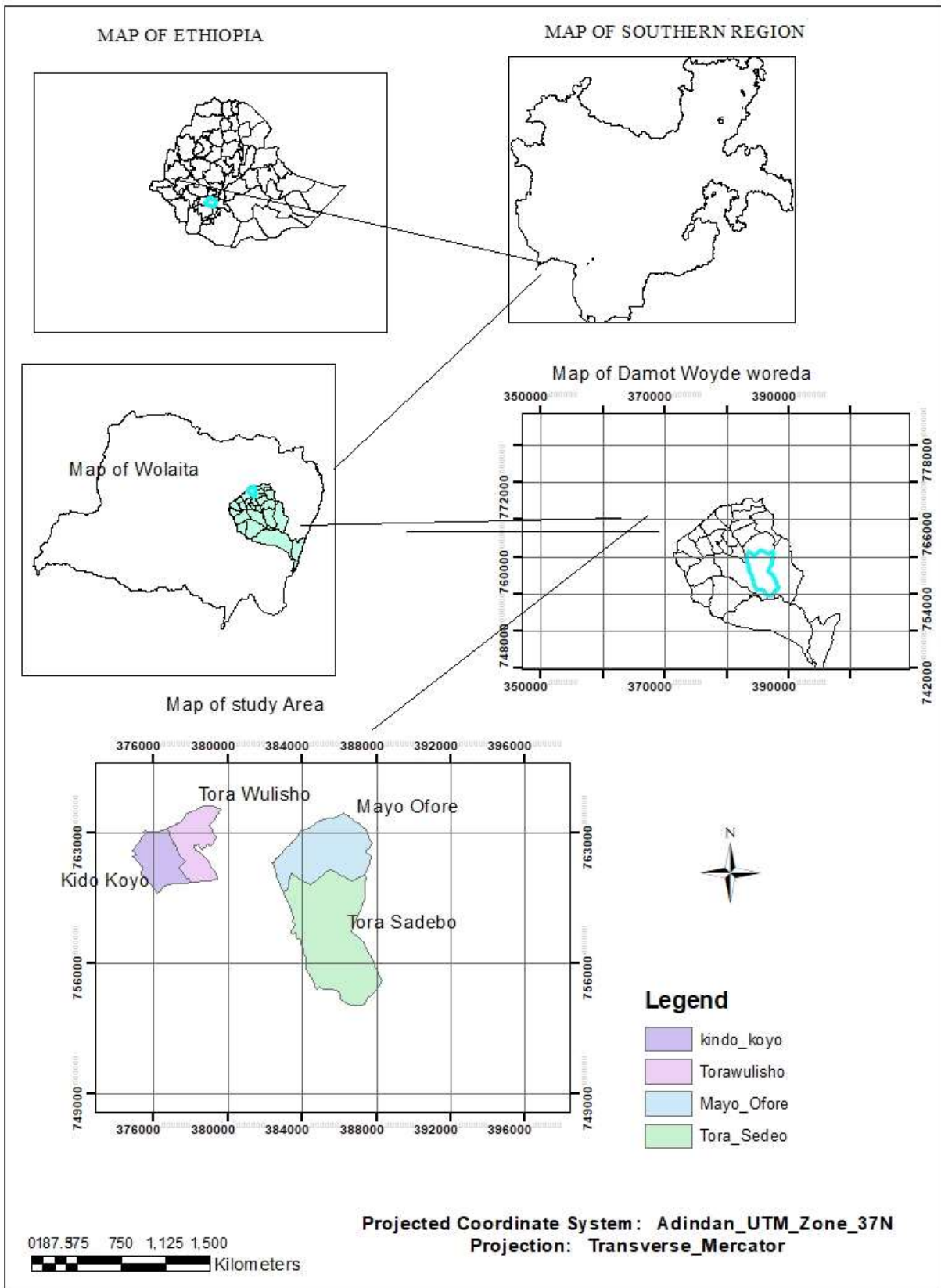


Figure 2 Map of study area

### **3.2. Climate, Topography and Soil type**

Overall area of the study area (228.8km<sup>2</sup>), 77.7% has a climatic condition of the total/ woynadega climatic condition and 122.3km<sup>2</sup> (23.3% of the total kola climatic conditions, CSA,(2017).Moreover, according to CSA,(2017) stated Damot-woyde district has a topography of flat lowland plain, degraded gentle slope to intensive gullies. Further, Damot-woyde district has temperature 17.6<sup>o</sup>cup to25<sup>0c</sup>per annum with rainfall of 923up to 1758mm per year.

On the other hand, Damot-woyde district has different types of soil. Accordingly, it has chromic vertisol, eutricnitsol, pellicvertisol, and vetricand osol. Hence of the arable land of the study area 10045 hectare there is 30% hectare of land with chromic- vertisol 40% is pellic-vertisol soil type, 15% hectare eutri nit sol soil type and 15% hectare is vetric-andosol soil types Eyasu,( 2002).

### **3.3. Vegetation**

Damot-woyde district has different kinds of flora and fauna resources. Hence; of the total area of the district 3520 hectare10% has been different types of forest, 1092ha 31%covered with man-made forest or afforested tree types and 598ha 17% covered with grass land and as well as the rest 809 ha27% being either barren land or cultivated land with temporary or permanent plants CSA,( 2017)

### **3.4. Agricultural production**

Damot-woyde district households have been engaged on agricultural production activities. Accordingly, of the total 25,637 households in the district 22036 have been engaged on production of different agricultural products CSA, (2017). Hence , as to the same source above the major agricultural products of the district includes: cereals(Maize, sorghum ,teff, wheat soy bean), fruits ( mango, avocado, papaya ,orange ,lemon , banana and others), vegetables( onion, garlic,potato,sweet potato, tomato cabbage ,pepper) and livestock –production including: sheep, goat, dairy and beef farming Damot-Woydedistrict Agriculture and Natural Resource

Report).The maize production practice of Damot-Woyde district has been in most cases being done with traditional method. That is why, according to the Damot-woyde district Agricultural office (2011E.C) yearly report, of the total 2555 hectare land being covered with maize crop, only 490 hectare had been employed all the modern method and input and the rest had used only quality seed. That had been disseminated force-fully through kebele administrative. Maize as staple foods of the in habitants of the study area, it has been reported by CSA (2016). (CSA, 2017)that 2155 hectare and 2555 hectare of land had been covered with the crop. Further as to the same source CSA, (2016). CSA (2017) forwarded, the study area had a total Maize product of 1tone and 3 tons respectively. Meanwhile, a maize production activity in the study area has been vulnerable to different types of constraints which affect maize yield in both quantity and quality.

### **3.5. Aqua crop model setup**

This study had been designed to investigate maize yield production of target district using dynamical model which needs time variable weather data such as: rainfall, maximum and minimum temperature, solar radiation and stationary variable such as soil texture, management condition, crop type, types of cropping and growing time. Time variable weather data had been collected from National meteorological Agency and solar radiation will be estimated from temperature data. The dynamical aqua crop calibration was adopted from calibration of Mirab Abaya Aqua crop model calibrated in 2017 with assumption of the area has similar climate pattern. Aqua crop model simulation flow chart is shown below

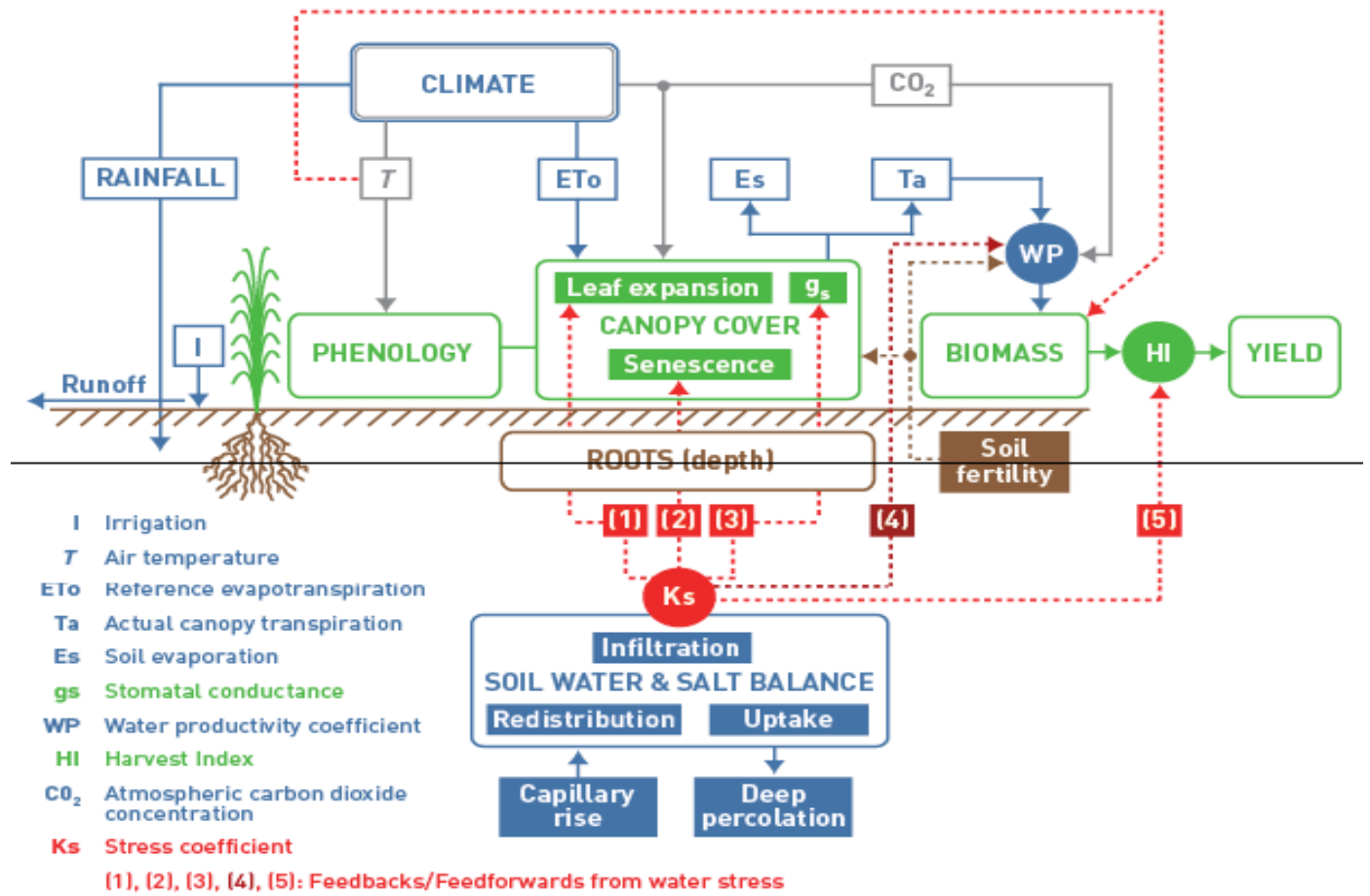


Figure 3: Flow chart of aqua crop, Source (Raes *et al.*, 2009)

### 3.5.1. Aqua crop model equations

Yield estimation in response to water is expressed in an equation 1

$$Y_x - Y_a = k_y \frac{ET_x - ET}{ET_x} \quad (\text{equa 1})$$

Hence,  $y_x$  and  $y_a$  will be the maximum and actual yields,  $ET_x$  and  $ET$  are the maximum actual evapo transpiration and also  $k_y$  is the proportionality factor between relative yield loss and relative evapo transpiration reduction.

### 3.5.2 Dataset for Aqua Crop model

Daily weather variables, soil data, crop data and other agronomic practices related with maize production collected from different documented materials and others during filed survey for both crop model in order to assess the overall activities at one shot. The details of used data for both crop models.

#### Meteorological data

Daily data of selected weather variables are important to run Aqua crop model. Data of daily air temperature and precipitation were directly used from the bias-corrected data of RCP 4.5 and 8.5 scenarios. Daily evapotranspiration in (mm) was calculated from maximum and minimum temperature using the Hargreaves method. These went as input into the model because the future RCP dataset was limited on the other weather variables to use in the Penn-man Monteith equation. For the adjustment of crop transpiration, biomass water productivity and Aqua Crop require the mean annual atmospheric CO<sub>2</sub> concentration. The 'Mauna Loa CO<sub>2</sub>' file contains observed mean annual CO<sub>2</sub> for the period of 1902 to till today. By using the CO<sub>2</sub> files with the projected atmospheric composition for the future, one can test the crop response for climate change scenarios. This CO<sub>2</sub> file selected for each RCP data is included in Aqua crop model Version 4.0 IPCC, (2013)

#### Crop data

Observed maize yield data of meher season was collected from Central Statistics Agency of Ethiopia (CSA) for the period of 2009-2018 to evaluate Aqua Crop model simulation with corresponding year. For the future evaluation of climate change impacts on maize yield over the area for selected maize crop data collected from the Mirab Abaya Wereda 2009 annual report and other documented materials and other farmer practices related with maize cultivation collected during filed survey and input into model.

### **Soil data**

Soil data used for this particular study; spatial analyzed soil data were used from major soil texture of the catchment selected first. After selection major soil texture choose from FAO soil classification which types of major soil under categorized used for both models. Clay loam soil was used for soil texture selection because of major soil type of the study area categorized under clay loam soil texture CVR Ethiopia of soil texture classification (Ashenafi et al., 2016).

### **3.5.3 Aqua Crop model calibration and simulation**

To project the biomass and grain yield simulation using Aqua Crop model, site-specific information such as growing season, planting date, moderate management and agronomical practices were provided based on field survey information of particular area. 135 days of (BH-540) maize varieties were used for simulation. Very sensitive crop parameters were changed and calibrated based on (Heng *et al.*, 2008). Sensitive soil parameters for selected soil were used from FAO, (2017) understanding Aqua crop Book 1 and the rain fed was considered for calibration of both scenario projections. Projected file (file with extension “PRO” for single and “PRM” for multiple running as used) for this particular study multiple “PRM”extension file was selected due to the future maize simulation setting for near-term 2019-2048 and mid-term 2049-2078 under both scenarios. Furthermore, all data input of Aqua Crop model Plug manual version 4.0 developed by FAO, (2012) used as references in this study to simulate future maize yield versus biomass in the study area.

### 3.5.4 Aqua Crop model evaluation criteria

The model evaluation in its simplest form is Comparison between observed and model simulation output values. The objectives of model evaluation are to match observed data set with model simulation to validate the model performance and how to model fit the purposes by using different statistical checking criteria. The model performance was evaluated by using root mean square error (RMSE) (Hsiao *et al.*, 2009) and the coefficient of efficiency (E) by Nash and Sutcliffe (1970).

**Root mean square error (RMSE)** it is a measure of the difference between observed and predicted values of the model. RMSE serves to aggregate them into a single measure of predictive power and its value ranges from 0 to  $\infty$ . The lower value can be better.

**Efficiency (E)** it is defined as one minus the sum of the absolute squared differences between simulated and observed which takes for model validation under the investigation period. The value of (E) ranges between 1.0 (perfect fit) and  $-\infty$ . Generally, it expresses how much is the overall deviation between simulated and observed and also measures the ability of model capture how well the model performs over the whole simulation period.

Both are computed by the equations:

$$RMSE = \sqrt{1/n \sum_{i=1}^n (S_i - O_i)^2} \quad 3.19$$

$$E = 1 - \frac{\sum_{i=1}^n (S_i - O_i)^2}{\sum_{i=1}^n (S_i - \bar{O}_i)^2} \quad 3.20$$

Where,  $S_i$ ,  $O_i$  and  $\bar{O}_i$  are the sum of simulated, observed and mean value of observed data respectively and is  $n$  is number of observations.

### 3.6. Target area and sample size

As stated earlier the target area of this study was Damot-woyde district with a total arable land of 10,045 hectare of it 2555 hectare was expected to be covered with Maize CSA, (2017). Moreover, of such 2555 hectare land being expected with Maize 444.3ha or 17.4% was located in kola agro ecology, 2110.7 or 82.6 % is located in woyna-dega climatic agro ecology. Consequently, so as to take appropriate and relevant sample size out of the target population the study had employed a scientific formula by (Kothari, 2004) which is

$$N = \frac{(z)^2 (p) (Q)}{E^2 (N-1) + Z^2 (P) (Q)}$$

Therefore, the total number of sample was 156 people

#### 3.6.1. Sampling technique

Based on the agro ecology of Damot-woyde district 20 maize producing kebeles were identified. Then 1 kebele from kola and 3 kebeles from Woyna-Dage agro ecology zones were taken as samples by using purposive sampling technique.

