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SPATIO-TEMPORALTREND, FARMERS PERCEPTION AND ADAPTATION STRATEGEIS FORCLIMATE VARIABILITYIN BORENA DISTRICT, SOUTH WOLLO ZONE,AMHARA REGION, ETHIOPIA

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A THESIS SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES OF ADDISABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTERS OF ARTS IN GEOGRAPHY AND ENVIRONMENTAL STUDIES (SPECIALIZATION IN GEOGRAPHIC INFORMATION SYSTEM, REMOTE SENSING AND DIGITAL CARTOGRAPHY)

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Abbreviations and Acronyms

AEZ	Agro-Ecological zone
AOI	Area of Interest
AEZs	Agro Ecological zones
BDAO	Borena District Agricultural Organization
BDHO	Borena District Health organization
CHIRPS	Climate Hazard Group Infrared Precipitation with Station data
DEM	Digital Elevation Model
ERDAS	Earth Resource Development Assessment System
ESRI	Environmental Systems Research Institute
GDP	Growth Demotic Product
GIS	Geographical information system
GPS	Global Positioning System
ITCZ	Tropical convergence Zone
LGP	Length of Growing Period
MAEZ	Major Agro-Ecological Zone
MOA	Ministry of Agriculture
MOARD	Ministry of Agriculture and Rural Development
NASA	National Aeronautics and Space Administration
NAM	National Meteorological Agency
NDVI	Normalized Difference Vegetation Index
NMSA	National Mission for Sustainable Agriculture
NOAA	National Oceanic and Atmospheric Administration
PSNP	Productive Safety Net Programme
SPI	Standard Precipitation Index
TRMM	Tropical Rainfall Measuring Mission
UNDP	United Nations Development Programme
UASAID	United States Agency for International Development
USD	United States Dollar
USGS	United States Geological Survey

Abstract

Climate variability and extremes are among the problems prevailing in most parts of Ethiopia. The influence of climate variability is very high for Ethiopian's especially for an agrarian, society where frequencies of extreme events are increasing. This study Analyzethe spatial and temporal trend, farmers' perception and adaptation strategies for climate variability in Borena District using time series rainfall data of CHIRPS for the period 1981–2018 and temperature data worldClim from 1961-2018. The main objectives of the study are to the trends of rainfall and temperature both in space and time, to evaluate farmers' perceptions of climate variability, to explore impacts and adaptation strategies for climate variability. Primary data were collected through FGD, KII, and observation. Qualitative and qualitative data analyze techniques were employed to the data. Long term Mean, CV, and SD, Maximum and minimum temperatures were used to rainfall and temperature variability. Magnitude and frequency of rainfall and temperature trend were evaluated using Sen's slope and Mann-Kendall trend test analyze methods. Trend analyze results showed staticallynon significantincrease in annual rainfall and statically significantKiremt rainfall while,belg rainfall is a decline in all AEZs. Almost all farmers have perceived an increasing amount of temperature and decreasing belg rainfall in all areas. Soil conservation, planting early maturing crops, diversifying livelihood, preservation of food, and seeds storage were used adaptation strategies for climate variability. The finding of this study used as an input for decision-makers takes appropriate measurements in different sectors like agricultural experts, and climate change officers.

Key words, worldclim, Mann–Kendall test,Sen's slope test, Climate variability, spatial, temporal, community perception and adaption strategies, Borena District

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Climate change is a contemporary problem and global in nature, but potential changes are not expected to be globally uniform; rather, there may be dramatic regional differences (Mulugojjam&Ferede, 2013). Climate change is current, real, and happening now. Nowadays, climate variability has altered and unseasoned rainfall is often observed (Conway et al., 2005). The basic climatic elements such as rainfall and temperature show seasonal and annual variation rather different from average expected climatic conditions. The average global surface temperature has heated by 0.8°C in the past century and 0.6°C in the previous three decades (Hansen et al., 2006).

Africa is one of the seriously affected continents by climate change in the world (IPCC, 2018). As the region attempts to accomplish sustainable development, national governments are enormously grappling with difficult trade-off and opportunity costs with observe to climate change (Muller et al., 2011). The increasing of earth's temperature due to the emission of Greenhouse Gases (GHGs) is now unquestionable; and over the last few years, the atmospheric concentration of CO2 has increased significantly which induced the average global temperature to increase by 0.74 C as compared with the preindustrial era (UNFCCC, 2007).

In Sub-Saharan Africa, climate variability and change such as drought are responsible for substantial economic, social, and environmental problems. Managing the risk posed by climate change and extreme events through implementing effective technological, institutional, and policy options are crucial (Shiferaw et al., 2014). This has a major indication for the agricultural sector. It will be critical for developing adaptive strategies to overcome this problem.

In several climate analyses, the East African region is considered that it will be drier, through a decrease in the length of the growing season. Climate change impacts have the potential to undermine and even, undo the progress made in improving the socio-economic well-being of East Africans (Ayalew et al., 2012). In the horn of Africa, Ethiopia is one of the symbols of the vulnerability to climate change in with the least capacity to respond (Thornton et al, 2006). Ethiopia is characterized by rising and falling geographical location, topography and heavily reliant on rain-fed agriculture, under-development of water resources, high population growth rate, low economic development level, inadequate road infrastructure in drought-prone areas, weak institutions in combination with low adaptive capacity, as a result, Ethiopia is one of from the most vulnerable east African country to the adverse effects of climate change (NAPA, 2007).

Ethiopia is more susceptible to climate change and drought which is the most important climate-related natural hazard impacting the country from time to time. The reason why Ethiopia is vulnerable to climate change is, because of its greater dependence on climate-sensitive economic sectors like subsistence crop cultivation and livestock production. Study of national climate trend from the 1960s shows in Ethiopia have enlarged by 0.5-1.3 degree centigrade and it is predicted to increase by 0.9-1.1 degree centigrade in 2030, 1.7-2.1 degree centigrade by 2050 and 2.7-3.4 degree by 2080 over compared to 1961-1990 normal (NMA.2007). World Bank (2008) provides that Poverty in Ethiopia is a constant problem and about two-thirds of people live on less than $2 a day. Consequently, Ethiopia is one of the most food-insecure countries in the world, a situation compounded by droughts and famine that cycle in and out.

Basically, there are two factors that directly or indirectly influence climate change in Ethiopia: natural and anthropogenic factors. For that reason, Ethiopia's climate is highly influenced by the general atmospheric and oceanic factor that affects the weather system and the time of beginning and strength of rain (Bekele, 1997). Climate change causes major challenges to Ethiopia's government and also its people. It has faced with increasingly erratic rains, and sometimes the complete failure of seasonal rains –a problem linked to climate change. Accordingly, millions of Ethiopians often face harsh food scarcity (Kaur, 2013).

Ethiopian GDP is highly sensitive to the variability of rainfall over time and space. Although agriculture has a major contribution to the overall economy, Ethiopia is challenged by many climatic related factors such as drought, flooding, and irregularities in different seasonal rainfall amount and distributions are the major ones (Deressa, 2007; Jaewon et al., 2015). The threats associated with climate variability in the region have been recognized since the 1960s and several efforts' are underway to develop both mitigation and adaptation strategies to cope with this risk, though the outcomes are variable. Climate variability plays a crucial role in a year-to-year reduction in crop production and on the overall economy of the nation (Ngetich et al., 2014). The vulnerability of crop production to climate variability and changes can be decreased with crop-specific climate information and the use of such information in crop management decisions. Climate information has shown the potential for improving the resilience of agriculture to climate shocks.

1.2 Statement of the problem

As indicated by IPCC (2007) climate variability and change are among the utmost developmental challenges of the 21st century. Developing countries as a whole and especially African nations are most the most vulnerable ones, due to the sensitive nature of their livelihoods or economic systems, and low adaptive capacity (Ayal and Muluneh, 2014). According to Easterling (2011), climate variability and change seriously hit smallholder subsistence farmers hence their low adaptive capacity and their dependence on rain-fed agriculture which is very sensitive to climate variability.

In Sub-Saharan Africa, climate change and extremes such as drought are responsible for significant economic, social, and environmental destruction (Ayal&Filho, 2017). IPCC report (2014) indicated that precipitation amounts are likely to decrease for most parts of Sub-Saharan Africa (SSA) while rainfall variability is expected to increase. Africa is expected to experience mainly negative climate change impacts, in terms of an increase in temperatures and a decrease in the largely unreliable rainfall in its context of widespread poverty and low development (World Bank, 2010). As stated by Below et al. (2010) parts of the Sahara are likely to be the most vulnerable, showing likely agricultural losses of up to 7% of GDP by the year 2100. Because they are highly dependent on the natural systems for growing crops and raising livestock, climate variability and change will be felt most acutely by smallholder farmers in sub-Saharan Africa (UNDP, 2014).

The same source further clarifies that changes in regional precipitation will ultimately affect water availability and may lead to decreased agricultural production and potentially widespread food shortages. Climate variability and changes in rainfall patterns will ultimately affect crop production and potentially widespread food shortages (Hulme et al., 2001). In relation to this, Bishaw et al., (2013) argued that Ethiopia is especially vulnerable to climate variability and change because a higher part of the population is poor and depends on agricultural productivity, which is highly exposed to rainfall variability. The diverse agro-ecological zones are characterized by various micro-climates and corresponding weather patterns.

Nowadays, climate variability is already brought a significant challenge to Ethiopia by deterring the struggle to reduce poverty and sustainable development efforts (NMA, 2007). Ethiopia is one of the most vulnerable countries in the world to the adverse effects of climate change; due to its high linkage on rain-fed agriculture, low adaptive capacity, and a higher reliance on natural resources base for livelihood, among others (World Bank, 2010). In terms of livelihood, smallholder rain-fed farmers and pastoralists are believed to be the most vulnerable to climate variability and change and need interventions to adapt their livelihood systems to changing climatic conditions (NMA, 2007; EPCC, 2015). The north-central part of Ethiopia where the study was conducted is among the drought-affected areas in Amhara National Regional State and it is also one of the food insecure areas of the country because their farming system practiced in the context of erratic rainfall and has serious frequent drought recurrently followed by shocking famine (Muluneh and Demeke, 2011).

Several studies on climate variability have been conducted in Ethiopia at different Spatio-temporal scales and came up with mixed results. A study by Seleshi&Zanke (2004) identified no trend in the annual and seasonal rainfall for northern and northwestern Ethiopia in the second half of the 20th century. A study by Meze-Hausken (2004) in Northern Ethiopia has stated that small rainy season (belg) has been lost and the main summer rains have shortened in duration. A study by Woldeamlak (2007) indicated that there were intra-annual and intra-regional differences in the amount and variability of rainfall in the Amhara region.

A relatively study conducted by Daniel et al. (2014) revealed a statistically significant positive trend of temperature while the case for precipitation was mixed over the upper Blue Nile river basin of Ethiopia. Jury & Funk (2013) observed a negative trend in rainfall over southwestern Ethiopia in the period 1948–2006. As further r studies were, conducted by Mengistu et al. (2014) in the upper Blue Nile River basin of Ethiopia showed statistically non-significant positive trends in annual rainfall for the period 1981– 2010. A study by Asfaw et al. (2017) in the Woleka sub-basin (in the North-central part of Ethiopia) depicted a statistically significant negative trend of annual and kiremt rainfall whereas the belg was not statistically significant. And also the study depicted an increasing trend for mean and minimum average temperatures through time significantly while the trend for maximum temperature showed a non-significant increasing trend. Gedefaw et al. (2018) in the Amhara region study the climate variability in terms of rainfall monthly, seasonal, and annual time scales and his result revealed significant positive and negative trends in the stations.

The majority of previous studies have been limited to data from a few meteorological stations which are spatially incomplete. In recent decades, satellite-derived rainfall products have been used for providing rainfall estimates on a global scale at ever-increasing spatial and temporal resolutions as a viable alternative to station observations (Dinku et al., 2018).

Likewise, satellite-derived rainfall estimates provide timely and cost-effective information about rainfall at different time scales rages from daily to annually, which makes them very crucial, particularly in drought monitoring and early warning systems (Berhan et al., 2011; Hazaymeh& Hassan, 2016). Nevertheless, there are doubts related to techniques for satellite rainfall estimates. These may affect the accuracy of satellite-derived rainfall estimates and may result in a significant error when they are used for different applications such as rainfall patterns and variability study. Thus, the reliability of the satellite-derived rainfall products needs to be evaluated before using them for the planned applications. At present, there is a lot of satellite-based rainfall products derived from multiple data sources. Climate Hazards Group InfraRed Precipitations with Stations (CHIRPS) is by far a new rainfall product with high temporal and spatial resolution. in addition, it has multiple data sources. This product was chosen due to its successful implementation in different studies in Ethiopia which has complex topography (Dinku et al., 2018; Bayissa et al., 2017). These studies indicated that CHIRPS performed very well during the monthly and seasonal time scales than other RFE. Additionally, CHIRPS data have a relatively higher spatial resolution (~5 km) and longer periods of records (1981-present) than other products. In addition, no prior comprehensive study was conducted in the study area.

As a result, this study aimed to analyze the Spatio-temporal trends of rainfall and temperature in Borena District during the period of 1981–2018 using CHIRPS data and 1961- 2018 using WorldClim temperature data for total annual, kiremt, and belg rainfall using descriptive and statistical tests; and the perception of farmers have been incorporated so as to have a better picture on the climate change-induced variability and trend.

1.3. Objectives of the Study

1. 3.1 General objective of the study

The main objective of this study was to *assess the spatial temporal trend, farmers' perception and adaptation strategies for climate variability* in Borena District using remote sensing and GIS techniques.

1.3.2. Specific Objectives

1. To the spatiotemporal trends of rainfall and temperature
2. To investigate farmers‘ perceptions on climate variability
3. To examine the impacts of climate variability
4. To explore adaptation strategies for climate variability

1.4. Research Question

1. What is the spatial and temporal trend of rainfall in the study area?
2. What is the spatial and temporal trend of temperature in the study area?
3. What is the farmers' perception for climate variability?
4. What are the impacts of climate variability in the study area?
5. What type of adaptation strategies should be done for climate variability?

1.5. Significance of the Study

The Spatial-Temporal Climate Variability Analyze has been used to design strategies and decisions for reducing the adverse impacts of climate variability and change. To do so, the use of Remote Sensing Data and Geographical Information System can effectively facilitate and quantify the detection, identification, and mapping of climate variability and change affected areas to enhance the decision making process for climate change and variability.

Climate variability and change issues are widely studied in different parts of the world. The impact of the climate brings severe damage, especially in developing countries. Ethiopia currently faces different problems resulted from climate variation even though the scale of climate change is not clearly identified. In light of the situation and profile of the project area, analyzing major climate change elements have been some paramount importance on account of the following reasons. Analyzing the spatial-temporal trend of rainfall and understanding the subsequent trends of the change have been vital importance to the present understanding of the dynamics of the climate system in the locality. Very little was done on the spatial-temporal climate variability study. Therefore, this study can be used as a benchmark for further studies. As it is evidently clarified in numerous kinds of literature, the vulnerability and adaptation to climate change in the Borena district have been given little attention. As a result, there is a severe impact from frequently recurring drought and flood on pastoral and agro-pastoral areas. Hence, the result which will be generated by this study will have paramount importance in improving efforts geared towards reducing the vulnerability and enhancing their adaptation mechanisms to climate change impacts. The finding will serve as an input for various governmental and non-governmental development organizations working on reducing the impact and influence of communities from the adverse impacts of climate variability and fill the gap. Furthermore, based on the findings it will be possible to devise interventions that adequately reach all communities. Moreover, it can encourage further research and study by other researchers, development practitioners, and local development actors. Therefore, the finding of this research has the following significance:

- The research is believed to provide inputs for decision making, policy change
- The study also helps to stimulate further investigation by Borena District agriculture and south Wollo zone climate change and disaster risk management office
- To review the pattern, variability, trend of rainfall and temperature in space and time
- It will be used as an important resource (reference material) for someone who is interested in undertaking similar research and it can be used for academic purposes and related sectors.

1.6. Delimitation of the Study

This research work was mainly designed to the spatial-temporal trend, farmer's perception and adaptation strategies for climate variability using GIS and remote sensing. Geographically, the scope of the study was restricted to the Borena District, South Wollo Zone, Amhara region, Ethiopia where both the distribution of rainfall and temperature are highly variable in nature. More specifically, among the various climate variables in this study particularly rainfall and temperature are thoroughly d.

The main reasons for selecting Borena District as a study area were due to the researcher's personal troubles with the area as his workplace was in Borena District, the researcher was fully aware of the problems of Spatio-temporal climate variability faced by the rural farmers of the Borena District since long. Climate variability is a critical issue requiring urgent attention in the south Wollo zone particularly in Borena District.

Methodologically, the study has incorporated Mean, SD, CV, and MK from CHIRPS precipitation data and worldClim temperature data respectively. Temporally, the study is also limited to 38 years (1981 – 2018) rainfall and 58 years (1961-1918) temperature data. The study was conducted in a small geographical area particularly only in one District namely Borena (five agro-ecological zones) from considering the trend and its scope is limited to assessing spatiotemporal climate variability. The study could have been much more interesting had it been possible to include more woredas from south Wollo zone woreda and beyond. And also it is better to see daily, ten-day variability, trend, and pattern of rainfall and temperature at the parcel level including the last two years 2019 and 2020.

1.7. Limitations of the study

One of the limitations of the study was the lack of historical record of climate, population, and livestock data affected by climate variability. Though CHIRPS has a consistently good agreement with ground rainfall at different Spatio-temporal scales in Ethiopia, it includes uncertainties that lead to errors in rainfall estimates. For Ethiopia, uncertainties are Potential and limitations mainly related to areas with a complex topography (Dinku et al., 2007). The other limitation of the study is unfortunately happing of COVID19 in our country it affects to obtain secondary source from different sectors, better internet from AAU, face to face contact for sharing the experience with friends and my advisor, face to face interview and questionnaires with farmers and concerned body, and also its psychological shock and influence of the pandemic were the major challenges faced the researcher during the study. However, the researcher tackles these challenges in different ways like using high spatial resolution satellite date from downscaled CRUTS (worldClim) temperature data for the study area, using the telephone to discuss with the advisor and other concerned body about the issue. The researcher Collected data through KII by keeping the interviewer the rule of "social distance" physical distance. The minimum distance between interviewee and interviewer was three meters with PPE (face mask and glove), sanitizer, and alcohol to protect the virus during the time of data collection. Communicate using the telephone for asking any questions with my friends, advisor, and other concerned body. The researcher Used a private and CDMA internet package to download necessary data and documents for the purpose of this study and by taken a strong commitment to reducing the shock and stress of Corona during the study.

1.8. Organization of the study

This thesis is organized into five chapters. Chapter one constituted the introduction, which focuses on the background, statement of the problem, objectives, research questions, significance, and scope of the study and limitation of the study. The second chapter deals with review of literature which contains a brief description of theoretical basis and some previous works relevant to the present research. The third chapter is devoted to brief description of the study area and a thorough explanation of the methodologies employed for data collection and analyze. Chapter four deals with the results and discussion and finally chapter five present conclusion and recommendations of the study.

CHAPTER TWO

2. Review of Related Literature

2.1 Theoretical framework

2.1.1 The Concept of Climate and Climate Change

Climate change is a change in the state of the climate that can be identified by the changes in the mean and/ or the variability of its properties and that continues for an extended period of time, normally can take decades or longer (Ali, 2017). It refers to any change in the climate over time, whether due to natural processes or as a result of the human process (IPCC, 2007). Climate change and variability are one of the most continual problems of our time. According to Yteal (2012) Climate is that the average weather in an exceedingly given space over an extended amount of your time. Climate includes the common temperature in numerous seasons, rainfall, and sunshine. Climate change or temperature change is any systematic change within the long-run statistics of climate variables like temperature, precipitation, pressure, or wind sustained over many decades or longer. Temperature changes are often thanks to natural external forcing (changes in star emission or changes within the earth's orbit, natural internal processes of the climate system) or it is often human elicited.

As drawn in the work of Yteal (2012) climate is described in terms of the variability of relevant atmospheric variables such as temperature, precipitation, wind, snowfall, humidity, clouds, including extreme or irregular ones over a long period in a particular region. According to WHO (2019) in the traditional period for performing the statistics used to define climate corresponds to as a minimum of 3 decades (30 years). As a result, the 30 year period planned by the WMO should be considered more like a sign than a norm that must be followed in all cases. Climate change and variability can, therefore, be viewed as a mixture or comprehensive of weather in a particular area for a long time Goosse, *et al*., (2010). A similar study further also underline that the two most important factors determining an area's climate are air temperature and precipitation Branch, (2013). Most of the time, as different studies indicates climate is the collective state of the atmosphere for a given place over a specified interval of time (Demircan2010).