Hence, the rationale for employing purposive sampling method was the fact that such method enables the researcher to take samples which can support established objectives accomplishment by providing needed data.

Accordingly; the stated kebele together with their background information was presented as follows

Table 2: Total population, households and maize field of sample kebele

No	Sample kebele	Ecology	Elevation	Total household			Total cultivated land(ha)	Farm size of maize (ha)
				Male	Female	Total		
1	Torasadebo	Kola	1490	480	84	564	448.5	100
2	Kindekoyo	Woynadega	1930	646	114	760	419	88
3	Moyo-ofore	Woynadega	1683	509	90	599	590	102
4	Torawulisho	WoynadeGa	1894	671	118	789	473	112

(Source (CSA, (2018))

Based on the purposive sampling techniques, sample size determination using similar sampling technique 156 small holder farmer households were the selected. The proportionality of sample size for each kebele was calculated as shown below employed by scientific formula by Kothari (2004).

nh:  $(Nh/N) \cdot n$  where, nh= sample size of each kebele

Nh= Total household head in each kebele

N= Total household head in the sample

n= sample size

h= each kebele

According to the above formulas, the proportion of sample collected for Torasadebo = nh =

$564/2732 \times 156 = 32$ , Kindokoyo=  $780/2732 \times 156 = 45$ , Mayo-ofore =  $599/2732$

$\times 156 = 33$  and Torawulisho=  $789/2732 \times 156 = 45$

### **3.6.2. Data collection procedure**

As the study requires quantitative data of climate, soil(physical characteristics such as soil texture, soil water content at saturation field capacity and wilting point), planting dates, and fertilizer management. Accordingly, by presenting Q letter from HawassaUniversity to national meteorology agency, the required climate data had been gathered. In addition, data as of the soil characteristics, planting dates and fertilizer management were collected.

### **3.6.3.Climate Data Analysis**

#### **3.6.3.1. Analysis of Climate**

The climate variables such as minimum temperature, maximum temperature and rainfall data were collected from National Meteorological Agency. The climatic trend of the study areas data was analyzed through the appropriate automated statistical software. Thus, regression of the data analysis is going to be employed so as to interpret and also draw conclusion.

**Climate Variability:** In order to identify the impact of climate variability on Maize was conducted by statistical techniques such as correlation and regression, coefficient of variation of rain fall and regression of climate variables with CSA historical yield

**Climate change:** climate projected minimum temperature, maximum temperature and rainfall had been used from regional models of CORDEX data. The model inputs were used to project yield data by using Aqua crop

After the needed data was collected and organized the data analysis had been done with employment of appropriate tools. Hence, climate predictability tool (CPT) statistical software package called CPT Version 9.10 together with setting of principal components regression with explanatory "X" variable and response "Y" had been used. Further, contingency table which contained the observed and predicted rainfall in two categories was employed. In addition the study did employ aqua crop model with its equations.

### **3.6.3.2 Correlation Analysis**

The statistical analysis was used to establish whether there is any significant relation exists or not in the current crop water requirement, to evaluate the future crop water use and to find the future climate change scenarios for RCP 4.5 and 8.5 over the study area based on historical data versus the estimated  $ET_C$  for the future period of near-term 2019-2048 and mid-term 2049-2078.

## CHAPTER FOUR

### RESULT AND DISCUSSIONS

#### 4.1. Demographic and Socio-economic characteristics of the farming households

This section emphasizes demographic and socio-economic characteristics of the farming households that play important role in maize production, such as age, sex, marital status, education level, family size farmland size.

##### **Marital status of householders**

During survey, 90% were male and 10% (table 4) , this implies that majority of the respondent were men which indicate that women participation in agricultural activities is very low due to either having high number of children or being engaged on different agricultural activities. This result is agree 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 business than female headed householders.

##### **Age of householders:**

The highest proportion of the respondent (67%) lies between 30-50 while 17% was between > 50 (table4), this implies that both younger and middle aged people were involved in farming activities. The mature the farmer the more experienced he/she had to the past and present climatic condition over longer periods of time. The age of household can be used to capture farming experience (Deressa *et al.*, 2009)

##### **Family size of house holders:**

The family size of the respondent was higher in which sample farmers had 47% of the sample farmers had 3-5 family members and 23% had more than 6 family members(Table4), that mans

about 47% of family size was greater than 5 persons/households. The studies by (Karanja et. al., 2016) showed that large house hold size might have positive impact on improvement of productivity spatially its members fully participated in farming activities and these householders are more likely to adapt climate change.

### **Marital status of household heads**

Majority (77%) of the household heads are married in study area, while only 11% and 2% divorced and widowed respectively (table4). As majority of the household heads are married,

There is advantage for these householders to increase their level 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 how to improve their main economic activity (Deressa *et al.*,2009)

### **Educational status of household heads**

The educational status of sample household heads result reveals that 39% illiterate 27% can read and write and 22and 12% are primary and secondary level (table 4.)

This result implies that the adaptation opportunities to climate change was very low in the study area because of lower education level of the household heads decreases as 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 level (Kumba, 2015).

### **Farm land size of householders**

Data collected on possession of land revealed that out of the total respondents 75% acquired  $\frac{1}{4}$  to  $\frac{1}{2}$  ha of land, 21% acquired  $< \frac{1}{4}$  and 1ha of land (table 4.)

This indicates that about 85% of the farmers acquire < ½ ha of land and unable to cope up climate change impact. Some studies found farm size to have positive influence on farmer’s perception on climate variability and change. Different studies noted that farmers with large farm size are more likely to perceive climate variability than their counterparts with smaller farm size.

Table 3: Demographic and socio-economic characteristics of respondents

Character	Items with their descriptions	Frequency	Percent
1/ sex	Male	140	90
	Female	16	10
2/ Age group	< 30 years	27	29
	30-50 years	105	61
	> 50 years	23	10
3/Martial status	Married	121	77.56
	Single	6	3.84
	Divorced	16	10.25
	Widowed	13	8.33
4/Educational status	Illiterate	60	39.
	Read and write	37	22
	Primary level	43	27
	Above primary level	16	12
5/ Family size	1-2	22	14
	3-5	75	48
	6-9	36	23
	>10	23	14.75
6/ Farm size	< ¼ ha	6	14.1
	¼ ha	30	47.93
	½ ha	87	23
	1 ha	24	15.38
	>1ha	9	5.76

Source, analysis based own survey 2020

**Sex** smallholder farmers ‘households’ sex had a 5% positive significance with that of climate change adaptation strategy implementation. Thus, these small-scale farmers’ household heads

being led by male were found out as engaged more than female headed smallholder farmer's households. And such phenomenon could happen as presence of male dominated societal make up in the study area that inhibited freedom and accessibility to that of various types of new phenomenon as well as events and issues in local life. On the other hand; the study by Gecho (2014) had founded out similar result as smallholder farmers households headed by male were implementing various types of adaptation strategies/using small-scale irrigation, rain water harvest, practicing mixed farming, change planting dates, soil and water harvesting/ more often than female headed households.

And similarly these smallholder farmers' households being headed by male would engage on alternatives which could improve maize yield that included employment of better and improved ways, methods and inputs for their production activities.

On the other hand; the study by Gecho (2014) had founded out similar result as smallholder farmers households headed by male were implementing various types of adaptation strategies such as using quality crop seed and livestock breed, rainwater harvest for agricultural production activities and shifting of planting dates more often than households headed female. And the justification had been that males were more experienced about the surrounding phenomena and environment that they could heard about the purpose of engagement and implementation of adaptation strategies as a result would be encouraged to practice them by themselves.

**Age:** A10% positive significance had been found out with that of climate change adaptation strategies implementation and age of smaller holder farmer's household head. Thus, these small-scale farmers' household heads with older age were found out as more participants in the climate change adaptation strategy than these of younger aged household heads. This may happen because of the fact that older households could have own family and so required to produce

enough amount of agricultural product to feed their family members that for such purpose they would engage themselves on climate change adaptation strategies implementation .

On the opposite; young smaller holder farmer's household heads may not engage themselves on the implementation of climate change adaptation strategies that during vulnerability to the climate change impact on their agricultural production activities, they may engage on other activities such as off-farm and non-off-farm activities or even they may migrate.

Similarly; a study by Alemayehu and Gecho (2016) found out same positive correlation in between elder aged smaller holder farmer household head and engagement to climate change adaptation strategy practice. Hence, as older heads had been responsible for feeding larger family size that their engagement had been more likely than these farmer household heads who had only very few family members to feed.

**Marital status:** the marital status of smaller holder farmer household heads had A10% positive significance in regard to engagement of climate change adaptation strategy.

Accordingly, these married household heads were additional responsibility of various types of supporting their partners' and also family members by fulfilling basic needs of life and socio-cultural responsibilities.

Thus, because of such realities and reinforcements smaller holder farmer's household heads who were married should have to engage on climate change adaptation strategies implementation. Meanwhile, similar findings in different study also identified that married smaller holder farmers' household heads were engaged on climate change adaptation strategies implementation in larger number than un-married ones.

And the drawn conclusions had been same ones that having married would enforce household heads more and more responsibility for having enough amount of product to feed family

members as well to fulfill other basic needs through earning financial incomes out of sell of surplus products.

**Educational level:** climate change adaptation strategy implementation engagement had A10% positive correlation with that of smaller holder farmers household heads educational level/ qualification/ in the study area. Thus, these of smaller holder farmer's household heads with relatively better educational level had been engaging on the climate change adaptation strategy more than their counter parts. And such phenomenon could arose out of the reality that increased a number of years passed at educational organization would enable smaller holder farmers household heads in capacity to understood and then decide on engagement on climate change adaptation strategies implementation . Because ;educated individuals could easily and willingly accept adaptation as well adoption of newly/ unheard by engaged climate change adaptation strategies implementation being based /relied/ up on their further knowledge and skill as well behavior.

Meanwhile; (Gedefaw et al., 2018) had indicated in their studies that educational level of smaller holder farmer household heads had positive significance and correlation with that of their involvement at implementation of climate change adaptation strategies. With that, it can be surmised that additional skill and knowledge acquisition through formal schooling had enabled smaller holder farmer household heads to had better perception of benefit of practicing climate change adaptation strategies than others.

**Family size:** A10% positive significance had been found out in between family size of smaller holder farmer's household heads and climate change adaptation strategy implementation engagement. Hence, these smaller holder farmers' household heads with larger family size had been practicing the adaptation strategy to climate change more often than these households with smaller family size. And such a phenomena might have occurred as the impact of climate change on their agricultural production activities was greater that they could not been able to produce

enough amount of products used for both consumption purpose as well as to sell the surplus product and gain money income. In addition, as large family might have additional number of larger force which could be engaged on the various types of activities of implementation strategy of agricultural products.

Similarly, larger family sized smaller holder farmers households were found out as practicing the adaptation strategies more often than households with smaller family size by other studies. Hence; it had been drawn that so as to have enough amount of food stuff as well to had money income through sell of surplus products through employment of active labor force. Smaller holder farmers household heads with larger size could be forced to practice the adaptation strategies to climate change and its impact

**Farm land size:** smaller holder farmers household heads farm land had 1% correlation with that of climate change adaptation strategy implementation engagement. Accordingly, these smaller holder farmers' households with smaller plots of land had been found out as practicing the various kinds of climate change adaptation strategies to upgrade their agricultural products size and quality. Hence, these households which owned larger farm land might not be experiencing the influence of existing climate change adaptation strategy since they had relatively good amount of maize product for their family as well to sell and earn financial income.

Further similar study result had been found out by Senbeta and Olsson (2009) that household heads with larger farmland were not practicing the adaptation strategies as often as these which had smaller farm land. And so these with smaller land size were experiencing the impact of climate variability on their agricultural production activities particularly production of maize more seriously and profoundly than households with smaller farm land. As a result smaller farm land owning households would certainly be engaged on climate change adaptation strategies at least to satisfy their and family members needs with the maize product.

**Farm land condition:** A0.9631 coefficient of variance and 10% positive significance had been found out in between unfertile and unflat farm land condition and implementation of adaptation strategies. Thus, as it could simply been perceived that farm land condition would certainly been very much vital and decisive as of having had best agricultural product on either the presence or absence of climate change impact with at most severely or minimum one. In addition; presence of unflat farming land /terrain farm land/ being very vulnerable to lose of top fertile soil through erosion that it would be certain as the land owner could come across with difficulties of producing quality and quantity maize product . As a result, the smaller holder farmer would engage on implementation of adaptation strategies as well employment of modern and improved methods and inputs of agricultural production

As smaller holder farmers who were engaged on producing maize in the study area required to have various types of support as well needed input accessibility so to combat the problem of climate variability through effective implementation of the adaptation strategies , Thus; it had been found out that of the various institutional information : quality crop seed and quality livestock breed with coefficient of variation of 2.1024 and 2.8620 were among the different types of extension services available. Consequently; crop seed and quality livestock breed had been accessible for smaller holder farmer's households who produce maize as well implement adaptation strategies to climate change.

And so it could be possible to had relatively good amount of maize production and also somehow livestock production output by these farmers who used the extension services.

Table 4: Multinomial logit model result of demographic and socioeconomic characters

	Sex	Age	Marital status	Education	Family size	Farm size	Land condition	Quality crop seed	Quality livestock breed	fertilizer	Pesticide	Climate change information
N	156	156	156	156	156	156	156	156	156	156	156	156
Valid	3	3	3	3	3	3	3	3	3	3	3	3
Missing												
Std. Deviation	.30437	.60272	.98043	.89450	.91906	.85760	.89524	.47515	.34917	.48955	.48807	34241
Variance	.093	.363	.961	.800	.845	.735	.801	.226	.122	.240	.238	117
Skewness	2.645	-.076	1.703	.273	.371	.187	.795	.683	2.083	.451	.479	2.162
Std. Error of Skewness	.194	.194	.194	.194	.194	.194	.194	.194	.194	.194	.194	94
Range	1.00	2.00	3.00	3.00	3.00	4.00	3.00	1.00	1.00	1.00	1.00	1.00

source, own survey data 2020

#### 4.2. Result and discussion of smaller holder perception about climate change

As it can be seen on the table 6 smaller holder household heads farmers perception towards existing climate change's impact on their maize production practice replies analysis being based on multinomial logit model has been presented. Accordingly, 10% significant, 5% significant and 1% significant positive correlation has been found out in between climate change impact and trend of decreasing rainfall, maize product per hectare as well as maize problem. Consequently, one can deduced that smaller holder farmer's household heads had good understanding about the existing climate change impact on their maize production practice. Meanwhile, climate variability had been experienced and observed by smaller holder farmers that other than scientific as well restricted climate change variability presences confirmation. Similarly, according to (Asfaw *et al*, 2013) study findings had disclosed that smaller holder farmers were able to clearly and exactly experience climate changes.

Table 5: Multinomial logit model result of farmer perception

<b>Result/perception</b>	<b>Maize problem</b>	<b>Maize production per hectare</b>	<b>Trend of rainfall</b>
Standard deviation	1.9293	0.41790	0.54284
Variance	0.037	0.175	0.2494
Coefficient of variance	51.1432	2.3977	1.8446

Source: analysis based on survey data 2020

#### 4.3. Result and discussion of smaller holder farmer household heads implementation of local climate adaptation strategies

Based on the data from household survey, the results indicated that 74% of farmers are using various types of adaptation strategies and mechanisms to avert climate variability and change on their farm while 24% of the farmers are not using any of the adaptation strategies being adopted by their partners. (Table7)

In order to combat the existing climate change impact on their maize and other agricultural product production practices, smaller holder farmers households had been engaged on a different kinds of adaptation strategies. Consequently; as CV 3.5682, 4.9766 and 2.886 are above one and positive correlation between Small scale irrigation, Rain and water harvesting and mixed farming. Hence, farmers were implementing various types of adaptation strategies that they could be able to produce relatively larger amount of maize and other agricultural product. Meanwhile; similar studies findings had been found out that smaller holder farmers households were engaged on implementation of various types of adaptation strategies including: use of quality and drought resistant crop and livestock seed such as short period ripening and improved maize together with needed fertilizer modern ploughing and row planting methods., change planting date, harvesting water, and use it for agricultural production activities. Accordingly; compared with those who were not implemented the adaptation strategies they had been able to produce relatively large amount and quality of agricultural products and so secure food presence for at least family members throughout the year.

Meanwhile; farmers' level practice of adaptation strategies to climate change impact had been coming across with challenging factors and this was confirmed by the respondent smaller holder farmers with a mean of 0.7845 and a coefficient of regression of 1.2023. As a result, it can be deduced that adaptation strategies practice of farmers' level been not as effective as it have to be also as desired. Similarly; a study by (*Asfawet al., 2013*) had found out same result as of adaptation strategies at farmer level in other areas which were including: lack of needed inputs, shortage of technical support by responsible bodies, absence of experience sharing among smaller holder farmers, as well as peer awareness level about the benefits of practicing adaptation strategies

Table 6: Multinomial logit model result of farmer perception

Result/ climate adaptation strategies	local	Changing planting dates	Mixed farming	Soil water conservation	and irrigation	Small scale irrigation	Change crop species	Rain water harvest	Constraints climate change adaptation strategies
Standard deviation		0.38677	0.34632	0.44692		0.20482	0.0000	0.28189	0.83203
Variance		0.150	0.120	0.200		0.042	0.000	0.079	0.692
Coefficient of variance		2.4448	2.886	2.2346		2.2346	0.0000	3.5682	1.2023

Source: Analysis based on survey data 2020

### 4.3 Crop Simulation and Climate of the study area

The crop model simulation experiment made by MSc Study (Elias and Bisrat, 2018) for rain fed agriculture was adopted from experimental Aqua crop maize simulation in Mirab Abaya wereda due to similar pattern of rainfall with minor differences in amount. The long term climatology of the study area shows bimodal rainfall pattern of one peak in April and the second peak in October as shown below in Figure 4. Both Damot-woyde and Mirab Abaya are located in rift valley with the same climatological pattern with rainfall but cooler in temperature and lesser rainfall in Damot-woyde than Mirab Abaya and as shown in Figure 5. Damot -woyde district experiences two major agro-ecological zones such as WoinaDega and kola.

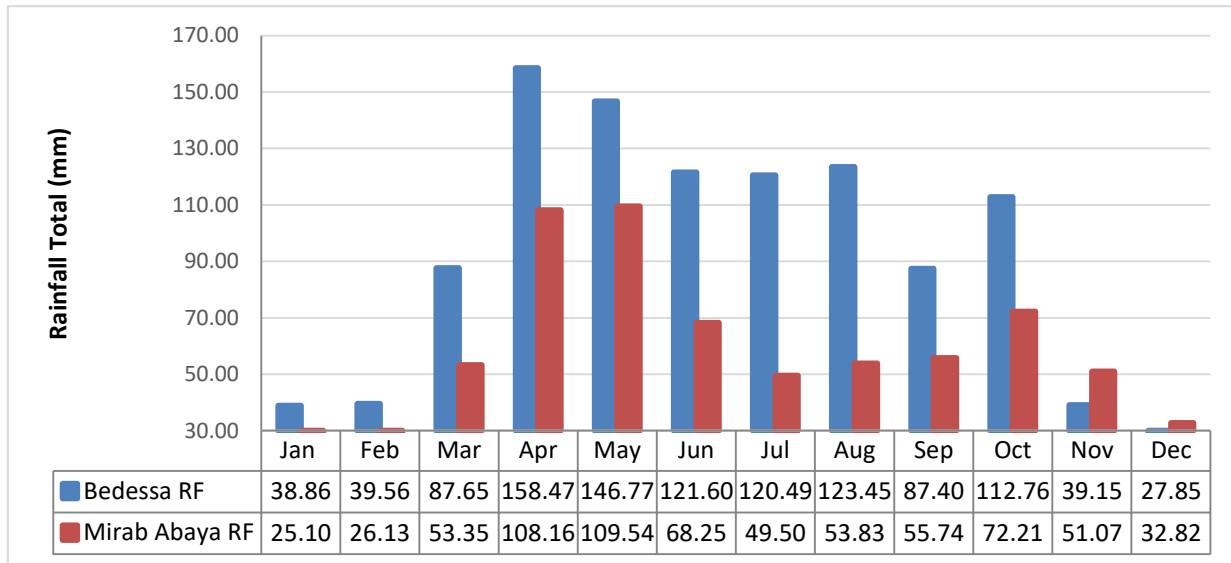


Figure 4: Average monthly rainfall 1987-2014

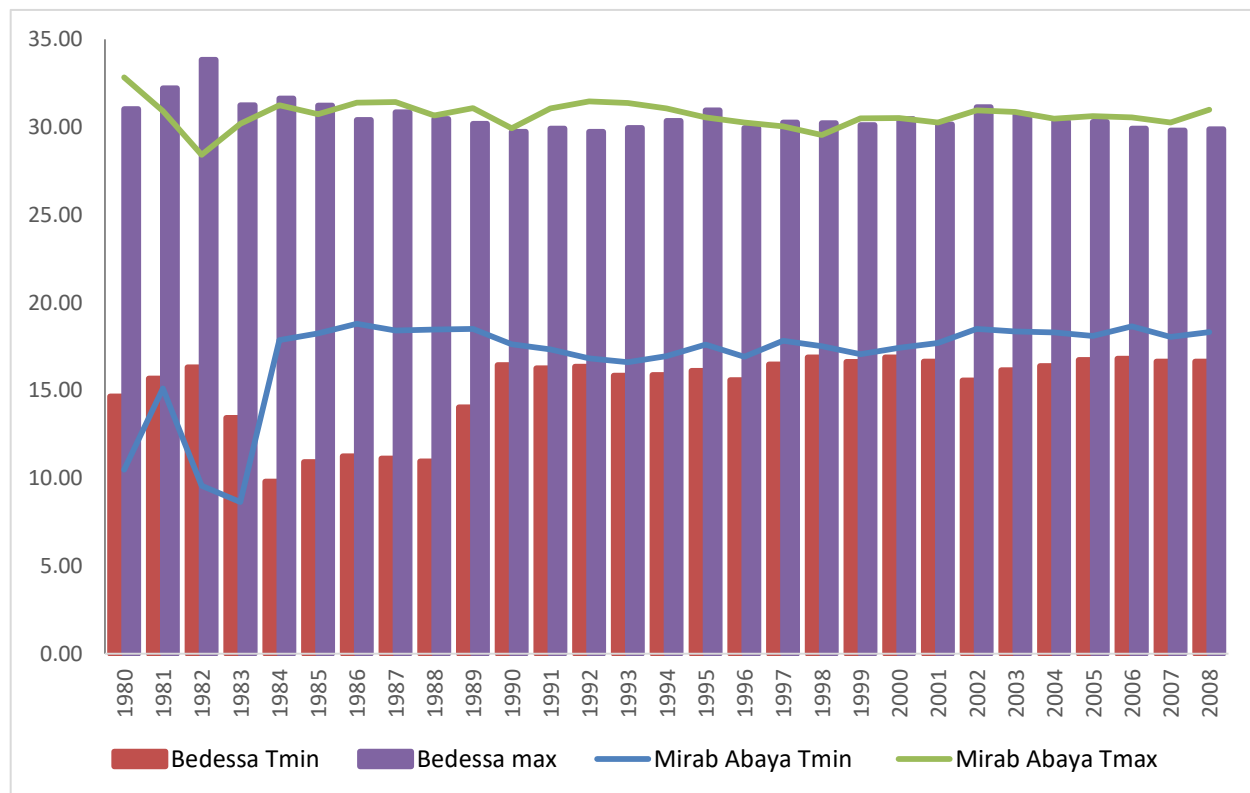


Figure 5: Average monthly maximum and minimum temperature of study area during 1980-2008

#### **4.4. Comparison between model output with observed data sets**

Comparison between monthly and annual mean of rainfall with dynamically downscaled Hadley Global Environmental Model2- Earth System (HadGEM2-ES) outputs from the period of (1987-2008) used in this study. The 28-year observed average areal annual rainfall (707.7 mm), bias-corrected RCP (698 mm) and historical RCP (658.5 mm) annum. The Comparison before bias correction and after bias correction is shown in Figure 6 model simulation shows good fitness with observed monthly average daily data and average areal in annual cycle. However, the model simulation in uncorrected RCP is slightly underestimating during October to April and slightly overestimating May to September. The statistical analysis shows very high degree of rainfall variability presents in observed and bias-corrected datasets with coefficient of variation (CV = 0.35% for observed, CV= 0.3% for bias-corrected RCP. The model simulation outputs show under biased -0.103 after correction and the model comparison with observed data shows good performance (linear relationship) with correlation coefficient of 0.76 for bias corrected datasets and bias correction improves the climate model simulation. Verification of maximum and minimum temperatures (Figures 6 B and C) also shows good agreement with observed data. The bias correction improved the fitness with observed minimum and maximum temperature. Therefore, it is recommended to use and evaluate the dynamical downscaled HadGEM2-Es, model outputs of rainfall and temperature for future climate projection for assessment of climate change impact for crop productivity and water resources assessment

(C)

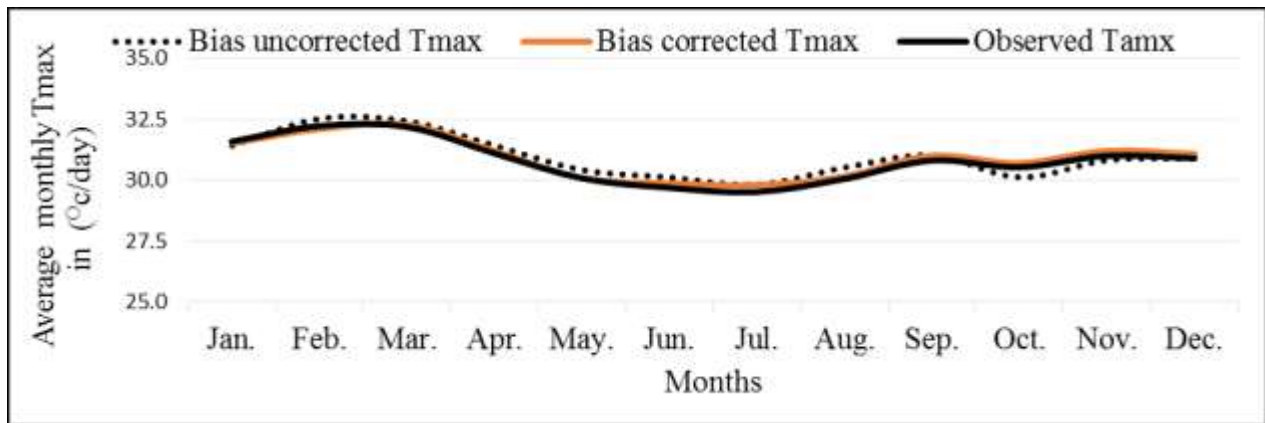
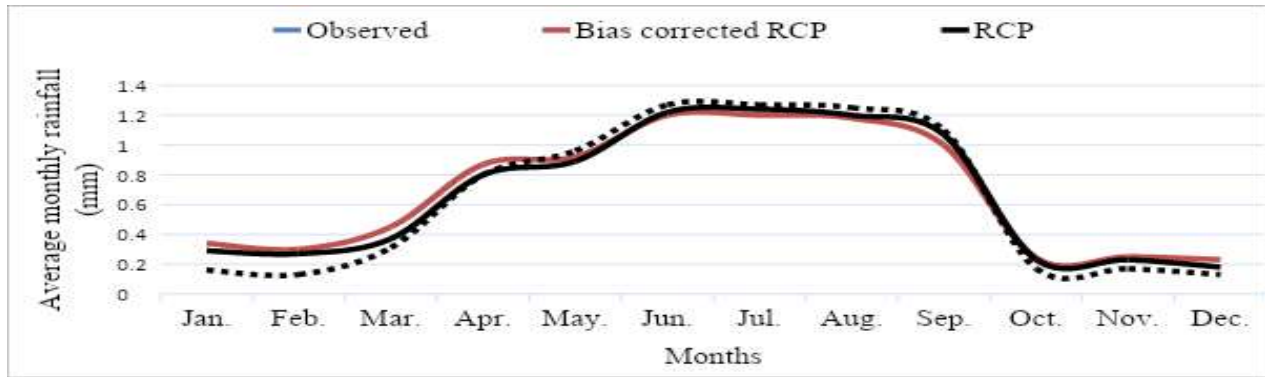


Figure 6: Comparison of average monthly rainfall (A), maximum (B) and minimum temperature (C) of observed data with bias uncorrected and bias-corrected RCP datasets from (1980-2008)

**4.5 Evaluation of future climate change under RCP scenarios**

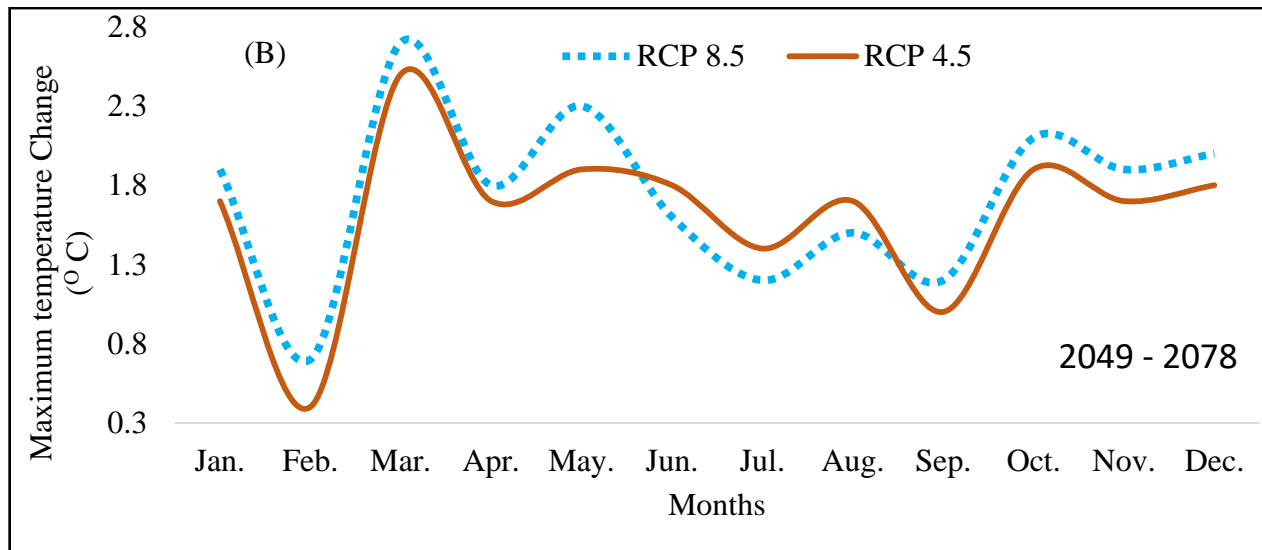
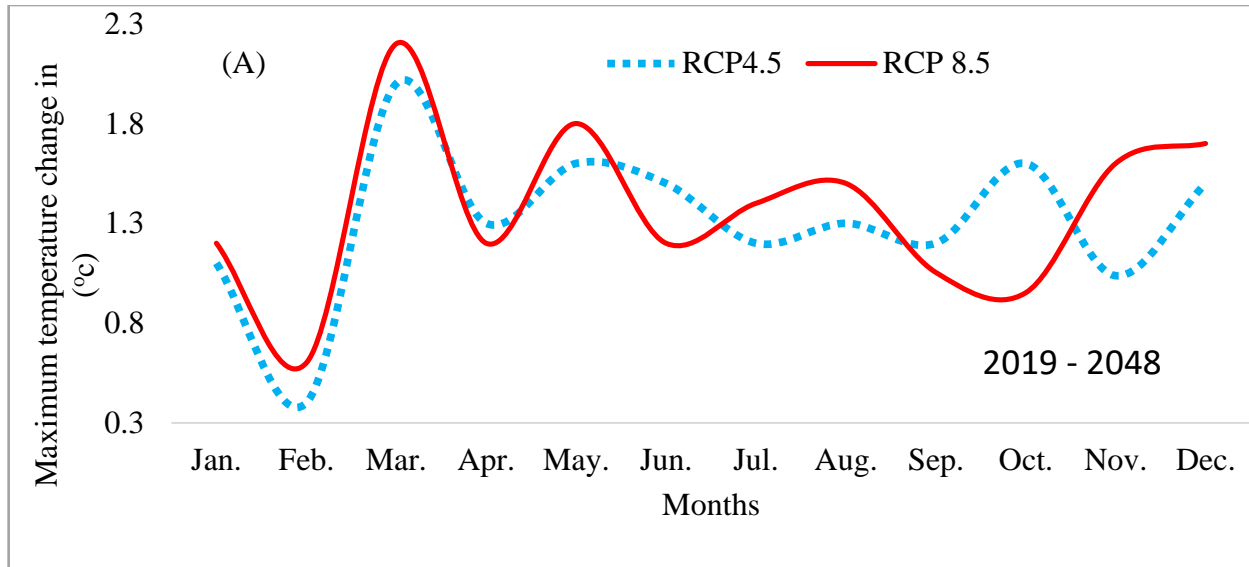
The future trends of air temperature, rainfall and evapo-transpiration were analyzed under RCP 4.5 and 8.5 scenarios for the study area. The analysis was made in two break time slices of non-overlap 30 years' data of near-term (2019-2048) and mid-term (2049-2078). The future projection change computed from baseline period because of point station has no future climate data set. World Meteorological Organization recommended baseline period (1971 - 2000) was used for this study. Further annual trends were tested by Mann- Kendall test for each climate variable and seasonal change and term- changes were evaluated from baseline period. The detailed discussion on these parameters further is given below separately:

#### **4.5.1 Temperature change**

##### **Maximum temperature**

The projected average monthly maximum temperature change from the baseline period for both periods under RCP 4.5 and RCP 8.5 scenarios for future near-term (2019-2048) and mid-term (2049-2078) periods are shown in Figures 7 a and b. The projected maximum temperature increases for RCP4.5 by 0.4 °C to 2°C for near-term and 0.4 to 2.5°C for mid-term with reference to the baseline period. The projection for high emission scenario (RCP 8.5) also increases in both near and mid-terms by 0.6 °C to 2.2°C and 0.7°C to 2.7 °C respectively. Lowest maximum temperature is projected in February in near and mid-terms whereas highest temperature change is projected in the March in both scenarios for near and mid-term periods. Therefore, March is going to be the hottest month in all parts of the country.

This research result from projected maximum temperature and the validation of model simulation with observed data in the study area reveals that temperature will increase as similarly as in the world with continuously from the time of pre-industrial period. Thus, the global warming effect is clearly seen in Ethiopia because of projected trends in future maximum temperature is increasing under both medium and high emission scenarios in future periods.



**Figure 7 :** Projected monthly maximum temperature change for near-term (A) and mid-term (B) from baseline period in the study area.

The Mann-Kendall statistics test result in Table 8 also presented that the projected maximum temperature increases in both RCP scenarios and periods. Sen.'s slope change of maximum temperature shows an increase of average  $0.004\text{ }^{\circ}\text{C}/\text{annum}$  in near and  $0.017\text{ }^{\circ}\text{C}/\text{annum}$  in midterm under RCP 4.5 while, for high emission scenario it increases  $0.024\text{ }^{\circ}\text{C}/\text{annum}$  in near and  $0.026\text{ }^{\circ}\text{C}/\text{annum}$  in mid-term. The upward maximum temperature trends are presented in both periods under both RCP scenarios. The summary of Mann - Kendall test result for maximum temperature shows increasing trend and statistically significant under both scenarios except RCP 4.5 in mid-

term. It indicates statistically insignificant increasing trends projected in the future equal to alpha 0.05 significance level in the study area.

Table 7: Mann-Kendall test for average annual maximum temperature under RCP scenarios

<b>Period</b>	<b>Scenarios</b>	<b>Mann-Kendall Statics</b>	<b>Kendall's tau</b>	<b>P-Value(two-tailed)</b>	<b>alpha</b>	<b>Sin's</b>
2019-2048	RCP 4.5	221	0.475	0.00	0.05	0.004
	RCP 8.5	179	0.385	0.002	0.05	0.024
2049-2078	RCP 4.5	37	0.08	0.544	0.05	0.017
	RCP 8.5	274	0.59	< 0.0001	0.05	0.026

The evaluation of seasonal temperature is very important for crop production because higher values above the normal temperature during cropping season have negative impact on crop production (Battisti and Naylor, 2009). Changes in the mean climate away from current states may require adjustments to current practices in order to maintain productivity. In the places where the water availability is low would generally be at risk of decreasing crop yield at even 1 to 2°c of warming (Hanson *et al.*, 2007). This is as a result of increased evapotranspiration and lower soil moisture level. Hence, higher temperatures may be more immediately detrimental; increasing the heat stress on crops and water loss by evaporation and the current finding also confirms higher temperature during growing season which can significantly impact agricultural productivity.

Table9 shows an average of seasonal change in maximum temperature in the future. Temperature is projected from high to low during Spring (MAM), Autumn (SON), and Winter (DJF) and Summer (JJA) under both the scenarios. The change from the near-term (2019-2048) to mid-term (2049-2078) is concerned, it increases more under both scenarios for Spring (MAM), Autumn

(SON) and summer (JJA) under both the scenarios and winter (DJF) for RCP 4.5, but projected to decrease in Winter (DJF) under RCP 8.5 at a rate of 0.14°c from near-term.

Table 8: Seasonal average maximum temperature change from baseline over in the study area under both RCP scenarios in (O c)

Period	RCP Scenario	DJF	MAM	JJA	SON
Near-term/2019-2048	RCP_4.5	1.0	1.63	1.3	1.26
	RCP_8.5	1.67	1.73	1.37	1.23
Mid-term/2049-2078	RCP_4.5	1.3	2.03	1.63	1.53
	RCP_8.5	1.53	2.67	1.43	1.73
Term-change	RCP_4.5	0.3	0.4	0.33	0.27
	RCP_8.5	-0.14	0.94	0.06	0.5

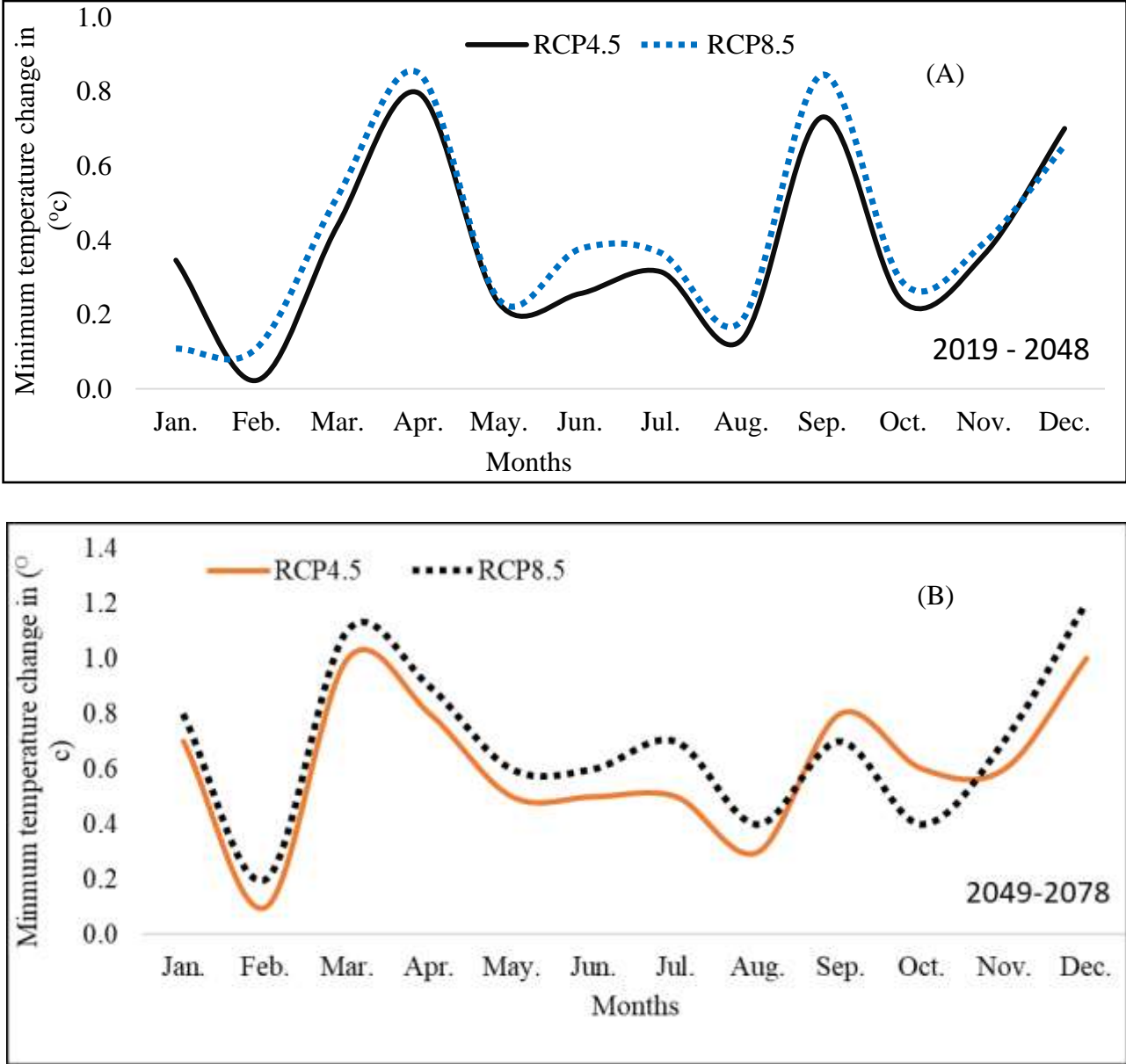
**Note:-** (DJF)December, January and February (Winter),(MAM)March, April and May (Spring ), (JJA)June, July and August (Summer) and (SON) September, October, and November (Autumn)for Northern Hemisphere

### Minimum temperature

The Projected average monthly minimum temperature change from the baseline period shows an increase in future under both RCP scenarios. According to figure 8, And B for RCP 4.5, the minimum temperature change is projected to increase between 0.1 to 0.8°c for near-term and 0.1 to 1°c for mid-term, while it varies between 0.1 to 0.9°c for near-term and 0.2 to 1.2°c for midterm for RCP 8.5.

Figure8 shows minimum temperature increases from February to May under both RCP scenarios, then shows decline during June to August, again rise during September to January in near-term under both the scenarios. It is projected to increase in mid-term during February to April and then

decline in May. Then again starts to increase during June to January under both the scenarios in mid-term. The minimum temperature is expected to increase more in mid-term under both the scenarios and the magnitude of change is projected to be high under RCP 8.5 compared with RCP 4.5 in both periods.



**Figure 8:** The Projected average monthly minimum temperature change

Mann-Kendall trend test and Sen.'s slope estimation confirm that the minimum temperature is projected to increase in future under both the RCP scenarios. The magnitude of increment projected under RCP 4.5 is 0.028 & 0.043°C /annum for near and midterms respectively. It is

projected to increase between 0.033 to 0.049<sup>o</sup>c/ annum under RCP 8.5 in near and mid-terms respectively. The summary of Mann-Kendall trend test (Table 10) shows maximum temperature statistically is significant and projected an increasing trend in both the periods under both RCP scenarios over the study area in future at alpha equal to 0.05significance level. More information on the annual average minimum temperature trends of both the scenarios can be seen in figures infigure8

Table 9: Seasonal average maximum temperature change from baseline over in the study area under both RCP scenarios in (O c) shows that the minimum temperature is expected to increase in all seasons in future.

Period	Scenarios	Mann Kendall Statics(S)	Kendall's tau	P-Value (two-tailed)	Alpha	Son's
2019-2048	RCP 4.5	225	0.484	< 0.0001	0.05	0.028
	RCP 8.5	175	0.376	0.003	0.05	0.033
2049-2078	RCP 4.5	127	0.273	0.032	0.05	0.043
	RCP 8.5	269	0.0578	<0.0001	0.05	0.049

The magnitude of increase is high for Spring under both RCP scenarios in both the terms. With regard to the change from near-term (2019-2048) to mid-term (2049-2078), the seasonal increment is between 0.17-0.29<sup>o</sup>c under RCP 4.5 and it is between 0.1-0.34<sup>o</sup>c under RCP 8.5 from the baseline period.

Table 10: Seasonal average minimum temperature change from baseline in the study area under both RCP scenarios in (O-<sup>c</sup>)

Period	RCP_Scenario	DJF	MAM	JJA	SON
Near-term/2019-2048	RCP_4.5	0.33	0.47	0.23	0.43
	RCP_8.5	0.3	0.53	0.33	0.5
Mid-term/2049-2078	RCP_4.5	0.6	0.76	0.43	0.6
	RCP_8.5	0.7	0.87	0.57	0.6
Term- change	RCP_4.5	0.27	0.29	0.2	0.17
	RCP_8.5	0.37	0.34	0.24	0.1

**Note:** (DJF)December, January and February (Winter), (MAM)March, April and May (Spring),(JJA)June, July and August (Summer) and (SON) September, October, and November(Autumn)in Northern Hemisphere.

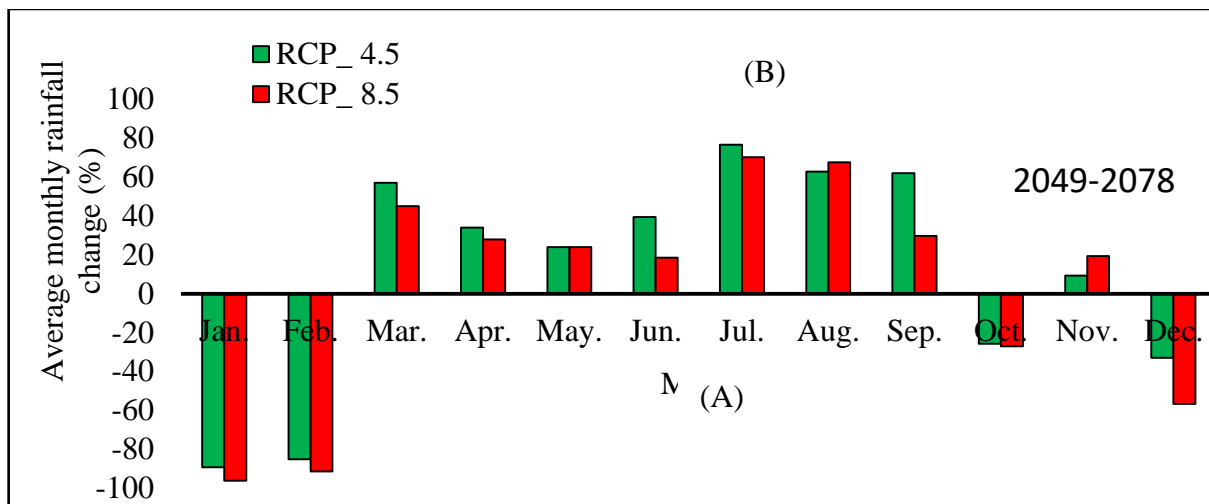
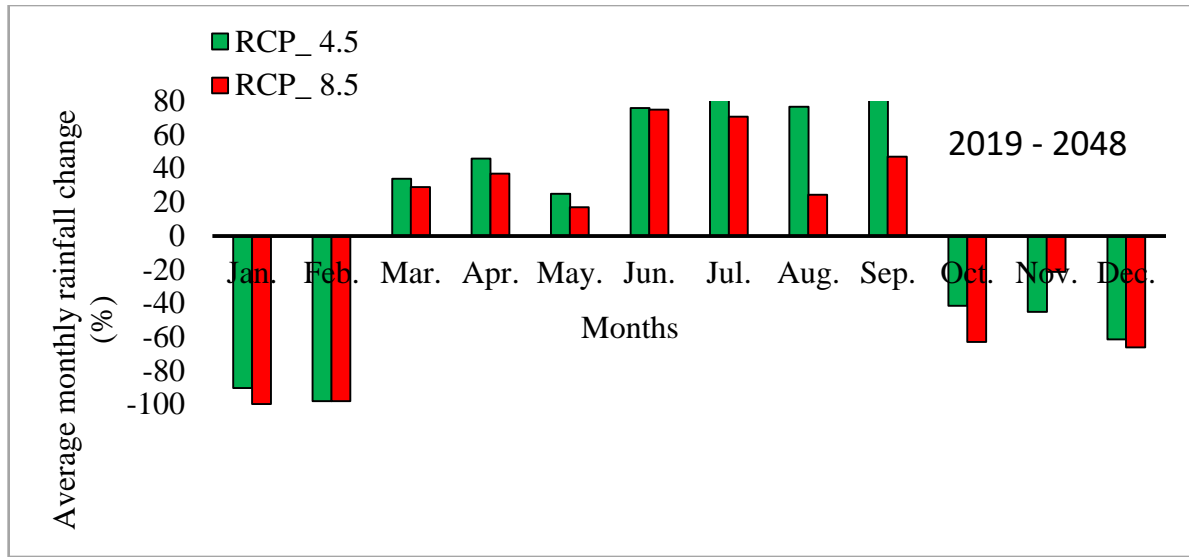
Generally insights into a changing climate consistent with the IPCC (2013) temperature projection continues to increase in future, however, projection over the last few decades, Ethiopia's mean temperature increased by about 0.2<sup>o</sup>c per decade and it will continue to increase in the next few decades with the same rate of change as observed earlier and the rate increases by 1.4 to 2.9<sup>o</sup>c by 2050 IPCC, (2007). The IPCC mid-range (A1B) emission scenario and the mean annual temperature will increase in the range of 0.9 to 1.1<sup>o</sup>c by 2030, in the range of 1.7 to 2.1<sup>o</sup>c by 2050 and in the range of 2.7 to 3.4<sup>o</sup>c by 2080 over Ethiopia compared to the 1961 to 1990 normal (baseline) similar results found in this both maximum and minimum temperature showing