Descriptions of the climatic condition are made from observations of the atmosphere and in terms of averages and extremes of a variety of weather parameters, including temperature, precipitation, pressure, and wind Demircan (2010). According to Hegerl (2011) the second fraction of the climate definition deals with a location. Since, location related to altitude is the major determinant of climate varies from area to area. In weather and climate studies we are mostly paying attention in small -scale, regional, and global climates. Climate conditions and variability should be defined in terms of purpose. Time is the other part of the definition of climate. Time duration is the most significant and is crucial to the description of a climate. Weather and climate both differ with time. Weather alters from day to day. Climate changes over much longer periods of time over large areas. Variations in climate are related to the shift in the power budget and resulting changes in atmospheric circulation patterns.

Climate change is the most complex environmental problem facing the world today. Hegerle*et al*., (2007) stated that climate change refers to a change in the state of the climate that can be identified by changes average temperature and variability of other properties that persist for an extended period may for decades or longer. The climate change caused by different factors among these internal processes and external forces is dominant.

External factors, for instance, changes in solar radiation and volcanism, occur naturally and contribute to the total natural variability of the climate system. Other external factors, such as the change in the composition of the atmosphere that start in on with the industrial revolution, are the result of human action. An atmospheric practice that generates internal variability is known to function on time scales ranging from close to instantaneous (e.g., condensation of water vapor in clouds) up to years (e.g., troposphere-stratosphere or inter-hemispheric exchange). In addition, the climate system has many other components of the, for instance, the ocean and the large ice sheets, tend to operate on longer time scales. These components produce internal variability of their own accord and also integrate variability from the rapidly varying atmosphere (Müller, 2010). Internal variability also is produced by coupled interactions between components, such as is the case with the El-Niño Southern fluctuation.

According to Parry (2007) having the same essential point out that climate change refers to "a change in the state of the climate that can be identified by changes in the mean and the variability of its properties and that bear for a prolonged period, typically decades or longer". The same source also explained that climate change may result from the internal and external processes of the climate system. Among external factors that contribute to climate change and variability, such as changes in solar radiation and volcanism, occur naturally and contribute to the total natural variability of the climate system. There are other external factors that lead changes, such as the change in the composition of the atmosphere that began with the industrial revolution, which is the result of human activity.

Furthermore, explained climate change as a statistically significant difference in either the mean state of the climate or in its variability, persisting for an extended period mostly for decades or longer Getnet (2010). Additionally, Changes in climate, which is generally defined as "average weather," is usually, explain in terms of the mean and variability of temperature, precipitation, and wind for a period of time. Climate Changes can be a pathway based on observational data for these parameters Kadir*et al.*, (2013). The climate system results from a complex interaction of atmosphere, land surface, snow and ice, ocean, and other bodies of water, and living things (Bako, 2018). Nowadays, climate change and its consequences affect every corner of the world its impact is diverse and globally witnessed. Take much attention in the public debate. It is the most complex and cross-cutting environmental influences food production, water, and, energy availability

Even though climate and climate change are usually presented in wide, there may be largely local and regional departures from these global means. These can either lessen or exaggerate the impact of climate change in different parts of the world (Kim et al., 2007). According to (IPCC, 2001) Climate variability is the difference in the mean state, and other statistics like standard deviations, the incidence of extremes temporal, and spatial scales beyond that of individual weather events. In contrast Variability happened due to natural internal processes within the climate system we call it internal variability and anthropogenic external forcing or external variability (IPCC, 2001).

2.1.2 Major characteristic of Climate Change

2.1.2.1 Precipitation and Temperature

The climate of a given location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their current and, are changes, both long-term and short term climate change represent periodic or intermittent changes that occur representing climate variability (Nicholls, 2012). In this regard, rainfall and temperature are the two most major variable influences the climate of a region. Precipitation is the general expression for rainfall, snowfall, and other forms of frozen or liquid water falling from clouds. Climate change is can directly influence precipitation amount, intensity, frequency, and type. Large natural variability and strong geographic variations in these parameters are manifest, substantially affected by atmospheric movement patterns such as the El Niño Southern Oscillation. Increased warming accelerates evaporation and increases the amount of water vapor in the atmosphere, resulting in definite areas getting wetter and others getting drier Branch,(2013). Extensive increases in heavy rainfall events have occurred even in places where total amounts have decreased (Kedir*et al*., 2013).

2.1.2.2 Rainfall and Temperature Trend

IPCC Ericson (2008) cited in Getnet (2010) except east Africa the Annual amount of raise in the majority of African regions where that rainfall continues more or less stable when averaged over the whole country while a declining trend annual rainfall is projected to increase. As indicates by trend analyze of annual rainfall data in Ethiopia shows have been practiced over the Northern half of the country and Southwestern Ethiopia. In addition to the rainfall trend temperature trend indicate, recent climate trends based on UNDP climate data indicate a change in temperature and rainfall. There is a clear and observable positive trend in temperature. Ethiopia confirms a reliable warming trend, with the observation of increasing minimum and maximum temperature over the past fifty years (McSweemy, *et al*., 2010 drawn in the work of Girmay, 2019).

According to Getnet, (2010) Surface of the Earth has hot between 0.4^{o}C and 0.8oC during the last century. This finding does, however, have to be interpreted with care. For example, the observed warming has not been constant, although the steady increase in greenhouse gas concentrations would suggest that any greenhouse-induced warming should have been steady over the past 100 years. Research by various authors indicates that there is an increase in temperature over all of the country. Earliest climatologically station of Gondar prior to 1993 had an anomaly of -4^{o} C while the result is immediately increased to 4^{o} C in the preceding years since 2006.

2.1.3 Climate System in Ethiopia

According to Oumer*et al*., (2007), Climate is commonly described by the statistical justification of precipitation and temperature data recorded over a long period of time for a given area. According to Reda (2015), the mean annual rainfall distribution over the country is differentiated by a large spatial variation which ranges from 2000 mm over some pocket areas like the Southwest to less than 250 mm in the Afar and Ogaden low lands areas.

In relation to rainfall during the year occurs in different seasons. Unlike most of the equatorial climate where two seasons are common namely one wet season and one dry season, three seasons are known in Ethiopia, namely Bega (dry season) which extends from October to January, Belg (short rain season) which widen from (February to May), and Kiremt (long rain season) which extends from June to September (NMSA, 2001)

In addition, Temperatures are very much adapted by the diverse altitude of the country. In general, Ethiopia has an experience of moderated or temperate temperatures for its tropical latitude because of topography. Mean annual temperature distribution over the country varies from about 100c covers the highlands of northwest, central, and southeast to about 350 c over north-eastern lowlands (Enquist, 2002).

2.1.3.1. Agro-Ecological Features of Ethiopia

Temperature and precipitation are the two most common and significant climate variables. These two constraints typically served to define the type of vegetation that can grow in the region. It is, therefore, functional to classify climate based on these variables (Sensoy and Demircan, 2010). The climate of Ethiopia is mainly determined by the seasonal movement of the Inter-tropical Convergence Zone (ITCZ), which follows the position of the sun relation to the earth and the related atmospheric movement, connection with the up and dawn topography of the country (NMSA, 2001). There are a number of techniques to classify the climatic systems of Ethiopia for instance the traditional, then Koppen's, the Throthwaite's, the rainfall management, and the agro-climatic zone classification systems (Deressa, *et al*., 2010).

The extremely different topography of Ethiopia contribute to having three distinct climate zones across the country; namely, Dega (cool zone), Weyna-Dega (temperate zone) and Kolla (hot zone); Within each climatic zone, seasonal distinction and shifting atmospheric pressure systems give to the formation of three seasons, which are known as the Kiremt, Belg, and Bega (Cheung et al., 2008). Climatic zones can be distinguished as a cool zone in the central part cross-cutting the western and eastern sections of the high plateaus above 2400 up to 4,620 meters above sea level, a temperate zone between 1,500 and 2,400m.a.s.l, and the hot lowlands below 1,500 m.

Average annual temperatures in the cool zone less than 7-12ºC and in the hot lowland zone is over 25ºC (NMSA, 2001). There are diverse types of climate classification systems depending on the climatic element used. The most widely used is the Koppen Climate Classification System (Pidwirny, 2006). Its classification is dependent on the annual and monthly averages of temperature and precipitation characteristics (Getahun, 2012). The most commonly used climate classification systems are the traditional and agro-ecological zones (AEZs). According to the traditional classification system, which mainly found on altitude and temperature, based on this classification Ethiopia has five agro-climatic zones.

Table 1 traditional agro climatic zone and their physical characteristics

Zone	Altitude (meters a.s.l)	Rainfall (mm/year)	Average annual temperature (^{0}c)
Wurch (upper highlands)	3200 plus	900 – 2200	<11.5
Dega (highlands)	2,300 – 3,200	900 – 1,200	17.5/16.0–11.5
Weynadega (mid-lands)	,500 – 2,300	1800 – 1,200	20.0–17.5/16.0
Kola (lowlands)	500 – 1,500	200 – 800	27.5 – 20.0
Berha (desert)	below 500	below 250	>27.5

Source: MoA (2000).

2.1.4Climate change and Ethiopian agriculture

Ethiopia is one of the least developed and the most victim countries to climate change and variability (NMA 2007; World Bank 2010) due to its geographical location, low adaptive capacity, and weather-sensitive economy (NMA 2007). Rainfall is highly variable and there is a high degree of variability in both spatial and temporally (NMA 2007; EPCC 2015). while agriculture (which employs around 85% of the labor force, give more than 50% of the GDP and supplies 90% of export values) is climate-sensitive, it is possible to remain the backbone of Ethiopian economic growth and climate-induced shocks will continue to be a risk to macroeconomic stability and could cause a notable loss in the total production unless best measurement actions are put into action (MoFED 2010; EPCC 2015). Vulnerability assessment based on basic information and rapid assessments carried out under the National Adaptation Program of Action of Ethiopia has shown that the majority of vulnerable sectors to climate variability are agriculture, water resources, and human health. Agriculture is the most vital sector in the Ethiopian economy (Temesgen, 2007). However, the productivity and competitiveness of this sector are increasingly embarrassed by the temporal and spatial variability of climate (NCCF, 2009). In addition, most of the country is becoming more prone to drought (NMSA, 1996). Droughts devastate farmlands and pastures; contribute to land degradation, causes crops to fail and livestock to pass away. During the 1984–1985 drought, the GDP declined by about 10 percent and the 2002-2003 drought cause over a 3 percent decline. Flooding in turn causes significant damage to livestock and animal health, and the water-logging of productive land undermines agriculture by delaying planting, reducing yields, and compromising the quality of crops, especially if the rain comes around harvest time (World Bank, 2006). Different national policies, programs, and strategies that propose to address climate change have been designed by the Ethiopian government (see, for example, MoFED 2006; NMA 2007; MoFED 2010; FDRE 2011; EPCC 2015; NPC 2016) which focused mainly on increasing the productivity of the agricultural sector so as to reduce the adverse impacts of climate change through increasing the human resource resilience, using modern inputs and technologies, develop watershed management, intensifying small-scale irrigation, intensify income-generating activities, improving infrastructure, f and early maturing crops, disease, and pest control mechanism, providing early warning and appropriate utilization of meteorological information which are basic for the sector.

2.1.5. Adaptations to Climate Variability/Changes

Adaptation to climate change impacts in common and to the agriculture sector in particular is an existing phenomenon. The agriculture sector has the capacity to adapt provided that technologies, resources, and management changes have been undertaken relatively quickly (Mendelsohn et al., 2000).

Throughout human history, societies have modified to natural climate variability by altering settlement and agricultural patterns and other facets of their economies and lifestyles. In the earlier period of human history, adaptations to climate change and variability have been really successful. Coping with climate change has not always been easy as the records of collapsed societies make known and there are still limits to adaptations. This long record of adapting to impacts of climate is through changes in behavior, choices of technology and infrastructure, use of market instruments, and public policies. Crop diversification, weather and seasonal climate prediction, drought and hurricane early warning systems, flood protection, weather derivatives, and establishment of coastal-setbacks are only a few examples of proactive adaptation measures (McCarthy et al., 2001). Decisions on the type of coping mechanisms are often made by individuals, groups within society, and organizations and governments on behalf of society. Some adaptation measures may be taken at the individual level.

Rainwater harvest and building dams, releasing new cultivars that are more drought resistance need the best mitigation measure. These time societies have natural capacities to adapt to climate change and have developed different adaptation and mitigation strategies to combat climate change. They have Communities that have at all times adapted to climate variations by making planning based on their resources and knowledge add through the experience of past weather patterns. The adaptive measures that households use when faced with climate change could also vary in terms of their simplicity of implementation, equity effects, the delay between implementation and effect, compatibility with other programs and agencies implement actions (Admassie, 2008).

The capacity to adapt to climate change also varies across the world, countries, social groups, and regions over time. These capacities is depended to a large extent on the availability of natural resources, their stage of development, their resource foundation, technological knowhow and level of information about climate change, and their scientific & technical capability (Meseret, 2009). Large economic resource availability increases adaptive capacity while the lack of it limits adaptation options. Technological options and access limit the range of potential adaptation choices. adaptation measures are very much linked to socioeconomic level of the community given basic forms of adaptations strategies as well as micro-level coping techniques such as diversification and intensification of crop and livestock production, changing land use, irrigation and altering the timing of operations, market responses, institutional changes and technological developments (Kabubo et al., 2006; Darwin et al., 1995).

2.1.6. GIS and Remote Sensing Applications to the Assessment of Climate Variability

The issue of climate change is currently an important concept that attracts the attention of numerous scholars. The problem of climate change is broadly studied from various angles that started due to the seriousness of the problem. Among those, the most recent is the application of satellite images which is used to through Remote Sensing and GIS techniques that are developed with the development of Earth Observing Satellites. Solving the problem due to climate change is a massive challenge facing researchers. Scientists, policymakers, developers, engineers, and many others have applied geographic information system (GIS) technology to improved understand complex circumstances and put forward some tangible solutions. A GIS support us to gain a scientific understanding of earth systems at global scale and leads to more thoughtful, informed decision making. GIS users represents a vast reservoir of knowledge, skill, expertise, and best practices in applying this cornerstone technology to the science of climate change and understanding its impact on natural and human systems (ESRI, 2008).

The same source further illuminates that is the key tool to understanding our dynamic climate is creating a framework to take many different pieces of past and future data from a variety of sources and combine them together in a single system. GIS creates a new framework for investigating global climate change by allowing users to inventory and display large, complex spatial data sets. They can also the potential exchange between different factors, getting us closer to a true understanding of how our dynamic climate may change in the coming decades and centuries (ESRI, 2008). Applications of scientific principles such as GIS and Remote Sensing equipped with GPS in detecting climatic variation is decisive in the world today both in developed and developing countries (Cracknel, 2001).

2.1.7 Empirical Evidence

Climate change is most likely the greatest long-term challenge facing the human race in the world. Humanity everywhere in the world is being troubled by multitudes of problems and challenges; and in effect, climate change is one of humanity's most devastating problems. Numerous researches conducted studies to only a few studies have been conducted on the issue of climate variability both in space and time. Among those, a study made by Getnet (2010) can be mentioned focusing on Climate Variability and Impacts in Central Rift Valley and Adjacent Arsi Highlands Using GIS and Remote Sensing, the finding of the study indicate that temperature is getting increased by 0.37o C in the rift valley and 0.48o C in highland and by 0.4o C in whole areas per 12 years and rain is constant and shows an insignificant rise.

In addition, another recent study carried out by Gojjam and Ferede (2012) emphasizing on Spatio-temporal Variability and Trend of Rainfall and Temperature in Western Amhara: Ethiopia: A GIS Approach. The study has used 5 meteorological stations with 30 years of daily rainfall, maximum and minimum temperatures data were used (1979-2008). The study discovered that the contribution of kiremit rainfall to the annual total rainfall was very high in all study areas. Temperature variation was observed between per month. The long term recorded rainfall data indicated an increasing trend during 1995-2008 and a decreasing trend during 1979-1994, except, inter-annual fluctuation. Further, late-onset and early ending of rainfall were noted in all study stations in recent years. Minimum temperature and maximum temperatures variation were observed in spatiotemporal.

On the other hand, Dereje et al., (2012) studied the variability of rainfall and its current trend in the Amhara region, Ethiopia. To accomplish this study, 10 meteorological stations with 30 years of daily rainfall data have been used. Variations of rainfall were found in every month in all stations. The spatial distribution of annual rainfall was differing from 850 to 1485 mm. small rainfall namely Belg in March to May rain makes a considerable contribution to the annual total in the central and eastern stations of the region. Annual rainfall has shown negative and positive anomalies for much of the 1980s and 1990s, respectively. Besides, the long term movements of rainfall in a time series data did not show any increasing or decreasing trend, contraction of the length of the growing period due to early stop of rainfall had been observed in recent years.

Different studies have been accomplished (Deressa et al. 2009; Tazeze et al. 2012; Tesso et al. 2012b; Debalke 2014; Balew et al. 2014) to assess the factors which regulate adaptation to climate change based on agroecology. Furthermore, results are not conclusive and there is no consistency in the outcomes of studies conducted so far in Ethiopia regarding the determinant factors, which suggests that a factor in an assured locality at a time might not be accurate in another locality. Based on the concept of ’one size does not fit all’ in spatial-temporal climate variability, the implication is, therefore, the need for conducting District level assessments.

2.2. Conceptual Framework

The conceptual framework depicts that diagrammatic representation of climate variability. The conceptual framework indicates that the cause of climate variability, its variables, and monitoring mechanisms. As shown in the framework, climate variability

Has two major causes these are naturally climate variability and anthropogenic climate variability. In addition climate variability related to vegetation cover and land use land cover change. climate variability is originated from short-term precipitation shortage that reduces moisture and temperature increasing or decreasing that causes an increase in evapotranspiration levels above water supply that adversely affect the economy and reducing food supplies. Hence climate variability adversely affects agricultural production, monitoring agricultural drought helps to climate variability related crises as well as food insecurity issues. In this study, climate variability is conceptualized as a function of three factors: temperature, rainfall and, and LULC. Climate variables (temperature, precipitation, and extreme weather events) are d by different applications such as Trend analyze(Menn-Kendal, and sen's slope analyze) for rainfall and temperature. This analyze applied using ARC GIS, Minitab and, GeoCLIM,

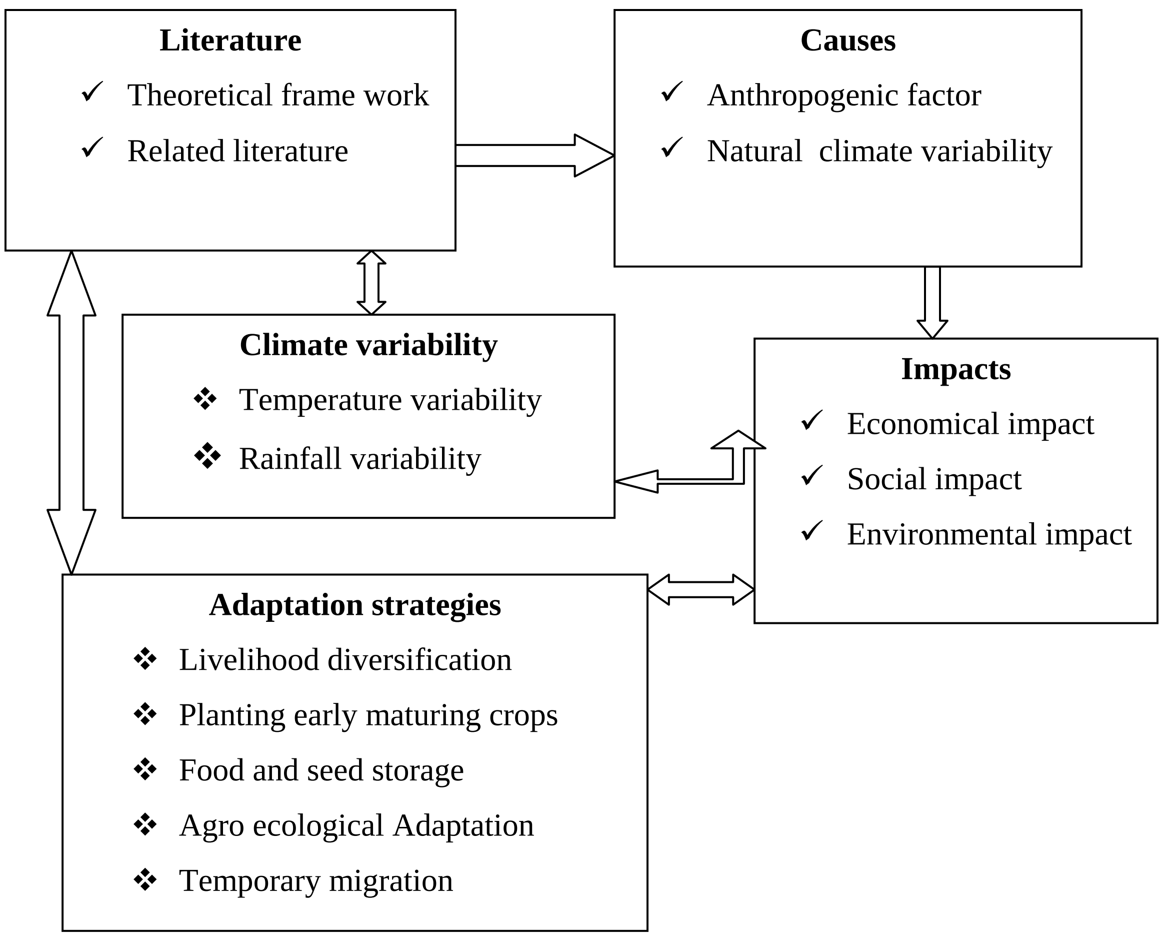


Figure1. Conceptual framework (Source: own Survey)

CHAPTER THREE

3. DESCRIPTION OF THE STUDY AREA AND METHODOLOGY

3.1 Description of the study area

3.1.1. Location

The study is conducted in Borena District which is located in the north-central highlands of Ethiopia (Figure 2). The area is located within the South Wollo administrative zone of the Amhara Regional State. The District shares boarder to the south with wogde District, to the north with Mehalsayint, to the east with Legambo District and to the west Abay River, Enebisesarmdir, and EnarjienawgaDistrict. Geographically Borena District is found between 10^0 34’ 2” N to 10^0 53’16” N latitude and 38^0 27’39” E to 38^0 55’49” E longitude (CSA, 2007). It is located about 181 Kilometers west of Dessie town (zone administration), 282Killometrs South-East of Bahir Dar town (Regional Capital), and 467 km from the capital Addis Ababa.

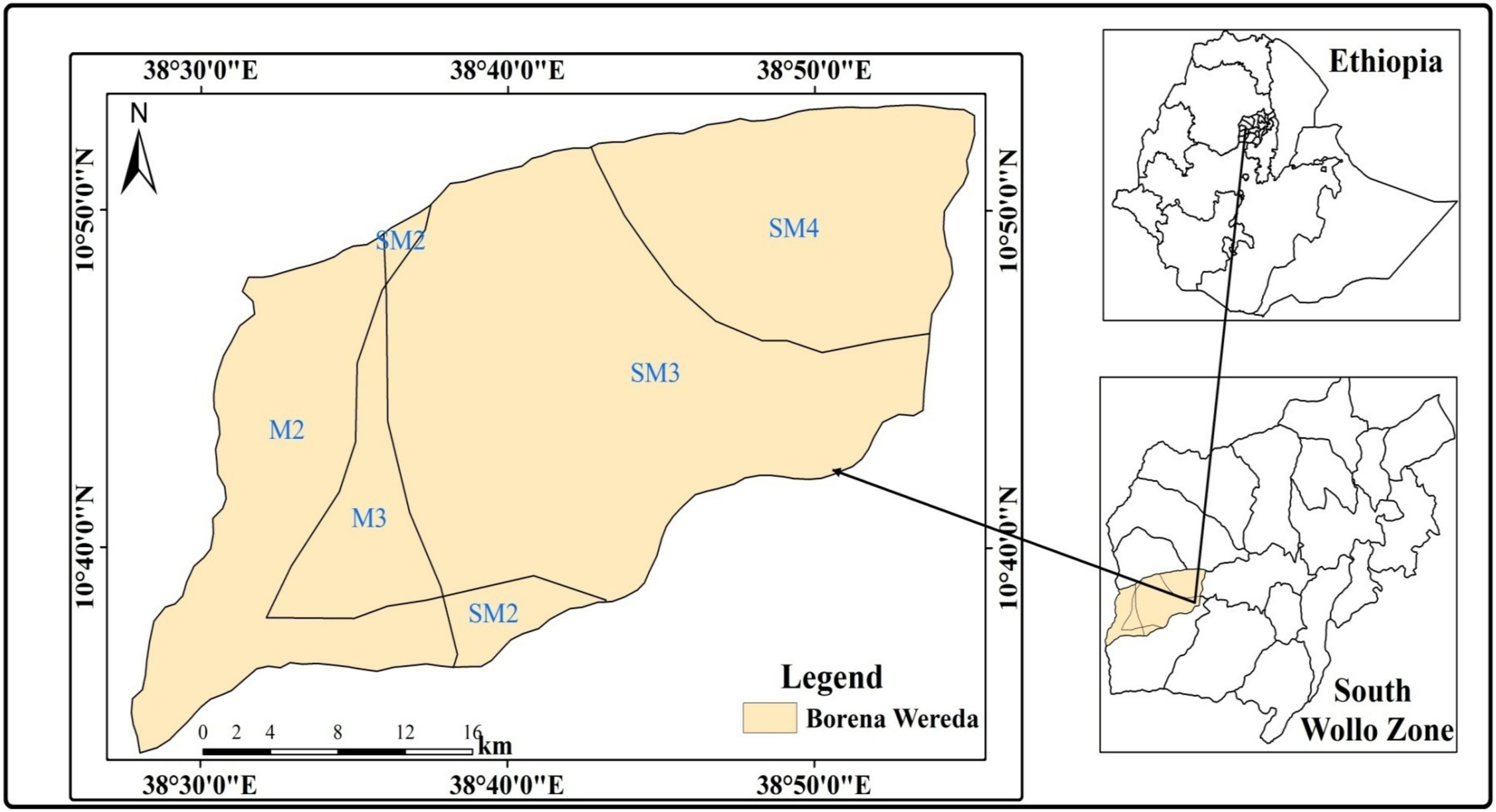


Figure 2 Location map of the study area (Source: CSA, 2007; GADM, 2018 data)

3.1.2 Topography and Climate

The District is characterized by different landscape features: mountains (10%), rugged land (40%), flat land (20%), and valley (30%). A mountainous and highly dissected terrain with steep slopes characterizes the upstream part of streams whereas up and down topography and relatively gentile slopes characterized the downstream part of streams in the District. Its altitude extends from 500 meters above sea level at the bottom of the canyon of Abay to 3200 meters above the sea level at the northeast corner of the District.

The area receives an average annual rainfall of 600-850 millimeters. Its mean monthly temperature is 22^0c, which ranges from a minimum of 13^0c to a maximum of 270c (BDAO, 2016). The highest rainfall falls during summer, which starts in June and ends in September and the short rainy season is in spring which consists of March, April, and May. The mean annual temperature of the region varies from 14^0c to 19^0c. The absolute maximum temperature occurs from March to May and the absolute minimum temperature occurs in December, July, and August. The upper North-Western part of the District is known for its minimum temperature which results in the prevalence of the Wurch type of climate while the South Western part of the District, has the highest temperature, characterized by Kolla climate (Mezid, 2019).

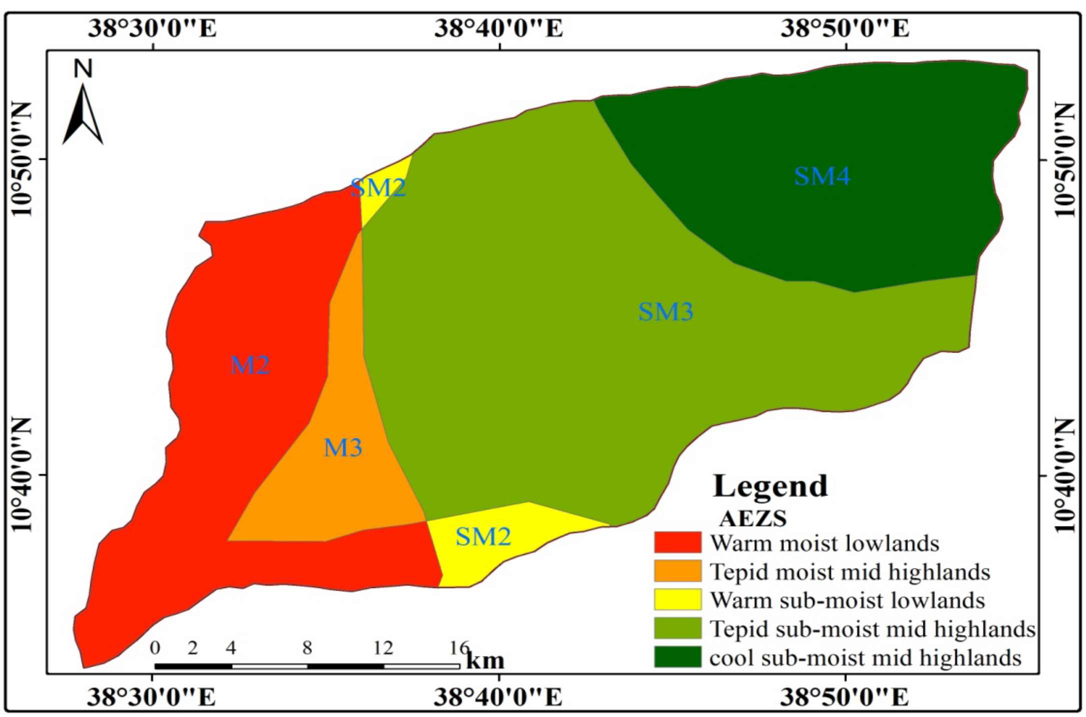


Figure 3 Agro ecological map of the study area (Source: Own Survey, 2019/2020)

Table 2 Characteristics of Agro Ecological Zone

No	AEZ31	climatic zone	latitude	longitude	Area	Percent (%)
1	M2	Warm moist lowlands	10° 41' 19.999" N	38° 32' 37.160"	211.58km^2	21%
2	M3	Tepid moist mid highlands	10° 40' 52.063" N	38° 35' 17.819"	68.63 km^2	7%
3	SM2	Warm sub-moist lowlands	10° 39' 57.622" N	38° 39' 21.080"	29.17 km^2	4%
4	SM3	Tepid sub-moist mid highlands	10° 44' 45.294" N	38° 42' 46.227"	456.76 km^2	46%
5	SM4	Cool sub-moist mid highlands	10° 49' 46.782" N	38° 49' 36.291"	222.34 km^2	22%
	Sum				988.48 km^2	100%

Source (MoA, 2000)

Based on modern and scientific, re modified, finalized, and mapped 32 Agro-ecological zones of Ethiopia (AEZE) which is developed by the Natural Resources Management and Regulatory Department (NRMRD) of the then Ministry of Agriculture there are five agro-ecological zones found in the study area (MoA, 2000).

The first AEZ is Warm sub-moist lowlands (SM2): It is found in the southeastern part and north tip of the Borena District. It covers 29.17 km 2 (4%) of the total land area. The elevation ranges from 400 to1400 m.a.s.l. The annual temperature falls between 210C and 27.50C. The growing period ranges from 61and to 120 days. The dominant soil types are Vertisols, Nitosols, Cambisols, and Leptosols. Boswellia, Oxytenatheraabysnica, and Accaciaspecies are the dominant natural growing trees. The zone has potential for large scale mechanized farming (sesame, cotton, sorghum, kenaf, etc), incense and gum harvesting, and bamboo production. Malaria and tsetse fly infestation are the major constraints(MoA, 2000).

Tepid sub-moist mid highlands (SM3) is the second agro ecological zone which found around in the central part of the study area. It covers 456.76 km^2 (46 %) from the total area. It is the dominant agro ecological zone in the study area. The elevation ranges from 1000 to 2000 m.a.s.l. The annual temperature varies between 16 ^{0}C and 21^{0}C. The growing period varies between 61-120 days. The dominant soil types are Camblsols, Vertisols with inclusion of Fluvisols. *Accacia species* are dominant trees(MoA, 2000). The zone has potential for rain fed agriculture. Low rainfall is the constraint for crop production.The third agro ecological zone is Cool sub-moist mid highlands (SM_4). It is located in northern part of the study area, covering a total area of 222.34 km^2 (22%). The elevation ranges from 1400 to 2200 m.a.s.l. The annual temperature varies between 11^0C -15^0C and the growing period between 61-120 days. The soil types found in this zone are Leptosols and Cambisols. Accacia and Balanities are the dominant plant species. Shallow soil depth and rugged land forms are constraints for crop production. The major potential of the zone is eco-tourism. The fourth agro ecological zone is warm moist lowlands (M2). Warm moist lowland AEZ is located in the north and south western part of the study area, covering 211.58km^2 of land and it accounts 21 % of the study area. The elevation ranges from 400 to 1500 m.a.s.l, and the annual temperature varies between 21 and 27^0C. The growing period is between 121 to 180 days. The dominant soil type is Cambisol. Acacia is the dominant plant species. The area has the potential for wildlife reserve and tourism. The fifth agro ecological zone is Tepid moist mid highlands (M3). This AEZ is located in south western part BorenaDistrict and it cover 68.63 km^2(7%) of the study area. The elevation varies between 1000 and 2000 m.a.s.l. The annual temperature varies between 16 and 210C. The growing period is between 121-180 days. Cambisols are dominant soil types. The dominant farming product is cereal production. The zone has the potential for agriculture and livestock production. However, soil erosion is the main constraint for crop production(MoA, 2000).

3.1.3 Population and settlement

As mentioned earlier, the study area consists of Mekane-selam town (having 5 urban kebeles) and Borena District (having 35 rural kebeles). According to to1994 national census report, a total population of a District 125,126 in 28,461 households, of whom 62,036 were men and 63,090 were women; 5,509 or 4.4% of its population were urban dwellers (mezid2019).

BornaDistrict has a total population of 158,209, an increase of 26.44% over the 1994 census, of whom 78,621 are men and 79,588 women; 8,709 or 5.50% are urban inhabitants. With an area of 1,027.61 square kilometers, DebreSina has a population density of 153.96, which is greater than the Zone average of 147.58 persons per square kilometer. A total of 37,193 households were counted in this District, resulting in an average of 4.25 persons to a household, and 36,006 housing units (https://infogalactic.com/info/Debre_Sina_(District). The majority of the inhabitants said they practiced Ethiopian Orthodox Christianity, with 55.52% reporting that as their religion, while 44.38% of the population was Muslim (CSA,2007),.

In an aggregated manner, in 2013, the total estimated population of the study area was 180,073. Of whom 89,198 are men and 90,875 are women. Moreover, 12,916 (7.2 %) and 167,157 (92.8%) are urban and rural inhabitants, respectively (CSA, 2015).

3.1.4 Land Use

According to thedataobtainedfromBDAO (2020) and shown in Table 3 about 40.72% of the District's Land was arable, 8.56% of the land was used for grazing, 18.98% of the Districts' land was covered with different bushes and forests, and 5.62% of the land is used for settlements and road construction purposes. Unfortunately, more than one-fourth (26.12%) of the land is not suitable for cultivation or other activities (BDAO, 2020).

Table 3. Land use land cover type of the study area

No.	LandUseTypes	Area(ha)	%
1	Arable land	39,780.17	40.72
2	Grazingland	8,365	8.56
3	Bushes and Forestland	18,521.55□	18.98
4	Uncultivated (not in use) land	25,515.975	26.12
5	Settlementarea, roadsand others	5,486	5.62
	Total	97,687.5	100.00

Source: BDAO (2020)

3.1.5 Economic Activities

Like other rural areas of Ethiopia, almost all of the rural households' economic activity has largely depended on agriculture (crop production and livestock rearing). Some of the most common crops grown in the study area are teff, wheat, barley, vetch, bean, pea, maize, lentil, sorghum, nug, flax, and chickpea. Besides, vegetables like cabbage, carrot, potato, tomato, and beetroot are also cultivated in the study area. Despite these facts, crop productivity has been threatened by a number of natural factors such as inadequate and unreliable rainfall, sometimes excess rain and floods, snowfall, weeds, frost, and crop pests, and human-induced factors, like small and fragmented land size, traditional farming practices, continuous plowing and low adoption of modern agricultural inputs (BDAO, 2016). These natural and human-induced factors negatively affect the rural farmers' ability to produce adequate subsistence and hence their food security successes have been mostly supplemented by a number of food security programs/projects. This implies that farmers have to depend on humanitarian and non-governmental aids for their food security.

In addition to crop production, most common animals domesticated by the rural households are cattle, pack animals (mule, horse, and donkey), shoats (sheep and goats), and poultry. According to Save the Children's report on BDLP (2015), in 2015, the District had 84,342 cattle, 11,591 pack animals, and 175,201 shoats. As can be seen in Table 4.2, oxen and cows constitute 59.6% and 16.7 % of the total cattle, respectively; heifer shared 12.1 % of the cattle; 9.5 % of the cattle were bulls and the rest 2.2 % of the cattle were calves. Moreover, three quarters (75%) of the pack animals in the District were donkeys. This may be because of the economic and transportation importance of the animal. On the other hand, one-fourth (25%) of the pack animals share went to mules and horses (BDAO, 2020)

3.1.6 Water Points

As documented by BDAO (2016), until 2008, the rural population of the District got drinking water from 188 streams and 32 hands pump water points although frequent damages and recovery were common. The document also revealed that; only 46.7 % of the District residents' have access to drinking water and the problem has been persisting until the time of the survey. Moreover, during field observation, the researcher witnessed that urban and rural residents suffer from a critical shortage of water. The researcher also observed a long line of people queuing for water service from public tap water (figure 4).

Figure 4 queuing for public water pump (Source: Field Survey, 2020)

3.2 Methodology

3.2.1 Research approach and design

Research design is considered as the base of any research since it facilitates various research operations. In this regard, Kothari (2006) argues that research design facilitates the researcher's plan in advance of the methods to be adopted to gather the pertinent data and techniques to be used during analyze. Regarding the selection of the research design, Kothari (2006) distinguished that, if the major emphasis of the study is on the find of ideas and insights the appropriate research design is found to be an exploratory while if the purpose of the study is on the precise description of a situation the appropriate research design is descriptive. For this study, a descriptive research design type was appropriately applied. Descriptive research designs used to offer answers to the questions of who, what, when, where, and how linked with a particular research problem (Kothari, 2006). Climate variability conditions of the different parts of BorenaDistrict were describe based climate variability indices that derived from vegetation, temperature and rainfall data. Besides descriptive research design, co- relational research design which is a non-experimental research design technique was apply to determine the association between climate variables.

This study also applied both qualitative and quantitative approaches. In fact, this study used more quantitative and some of the qualitative approaches in an integrated system. The approaches helped the researcher to connect diverse ideas about spato temporal climate variability and assisted in cross-checking the results which increase the validity and reliability of the findings.

3.2.2 Data type, Sources, and Acquisition

Spatial-temporal climate variability relies on the availability, acquisition, and sources of data. In precise, the accuracy of the findings of empirical research undertakings, like this one, has to be supported by reliable, relevant and quantitatively adequate data to be considered genuine. In order to ensure the validity of the present study, therefore, especial efforts was make to carefully secure the necessary data. Due to this, both primary and secondary sources were employed. Primary information was available through an interview with key informants, focus group discussion and field observations from farmers found in the five agro ecological zones, Agricultural Extension office of Borena District and Disaster Prevention and Preparedness Commission [DPPC] of Borena district. Different secondary sources of data were used to derive the required information for this study. This includes relevant documents like; available recorded documents in Borena District, previous works of literature, and review of relevant published and unpublished documents, journals, and reports which are written on the subject under investigation consulted and important ideas was taken and included in this study.

Sampling Techniques

This was done in order to obtain in-depth information about the issue under investigation. Purposive sampling was be used to select both FGD and key informants to get general information. Purposive sampling was mainly used because this type of data collection technique is based on reason methodology. It helps to clearly discover target groups and to generate the desired information. The researcher also used a purposive sampling technique to identify and undertake 7 focus group discussions (one per AEZS)and 20 key informant interviews (four per district) to gather qualitative information to corporate climate change perceptions, both on temperature and rainfall indicators, and demographic, socioeconomic impacts and adaptation strategies for climate change perception.

3.2.3. Data Collection Method and Instruments

Both primary and secondary sources of data was be used to get reliable information for the study. The primary information would collect through FGD, KII and field observation. Focused group discussion was being carried out with peasants to capture the reality on the ground and an in-depth interview was held with heads of Borena District agricultural extension officers and respective DPPC heads. Secondary data was also employing which was obtained from administrative Districts which revealed spatio temporal climate variability in past 30 years.