increasing in the study area under both RCP scenarios. Maximum temperature increases between 0.6 to 2.2°C for 2048 under high emission scenario for and between 0.7 to 2.7°C for 2078 under the same scenario while for medium emission scenario increases between 0.4 to 2.0°C for 2048 and increases between 0.5 to 2.5°C for 2078 under the same scenario.

#### **4.5.2. Rainfall change**

The average monthly areal rainfall computed for near-term (2019-2048) and mid-term (2049-2078) from the baseline period. Projected percentage of average monthly rainfall change Figures 9 A and B shows an increase from March to September and it decreases from October to February except November in mid-term under both the RCP scenarios of 4.5 & 8.5. The magnitude of positive change projected is 25- 85 % for near and 9- 77% for mid-term under RCP 4.5 scenario, whereas negative monthly rainfall change projected is between 11- 98% for near and 19-89% for mid-term under the same scenario from baseline period. For, high emission scenario positive and negative change projected similar months between (17-75%) for near and (18-70%) projected for mid-term under RCP 8.5 scenario whereas, negative change projected (23- 100%) for near and (19-96%) projected for mid-term under the same RCP 8.5 scenario

Compared with observed as well as baseline period peak distribution of rainfall shifting June to September Figure 8 illustrates, projected change of monthly rainfall distribution from baseline period rise to increases in March to April in near-term then decline to May and again rise to increases June to September, peak rainfall distribution projected June to September under RCP 4.5 and June to July for RCP 8.5 in near-term, whereas, for mid-term rainfall distribution change rise to increases March under both scenario then decline to May in similar trends and again rise to increases June to September. Peak rainfall distribution projected July to September under RCP 4.5 and July to August for RCP 8.5 in the future.



**Figure 9:** Projected change of average rainfall distribution for near-term (A) and mid-term (B) from baseline period in the study area

Seasonal evaluation of rainfall distribution is very important for rain-fed agriculture because agricultural activity highly depends on the rainfall distribution. The projected evaluation of future rainfall distribution over the study area decreases for winter (DJF) and Autumn (SON) in mid-term under both RCP scenarios and it is expected to increase for spring (MAM) and summer (JJA) under both RCP scenarios. The magnitude of positive change is better projected for summer (JJA) and spring (MAM) under both scenarios compared with other two seasons and negative change is projected for winter (DJF) and autumn (SON) under both scenarios in near-term from

the baseline period. This is due to better rainfall distribution expected in summer, spring, and autumn in near-term.

Table 11: Seasonal average rainfall change from baseline period in the study area under both RCP scenarios in (%)

Period	RCP Scenario	DJF	MAM	JJA	SON
2019-2048	RCP_ 4.5	-69	38.33	59.6	15.33
	RCP_ 8.5	-81.3	32.33	52	7.3
2049-2078	RCP_ 4.5	-83	35	79.3	-0.33
	RCP_ 8.5	-88	27	57	-12.3

**Note:** (DJF)December, January and February (Winter),(MAM)March, April and May (Spring),(JJA)June, July and August (Summer) and (SON) September, October and November(Autumn)in Northern Hemisphere

The Mann- Kendall statistical test results confirm the projected annual rainfall decreasing and increasing trends in future under both RCP scenarios. The Sean’s slope change estimation results shows annual rainfall projected to decrease by 3.7 mm/annum in near-term and projected to increase by 4.6 mm/annum under RCP4.5 in mid-term while, for high emission scenario annual rainfall will expect to decrease by 2.6 mm/annum in near-term and projected to increase by 1.94 mm/annum in mid-term under RCP 8.5. The summary of Mann- Kendall statistical Table 13 test shows statistically insignificant decreasing and increasing trends in annual rainfall distribution under both RCP scenarios at alpha 0.05 significance level in the both the periods over the study area.

Table 12: Mann-Kendall test results for annual rainfall in the study area under RCP scenarios

Period	Scenarios	Mann Kendall Stastic (S)	Kendall's tau	P-Value two- tailed	alpha	Son's
2019-2048	RCP 4.5	-58	-0.133	0.301	0.05	-3.7
	RCP 8.5	-80	-0.184	0.153	0.05	-2.6
2049-2078	RCP 4.5	75	0.175	0.175	0.05	4.6
	RCP 8.5	39	0.090	0.502	0.05	1.94

#### 4.5.3. Evaluation of Rainfall Variability

##### Coefficient of variation (CV)

Rainfall is the most important element for crop production. The decrease in rainfall has reduced the production of crops in the study area. In this remark, drought has adverse effect to the production of food crops. The findings show that in years when rainfall was little during the growing season, crops yield was also minimal. So for this purpose rainfall variability was analyzed by calculating the coefficient of variation (CV) as the ratio of the standard deviation to the mean rainfall in a given period, then it was expressed as a percentage (CV %) and classified according to NMSA, (1996).

Table 14 shows high rainfall variability between seasons. The CV ranged between (1.2-1.3%) for combination of dry months winter (DJF), 0.7% for spring (MAM), (0.6-0.9%) for summer (JJA) and it varies for autumn (SON) between (0.8-1.2%). This indicates the study area accounts for nearly 90% of total rainfall amount received annually, implying that smaller proportions of rainy days supplied much of the total amounts of rainfall received in the study area during 1980-2008.

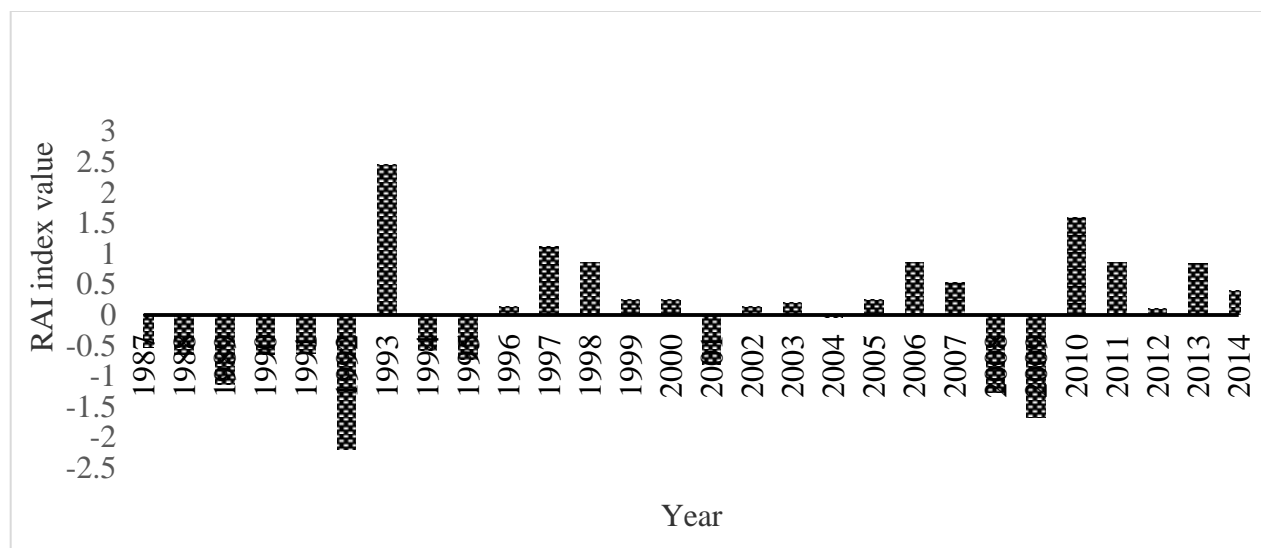
Table 13: Observed yearly rainfall variability over the study area during (1987-2008)

Months	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Total	1389	1351	1581	2645	3342	2115	1799	1482.6	1489	1850	1229	923
Rf mm												
Mean	49.6	48.3	56.5	94.5	119.4	75.5	64.3	53.0	53.2	66.1	43.9	33.0
Stv	66.2	61.5	40.5	64.2	86.6	49.4	56.3	29.2	40.8	53.5	50.9	41.1
CV	130	130	70	70	70	70	90	60	80	80	120	120

### Rainfall anomalies indices (RAI)

The rainfall anomaly index (RAI) as shown below in Figure 10 shows the rainfall variability in Annual cycle for the year 1987 to 2014. The deviations from the long-term mean shows annual rainfall variability as above normal, below normal and normal rainy time from long-term rainfall data record. The mean rainfall with zero RAI is considered to be reference or normal period. The data variation shows that, extreme dryness or highest negative RAI value -2.2 (in 1992) to Extreme wet time or highest positive RAI value +2.5 in 1993. Out of 28 years of observational data record, 11 years (39%) below normal, 5 years (18%) above normal and 12 years (43%) was normal period in the study area.

Rainfall anomaly index shows the years with above normal or normal periods which may be more suitable for rain-fed cropping are 1993, 1997, 1998, 2006, 2010, 2011 and 2013 from 28- year observations. Whereas, the rest 21 years show that, the rainfall amount was below normal or Water stress time for crop production. The rainfall data record shows an agricultural drought time in the years 1992, 1989, 2008, and 2009 based on RAI in Figure 9. The severe dry periods of study area are indicated and explained by RAI index.



**Figure 10:** Observed annual rainfall anomaly index over the study area during 1980-2007

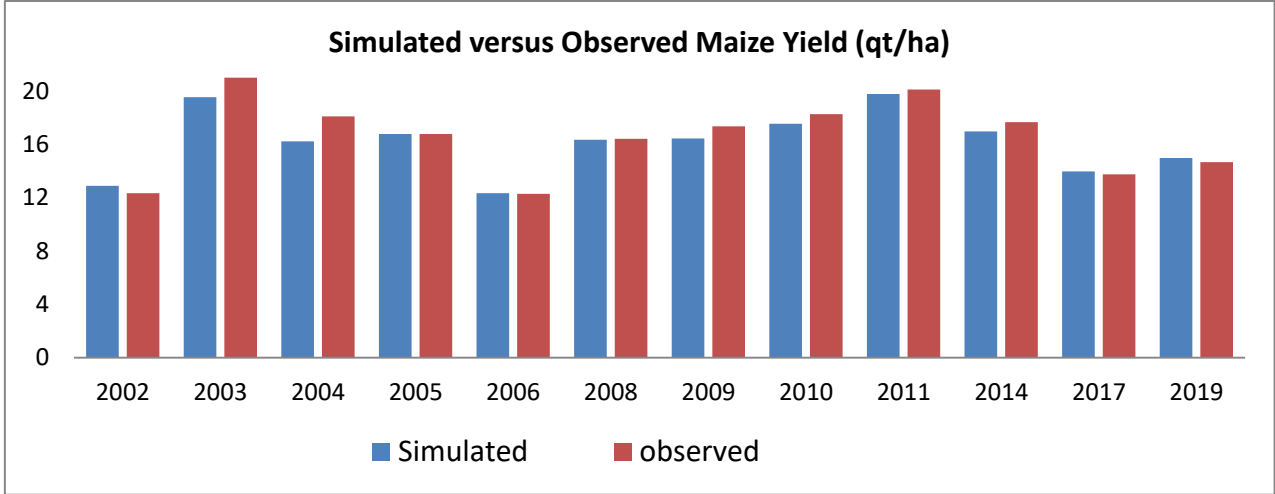
#### 4.6 Evaluation of Climate Change Impact on Maize Yield under RCPS scenarios

Evaluation of climate change impacts on future maize yield is projected using Aqua crop model. The Aqua crop model simulation was evaluated using the observed maize yield data from Central Statistical Agency (CSA) for the year from 1995 to 2007 of Meher season. Table 15 shows the statistical analysis between observed and simulated values of root mean square error, efficiency and coefficient of variation. The statistical results also show the capability of Aqua crop model to reproduce the maize yield with good correlation with RMSE value of 0.82, efficiency (E) value 0.87 and coefficient of variation of 0.14 with a good agreement with observation. Therefore, the model was used for projection of future maize yield under changing climate condition.