Focus group discussion (FGD)

Focus group discussion is essential to generate data on group dynamics and allows small group respondents to be guided by skilled moderator, to focus on the key issues of the research topic. To describe the previous and the present situation of the study area, to know the previous trend and present perceptions of the community view purposively select five FGD from five agro ecological zone were made which have 7 members in each group.

FGD respondents comprising the elderly people men and women, rich people men and women, medium people men and women, poor men and women, model farmers and adult. Data collected through Focus Group Discussion include trend and pattern of rainfall, perception of climate change, impacts of climate changes, adaptation strategies to adopt climate variability.

Key informant Interviews (KII)

In this study, the researcher employed key informant interview because of its flexibility and to make clear any time when there is doubt. Interviews were held with key informants from five Agro ecological zones that were purposively selected from with resourceful 20 farmers and 2 development agent persons were conducted. Key informant interviews include model farmer, elder, women, young, Agricultural expert and DPPC expert. To gain enhance, explanation about the local perception, impact, adaptation mechanisms. An unstructured interview type was used in this study as the main method of gathering data from the subjects under investigation. The participants of the interview were selected based on careful judgment of the researcher in such a way that is inclusive of all varieties of participants; it became comprehensive and captures most realities. The researcher was use the unstructured interview because it helps the investigator to make an in-depth investigation of the issue (Ravi, 2009). Regarding the procedure, first, a full consent was be obtained from each informant before the interview, and then the researcher addressed all the questions listed in the interview guide and asked follow-up questions in order to probe the informants for further elaboration of their responses. The information was recorded by note taking and the interview was finalized for report.

Field Observation

Field work is used as a data triangulation which collected from satellite and farmers set in perspective data obtained by other means. The field work was arranged for two consecutive weeks. The field work was conducted from March 16 to 30/03/2020. The trip covered the main parts of the study area started from lowland kebeles or warm sub moist lowlands (M2) agro ecological zone which is closed to Abay River namely Menedega (m2) to cool sub moist mid highland (SM4) agro ecological zone namely Chirokadis and Dilfre. The field work involved office secondary data collection in appropriate institution and a field campaign. The climatic situation of the study area and Rainfall and temperature pattern as well as trend was also identified.The field work consisting interviewing of local farmers and agriculture experts and observations of land cover. Observation was made with the support of checklist reflecting Crop production and livestock rising, farmers and government activities on environmental conservation, Major people economic activities in their environment, Grazing land (degradation), other livelihood bases, local adoption strategies, settlement and rangelands. The observation helps better understanding for trend as well as impact and adaptation at household and community level and serves as data triangulation (Ali, 2017).

3.3. Major Data Types and Sources

Table 4.Data type and sources

No	Data set	Variable	Source	Coverage		Resolution		Format
				Temporal	Spatial	Temporal	Spatial	
1	CHIRPS	Precipitation	FEWS NET	1981-2018	Global	1 Month	0.05 1	BIL
2	Worldclim	Temperature	Worldclim	1960_1918	Global	1 month	0.86	GeoTIFF (.tiff)

3.3.1 Remotely sensed data

Rainfall and temperature data for spatio temporal climate variability and trend analyze have been obtained from different sources.

Climate Hazard Group Infrared Precipitation with station data (CHIRPS)

In this project work, Climate Hazard Group Infrared Precipitation with Station data (CHIRPS) was use in order to assess climate variability. This product was be chosen due to its successful implementation in different studies in Ethiopia which has difficult topography (Dinku et al., 2018; Bayissa et al., 2017). This project indicated that CHIRPS performed very well during the monthly and seasonal time scales than other RFE. Additionally, CHIRPS data have a relatively higher spatial resolution (~5 km) and longer periods of records (1981-present) than other products.

The Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) dataset is developed by the United States Geological Survey (USGS) and the Climate Hazards Group at the University of California, Santa Barbara, and providing data from 1981 to present. It is a blended product combining, quasi-global geostationary Thermal Infrared (TIR) satellite observations from two National Oceanic and Atmospheric Administration (NOAA) sources, the Tropical Rainfall Measuring Mission (TRMM) 3B42 product from NASA, atmospheric model rainfall fields from NOAA Climate Forecast System and in situ precipitation observations obtained from a variety of sources including national and regional meteorological services (Funk et al., 2014). The data have a spatial resolution of approximately 5.3 km (0.05° × 0.05°), with coverage between 50°N to 50°S, 180°W to 180°E.

CHIRPS time series have been used for trend analyze and climate variability monitoring. It is available at daily, pentad, decadal, and monthly temporal intervals (Funk et al., 2015). For this thesis, the monthly time series data of CHIRPS Version 2.0 rainfall was acquire for the period 1981 to 2019. To maintain the seasonal (longer time) effect of rainfall on vegetation, a 1-month SPI was be calculated using the long-term monthly time-series data (1981–2018) (ftp://ftp.chg.ucsb.edu/pub/org/chg/products/CHIRPS-2.0/).

WorldClim data

WorldClim is a database of high spatial resolution global weather and climate data. These data can be used for mapping and spatial modeling (https://worldclim.org/data/index.html). The data are available at 4 different spatial resolutions; from 0.86 km^2 to 344 km^2. The original data were at a 0.86 km^2 resolution, the other data have been resulting through aggregation, by calculating the mean of groups of cells. In other words, if some of the original cells were on land, and some cells were on the sea, the aggregate cells have data. Only if all original cells have 'no data' then the aggregate cell has 'no data'. Aggregation was done for monthly precipitation, minimum, mean, and maximum temperature. The Bioclimatic variables were calculated from these aggregated data. Temperature data average minimum temperature (°C), average maximum temperatures (°C) for spatiotemporal climate variability and trend analyzehave been obtained WorldClim (https://www.worldclim.org/data/monthlywth.html).WorldClim is a spatial analyze tool designed for climatologically analyze of historical rainfall and temperature data (Hijmans et al., 2005). The WorldClim provides non-scientists with an array of accessible analyze tools for climate-smart agricultural development (Kassie, 2014). These user-friendly tools can be used to obtain and climate data, blend station data with satellite data to create more accurate datasets, seasonal trends and/or historical climate data, create visual representations of climate data, create scripts (batch files) to quickly and efficiently similar “batches” of climate data, view and/or edit shape files and raster files, and extract statistics from raster datasets to create time series. These data are downscaled from CRU-TS-4.03 by the Climatic Research Unit, University of East Anglia, using WorldClim 2.1 for bias correction (Fick and Hijmans, 2017).

Ancillary Data

Other applicable datasets were used in this study, like shapefile which is developed for the 2007 population and housing census obtained from the Central Statistical Agency (CSA). The shapefile was basically be used to delineate the study area boundary. Besides, all datasets used in this study including satellite imageries of different sources, thematic layers like road, towns, and rivers were being projected to the geographic coordinate system WGS_1984. This was made to ensure consistency between the datasets.

3.4. Tools and Software's

In this study the following software packages were used at different level of the study

Table 5 software used for the study

No	Software	Major application Area
1	Arc Map 10.5	Image processing and statistical analysis, spatio temporal rainfall and temperature trend and distribution mapping
2	Microsoft Excel 2016	For statistical computations such as mean, CV, crop yield and regression analyze
3	Geo CLIM software 1.2.0	For downloading CHIRPS precipitation data and to calculate long term average
4	Minitab	Statistical analyze

3.5. Method of Data processing and Analyze

Both qualitative and quantitative methods of data analyze were useto the data gathered from field. Qualitative data that was gather through personal interview, key informant information interview and secondary data (document review) obtained from different offices were d qualitatively. And quantitative analyze method was dominantly employed for the purpose of d Satellite based rainfall chirps data rainfall and research worldclim temperature data.

The minimum and maximum Rainfall, as well as temperature data, was capture into Microsoft excel, 2016 spreadsheet on a monthly basis. Data qualities direct was done by careful check of the completeness, spatial and temporal steadiness of the rainfall, and temperature records in the study areas.

Then the next step was data preparation, at this stage, all the datasets were be organized and arranged in the most wanted order to make preparation for the analyze. For every climate variables, total records of temperature (maximum and minimum) and rainfall data obtained from worldClim and open-source satellite data (chirps). All data was carefully clean. Both the rainfall and temperature data cumulative was changed into seasonal and annual ones. Time series annual rainfall and temperature datasets were being subjected to exhaustive analyses of using sequences of statistical packages available on the Arc GIS environment and mapped. In addition, seasonal rainfall variability of the study stations was d and mapped using Arc GIS 10.5. The coefficient of variation (CV) was calculated as the ratio of the standard deviation to the mean (NMSA, 1996 quoted in Taye et al., 2013). In addition to quantitative analyze method the researcher applied qualitative analyze for data which collected through FGD, KII and observation. Qualitative analyze used to understand the real world situation.

Trend analyze

The researcher applied different data analyze techniques for spatiotemporal climate variability. According to Asfaw (2018), a number of techniques have been developed for the analyze of rainfall and temperature, which generally fall into viability and trend analyze and categories. Climate variability analyze includes a coefficient of variance (CV), percentage departure from the mean (anomalies), SPI, and moving average trend detection and analyze are conducted by parametric and non-parametric tests only for consistency of data. Normality and homogeneity of variance through series may be highly affected by outliers and missing data in parametric tests. The main merit of non-parametric statistical tests than the parametric tests is that the non-parametric tests are more suitable for none normally distributed outlier, suppressed, and missing data, which are frequently encountered in hydrological time series. As a result, Menn -Kendal (MK) test is widely used to detect trends of metrological variables (Asfawet ale, 2018). MK test is a non-parametric test which, tests for a trend in a time series without specifying whether the trend is linear or non-linear.

For this study rainfall and temperature, variability has been calculated by using CV. In addition to this MK was used to check rainfall and temperature trend with sen's slope estimator (test Pettitt's) test was used to test the degree of homogeneity of the data. Data analyze was analyze performed using XLSTAT software and excels spreadsheet (Asfaw et al, 2018). To increase the validate and reliability of the satellite based rainfall and temperature data the researcher collect data from Farmers' about their perception for rainfall and temperature variability and trend or change through time and space. This type of data was d using descriptive statistics and qualitative analyze.

Coefficient of variance

CV is calculated to calculate the viability of the rainfall.

A high value of CV is the indicator of large viability and Vis versa which is computed as:

$$CV = \frac{\sigma}{\mathrm{N}}$$

Where CV is the coefficient of variation; σ is standard deviation and μ is the mean precipitation. According to Hare (2003), CV is used to classify the degree of variability of rainfall events as less (CV < 20), moderate (20 < CV < 30), and high (CV > 30).

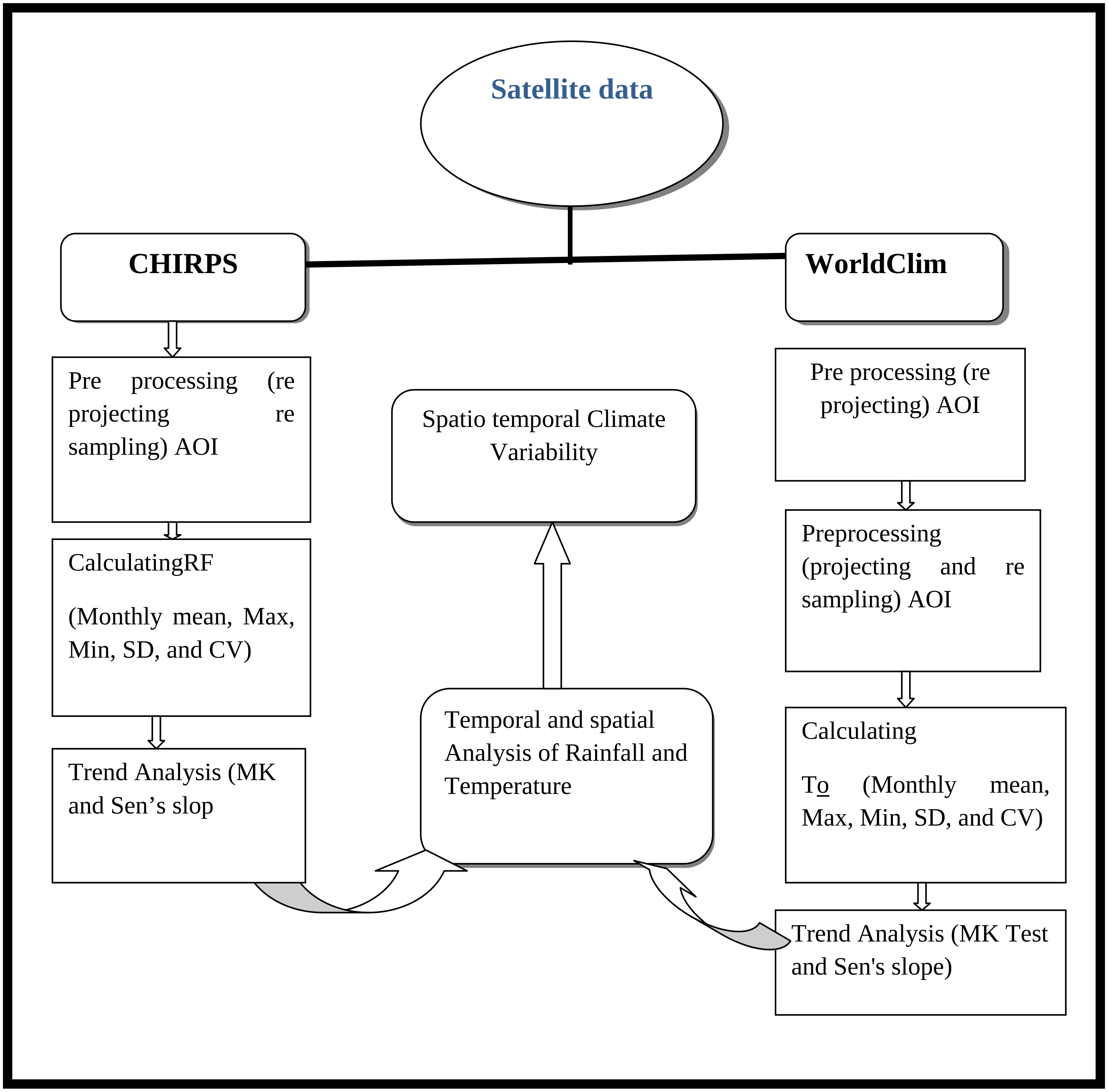


Figure 5.Schematic flow chart of the study

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

This chapter deals with results and discussions of climate drive factors for analyzing and mapping the frequency, magnitude and spatiotemporal patterns of climate variability analyze. Moreover, the analysis of finding includes trend and pattern of the temperature and rainfall in time series with space to assess the spatio temporal variability of climate.

4.1 Descriptive statistics and rainfall variability analyze

The mean annual rainfall of the area throughout the study period was 987.73 mm with 113.68 mm SD and 11.5 % CV. The minimum and maximum recorded rainfalls were 715.89 mm (in 1998- the driest year) and 1200.05 mm (in 2015-the the wettest year) per year respectively. *Kiremt* is the major rainy season in the study area which contributes about 71% of the total rainfall (where nearly 53% comes only in two months: July and August while June and September contributed 7.57 and 10.25 percent of the summer rainfall respectively) which clearly revealed the presence of a high concentration of rainfall. The short rainy season which started from March to May (called *belg*) also contributes a significant amount of rainfall (around 27% of the total).

The mean annual rainfall in the cool sub moist mid highland agro-ecological zone during the study period was 1171.42 mm with 143.01.mm standard deviation and 17.91 % CV. The minimum and maximum ever recorded rainfalls were 825 mm (in 2015- the driest year) and 1420.76 mm (in 1998-the the wettest year) per year respectively. The mean annual rainfall of tepid sub moist mid highland (SM3) during the study period was 1069.66 mm with 115.38 mm standard deviation and 10.79 % CV. The minimum and maximum ever recorded rainfalls were 790.94mm (in 2015- the driest year) and 1273.24 mm (in 1988-the the wettest year) per year respectively.

While the tepid moist mid highland(M3) the mean annual rainfall was 896.89 mm with 108mm standard deviation, and 12.04 % CV. The minimum and maximum ever recorded rainfalls were 659.25 mm (in 2015- the driest year) and 1127.63 mm (in 1998-the the wettest year) per year respectively and in warm moist lowland(M2) the mean annual rainfall 868.43 mm with 100.72

mm standard deviation and 11.60 % CV. The minimum and maximum ever recorded rainfalls were 639.24mm (in 2015- the driest year) and 1067.44 mm (in 1998-the the wettest year) per year respectively. And, in warm sub moist lowland (SM2) the mean annual rainfall during the study period was 927.82 mm with 313.3 mm standard deviation and 33.8 % CV.

Table 6 Basic statistics and mean Annual rainfall, SD and CV in five AEZ and Borena District (1981–2018).

	m2			sm2			sm3			m3			sm4			District		
Month	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**
January	11.9	4.1	34.3	11.9	3.9	33.0	10.9	3.6	33.4	11.7	6.1	23.5	11.3	4.2	37.2	11.6	4.0	34.1
February	17.9	12.0	67.1	18.4	12.3	66.8	18.8	12.1	64.1	17.5	7.1	67.6	20.9	13.2	63.3	18.8	12.2	65.0
March	40.3	22.6	56.2	46.9	25.4	54.1	57.7	28.1	48.7	44.5	10.9	113.6	69.6	32.5	46.7	52.0	26.5	51.0
April	53.0	20.8	39.2	60.4	25.0	41.3	76.2	28.0	36.7	54.6	17.5	124.8	88.8	33.5	37.7	66.9	25.5	38.1
May	67.7	38.4	56.7	69.9	39.9	57.1	83.0	40.3	48.5	69.6	17.3	153.1	87.0	47.1	54.2	75.2	40.6	54.0
June	65.6	28.0	42.7	67.6	30.2	44.6	79.9	31.2	39.1	66.7	29.0	156.5	80.1	39.4	49.3	71.6	31.2	43.6
July	244.0	66.5	27.3	261.1	71.8	27.5	286.4	77.3	27.0	251.1	97.4	419.8	323.7	95.1	29.4	274.4	76.2	27.8
August	224.9	39.1	17.4	242.3	42.2	17.4	273.4	44.5	16.3	233.4	140.4	319.1	299.7	56.1	18.7	255.1	44.2	17.3
September	88.1	23.5	26.7	93.4	25.6	27.4	114.9	28.7	24.9	92.4	47.9	175.0	120.7	31.8	26.3	101.4	26.1	25.7
October	27.6	18.8	68.3	29.4	20.2	68.8	43.8	21.3	48.6	28.5	6.3	82.0	44.5	24.4	54.8	34.4	20.4	59.3
November	17.7	11.7	66.1	16.4	11.3	68.8	14.8	9.4	63.2	16.9	7.0	45.5	13.8	9.7	69.9	15.9	10.5	65.9
December	10.0	5.6	56.2	10.2	5.7	55.8	10.0	5.9	59.0	10.0	5.6	34.3	11.5	7.6	66.4	10.4	6.1	58.4
Annual	868.4	100.7	11.6	927.8	313.3	33.8	1069.7	115.4	10.8	896.9	659.3	1127.6	1171.4	143.0	12.2	987.7	113.7	11.5
***Kiremt*(JJAS)**	622.6	104.8	16.8	664.3	113.2	17.0	754.6	121.5	16.1	643.6	400.1	920.0	824.1	147.8	17.9	702.5	119.1	16.9
***Belg*(MAM)**	160.9	49.9	31.0	177.1	54.7	30.9	216.9	58.7	27.1	168.7	77.8	305.5	245.3	70.1	28.6	194.0	56.5	29.1

The minimum and maximum ever recorded rainfalls were 409.3 mm (in 2015- the driest year) and 1760 mm (in 1998-the the wettest year) per year respectively. This implies 2015 is the driest year in the whole part of the study area. However, the year1998 was the wettest year in all agro-ecological zones of the study area except tepid sub moist mid highland (SM3) AEZ. This result agreed with Zerihun (2019) agricultural drought in the highland part of Ethiopia and Asfaw(2018) in the case of woleka watershed respectively.

4.2. Sptio-temporal Trend of rainfall

Rainfall is one of the major indicators and elements of climate variability. It is preferred by various researchers to study climate variability and change for the reason that it is easily interpretable and show what changes were taken place in the environment and easily understandable Feyissa (2010). In addition changes and variations succeeded rainfall variation have an adverse influence on agriculture as well as the whole ecosystem. The annual total rainfall for cool sub moist mid highland between 1981 and 2018 was 1175 mm, in Tepid Sub moist mid-Highlands was 1069.66 mm, in Tepid moist mid highland was 896.89 mm in warm sub moist low land was 927.82mm while in warm moist low land the annual mean rainfall was 868.43mm (see Table 7).

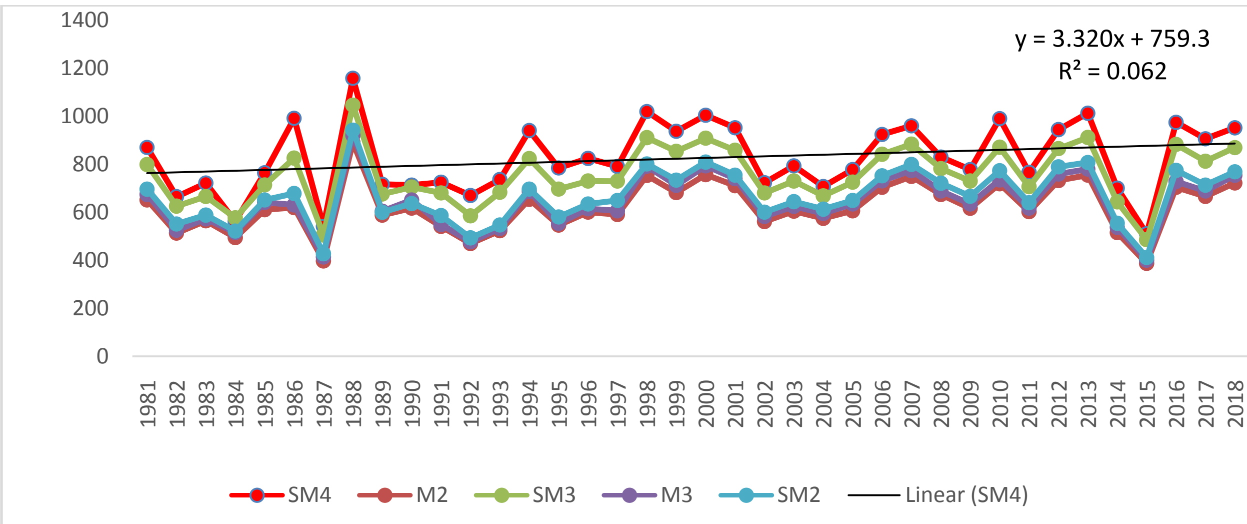
Table 7 MK trend analyze of rainfall in Five AEZs and Borena District (1981–2018)

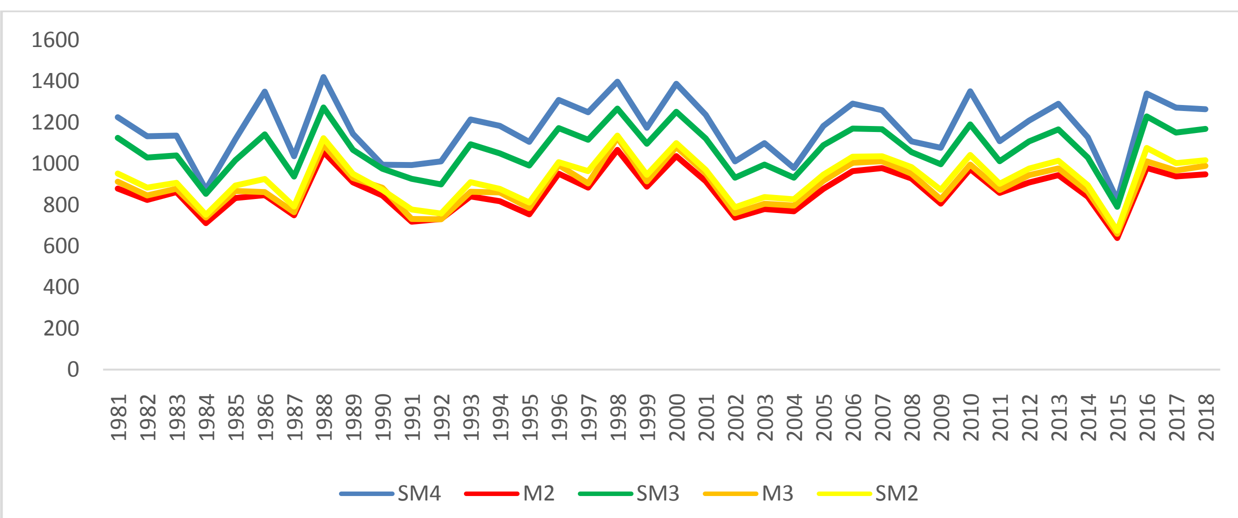
	m2		sm2		sm3		m3		sm4		District	
Month	**MK test**	**Sen's slope**	**MK test**	**Sen's Slope**	**MK test**	**Sens's slope**	**MK test**	**Sen's slope**	**MK test**	**Sen's slope**	**MK test**	**sen's lope**
January	-0.23	-0.006	-0.04	0	-0.36	-0.015	-0.45	-0.03	-0.45	-0.03	-0.25	-0.016
February	-1.17	-0.108	-1.21	-0.145	-1.19	-0.153	-1.13	-0.21	-1.13	-0.21	-1.16	-0.158
March	-0.85	-0.212	-1.02	-0.293	-0.89	-0.274	-1.21	-0.46	-1.21	-0.46	-1.03	-0.299
April	-0.88	-0.228	-0.75	-0.288	-1.08	-0.467	-1.35	-0.7	-1.35	-0.7	-1.06	-0.440
May	0.78	0.437	0.78	0.5	0.78	0.332	0.43	0.23	0.43	0.23	0.78	0.488
June	2.14	0.703	2.36*	0.767	2.36*	0.829	2.38*	0.96	2.38*	0.96	2.41*	0.711
July	1.86*	2.014	2.24*	2.5	1.81	2.432	1.48	2.38	1.48	2.38	1.96*	2.371
August	1.23	0.781	1.22	0.864	1.23	0.906	1.19	1.12	1.19	1.12	1.18	0.837
September	-0.85	-0.275	-0.64	-0.306	-1.27	-0.494	-1.55	-0.64	-1.55	-0.64	-0.96	-0.439
October	0.1	0.008	-0.04	-0.012	0.18	0.029	0.45	0.13	0.45	0.13	0.23	0.061
November	1.16	0.11	1.08	0.104	1.76	0.11	1.5	0.09	1.5	0.09	1.58	0.106
December	0.15	0.002	0	0	-0.15	-0.003	-0.6	-0.02	-0.6	-0.02	-0.13	-0.002
Annual	1.79	2.827	1.89	3.138	1.33	2.827	0.93	2.54	0.93	2.54	1.61	2.848
***Kiremt*(JJAS)**	2.16*	3.731	2.30*	4.263	2.24*	3.496	1.86	4.203	1.86	4.203	2.16*	3.659
***Belg*(MAM)**	-0.18	-0.115	-0.25	-0.394	-0.83	-0.65	-1.11	-1.331	-1.11	-1.331	-0.53	-0.420

Note: * statistically significant 0.05 alpha level of significant respectively (Asfaw, 2018).

The results of the MK test for trend analyze were presented in Table 8. The trend analyze has been done for all months of the year, belg and kiremt seasons and annually. The results of the MK test for monthly precipitation data revealed a statistically significant positive trend for the month of June in all AEZS and at the district level except warm moist lowland. Similarly, a statistically significant increasing trend was observed for July (at a 0.5% level of significance) two AEZs namely warm moist lowland and warm sub moist lowland. In January, February, March, April, and September non-significant decreasing trend was observed while the remaining months have a non-significant increasing trend. A statistically significant increasing trend was observed for *kiremt* season (the major rainy season in the study area) at 5% of the level of significances. In contrast to *kiremt*in *Belg* season, a non-significant decreasing trend was observed in all parts of the study area. The Pettitt's homogeneity test revealed the presence of homogeneity except for September, January, and *belg*season. In this study, the result reveals especially the non-significant decreasing trend of belg rainfall through time was obtained which coincides with Arragaw and Woldeamlak (2017) where *belg*rainfall showed a significant decreasing trend and where statistically significant increasing trends in July in *dega* and would *Dega* agro-ecologies of central highlands of Ethiopia were reported.

The results were also related to the findings of Danieal et al (2014) where the statistically non-significant increasing trend was recorded in all seasons (including annual time scale). The statistical test result coincides with the information obtained from the interview and experience of the farmers except for the case of *belg* rainfall where a drastic reduction in amount and variability in the distribution of *belg*rainfall has been reported by smallholder farmers. But, the result of this study different from the result of Osman and Sauerborn (2002); Cheung et al. (2008); Negash et al. (2013) where statistically significant declining kiremt rainfall at the watershed level was reported in a different part of Ethiopia including the central highland (where Woleka sub-basin also belongs).





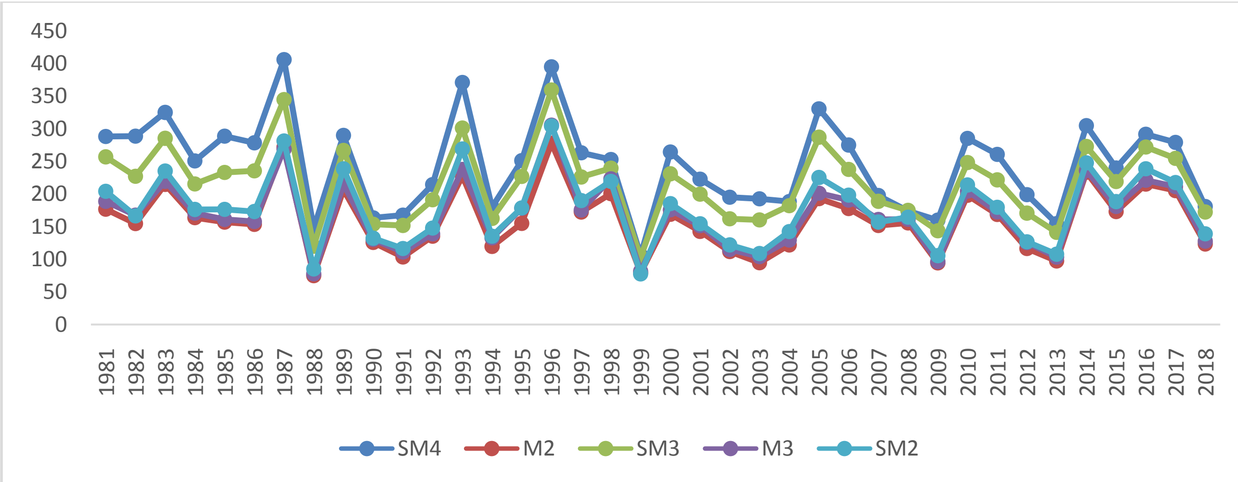


Figure 6 Rainfall patterns of (Mean annual, Kiremt and Belg) in Borena AEZ (1981-2018)

Table 8 Mean Decadal Maximum, Minimum Rainfall (1981 -2018) in all over the study area

Decade	**Mean**	**Mean Maximum**	**Mean Minimum**
1981-1990	1144	1421mm	712mm
1991-2000	1203	1398mm	718mm
2001-2010	1160	1352mm	738mm

As the above table indicates the maximum annual rainfall was registered in the first study period (1981-1990). The ten years' average maximum and minimum precipitation distribution reflect that the rainfall pattern across the three decades showed a different trend. The mean maximum rainfall in the second decade of the observation, the intensity of rainfall decreased by 23 mm as compared to the first decade of the observation time. And also the third period (2001-2010) rainfall reduced by 69mm, 46mm rainfall as compared from the first and second decade respectively.

The mean decadal minimum rainfall record shows that there is an increase in the rainfall trend across the decades. In the first observation, the mean annual minimum rainfall was found to be 712 mm, while in the second decade of the study period 718 mm, and also 738mm in the recent decade (2001-2010). This indicates the minimum decadal rainfall showed a slight increment continuously from the first decade to the last decadal rainfall by 6 mm and 20 mm. The time series trend analyze of total annual rainfall was done to reveal the general trends of rainfall amounts over the study area. In addition, the result obtained from KII reflected a reduction in annual rainfall amount from time to time. This implies that there is a direct relationship between the outputs of the chirp's data obtained from remote sensing satellites with the primary information obtained from FGD and KII. This study results related to the Nebebe (2014) decadal rainfall trend in the case of Ziway dough and Asfaw 2018 Woleka watershed. The result of standardized rainfall anomalies depicted the Interannual variability of rainfall and shows a lack of annual total rainfall trends for the period from 1981 to 2018 in the study area.

4.2.1. Spatial distribution of rainfall

The spatial distribution of annual rainfall in Borena District during the period (1981–2018) is presented in Figure 7. As the figure indicated that the highest rainfall values were recorded in the north eastern part and the lowest annual rainfall values were recorded in the south western part of the study area. Mean annual rainfall distribution Based on in AEZ. As the figure indicated that higher rainfall distribution were recorded in cool sub moist AEZ and the lowest rainfall distribution were recorded in warm moist lowland and warm sub moist AEZ of the study area.

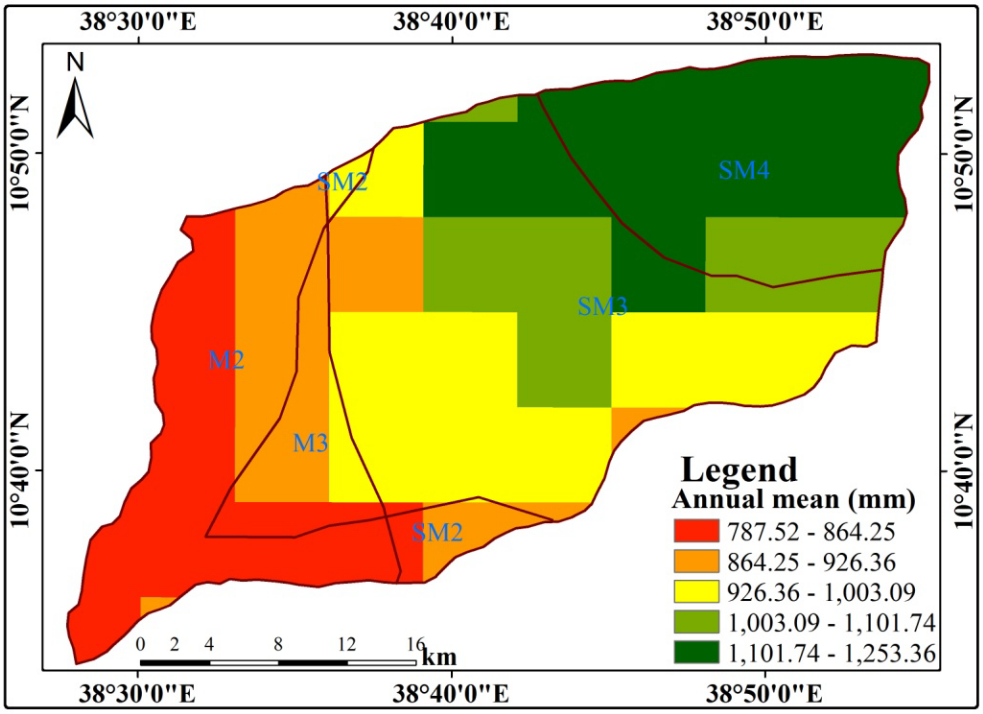


Figure 7 spatial distribution of mean annual rainfall of Borena District (1981-2018)

4.2.2. Seasonal distribution

The spatial distribution of rainfall for all seasons is shown in Figure 8. During kiremt, the northeastern part of the study area (Cool sub moist and some part of tepid sub moist mid highlands AEZ) received maximum rainfall while the northern (warm sub moist lowland) and southwestern parts (warm moist lowland) of the study area received low rainfall. Similarly, as figure 8 depicted during the Short rainy season (belg), the highest rainfall was observed in the northeastern parts of the study area (cool sub moist mid highland). However, the southwestern (warm moist lowland and warm sub moist lowland) part of the study area receives minimum rainfall in belg season.

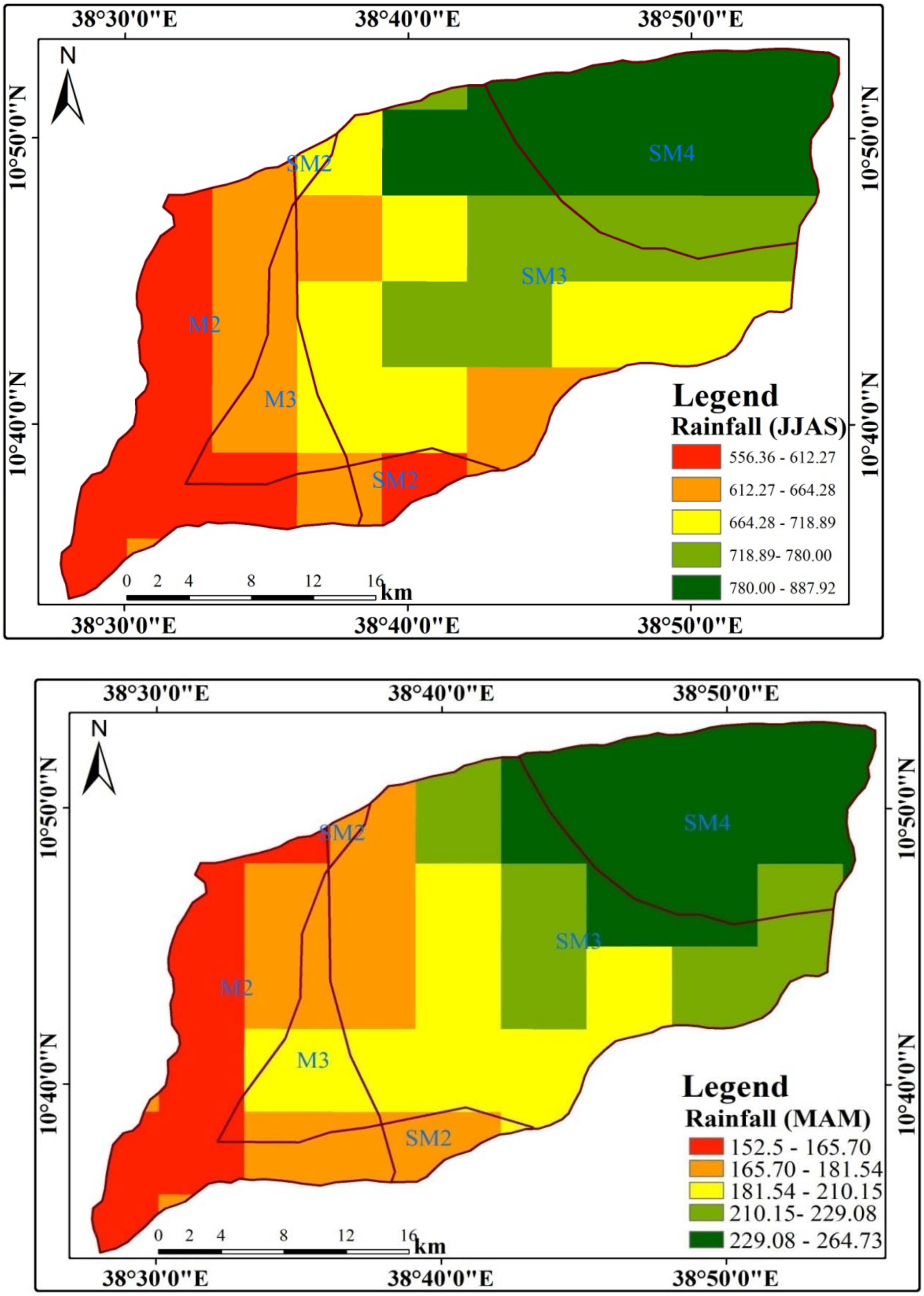
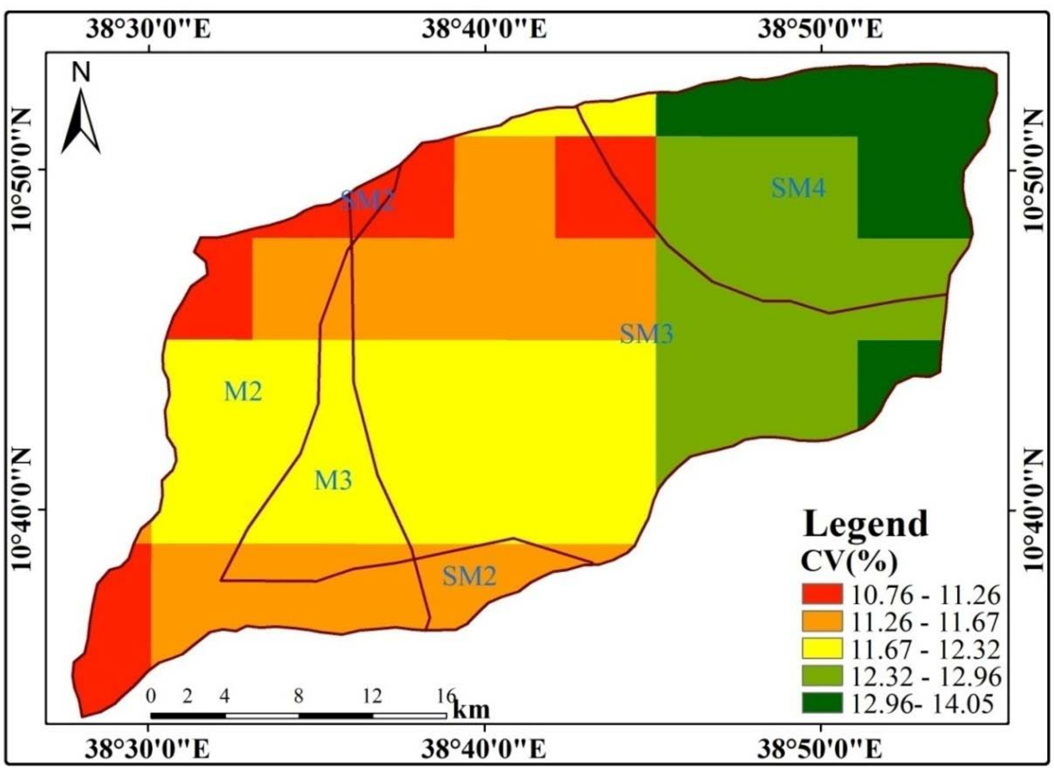


Figure 8 Spatial distribution of seasonal rainfall (mm) of the Borena District AEZS (1981–2018): (a) kiremt (JJAS), (b) Belg (MAM)

4.2.3. Variability of rainfall (CV)

The spatial distribution of the coefficient of variation of the annual rainfall in the study area was shown in figure 9. The Coefficient of variance rages from 10.76% in south western and north western to14.05% in the northwestern part of the study area. An area with maximum rainfall indicated that less inter annual variation whereas area with minimum annual rainfall indicated moderate inter annual variation. The moderate inter-annual variability in lower rainfall areas depicted that comparability there was a great contrast in annual rainfall values from year to year. It also suggested that in such areas, water availability became somehow more unreliable as compared to the area with low coefficient of variance (Mesert&Taye, 2019). General as the result of CV implies based on annual rainfall the spatial variability of rainfall in the study area was less because the result of CV was less <20 (Asfaw, 2019).