Table 14: Aqua crop model validation results with observed available maize yield data from (2002-2019)

Model validation	Total Yield in Q	Mean	Stv	CV	RMSE	E
Simulated	193.85	16.15	2.32	0.14	0.82	0.87
Observed	198.84	16.57	2.81	0.17		

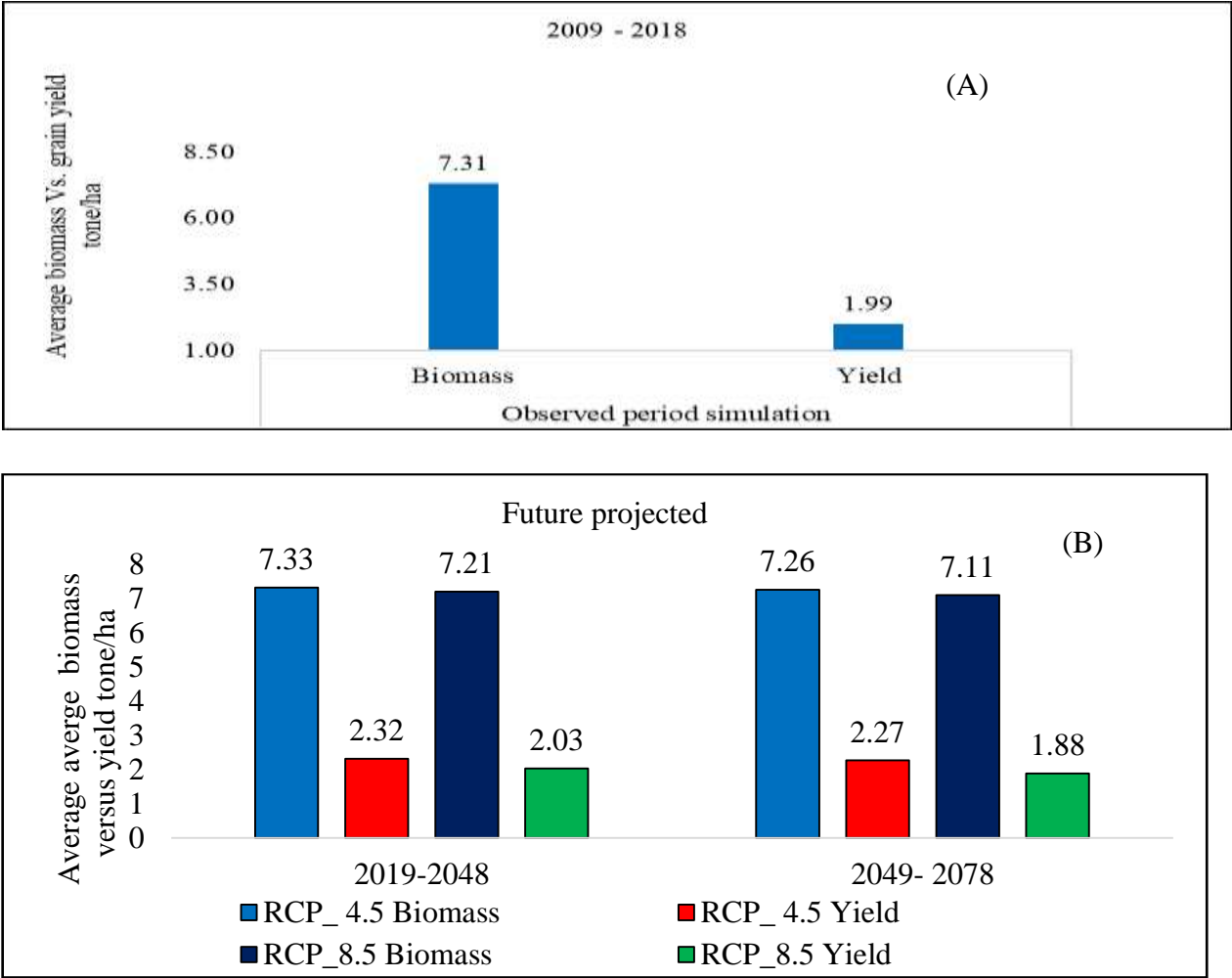
Figure 10 also illustrates the simulated versus observed maize yield data from CSA. Aqua crop model slightly over-estimate in 2003, 2004 and 2010 and under-estimates in 2014. This shows that the simulated versus observed plot shows a good agreement with slight biases with small error and high efficiency. Therefore, the good agreement of the model output with observed data implies that model has less error and high efficiency of capturing the future simulation



**Figure 11:** Aqua model simulated versus observed maize yield data for the period the (2009-2019)

The 28-year mean change of projected maize yield simulation by Aqua crop and mean of observed period (2009-2019) and yield is given in Figure 12 (A) and (B). The yield is fluctuating from year to year related to variation of the climate input parameters. The model projection of grain yield and biomass by Aqua crop shows slightly increased for both RCP 4.5 and RCP8.5 for

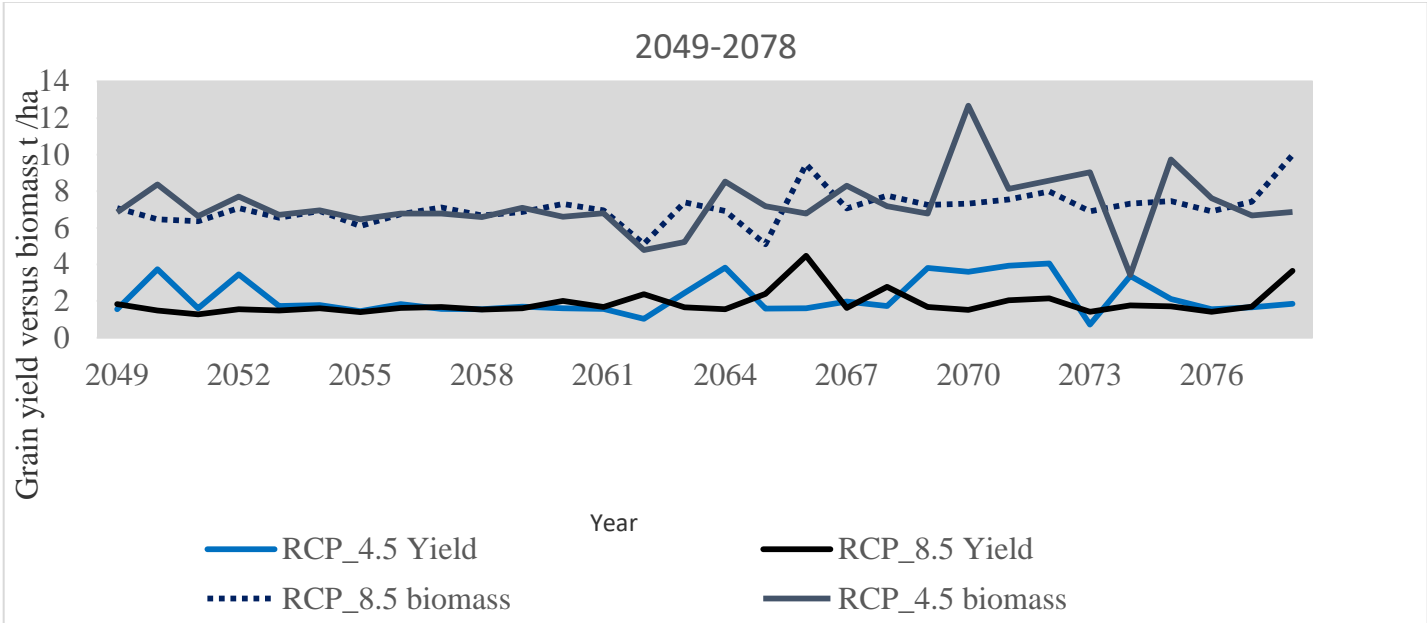
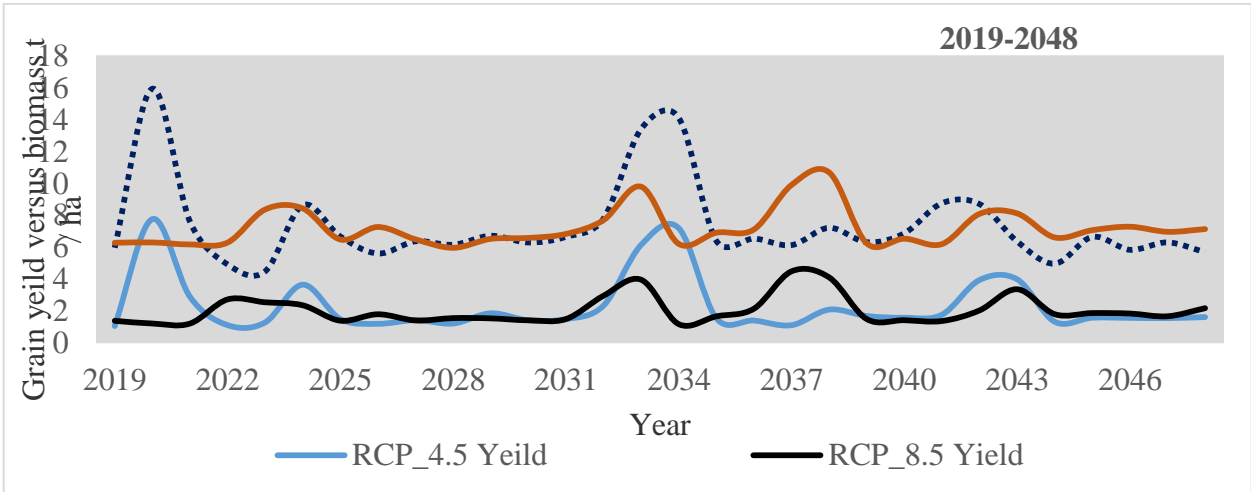
both near-term scenarios, but slightly decreased in yield the mid-term for both scenarios. The mean value of maize yield projection for the first 20 year average under medium emission scenario is 7.33 tones ha biomass and 2.32 tones ha grain whereas for the second 30-year projection biomass projected 7.26 tones ha and 2.27 tones ha grain yield under the same RCP 4.5 scenario. This shows slight decreasing trend of yield from near-term to mid-term projection due to projected emission of CO<sub>2</sub> and warming effect of the climate but increasing trend from now yield under RCP 4.5.



**Figure 12:** Observed /A/and projected/B/ average yield for grain and biomass of Maize. (2009-2018)

The time series variations of projected maize yield and biomass values are also given in Figure 13 (A) and (B) for near-term (A) and mid-term (B) under both RCP scenarios for the area.

Better yield of biomass and yield is expected in both near-term and mid-term period under RCP 4.5 except in RCP 8.5 scenarios in mid-term projection. This shows that Elevated CO<sub>2</sub> enhances crop productivity related to photosynthesis processes and increasing temperature also uphold faster crop growth and leads to increased yield and biomass. It is understood that under well-watered conditions maize responds positively to increasing CO<sub>2</sub> concentration levels, up to a point, because of an increase in canopy size which translates to higher productivity and yields through CO<sub>2</sub> fertilization.



**Figure 13:** Projected grain yields versus biomass for near-term (A) and mid-term (B) of maize crop under both RCP scenarios in the study area

Aqua Crop model sensitivity analysis shows that the grain and biomass yield are more controlled by precipitation than temperature and then CO<sub>2</sub> concentration. Three years successive grain and biomass yield sensitivity analysis and comparison of Aqua Crop model outputs are given in Table 16 for 2019 to 2021 for both RCP 4.5 and RCP 8.5 scenario. The sensitivity result shows the different responses for yields but common understanding viewed from the model outputs.

The first 2019 year cumulative degree days 1788.1<sup>o</sup>c total rainfall recorded for such growing season 236.3 mm and CO<sub>2</sub> 409 ppm, simulated yield both biomass and grain yield 5.955 tone /ha and 1.030 tone/ha respectively for next 2020 year GDD's increased by 20.7<sup>o</sup>c precipitation also increased by 234.6mm CO<sub>2</sub> increased by 2ppm biomass yields increased by 8.348 tone /ha and also grain yield increased by 6.577 tone /ha from the first 2019 for RCP 4.5 while, RCP 8.5 first 2019 cumulative GDD's 1822<sup>o</sup>c, CO<sub>2</sub> 413 ppm, precipitation also 156.9 mm for that growing period simulated yield both biomass and grain 6.268 and 1.359 tone /ha respectively for the next 2020 CO<sub>2</sub> increased by 3ppm cumulative GDD's increased by 50.8<sup>o</sup>c precipitation increased by 51.8 mm grain yield decreased by 0.169 tone /ha biomass increased by 0.02 tone /ha this, results also not conclude CO<sub>2</sub> concentration has only negative effects on maize productivity but it well fertilizing when the sufficient of water available for crop growth and plenty soil moisture contents during cropping season higher concentration of CO<sub>2</sub> in the atmosphere enables plants to adapt the required amount of CO<sub>2</sub> at a faster rate through smaller stomata opening and thus reduces the level of transpiration.( Table,16)

Table 15: Yield sensitivity Comparison from Aqua crop model outputs

Parameters /	RCP 4.5			RCP 8.5		
	years					
	2019	2020	2021	2019	2020	2021
CO <sub>2</sub>	409.ppm	411ppm	413 ppm	413 ppm	416 ppm	419 ppm
GDD	1788.1	1808.8	1828.9	1822.1	1872.9	1916
Rainfall in mm	236.3	470.9	360.3	156.9	208.7	237.2
Evapotranspiration	709.8	709.9	717.2	736.3	730.3	731.5
Transpiration mm	98.8	260	126.1	106.8	103.9	102.6
Early senescens %	0%	8%	0%	0%	0%	0%
Stomata closure %	38%	26%	40%	37%	38%	38%
Canopy expansion%	54%	2%	54%	54%	53%	55%
Soil fertility %	44%	44%	44%	44%	44%	44%
Biomass yield tone/ ha	5.955	15.956	7.607	6.268	6.289	6.162

## CHAPTER FIVE

### CONCLUSSIONS AND RECOMMENDATIONS

#### 5.1. Conclusions

This study attempted to investigate the impact of climate change on maize yield and adaptation strategies in Damot-woyde district. 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 research findings conducted in Ethiopia. The rainfall is also described by alteration of wet and dry years in a periodic pattern over 28 years /1987- 2008/

The study has also confirmed that Damot-woyde district found to be increasingly vulnerable to the risk of climate change associated extreme events including drought.

The pattern of rainfall distribution in Damot-Woyde District shows bimodal with peak rainfall in April to October. The rainfall variability is very high ( $CV > 30\%$ ) and high amount of rainfall is recorded during spring. The Mann- Kendall trend test result also shows warming trend observed in air temperature with statistically significant upward trend. This is also resulted with high evapotranspiration rate, loss of soil moisture content experienced over the study area. The annual rainfall pattern is projected to decrease in future for RCP 4.5 and RCP 8.5 scenarios in near-term (2019-2048) but slightly increasing for mid-term (2049-2078) for both scenarios. Seasonal evaluation of projected rainfall distribution in the study area shows decreasing pattern in winter (DJF) and Autumn (SON) in mid-term under both RCP scenarios but increasing for both spring (MAM) and summer (JJA) under both RCP scenarios. Monthly mean of projected peak distribution of rainfall for both near and mid-term scenarios shows shifting of peak rainy season from spring (MAM) to summer (JJA) compared to baseline period and observed period. This shows that the study area will have better rainfall during summer (JJA) from now as rainfall is

expected to increase in future and shifting of rainy season from spring (MAM) to summer (JJA). The decline of cropping during spring rainfall is also expected as projected.

Air temperature is projected to increase under both future scenarios projected from CORDEX climate projection data with statistically significant increasing trend. Temperature change is also increasing from the near to mid-term projection in both maximum and minimum temperature. Magnitude of temperature change projected is high under RCP 8.5 scenario compared with 4.5 in both term as expected. This is because, more rapid socioeconomic and population growth, with limited climate change mitigation and adaptation under the RCP8.5 climate change scenarios with high emission of CO<sub>2</sub> resulting more atmospheric forcing. Therefore, evapotranspiration calculated from minimum and maximum temperature is also projected to increase under both scenarios. Higher magnitude of evapotranspiration change is projected under RCP 8.5 with more warming trend of temperature compared to RCP 4.5. This initiates more amount of water to be evaporated from soil and plant canopy and affects plant growth and yield. More evaporative effect causes lack of moisture in soil layers and affects plant growth, development, and yield.

Observed annual rainfall anomaly from observed data shows increasing trend of rainfall. However, out of 28 years of observed data 11 years (39%) below normal, 5 years (18%) above normal and 12 years (43%) was normal period. This shows that a rainfall distribution is uneven and inconsistent with high variability with more below normal record than above normal. This variability is also confirmed by coefficient of variation between 60% and 130% which very difficult for rain fed agriculture. The future projected rainfall anomaly slightly decreasing in near-term and projected to increase in future mid-term under both RCP scenarios. The percentage of drought in this year shows 14.3% of moderate drought, 3.6% extreme drought and 3.6% severe drought year recorded.

The sensitivity analysis of Aqua Crop model shows that, rainfall is more dominant controlling weather factor. Aqua Crop model well simulates the maize yield as verified by 12 years of observed maize yield from CSA. The model simulations show annual variability related to variation of weather variables. Model validation shows a good agreement with slight biases with small error and high efficiency. Therefore, the model simulation could be used as best option for maize yields assessment for data scarce areas. The maize yield simulated using Aqua Crop model and input data from projected weather data shows increase of mean value from observed period to near-term projection. But both the grain and biomass yield simulation is decreasing from near-term to mid-term projection. Maize yield could be decreased for future projection from 0.1 tone/ha and 0.15 tone/ha for biomass and grain yield respectively from near to mid-term on average.