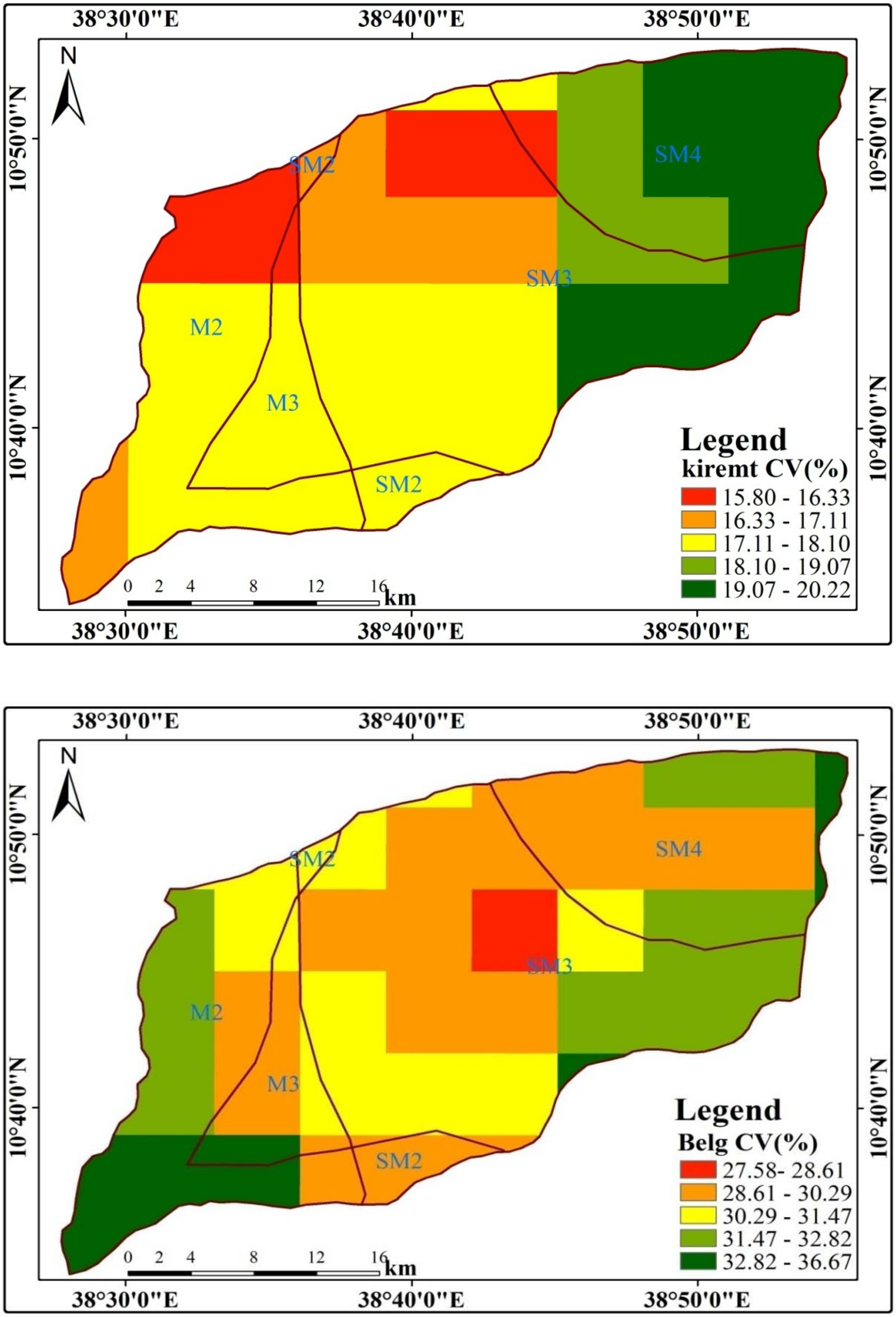


Figure 9 Spatial distribution of CV (%) of annual rainfall, Kiremt and Belg (1981–2018)

Figure 9 (a) and (d) show the spatial distributions of the CV of seasonal rainfall in the study area. Spatial distribution of CV of the seasonal rainfall of the BorenaDistrict (1981–2018): (a) (summer (JJAS) (b) spring (MAM). Similar to annual CV in the *kiremt*season the CV of rainfall observed less variability result. Although CV of rainfall in *Kiremt* season had less CV result relatively north eastern part (cool sub moist mid highland) of the study area observed high CV value than the other part of the study area. While in south western and western part (warm moist lowland and warm sub moist lowland AEZ) of the study area recorded less CV.

Although annual rainfall and seasonal rainfall showed less inter-annual variability *belg* showed moderate to higher coefficient of variation. This implies much larger variation in the seasonal rainfall (Belg) between the years. Maximum CV rainfall in *belg* (MAM) was observed in the north eastern (cool sub moist mid highland AEZ) and south western (warm moist lowland) parts of the area, whereas the moderate CV was observed in the central (Tepid sub moist mid) parts of the study area. Generally, results of CV of seasonal rainfall revealed variable spatial and temporal trends in the study area.

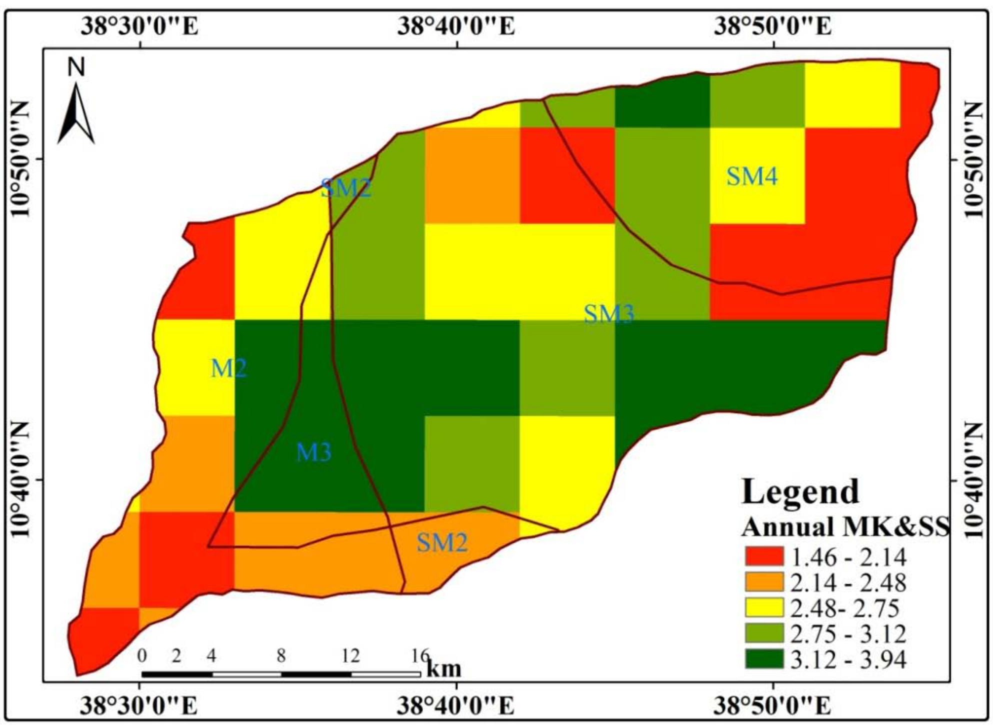
Moreover, the CV of *Belg* (27.58-36.67%) was higher than annual (10.76%-14.05%) and summer rainfall (15.8-20.22%) which implied more inter-annual variability of *Belg* than summer. The result agreed with the findings of other studies in most parts of Ethiopia (Seleshi&Camberlin 2006; Asfaw *et al.* 2018). Seasonal rainfall especially *Belg* and inter-annual variability in rainfall amount could negatively affect the capability of farmers to mitigate and adopt the effects of climate change and variability (Ayalew *et al.* 2012).

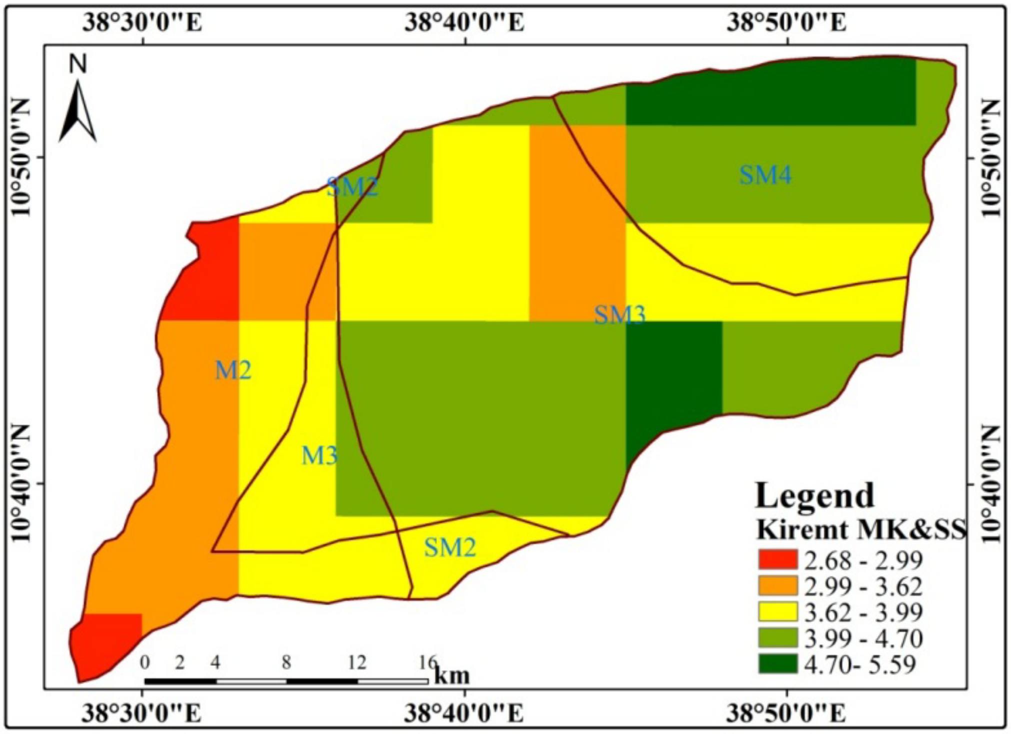
4.2.4. Spatial distribution of MK trend test and sen's slope rainfall

As the figure10, indicated Spatial Distribution of Mk trend test and sen's slope rainfall in Annual, Kiremt and Belg from (1981-2018).

The results of MK test for annual rainfall data revealed a statistically significant increasing trend observed in central part northern and south eastern (Tepid moist mid highland, tepid sub moist mid highland, warm sub moist and some part of cool sub moist mid highland AEZS) of the study area whereas, North eastern and south western part (warm moist lowland and cool sum moist mid highland) of the study area was observed non significance increasing trend. Generally in all agro ecological zones except warm moist lowland all AEZ was observed positive trend.

Similarly in kiremt season in almost all part of the AEZ or study area was observed statically significant increasing trend were observed. Contrast to kirmt and annual Mk trend *belg* have a non-significant decreasing trend in all part of the study area. The highest positive rate of change (was observed in the in kiremt season especially in month of July. This finding is related with Meseret and Taye (2019), and Asfaw (2018) in spatio-temporal rainfall trend in case of Amhararegion and woleka watershed respectively. Generally, the large percentage of MK trends in most part of the study area was positive rather than negative. A statistically non-significant increasing trend was observed for *kiremt* rainfall at 5% significance level. On the other hand, belg had a non-significant decreasing trend observed in All AEZs. The annual rainfall has shown a significant increasing trend at 5% significance level. Other studies in different parts of Ethiopia also did not find a statistically significant trend in the annual rainfall (Viste et al. 2013; Mengistu et al. 2014).





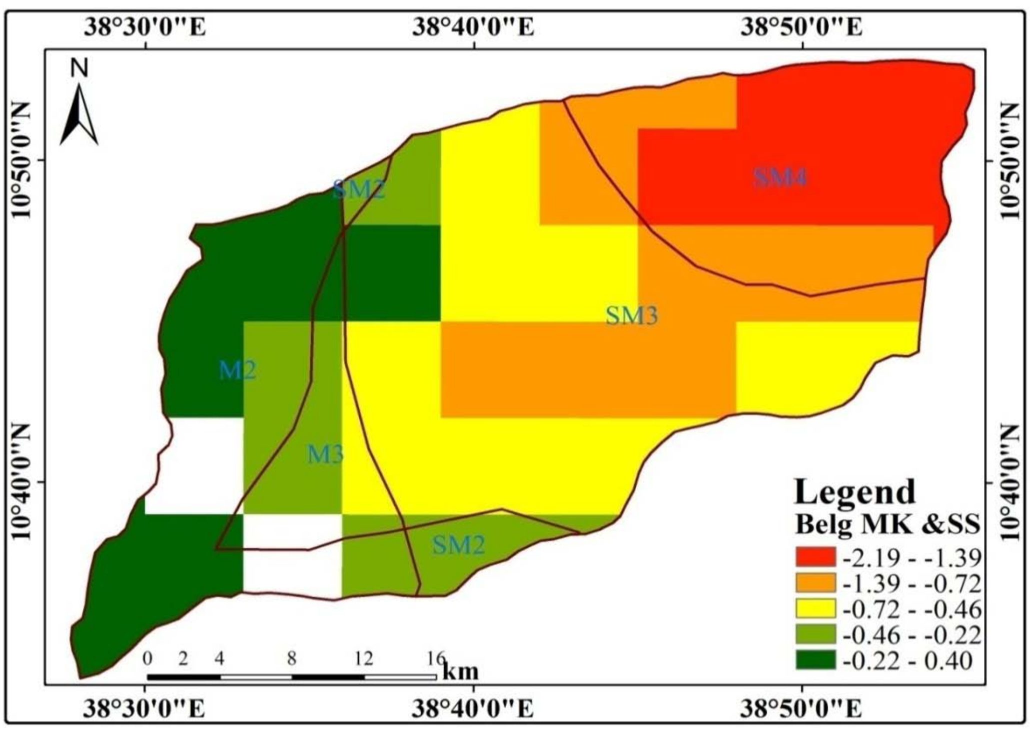


Figure 10 spatial Distribution of Mk trend test and sen's slope rainfall in Annual, Kiremt and Belg from (1981-2018)

4.3. Temperature trend analyze

An increase in temperature is among the manifestations of global climate change (Asfaw et al., 2018). Increase temperature is one of the major indicators of global warming and climate change. Analyze of annual and monthly temperature data was conducted to show the variability and trend of temperature in five AEZS of study area for the study period of 1961–2018.. The long term annual mean temperature in the study area is 18.108^{0}C. The long term annual mean minimum and maximum temperatures are 11.124 ^{0}C and 25.092 ^{0}C, respectively.Annual maximum, mean and minimum temperature have been increasing by 1.254^{0}C, 1.539^{0}C, and 1.368^{0}C degree Celsius respectively for the last 58 years or 0.21^{0}C, 0.26^{0}C, and 0.23^{0}C per decade from 1961-2018 respectively.

Table 9 Basic statistics and Average, SD and CV Temperature in five AEZS (1961–2018)

m2				sm2			sm3			m3			sm4		
Month	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Jan	21.2	0.6	2.8	19.8	0.6	2.9	19.3	0.5	3.3	19.3	0.6	3.0	13.6	0.6	4.3
Feb	22.5	0.9	4.1	21.1	0.9	4.4	20.4	0.9	5.3	20.4	0.9	4.5	14.3	0.9	6.3
Mar	23.6	0.8	3.2	22.0	0.8	3.4	21.3	0.8	4.3	21.3	0.8	3.6	14.9	0.8	5.1
Apr	24.0	0.8	3.2	22.4	0.8	3.4	21.7	0.8	4.3	21.7	0.8	3.6	15.5	0.8	5.1
May	24.1	0.7	2.7	22.4	0.7	2.9	21.6	0.6	3.5	21.6	0.7	3.0	15.2	0.7	4.3
June	23.4	0.8	3.6	21.7	0.9	4.0	21.0	0.9	4.9	21.0	0.9	4.2	14.8	0.8	5.5
July	21.0	0.7	3.4	19.2	0.7	3.7	18.4	0.7	4.6	18.4	0.7	3.8	13.0	0.7	5.4
August	20.4	0.7	3.2	18.7	0.7	3.5	17.9	0.7	4.5	17.9	0.7	3.7	12.9	0.7	5.2
Sep	21.0	0.6	3.0	19.4	0.7	3.2	18.7	0.6	3.8	18.7	0.6	3.3	13.7	0.6	4.4
OC	21.1	0.6	2.6	19.5	0.5	2.8	18.9	0.6	3.5	18.9	0.5	2.9	13.2	0.5	4.1
No	20.8	0.7	3.2	19.2	0.7	3.4	18.7	0.7	4.4	18.7	0.7	3.5	12.9	0.7	5.1
Dec	20.6	0.7	3.2	19.1	0.7	3.4	18.6	0.7	4.4	18.6	0.7	3.6	12.7	0.7	5.2
Annual	22.0	0.5	2.3	20.4	0.5	2.4	19.7	0.5	3.0	19.7	0.5	2.5	13.9	0.5	3.6

As figure 9 depicted the monthly and annual temperature of the five Agro ecological zones in the observation period (1961-1918).The mean annual temperature in cool sub moist mid highland agro-ecological zone during the study period was 13.9^{0}c with 0.5 SD, and 3.5 % CV. The mean annual temperature of tepid sub moist mid highland (SM3) during the study period was 19.7^{0}c with 0.5 standard deviation and 3 % CV.While the tepid moist mid highland (M3) the mean annual temperature was 19.7^{0}c with 0.5 standard deviation, and 2.5 % CV. In warm moist lowland (M2) the mean annual temperature 22^0c with 0.5 standard deviation and 2.3 % CV. And, in warm sub moist lowland (SM2) the mean annual temperature during the study period was 20.4^0c with 0.5 standard deviation and 2.4 % CV.This implies in less temperature variability observed in the study area since the value of CV less than 20% (Zerihun, 2019). Even though less CV observed in all AEZs the highest average temperature was observed in m2 and lowest recorded in sm4AEZs.