In regard to climate variability and change, the community response shows that 86.5% said shortage of rainfall, 33% responded the existence of drought and 9.6% said the prevalence of high/extreme/ temperature are the main reason and indicators. Similarly, rainfall was declining for the last 30 years by 33% and such phenomenon is confirmed by the community. As the impact of climate variability and change for maize production, the community response association shows that, very high rainfall variability (53.8%), high temperature (25.6%), increased soil acidity (12.8%), drought (86.5%), too little rainfall (92.9%), high temperature (98 %) and mix of all (91%). Regarding the production, the community response shows that maize production (82%) had been decreasing in the last 30 years and so small holder farmers were forced to diversify cereal crop production because of factors including risks related with: rain fall (63%), temperature (15%) pest and diseases (9.6%) and low soil fertility (11.5%). Consequently; smallholder farmers had been experienced to do different adaptation mechanisms responded as doing farmer level adaptation strategy (74%), change crop species (63%), mixed farming (64%), soil and water management (56%), planning trees (53%), irrigation (91%), change planting dates (60.8%), seed

off farm (55%) as well as rain water harvesting (67.9%). Regarding support from extension workers for adaptation to the community, the response shows that, farmer to farmer extension (55%), formal extension (19.8%), relative (14.7%) and formal credit (10 %). The major constraints to the adaptation strategy were lack of information (35 %), lack of technology (19.8 %) as well as lack of money (19 %).

Meanwhile; as of demographic and socio-economic characteristics of household's engagement in production, it had found out that sex type, age, marital status, educational level and family size were positively correlated with the involvement in adaptation strategies. Therefore; one can deduce from these positive significance and correlations that, male headed smaller holder farmer households are dominant. Similarly, as of age of the smaller holder farmer households head ; those who were aged older could be engaging on implementation of the strategies as they had passed many years on agricultural production activities and could not afford to take part in off and on farm activities to earn an income and buy feed their family's consumption. In regard to marital status and family size, positive correlation with that of adaptation strategy implementation's engagement, we can summarize that a married household head would certainly would have own family member who need feed that producing enough amount of food could be unavailable issue. Therefore; engagement on practice of the adaptation strategy for married and or active labor force, the need for enough amount of maize production for family consumption would be must. The active labor /nondependent/ family members presence would be another pushing factors for smallholder farmer households for engagement and practicing the adaptation strategies since support would be available on various types of activities in the agricultural field. There were a positive correlation between educational level and practicing adaptation strategies to climate change. Accordingly; an increase in the level of educational qualification / additional years spent on education had positive significance with practicing different kinds of adaptation strategies. In regard to farmer's level adaptation strategy towards climate change impact on their agricultural

production activities, smaller holder farmers were implementing: changing crop species, mixed farming, small scale irrigation, changing planting dates, as well as soil and water management activities. Consequently; it can be concluded that those smaller holder farmers might be able to cope up with the climate change and also adapt to the new situation as well being able to produce somehow quantity and quality maize product and also other agricultural products.

## **5.2.Recommendations**

To facilitate proper adaptation options to the impact of climate change in maize yield stakeholders should

1. Ministry of education and different NGOs invest more in education since educated householders performed better than non educated in using yield increasing technology packages which could increase farm income
2. NMA install meteorological station in 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 smaller holder farmers
4. Indigenous knowledge with science based technologies in order to support adaptation capacity of farming community

## REFERENCES

- Agumagu, O., & Todd, M. (2015). Modeling the climatic variability in the Niger Delta region: influence of climate change on hydrology. *J*
- Aklilu, Amsalu, Alebachew Adem. (2009a). Assessment of Climate change Induced hazards, impacts and responses in the Southern Lowlands of Ethiopia. Forum for Social Studies (FSS) Research Report No. 4. Addis Ababa, Ethiopia
- Alemayehu, D. and Gecho, Y. (2016) Determinants of Micro and Small Enterprises Growth: The Case of Durame Town, Kembata Tembaro Zone, Southern Nations and Nationalities and Peoples Region, Ethiopia, 2016. International Journal of Business and Economics Research, 5, 161. <https://doi.org/10.11648/j.ijber.20160505>.
- Asfaw, A., Lemenih, M., Kassa, H., & Ewnetu, Z. (2013). Importance, determinants and gender dimensions of forest income in eastern highlands of Ethiopia: The case of communities around Jelo Afromontane forest. *Forest Policy and Economics*, 28, 1-7.
- Ashenafi, W., Bobe, B., & Muktar, M. (2016). Assessment on the status of some micronutrients of salt affected soils in Amibara area, central rift valley of Ethiopia. *Academia Journal of Agricultural Research*, 4(8), 534-542.
- Bates, B., Kundzewicz, Z., & Wu, S. (2008). Climate change and water. Intergovernmental Panel on Climate Change Secretariat. Bates, B., Kundzewicz, Z., & Wu, S. (2008). *Climate change and water*. Intergovernmental Panel on Climate Change Secretariat.
- Battisti, D. S., & Naylor, R. L. (2009). Historical warnings of future food insecurity with unprecedented seasonal heat. *Science*, 323(5911), 240-244.
- Bethlehem, D. (2014). The end of geography: the changing nature of the international system and the challenge to international law. *European Journal of International Law*, 25(1), 9-24.
- Bjørnæs, C. (2013). A guide to representative concentration pathways.

- Chambwera, M. (2010). Climate change adaptation in developing countries: issues and perspectives for economic analysis
- Central Statistical Agency (CSA). 2017. Federal Democratic Republic of Ethiopia. Addis Ababa, Ethiopia. CD-ROM.
- CorethaK, Edwin M.,(2015). Adaptation to Climate Change by Smallholder Farmers in Tanzania Environment for Development. Discussion Paper Series
- Dayon, G., Boé, J., & Martin, E. (2015). Transferability in the future climate of a statistical downscaling method for precipitation in France. *Journal of Geophysical Research: Atmospheres*, 120(3), 1023-1043.
- Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, 149(1), 23-31.
- Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yusuf, M. (2008). Analysis of the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia [in Amharic](No. 15 (9) AMH). International Food Policy Research Institute (IFPRI).
- Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Kadner, S., Minx, J. C., Brunner, S., ...& Zwickel, T. (2014). Technical summary.
- Ellis, E. C., Klein Goldewijk, K., Siebert, S., Lightman, D., & Ramankutty, N. (2010). Anthropogenic transformation of the biomes, 1700 to 2000. *Global ecology and biogeography*, 19(5), 589-606.
- Elias, Sorsa and Bisrat, Elias (2008). Evaluation of Climate Change Implication on Agricultural Drought and Its Impact on Maize Productivity in Mirab Abaya Wereda, Gamo Gofa Zone, Southern Ethiopia

- Eyasu, A. E. (2002). A History of Interaction and Integration: The Case of Agew in Eritrea and Ethiopia (Doctoral dissertation, University of California, Los Angeles).
- Food and Agricultural Organization (FAO) (2009). Agricultural Based Livelihood Systems in Dry Lands in the Context of Climate change. Inventory of Adaptation Practices and Technologies of Ethiopia: Ethiopia Institute of Agricultural Research (EIAR).Rome Working Paper, 38.
- Food and Agricultural Organization (FAO) (2015). Agricultural Based Livelihood Systems in Dry Lands in the Context of Climate change. Inventory of Adaptation Practices and Technologies of Ethiopia: Ethiopia Institute of Agricultural Research (EIAR).Rome Working Paper, 38.
- Fisher, M., Abate, T., Lunduka, R. W., Asnake, W., Alemayehu, Y., &Madulu, R. B. (2015). Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa. *Climatic Change*, 133(2), 283-299.
- Fujino, (2006).Multi-gas mitigation analysis on stabilization scenarios using AIM global model.Multigas Mitigation and Climate Policy. The Energy Journal, Issue 3 (Special Issue).
- Gädeke, J. C., Föcker, J., &Röder, B. (2013). Is the processing of affective prosody influenced by spatial attention? an ERP study. *BMC neuroscience*, 14(1), 1-15.
- Gecho, Yishak, GezahegnAyele, Tesfaye Lemma, DawitAlemu (2011). Livelihood Strategies and Food Security of Rural Households in Wolaita Zone, Southern Ethiopia, International Knowledge Sharing Platform
- Gedefaw M, Girma A, Denghua Y, Hao W, Agitew G (2018) Farmer's Perceptions and Adaptation Strategies to Climate Change, Its Determinants and Impacts in Ethiopia:

Evidence from Qwara District. *J Earth SciClim Change* 9: 481. doi: 10.4172/2157-7617.1000481

Giorgi, F., Jones, C., & Asrar, G. R. (2009). Addressing climate information needs at the regional level: the CORDEX framework. *World Meteorological Organization (WMO) Bulletin*, 58(3), 175.

Grotch, S. L., MacCracken, M. C. (1991). The use of general circulation models to predict regional climatic change. *Journal of climate*, 4(3), 286-303.

Grouillet, B., Ruelland, D., Ayar, P. V., Vrac, M. (2015). Sensitivity analysis of runoff modeling to statistical downscaling models in the western Mediterranean. *Hydrology & Earth System Sciences Discussions*, 12(10).

Hanson, J. D., Liebig, M. A., Merrill, S. D., Tanaka, D. L., Krupinsky, J. M., & Stott, D. E. (2007). Dynamic cropping systems: increasing adaptability amid an uncertain future. *Agronomy Journal*, 99(4), 939-943.

Hibbard, J. P., Van Staal, C. R., & Rankin, D. W. (2007). A comparative analysis of pre-Silurian crustal building blocks of the northern and the southern Appalachian orogen. *American Journal of Science*, 307(1), 23-45.

Hsiao, T. C., Heng, L., Steduto, P., Rojas-Lara, B., Raes, D., & Fereres, E. (2009). AquaCrop—the FAO crop model to simulate yield response to water: III. Parameterization and testing for maize. *Agronomy Journal*, 101(3), 448-459.

Huntingford, C., Hugo Lambert, F., Gash, J. H., Taylor, C. M., & Challinor, A. J. (2005). Aspects of climate change prediction relevant to crop productivity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360(1463), 1999-2009.

**IPCC**, 1997. Climate change 1997: The Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University press, UK.

- IPCC, 2001. Climate change 2001: The Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University press, UK.
- IPCC, 2007: climate change 2007: impacts, adaptation and vulnerability
- IPCC, 2014: *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change* (p. 151)..
- IPCC, 2016: *Climate change 2016: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*.
- Jones, J. W. (2003, November). Agricultural responses to climate variability and climate change. In *climate adaptation.net conference insights and tools for adaptation: Learning from climate variability* (pp. 18-20).
- KaranjaNg'ang'a, S., Van Wijk, M. T., Rufino, M. C., &Giller, K. E. (2016).Adaptation of agriculture to climate change in semi-arid Borena, Ethiopia.*Regional Environmental Change, 16*(8), 2317-2330.
- Khanal, U., Wilson, C., Hoang, V. N., & Lee, B. (2018). Farmers' adaptation to climate change, its determinants and impacts on rice yield in Nepal. *Ecological Economics, 144*, 139-147.
- Kide, G. T. (2014). *Smallholder farmers' adaptation strategies to climate change in Ethiopia: Evidence from Adwa Woreda of Tigray region* (Doctoral dissertation, Mekelle University).
- KRiahi, Gruebler, Nakicenovic (2007).Scenarios of long-term socio-economic and environmental development under climate stabilization.*Technological Forecasting and Social Change, Volume 74, 7*, pp. 887-935
- Möhner, A. (2018). The evolution of adaptation metrics under the UNFCCC and its Paris Agreement.*Adaptation metrics: Perspectives on measuring, aggregating and comparing adaptation results, 15*.
- Moss, 2010. The next generation of scenarios for climate change research and assessment.. Volume 463, p. 747–756.

- Moss, R. H., Edmonds, J. A., Hibbard, K. A., Manning, M. R., Rose, S. K., Van Vuuren, D. P., & Wilbanks, T. J. (2010). The next generation of scenarios for climate change research and assessment. *Nature*, *463*(7282), 747-756
- Nash, J. E., & Sutcliffe, J. V. (1970). River flow forecasting through conceptual models part I—A discussion of principles. *Journal of hydrology*, *10*(3), 282-290.
- Senbeta, A. F., & Olsson, J. A. (2009). Climate change impact on livelihood, vulnerability and coping mechanisms: A case study of West-Arsi Zone, Ethiopia. *Lund University, Lund*, 54.
- Singh, J. P., Desmarais, S. L., Hurducas, C., Arbach-Lucioni, K., Condemarin, C., Dean, K., ... & Otto, R. K. (2014). International perspectives on the practical application of violence risk assessment: A global survey of 44 countries. *International Journal of Forensic Mental Health*, *13*(3), 193-206.
- Steduto, P., Hsiao, T. C., Raes, D., & Fereres, E. (2009). Aqua Crop—The FAO crop model to simulate yield response to water: I. Concepts and underlying principles. *Agronomy Journal*, *101*(3), 426-437.
- Sylwia, T., Emilie S. (2014). a review of downscaling methods for climate change projections, 1 center for international earth science information network (ciesin)
- Temesgen, T., Hassan, R., Ringler C., Tekie A., Mahmud, Y. (2008). Analysis of the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia. IFPRI Discussion Papers *International Food Policy Research Institute*, Washington, pp. 798
- Thomson, A. M., Calvin, K. V., Smith, S. J., Kyle, G. P., Volke, A., Patel, P., ... & Edmonds, J. A. (2011). RCP4. 5: a pathway for stabilization of radiative forcing by 2100. *Climatic change*, *109*(1), 77-94.

- van der Velde, M., Tubiello, F. N., Vrieling, A., Bouraoui, F. (2012). Impacts of extreme weather on wheat and maize in France: evaluating regional crop simulations against observed data. *Climatic change*, 113(3), 751-765.
- ,Wilby, R. L., & Dawson, C. W. (2013). The statistical downscaling model: insights from one decade of application.
- Zenebe, G., Alemayehu, M., Asmera, J. (2005). Characteristics and outcomes of stroke at TikurAnbessa Teaching Hospital, Ethiopia. *Ethiopian medical journal*, 43(4), 251-259.
- Zou, L., & Zhou, T. (2016). Future summer precipitation changes over CORDEX-East Asia domain downscaled by a regional ocean-atmosphere coupled model: A comparison to the stand-alone RCM. *Journal of Geophysical Research: Atmospheres*, 121(6), 2691-2704.

## **APPENDICES**

### **Appendix1. Questionnaire for Household Survey**

#### **Introduction and Objectives:**

Appendix 1: Questionnaire for household survey

**Hawassa University**

**School of Graduate Studies**

Department of Climate change and sustainable agriculture

Household survey questionnaires

My name is Damtew Datta graduate student of Hawassa University; I am conducting a research for partial fulfillment of Master of Science (MSc) degree in climate change and sustainable agriculture. The aim of this questionnaire is to gather data on my title and I am interested in your idea and experience and so I want your frank and honest opinion on this issue. Therefore, you are kindly requested to answer all questions and give clear, appropriate and reliable information on the issue. Be sure that the information you provide is only for the purpose of this study.

Thanks in advance!

**A – General information**

Respondent name -----Kebele-----

**B- Demographic and socio- economic characters tics**

- 1/ Sex of the respondent  male  female
- 2/ Age group  Ihan 30 years old  up to 50 years old  At 50 years old
- 3/ Marital status  Married  Single  Divorced  Widowed
- 4/ Educational statuses  Illiterate  Only read and write  Primary level education  above primary
- 5/ Family sizes  1-2  3-5  6-9  >10
- 6/ Farm size  less than ¼ hectare  ¼ hectare  1/2 hectare  1hectar  Above 1hectar
- 7/ Farm land condition  Fertile flat land  Fertile and terrain  Not fertile and flat land  Not fertile and terrain
- 8/ Livestock population ox cow sheep goat hen mule donkey horse other/ please specify/
- 9/ Fruit and other trees population  Mango  Avocado  Coffee  Papaya  Eucalyptus  Wanza

**C: Institutional information**

10/ Available Extension services

(Please select the available type of extension service in your locality)

---

No	Yes	No
----	-----	----

Types of extension service being available and provided

- 10.1 Quality crop seed
- 10.2 Quality livestock breed
- 10.3 Fertilizer
- 10.4 Pesticides and insecticides
- 10.5 Short term training
- 10.6 Rain water harvesting and storing equipments and technology advice
- 10.7 Other type of service ( indicate)-----

11/ Of the following listed improvements for being user of the extension services provided in your locality , which one ( which one is/are) gained by you?

No	Type of improvement in your agricultural production activity	Yes	No
----	--	-----	----

(particularly maize, crop and livestock)

- 1 Increased crop production
- 2 Increased livestock product
- 3 Increased amount of money out of surplus agricultural products
- 4 Appropriate , easily accessed input (fertilizer, insecticide and pesticide)
- 5 Other gained improvement (please indicate)

**D/ About climate variability and change**

12/ Have you heard of the word climate variability and change before?

1/ yes     2/ No

13/ If yes what are the indication of the climate variability and change

1/ Temperatures variability    2/ Erratic rainfall    3/ Drought    4/ Flood    5/ Shifting of crop growing season 6/prevalence of pests and insects 7/ prevalence of various diseases

14/ as of your perception, the trend of rainfall for the last 30 years has been what?

A/ increasing    B/ Decreasing    C/ No difference

15/ Do you think that the timing of the rainfall is a problem?

.1 Yes, it is onset late and ends up late    2 Yes, it is onset early and ends up early

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

4 Yes, it on sets time but ends of early 12.5 Yes, it on sets late and ends up early

16/ how was the trend of temperature for the last 30 years to date according to your perception

1/ Increasing     2/ Decreasing     3/ No change

17 Types of climate change effect observed in regard to agricultural production practice

No    Types of climate change effect you have observed    Yes    No

1    Flooding or washing away of the top soil has been occurring at your agricultural field

2    Frequent prevalence of various diseases have been attacking your livestock

3    In your locality there have been frequently occurring pests and insects which attack crops

**E/ Information about climate change impact on maize yield**

18/ Do you face problem in cereals particularly maize production? 1/ Yes 2/ No 3/ No  
change

19/ If yes, what is the main cause for problem in regard to cereals production and specially  
maize production

A/ Increasing temperature B/ Rainfall variability C/ Soil acidity D/ Disease and infestations E/  
others

20/ How do you think cropping system will be affected by impact of climate change

No	Have you experienced with the following types of climate variability and change indicators	Responses		How oftenlinkpast decade
		Yes	No	

- 1 Drought
- 2 Flood
- 3 Too much rainfall
- 4 Too little rainfall
- 5 Higher temperature
- 6 Frost/ coolness
- 7 High wind
- 8 Mix of them all
- 9 Others

21 /how was cereals production per unit area of since the last 30 years

A/ Increasing B/ Decreasing C/ No change

22/ how was maize productivity per hectare has been since the last 30 years A/ Increasing B/  
Decreasing C/ No change

19/ Do you think the cereals productivity increase or decrease specially maize since last 30 years

-----

23/ what do you think the major factor to diversify cereals crop production in this area

1/ Reduce the risk of unpredicted rainfall.2/ Reduce the risk of increased pest and disease

.3/Reduce the risk of increased temperature.4/ Reduce the risk of increased low soil fertility

5/Reduce the risk of increased low soil fertility

### **F /Farmers level adaptation strategy**

24/ in your response to climate change, have you taken any adaptation measures in order to reduce the impact of climate change 1/ Yes 2/ NO

25 If your answer is No why a/ lack of information b/ lack of capital c/ lack of knowledge d/ shortage of farming land

26/ If Yes, have you employed any of the following climate change impact adaptation strategies in your farm in the last decade

No	Climate change adaptation	Response		If no please specify the reason why
		Yes	No	
1	changing crop species			
2	Mixed farming			
3	Soil and water management			
4	Planting trees			
5	Irrigation			
6	Changing planting dates			
7	Seek off farm			
8	Rain water harvesting			

Other than the above mentioned climatic variability and change adaptation strategies, have you any other small holder farmers households have been able to employ an indigenous skill and knowledge to cope up with and produce quality and quantity products 1/ yes 2/ no

27/ in the past two decades do you received any agricultural technical support from government in implementation of adaptation 1/ Yes 2/ No

28/ If Yes, what kind of technical support do you received in your effort to reduce the impact of climate change and improve your farming system, please list them?

29/ If No what kind of support would you like to receive please list

30/ what do you suggest to be done so as to implement adaptation strategy to adapt the impact of climate change in your district

31/ what is your source of information on presence of climate change 1/ Flyer 2/ magazines 3/ Radio 4/ local newspaper 5/ neighbor 6/ friends 7/ kebele DAs

32/ what kind of support do you receive for climate change impact from all concerned stakeholders like government and nongovernment institutions

1/ Formal extension 2/ Farmer to farmer extension 3/ Formal credit 4/ Relatives in village

33/ what are that major constraints that hinders you to your adaptation mechanism

1/ lack of climate information 2/ lack of access to climate information 3/ lack of technology  
4/ Lack of money

Appendex 2 Damotwoyde Monthly Rainfall 1987- 2008

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	2.5	35.7	118.6	144.0	366.4	108.2	42.6	94.0	88.4	121.4	0.0	0.0
1988	11.8	27.5	39.0	175.7	80.1	115.1	240.0	179.1	0.0	402.8	0.0	3.4
1989	56.7	102.1	24.3	124.1	89.1	115.2	108.7	95.2	160.4	103.9	58.0	67.2
1990	67.2	79.4	246.3	67.2	100.3	144.4	44.9	89.6	139.4	85.0	69.1	31.0
1991	26.7	68.8	118.3	82.6	205.9	81.7	84.4	44.0	45.7	20.4	10.6	50.2
1992	48.7	104.8	67.1	121.8	107.8	101.4	150.6	138.4	80.5	127.6	91.2	31.9
1993	76.2	68.1	14.4	197.9	220.0	78.3	56.0	61.7	20.5	48.9	17.7	10.6
1994	2.8	15.9	95.2	154.6	117.9	95.5	167.5	116.4	48.9	25.4	50.0	3.1
1995	0.0	64.3	104.7	255.6	65.6	115.3	82.1	31.2	132.0	58.0	8.1	32.7
1996	55.7	13.9	208.2	98.0	150.1	301.8	152.8	179.5	116.0	15.6	16.8	6.2
1997	4.1	0.6	38.7	322.7	85.0	129.1	80.3	67.1	85.8	215.5	251.4	50.5
1998	99.0	43.1	73.9	145.8	113.4	154.5	98.3	149.4	103.5	160.1	14.3	6.2
1999	26.2	0.0	65.9	53.6	80.7	64.9	131.1	118.0	44.8	103.6	13.3	10.1
2000	4.6	0.0	21.8	89.1	217.7	115.8	86.2	69.1	67.3	165.1	61.4	18.5
2001	5.9	59.8	77.5	145.8	236.1	152.4	159.1	218.0	146.0	109.6	16.5	19.8
2002	87.2	17.9	83.7	139.9	197.0	49.2	80.8	137.5	47.1	52.9	15.6	112.6
2003	81.2	9.5	177.5	196.6	82.6	156.5	151.6	143.6	30.5	114.3	45.4	47.6
2004	111.8	28.7	26.0	227.0	111.6	49.3	69.7	103.8	67.4	60.4	19.0	21.1
2005	42.7	16.4	100.3	216.0	134.7	119.0	213.1	87.4	111.6	105.8	51.2	6.6
2006	5.1	49.3	85.4	308.6	142.3	80.9	89.1	180.5	81.2	137.6	37.0	83.4
2007	32.5	34.2	79.2	119.5	212.2	242.9	158.4	191.1	179.8	36.6	7.4	0.0
2008	6.4	30.3	62.2	100.2	112.4	103.8	203.5	221.4	125.9	210.3	7.4	0

Source, National Meteorology Agency (2019)

Appendix 3 Damotwoyde Minimum Temperature 1980-2008

<i>Year</i>	<i>Jan</i>	<i>Feb</i>	<i>Mar</i>	<i>Apr</i>	<i>May</i>	<i>Jun</i>	<i>Jul</i>	<i>Aug</i>	<i>Sep</i>	<i>Oct</i>	<i>Nov</i>	<i>Dec</i>
<b>1980</b>	14.7	15.2	16.1	15.8	16.0	14.6	14.0	14.2	13.5	13.5	13.5	14.7
<b>1981</b>	15.4	16.2	15.5	16.3	16.6	15.1	16.6	16.6	15.9	14.5	14.3	15.2
<b>1982</b>	16.0	17.2	14.8	16.9	17.2	16.6	16.1	17.0	15.9	15.7	16.3	16.0
<b>1983</b>	9.4	17.2	18.5	16.9	16.3	15.4	11.3	12.0	14.0	11.7	9.2	9.4
<b>1984</b>	8.2	8.2	9.0	9.5	9.5	12.8	11.9	12.3	9.7	9.7	9.0	8.2
<b>1985</b>	8.4	9.8	10.5	11.9	10.4	10.1	12.5	12.5	10.8	10.8	12.2	11.3
<b>1986</b>	9.0	10.1	11.7	11.6	11.5	11.2	12.1	11.7	13.8	11.2	10.7	10.5
<b>1987</b>	9.7	10.4	12.8	11.3	12.6	12.3	11.7	10.9	11.3	11.6	9.2	9.7
<b>1988</b>	12.3	12.5	11.5	12.7	12.1	11.3	11.4	10.9	10.9	9.6	7.1	9.0
<b>1989</b>	13.8	15.1	13.8	15.0	14.3	13.9	14.1	14.0	13.8	12.5	11.6	16.7
<b>1990</b>	15.4	17.8	16.0	17.3	16.4	16.4	16.7	17.0	16.6	15.3	16.1	16.2
<b>1991</b>	17.4	17.5	17.3	15.8	17.1	17.4	16.6	16.5	15.7	13.2	15.1	15.5
<b>1992</b>	17.5	18.1	16.6	16.8	16.3	16.3	16.0	16.7	16.1	16.1	14.5	15.1
<b>1993</b>	15.9	15.7	14.2	17.0	16.8	16.7	16.7	16.2	15.3	15.6	14.1	15.7
<b>1994</b>	16.6	16.9	17.1	15.9	16.8	16.5	16.1	16.2	16.0	13.2	14.2	14.9
<b>1995</b>	16.0	17.0	16.3	17.0	16.3	16.1	16.8	16.3	15.6	16.1	13.6	16.2
<b>1996</b>	16.9	16.0	16.0	16.3	16.4	16.9	16.5	16.3	16.2	13.5	12.1	14.1
<b>1997</b>	16.8	17.3	17.5	16.8	16.2	15.8	16.7	16.5	15.6	16.9	16.6	15.1
<b>1998</b>	16.5	17.2	16.3	17.8	18.1	16.9	18.0	17.6	16.9	17.0	14.4	15.9
<b>1999</b>	16.5	16.0	17.5	16.3	16.7	17.4	17.1	16.3	16.6	17.3	15.6	16.1
<b>2000</b>	17.2	17.7	18.0	17.7	16.6	16.5	17.0	17.1	16.6	16.9	14.8	16.3
<b>2001</b>	17.4	16.8	17.5	17.1	17.1	16.5	16.7	16.6	16.0	16.5	14.7	17.0
<b>2002</b>	17.9	16.6	17.5	16.6	15.4	15.2	15.5	15.3	14.9	14.3	13.3	14.4
<b>2003</b>	17.1	16.5	17.4	16.8	15.8	15.6	15.9	16.1	15.4	14.8	16.8	15.6
<b>2004</b>	16.3	16.4	17.3	17.0	16.1	15.9	16.4	16.9	15.9	15.4	15.7	17.4
<b>2005</b>	17.2	18.4	18.2	17.8	16.8	16.9	16.1	16.7	16.0	15.9	15.0	15.8
<b>2006</b>	17.9	17.1	17.3	16.9	16.7	16.4	16.8	16.9	16.6	16.6	15.3	17.2
<b>2007</b>	17.6	18.3	16.9	16.9	17.2	16.8	16.3	16.4	16.7	14.3	15.8	16.5

Source, National Meteorology Agency (2019)

### Appendix 3 Damotwoyde Maximum Temperature 1980-2008

<i>Year</i>	<i>Jan</i>	<i>Feb</i>	<i>Mar</i>	<i>Apr</i>	<i>May</i>	<i>Jun</i>	<i>Jul</i>	<i>Aug</i>	<i>Sep</i>	<i>Oct</i>	<i>Nov</i>	<i>Dec</i>
1980	32.6	33.4	33.6	31.6	30.1	28.7	28.7	29.0	29.7	29.7	32.6	32.6
1981	33.5	33.9	34.6	33.1	32.0	31.9	29.6	29.7	29.3	31.8	33.5	33.5
1982	34.1	34.4	35.6	34.6	33.9	33.7	33.4	33.6	33.3	32.9	33.3	33.3
1983	32.1	34.1	35.6	34.2	31.1	29.4	27.6	27.2	29.5	30.4	31.4	32.1
1984	33.0	34.2	35.5	35.2	30.6	29.3	27.4	27.4	29.6	32.1	32.2	33.0
1985	33.9	34.3	34.0	31.8	30.1	29.2	27.2	27.6	29.7	31.4	32.6	33.0
1986	32.5	32.8	33.1	31.4	29.8	28.3	26.7	27.6	29.3	30.3	31.3	31.6
1987	33.8	33.5	32.8	31.0	29.1	28.0	28.5	29.0	30.3	30.0	31.7	32.4
1988	33.0	33.5	34.6	33.4	29.7	28.6	25.8	26.5	27.9	29.3	31.3	31.8
1989	32.2	32.7	32.9	31.3	29.6	28.2	26.7	27.6	29.3	31.0	31.8	29.0
1990	30.6	30.1	30.2	30.1	29.1	28.1	26.6	27.7	29.9	31.1	31.6	31.6
1991	32.2	31.6	31.6	31.5	30.0	27.7	25.1	27.6	28.4	30.5	31.7	31.0
1992	31.8	31.6	33.2	31.4	29.1	28.0	27.1	26.7	28.3	28.4	30.0	31.2
1993	30.3	30.0	33.4	30.7	28.8	27.1	26.9	28.3	29.8	29.6	31.8	32.5
1994	33.6	33.8	32.8	30.7	28.8	27.4	25.8	26.9	29.6	31.2	31.4	32.2
1995	33.5	33.7	31.5	30.2	30.8	30.1	27.6	28.4	29.7	31.2	31.9	32.7
1996	32.3	34.0	33.1	32.0	31.6	26.4	25.6	26.5	27.4	29.2	30.6	30.8
1997	31.7	33.4	34.3	29.3	29.7	29.5	27.1	29.1	31.2	29.4	28.6	29.8
1998	30.3	31.7	33.1	32.8	29.9	28.9	27.3	26.7	29.3	28.9	31.6	32.0
1999	32.4	34.5	32.2	31.7	29.1	29.1	26.6	28.0	27.2	27.7	31.0	31.8
2000	32.9	34.2	35.0	32.5	28.8	27.9	27.0	27.1	29.0	28.6	30.5	31.8
2001	31.8	33.3	32.3	31.0	29.2	26.9	27.0	27.8	29.2	30.1	31.0	32.2
2002	31.6	33.7	31.9	33.3	33.3	33.3	26.7	27.6	29.1	29.8	31.6	31.6
2003	32.0	33.1	30.7	31.5	31.2	30.8	27.4	28.2	29.4	30.4	31.8	32.0
2004	32.4	32.4	29.6	29.6	29.1	28.2	28.2	28.8	29.7	31.1	32.1	32.4
2005	32.3	34.4	32.8	32.3	27.8	28.0	27.4	28.4	28.3	29.6	30.8	31.6
2006	32.8	33.1	31.5	29.5	29.8	28.6	27.1	27.0	28.8	29.7	30.2	30.8
2007	31.8	33.5	33.8	30.9	29.6	26.7	26.7	26.3	27.5	28.3	30.6	31.8

Source: National Meteorology Agency (2019)

## **BIOGRAPHY**

The author, Damtew Datta was born on January 13, 1974 from his father Data Kolbaya and his mother Ayikale Yaya in, Southern Nation Nationalities and People Regional State, Ethiopia at Adecha kebele. He attended primary school at Adecha elementary and secondary High school at bedessa town. He joined Hawassa University College of Agriculture in 2002 graduate with diploma in plant science program, after graduation he employed as agricultural officer in Damot-woyde woreda. Later 2010 graduate with degree in plant science and continued his regular work, .and He was been working Damot-woyde woreda as an expert until he joined Hawassa university school of graduate studies in 2018. He was married and have doughtier.