Table 10.Monthly and annual MK result of temperature (1961–2018)

	m2		sm2		sm3		m3		sm4		District	
Month	**MK test**	**Sen's slope**	**MK test**	**Sen's Slope**	**MK test**	**Sens's slope**	**MK test**	**Sen's slope**	**MK test**	**Sen's slope**	**MK test**	**sen's lope**
January	3.56*	0.006	3.47*	0.013	2.78*	0.004	3.5	0.008	3.53*	0.007	3.5*	0.008
February	4.48*	0.014	4.49*	0.018	4.75*	0.021	4.52	0.018	4.51*	0.019	4.8*	0.08
March	4.68*	0.011	4.68*	0.015	4.74*	0.014	4.64	0.014	4.66*	0.015	4.68	0.04
April	4.80*	0.016	4.92*	0.019	5.02*	0.021	4.86	0.019	4.83*	0.019	4.8*	0.01
May	4.66*	0.012	4.78*	0.016	4.82*	0.015	4.7	0.016	4.72*	0.015	4.6*	0.018
June	4.3*	0.011	4.42*	0.014	4.60*	0.015	4.37	0.014	4.44	0.015	4.5*	0.017
July	6.1*	0.019	6.21*	0.021	6.65*	0.022	6.24	0.022	6.17*	0.02	6.17*	0.021
August	5.57*	0.015	5.58*	0.017	5.54*	0.017	5.51	0.017	5.45*	0.017	5. 1*	0.017
September	5.8*	0.016	5.80*	0.018	5.88*	0.018	5.82	0.018	5.86*	0.018	5.4	0.06
October	5.17*	0.011	5.24*	0.013	5.27*	0.012	5.22	0.013	5.17*	0.012	5.1	0.033
November	5.2*	0.015	5.23	0.018	5.42*	0.02	5.17	0.018	5.03*	0.017	5.9	0.01
December	4.3*	0.009	4.32*	0.012	4.37*	0.013	4.32	0.012	4.11*	0.011	4.3	0.01

Analyze of annual and monthly temperature data was undertaken to discover the variability and trend of temperature change in the study area for the periods of 1961–2018. Table 14 portrayed the monthly and annual temperature. The results of the MK test for trend analyze were presented in Table 10. Thetrend analyze has been done for all months of the year. The results of the MK test for monthly data revealed a statistically significant increasing trend for the month of all agro ecological at 5% level of significance. The Pettitt's homogeneity test revealed the presence of homogeneity except for all month of the year and part of the study area. . The overall increase in annual temperature observed in all AEZS is attributed to an increase in the average, minimum temperature (the increment of the minimum temperature is more pronounced than the maximum). The empirical result related with the views of respondents; particularly farmers in all AEZS have confirmed an increasing trend of temperature. The result is in agreement with the findings of Stafford et al.

(2000), Conway et al. (2004), Tabari and Talaee (2011), Roy and Das (2013) and Daniel et al. (2014) where the increasing trends in the Temperature minimum series were higher than those in the Temperature maximum series.

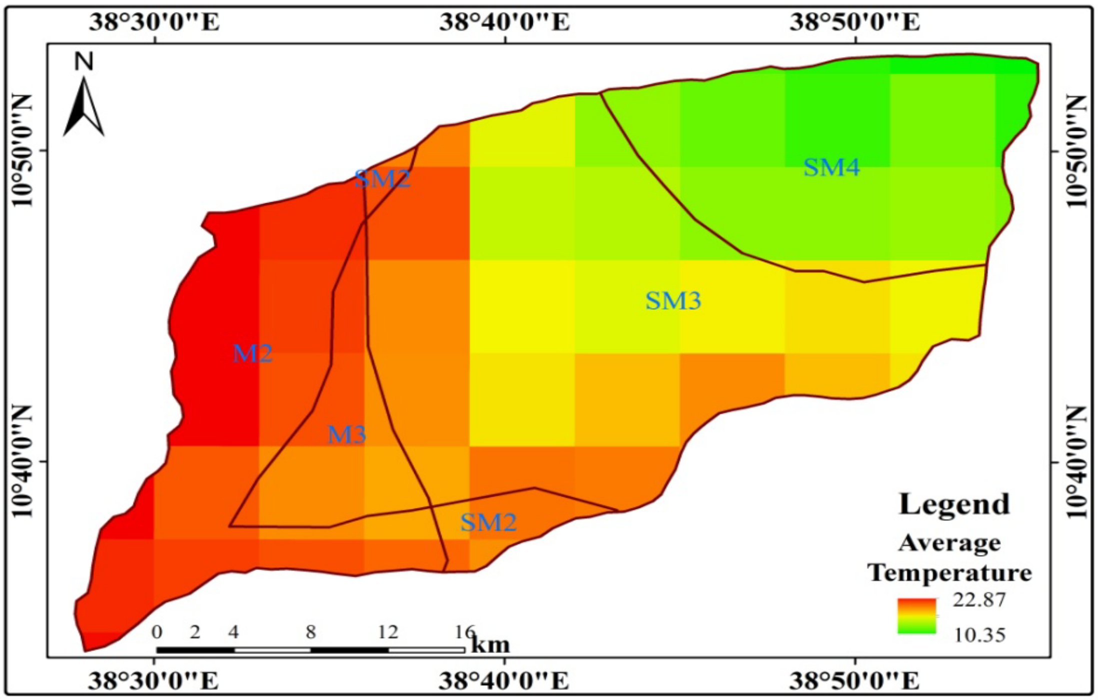


Figure 11 Average temperatures from 1961_2018

As the above Figure 11 depicted south western part of the study area particularly warm moist lowland, warm sub moist lowland and tepid moist mid highlands AEZS has relatively high average temperature than the rest part of the study area (tepid sub moist and cool sub moist mid highland). The average temperature during the study period was between 10.35^0 c and 22.87^0c. Similarly as the Figure 12 showed that maximum temperature was recorded in south western part of the study area especially in warm moist lowland, warm sub moist lowland and tepid moist mid highlands AEZS than tepid sub moist and cool sub moist mid highland). The maximum temperature during the study period was between 17.76^0 c and 30.16^0c.

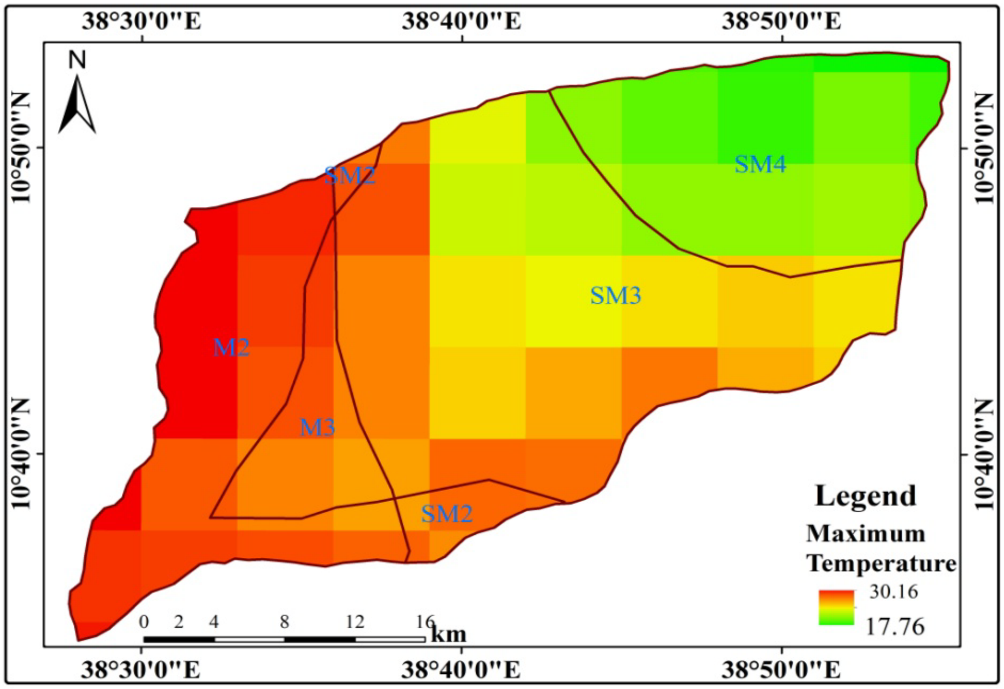


Figure 12 Maximum temperature of the study area from (1961-1918)

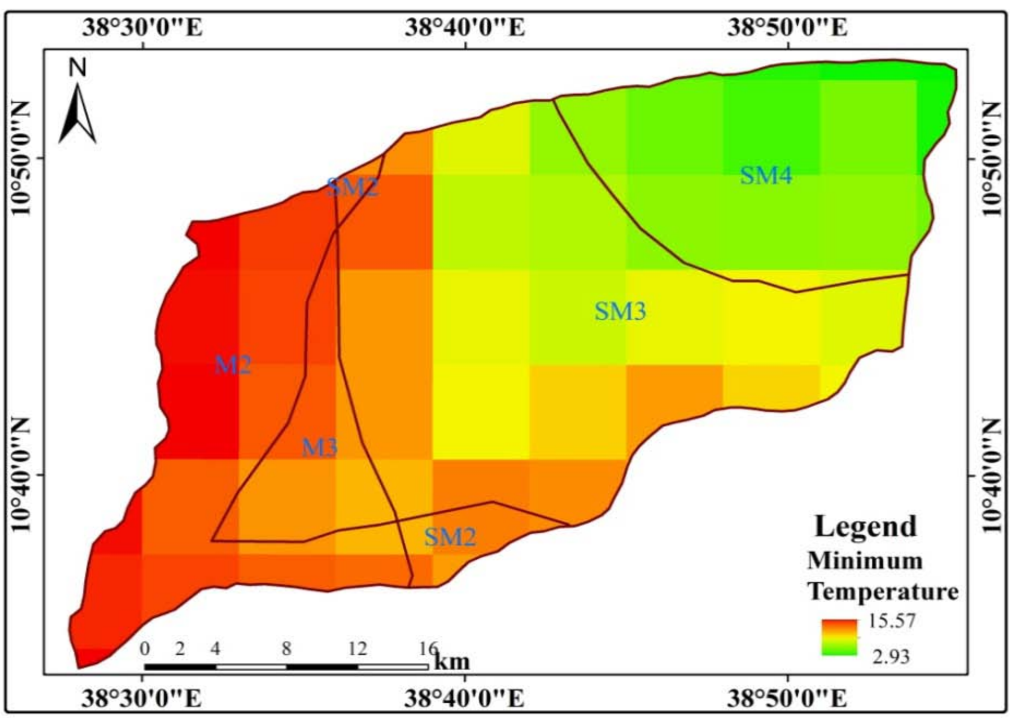
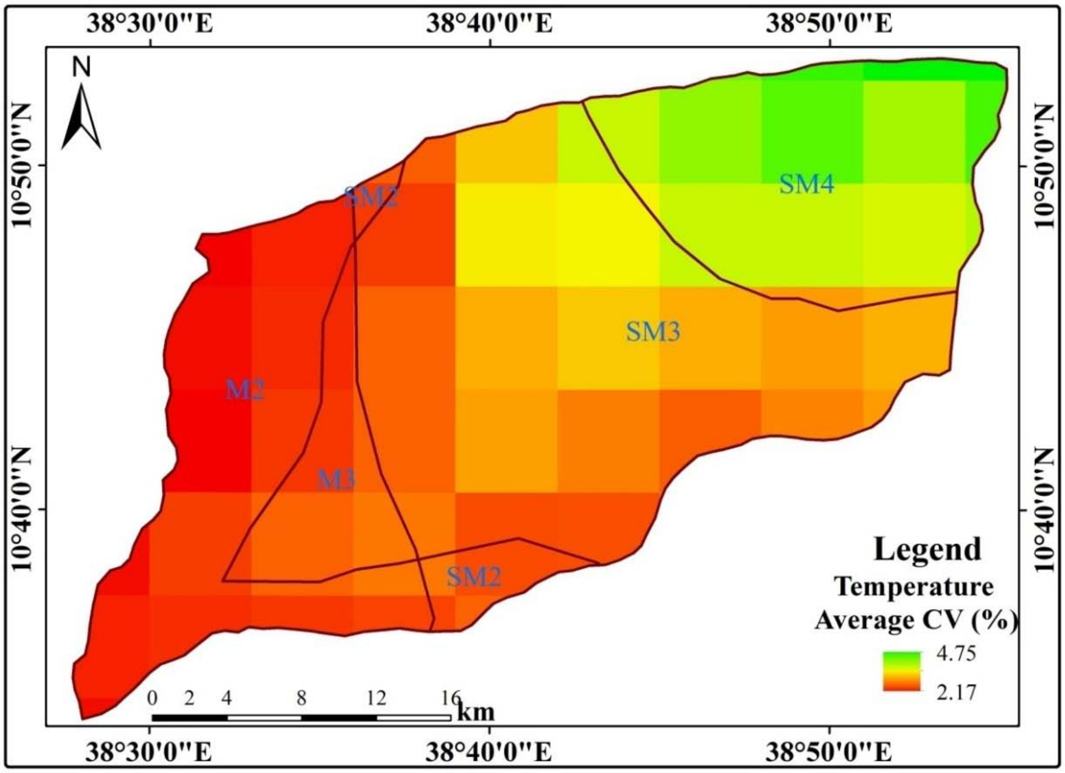


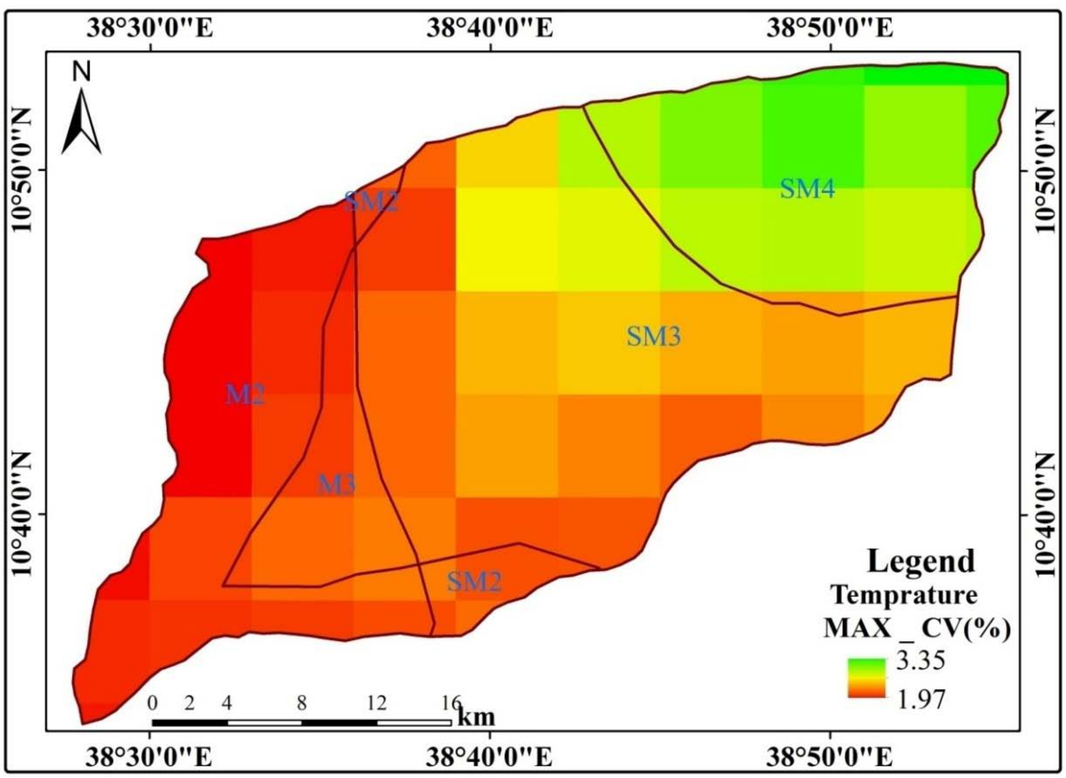
Figure 13 Minimum temperature of the study area from (1961-1918)

The mean temperature in the study area varies from 13.89^{0}C (minimum) to 21.97^{0}C (maximum) with an annual average temperature of 17.93^{0}C. The temperature trend and variability is varying spatially and temporally. For instance cool sub moist mid highland agro-ecological zone observed 13.89^{0}c, 21.24^{0}c, and 6.5^{0}c mean, maximum and minimum temperature respectively, In tepid sub moist mid highland agro-ecological zone observed 16.480c, 23.96^{0}c, 8.99^{0}c mean, maximum and minimum temperature respectively. In tepid moist mid highland agro-ecological zone observed 19.7^{0}c, 27.14^{0}c, 12.28^{0}c mean, maximum and minimum temperature respectively. In the warm sub, moist lowland agro-ecological zone observed 20.37^{0}c, 27.73^{0}c, and 13.02^{0}c mean, maximum and minimum temperature respectively. While, in warm sub moist lowland agro-ecological zone observed 21.97^{0}c, 29.16^{0}c, 14.78^{0}c mean, maximum and minimum temperature respectively.

Table 11 Mean, Max and Min Temperature

AEZ	**Mean**	**Max**	**Min**
cool sub moist mid highland(SM4)	13.89	21.24	6.55
Tepid sub moist mid highland(SM3)	16.48	23.96	8.99
Tepid moist mid highland(M3)	19.7	23.96	12.28
Warm sub moist lowland(SM2)	20.37	27.14	13.02
Warm s moist lowland(M2)	21.97	29.16	14.78


38°30'0"E
38°40'0"E
38°50'0"E
N
10°50'0"N
10°40'0"N
SM2
SM4
SM3
M2
M3
SM2
Legend
Temperature
Average CV (%)
4.75
2.17
0 2 4 8 12 16 km


38°30'0"E
38°40'0"E
38°50'0"E
N
10°50'0"N
10°40'0"N
SM2
SM4
SM3
M2
M3
SM2
Legend
Temprature
MAX _ CV(%)
3.35
1.97
0 2 4 8 12 16 km

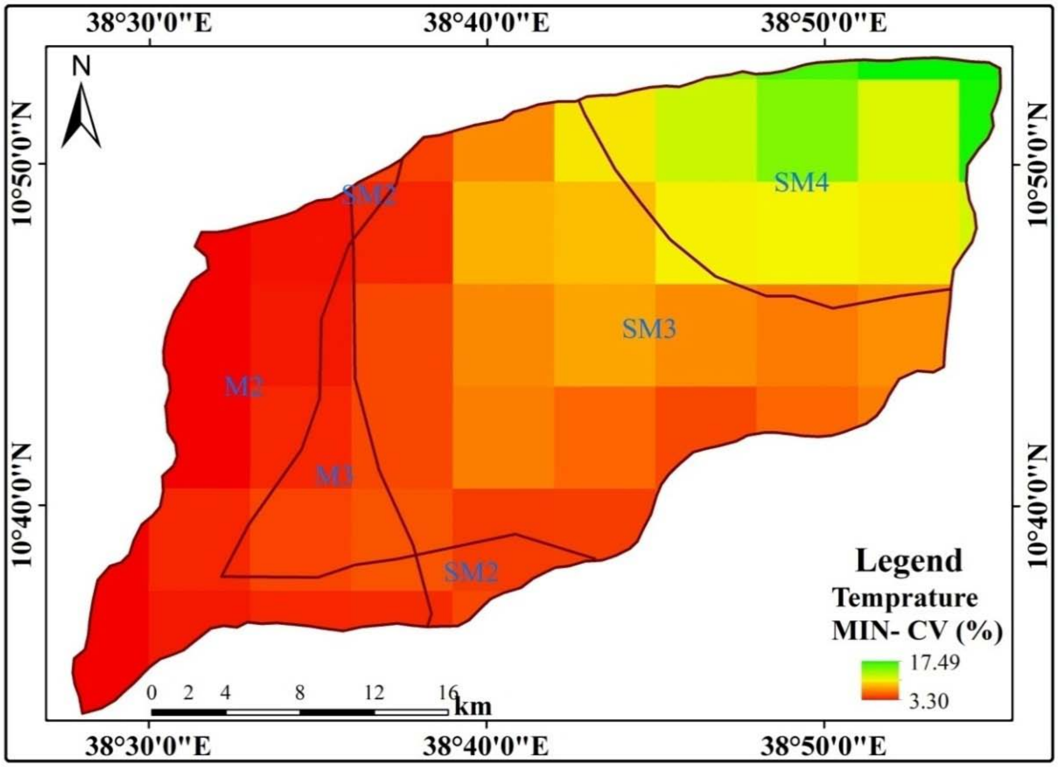


Figure 14Average, Maximum and minimum temperature coefficient variance

As figure14 revealed that maximum temperature observed in warm moist lowland (M2) and minimum average temperatures observed cool sub moist mid highland (SM4). The overall increase in annual temperature observed in the study area is attributed to an increase in the minimum temperature (the increment of the minimum temperature is more prominent than the maximum). The empirical result agrees with the views of respondents; particularly farmers in warm sub moist lowland and tepid moist mid highland agro-ecologies have confirmed an increasing trend of temperature. The result is in agreement with the result of Asfaw, (2018) in case of waleka watershed, Stafford et al. (2000) where the increasing trends in the Time in series were higher than those in the T max series.

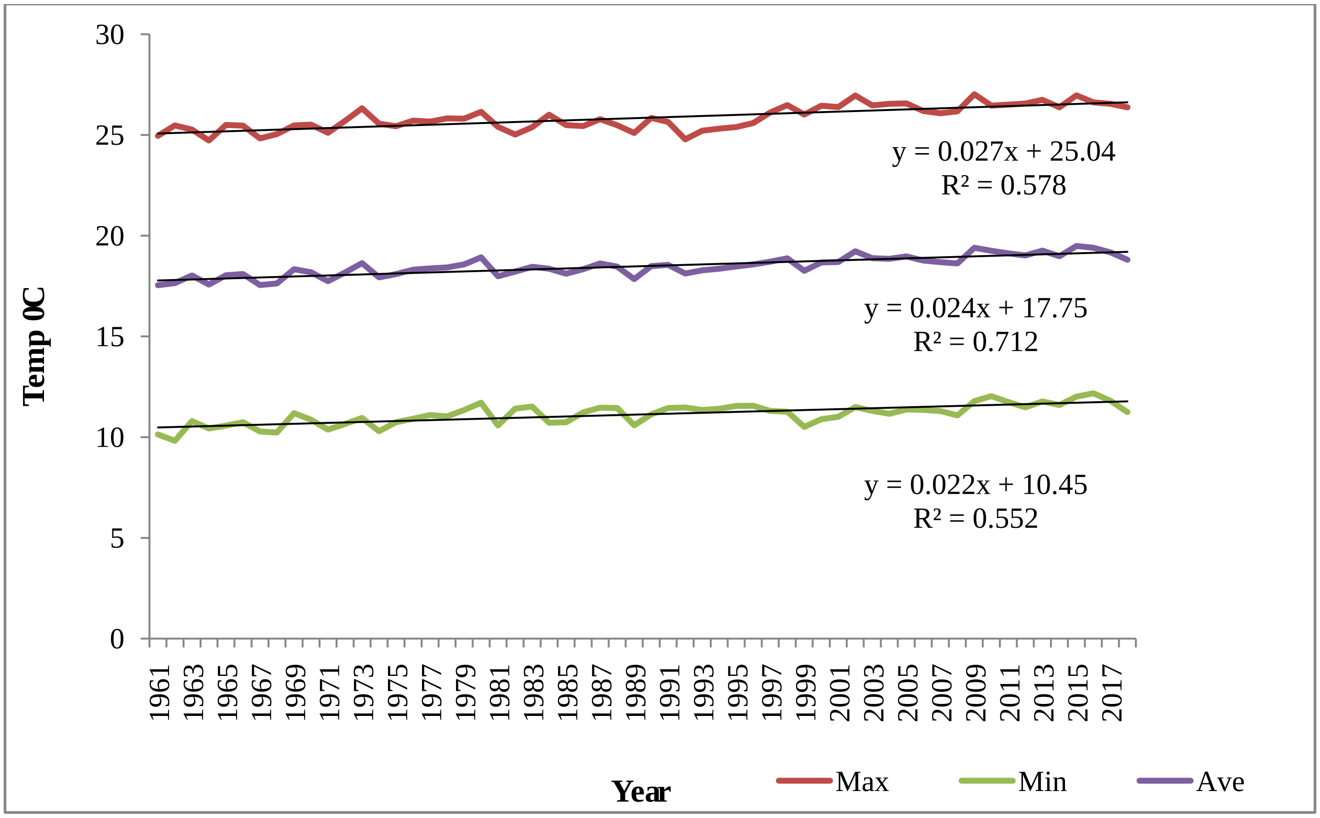


Figure 15 Average, Maximum and minimum trend within the study period (1961-2018)

As the above figure, 15 indicated temperature trend (average, maximum, and minimum) has shown a statistically significant increasing trend by 1.254^{0}C, 1.539^{0}C, and 1.368^{0}C in 58 years and similarly 0.21^{0}C, 0.26^{0}C, 0.23^{0}C increasing trend per 10 years respectively. Based on the responses of KII the temperature situation in their locality has been increasing 30 years back and the amount of rainfall has been decreasing. The majority of interview respondents reveal that rainfall has been decreased for short rainy seasons or*belg*. Most of the KKI response has manifested more variability and inconsistency observed in the *belg* season than the main rainy season. The response of farmers was similar with the result of trend analyze, particularly for *belg* rainfall pattern, which proved for the assimilation of the actual experience of farmers. But in main ran season or *kiremt* there were difference between KII response and trend analyze test.

4.4. Farmers' perception on climate variability

The majority of farmers perceived the increasing trend of temperature, hot days and warm nights and decreases in the number of cold nights from time to time in their localities. Their perceptions of increasing temperature mark with the worldclim of mean temperature. Agricultural experts and elders were asked to point out the manifestations of temperature variability from time to time particularly for the last 30 years. As narrated by elders, there is a shift in the agricultural calendar due to variability in the cessation and onset days and months of the rain; even they have shown their negative attitude for the future particularly in their social economical aspect. Presents bio-physical and socio-economic impact associated with climate variability and change. Farmers narrated various aspects of climate induced effects such as decline in agricultural productivity, migration, loss of livestock and consequently increased food insecurity. A more qualitative response on perceived effects showed that reduction in agricultural products and loss of livestock, drying of water especially streams and ponds were the most prevalent effect mentioned by all Key informant interviews the respondents. Majority of FGD respondents in the warm moist lowland and cool sub moist mid highland AEZs indicated that pest and disease prevalence has increased in recent years associated with the variability in climatic conditions. Respondents from tepid sub moist mid highlands loose of livestock and pests on sorghum are associated with low rainfall and high temperature, causing serious yield reductions and exposed for famine.

Table 12.Effects of climate variability and change on agricultural production and resources as perceived by (focus group discussions, 2020).

Attributes of climate	**Cases mentioned**	**Perceived impacts**
Increased temperature	Increased heat stress for crops and livestock, increasing evapotranspiration, increased pest and disease incidences	Increased occurrence of crop pests such as stalk borer on sorghum and shoot fly on teff , increased crop failure
Decreased rainfall	Decline of fresh surface water resources Inadequate moisture for crops Shortage of water for domestic and livestock use	Drying up of ponds and rivers (e.g. Lege Amara for Derami and Debrsenbo), River flows have reduced, some perennial rivers/streams have become ephemeral rivers/streams (e.g. Kulbit river), local springs and pip dried out egLegedebr in sembochilelo
Delayed onset and early set of the rainy season	Change in cropping calendar , reduced length of growing period, loss of crop diversity	High yielding, long duration crop varieties cannot be grown successfully (e.g. long duration sorghum variety is not used any more)
Rain out of season	Damage to crops Delay in harvesting time	Unexpected rain in November/December caused damage and delay in harvesting
Increasing drought events	Damage on resource base (crops, water, livestock) Increasing food insecurity	Number of households appealing for food aid increases

Farmers indicated that climate risks affect livestock feed availability as well. In the warm moist lowland, elderly interview result stated that their herds were considerably larger 20 but reduced significantly in recent years into 5. And also Declined water resources and increased soil erosion were also mentioned as environmental problems being happened by increasing gradual climate variability. The overall effect of climate variability and change was felt within households in terms of increasing food insecurity. All respondents and key stakeholders assured that the number of households appealing for food aid has been increasing.

4.5. Climate variability adaptation strategies

One of the intended objectives of this study was to identify some of coping and adaptation methods practiced by farmers, in response to impacts of climate change and variability. The local farmers had adapted to cope up the impacts of climate change and variability. The most widely adapted strategies were that have little cost to the household and relatively easy. Thus, in order to minimize the problem related to climate change, the local community was familiar to producing and practicing some adaptation strategies in the area since long years ago.

Likewise, the most common household adaptation practices in the area were discussed being categorized under, Planting early maturing crops appears to be the major adaptation mechanism of communities, preservation of food and seed storage, diversifying livestock composition, Sale old/ weak animal before drought occurs, migration and Soil and water conservation. Generally, this study included local (indigenous) and introduced (governmental and nongovernmental) adaptation mechanisms.

Crop diversification in space and time is the most widely used income smoothing mechanism, i.e. a farmer sows different types of crops at various moments and fields to minimize crop losses and to spread farm risk. Farmers also adjust some agronomic practices such as planting density, fertilizer rates and frequency of tillage to maximize utilization of the scarce water resource in low rainfall seasons.

Livestock husbandry is an integral component of mixed-farming systems in the study areas. The main adaptation strategies to minimize the risk of livestock production consisting the use of alternative feed sources (e.g. feeding tree branches), conservation of fodder, collection and use of crop residues, and reduction of the herd. In the warm sub moist lowland, warm moist lowland AEZSand tipped sub moist mid highland of KKI respondents indicate that seasonal migration of livestock from risk area to the better zone is another strategy to cope with feed shortage in low rainfall seasons.

Agricultural related adaptation strategies

As the researcher observed during field observation, over the entire area of Borena districtkebele, the predominant crops in the area are barley, teff, wheat, maize, millet, bean and sometimes sorghum. Crop production has been the most and basic economic activity for the local community and the respondent's use different local adaptation practices. Different local adaptation measures are undertaken by farmers in response to changing climatic variation in the study area. As elderly people revealed during FGD, the types of adaptation practices of crop production such as short growing season crops (barley, wheat and bean), crop rotations which means changing the type of crop from one year to the next year, for example from bean to barley, from barley to sorghum, from figermillet to teff and storing food crop by buying cheaply from the nearby vicinity and Practice fallowing, are the major and common adaptation practices of the community.

Fallowing, is local type of adaptation practice, there are two types of fallow: natural and improved. Natural fallow consists of allowing land that is usually cultivated to remain uncultivated and instead using it for grazing or left to natural vegetation to restore soil fertility. Improved fallow consists of planting trees, mainly legume tree species, in order to enrich the soil within a shorter time period, compared with natural fallow (Bekele-Tesemma 2007). Similar to this the respondents said, white fallowing and legume fallowing.

Mixed cropping: Mixed cropping is complex cropping systems in which two or more crop species are planted within sufficient spatial proximity to result in competition or complementation. Mixed cropping is growing of two or more crops simultaneously on the same land (field), there is crop intensification in both time and space dimensions by this means enhancing

Inter cropping: is the other best method of local crop adaptation practices and most uses in the western part of the study area. This is type of farming practice means that growing of one dominant crop and the other types of crop sow rarely (in one cultivated land more than one seeds). This is important to compensate one to the other types of crop and to get many types of crop in the same time or one year from the same land area.

Fallowing system is most dominated and less cost in the most lowland part of study area they use pluses types of crop, as well as crop rotation, inter cropping, mixed cropping and short cropping season are the other most dominant adaptation strategies in the western part of the study area. Generally from the survey result and KII the information indicates that agronomic adaptation practices are different with labor force availability, land size, wealth and land of the village type.

Line seeding: As the researcher observed during the field, the line seeding types of adaptation mechanisms was use very small number of communities because it takes time and technique. As the adult people responded during FGD, line seeding is one of the introduced adaptation mechanisms and very important practice, but as that of significance it includes drawbacks. In the practice of line seeding it needs high man power in the seeding time and also creates very weeds since it have large gape of space entire crops of the land.

Case study one

Case 1: '*belg*rainfall is decline'. The key informant from the warm moist lowland area of Borena Dist (aged 57 and a father of 6 children) shared his experience regarding to trend and the contribution of sm rain (called *belg*) as: [… …] for agrarian communities, *belg* rainfall is as crucial as that of *kiremt* due different reasons. Availability of water and pasture becomes scarce after the long dry season (which exte from September 21 up –February end). It is the *belg* rainfall which saves our livestock's life. Not only also keep psychological feeling of community and stable the price of goods in the local the market beca when rain is come the relative rich donors became happy to borrow cereal products credit for poor. The b rain is garneted for paying their cordite in the next year. Besides, we are using the *belg* rainfall to grow crops (like sorghum millet and maize) which need longer growth period for harvesting. In short, *belg* rain is crucial for smallholder farmers. But, we lost all these opportunities due to failure or/and inadequate b rain for the successive years. This interview result indicates the importance of *belg* rainfall in the study a especially in lowland area not only for *belg* dependent areas but also for *kiremt* rainfall dependent areas Borena District. Land preparation for*kiremt* planting should be prepared ahead rain began and it is the rain which makes the task easy. It solves the scarcity of water for animals and people.

Case study two

Narratives of farmers ‘perceptions on climate variability and respondents ‘way of understanding variability climate and associated risks (KII, 2020)

A 71-year-old farmer from AychalBonya presented his perception on climate variability as “Just 30 years ago, I used to cultivate “*Guret*” (long duration sorghum variety) year to year and the crop harvest was too much (about 4 “*Gudgad*” or Hole which is equivalent to 120 *Kuntal*per hectare). But In recent times, I am not able to plant “*Guret*” because the rain starts too late. In previous years, the rain used to start around the mid of February to early *belg* and continued till the end of October but recently it starts late (usually mid of July) and stop early (mid of August or sometimes early September). Not only *belg* rain delay but also *kiremt* rain consistency also under question in the last 30 years. Shrinking of *belg* season, Season breaks, the unreliability of rainfall, and dry spell are common challenges for us. Furthermore, in the past, the amount of rainfall per rainy day was not too much or too little but recently, it looks as if "it gets angry at something", i.e. higher rainfall intensity over shorter periods. In the past, the seeding seasons were known and almost reliable from year to year. Even the farmers seeding sewed at ahead of the rain or *AntfehTebk* which means the farmers were confidential by *belg* rain planting at the dray time and waiting for rain. But recently we apply the approach of “*Ende-Tale Zira*” which means plant whenever it rains. Livestock are gating extremely affected by the unreliability of rainfall and shortage of *belg* rainfall. In 1994 E.C I had 120 cattle I lost more than half cattle due to drought, which was as severe as in 1984 and 20 cattle in the 2009 drought which indicates the shortage and delay of *belg*rainfall and *Kiremt* respectively. After this harsh situation now I sold the rest cattle and remain only 5 cattle only (Two oxen, one caw with two calves”.

Case study 3

A 70-year-old farmer at ChiroKadis expressed his perception of climate variability: “Thirty years ago, we were suffered by heavy rainfall and swapping of the garden and our surrounding area. Even it was difficult for mobility during the rainy season which starts from early May and ends of April. Especially Kiremt season was a severe challenge to perform the day-to-day farming activity. Due to this reason, we forced to move to the Kola (lowland part of Borenaworeda namely Abay and Yeshum) with our cattle bay group to stay there for three up to four-month or Until the Meskel holiday or finding true cross. Kola is good for kiremt season since it is hot and wet even the life is good than Dega (Chirokadis) because due to heavy rain thunderstorm, flood, and the marsh nature of soil the grown crops were only barley and wheat which did not require labor and effort so only my wife and Two girls are enough. Hence these factors me and the rest two boys went to Dereba (a house constructed for a temporary life in kola Agro-ecological zone.

But now our climate is changed because the amount of rainfall is reduced, the swamp area is dry and the amount of temperature is increasing. These situations help us to produce other cereal crops like Teffe and pluses. In recent years, our local area is becoming hotter and hotter. I am afraid it is going to be as hot as in the lowland part. In the past, the rainy season was on time, and once the rainy season started it extended to October. But in recent years, the rainy season starts late and is short. Previously, the area was very swap and grassland we had large herds but recently the livestock population has been reduced because of climate variability. For example, I had 15 animals but now I have only two oxen for farming or plowing land. Even thou crop Variety and potential to grow in this area increase the Crop yields amount has been reduced. We never expect food aid but now we are going asking to register on seeft net for food aid.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusions

The mean annual rainfall of the area throughout the study period was 987.73 mm with 113.68 mm SD and 11.5 % CV. The result shows thatthe mean annual rainfall of the study area during the study period was 987.74mmmm with 113.68 mm standard deviation and 11.5 % CV. The minimum and maximum recorded rainfalls were 715.89 mm (in 1998- the driest year) and 1200.05 mm (in 2015-the the wettest year) per year respectively. *Kiremt* is the major rainy season in the study area which contributes about 71% of the total rainfall. The short rainy season which started from March to May (called *belg*) also contributes a significant amount of rainfall (around 27% of the total). The maximum rainfall was observed in cool sub moist mid highland and the minimum rainfall was recorded in warm moist lowland AEZ of the study area.Statistically non-significant declining trends were observed for *belg* season in all part of the study area.In warm moist low land, cool sub moist mid highland AEZ of the study area recorded high CV of rainfall in Belg season.

Annual maximum, mean and minimum temperature have been increasing by 1.254^{0}C, 1.539^{0}C, and 1.368^{0}C degree Celsius respectively for the last58 years or 0.21^{0}C, 0.26^{0}C, and 0.23^{0}C per decade from 1961-2018 respectively. The impact of climate change is reflected in crop failure due to insufficient rainfall amount and distribution and associated diseases incidences during production and harvesting period.Climate change negatively affects agriculture, ground water availability, and soil quality. Climate variability in the form of higher temperature, reduced rainfall, and increased rainfall variability reduces crop yield and threatens food security, and loose of livestockin low income and agriculture-based economies.Farmers have their own adaptation strategies against climate change and variability to sustain their lives and livelihood and the figure below illustrates the actual adaptation strategies practiced by the respondent farmers in the study area. Among these adaptation strategies, use of improved crop varieties, off-farm activities,agro forestry practices, crop diversification, tree planting, soil conservation practices, irrigation practices and temporary migration were the most important adaptation strategies in the study area.

5.2. Recommendations

Based on the findings indicated in this research, the following recommendations are formulated.

- This study has used satellite data monthly CHIRPS at 5 kilometer spatial resolution. Therefore, it is important for future researches to conduct a research with better spato-temporal resolution.
- Hence, spatio temporal climate variabilityvaries spatially, prioritization and implementation of adaptation and mitigation schemes should be focused on site specific. Selection of adaptation and mitigation strategies such as agricultural technologies and information should be made to fit in to the climate variability levels as well as the nature of the site.
- Mainstreaming and strengthening climate change and adaptation research in the National Agricultural Research System (NARS) towards developing adaptive technologies for managing climate risk and uncertainty.
- Strengthening the knowledge base (capacity) on using advanced tools and approaches (e.g. crop-climate simulation models) for climate change and adaptation assessment;
- Communicating projected climate change impacts and possible management strategies effectively among farmers and decision makers;
- Improving institutional arrangements towards enhancing the adaptive capacity of farmers through providing agricultural credit and effective extension services.
- Government and NGOs empower the community through training to develop the sense of owner ship to their natural resources to conserve and protect.
- Government introduce new climate adaptation technologies, drought resistance crops and animals, early maturing varieties of crops; promote off farming income sources in different AEZS of the study area community.
- Government should increase the resilience of affected community by economy, Networks, climate information, local training institutions, veterinary services, schools and health centers.
- Local or regional governments should control anthropogenic cause of climate variability.
- Government should provide agricultural inputs to reduce the impact of climate variability on their agricultural productivity.
- Public participation as well as awareness creation is highly needed in the field of climate variability and change.

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Annex-one

I. Elder's perception on climate variability

1. Have you heard of "climate variability in your locality?
2. Have you observed changing rain fall and temperature patterns?
3. What kind of patterns have you observed so far about the onset and recession of rain fall in your area?
4. When do both dry and wet season begin and end in your locality?
5. People's perception climate variability based on the rain fall, temperature on the three regimes. How can you describe rainfall and temperature pattern in different seasons of last 30/40 years.
6. Do you presume that climate variability has been affecting your livelihood and crop production at household level? How?
7. What type of adaptation strategies should be done to adapt climate variability?

II. Agriculture and Rural Development Office officials convenient

Qualification ____

Total year of experience in the area ______________________________

Sex: Male [ ] Female [ ]

Age: A. 18-25 B. 26-30 C. 31-35 D. 36-40 E. 41 &

Position/profession _________________________________

1. What is the agro-ecology of your zone/district/peasant association?
2. Is there any form of climate change in your zone or district? Yes/No, if your answer is yes, please can you explain?
3. If the answer to Q2 is yes, please would you like to explain the extent of climate change and variability?
4. Was there unexpected rain in the month November?
5. If the answer is yes to Q4, How do view its damage on crop productivity in the area in terms of yield? Evidences for example in year _____ yield is lost by ____ Qt or ____ %

III. Interview Questions: woreda Experts

Qualification ____

Position/profession __________________________________

1. How do you view the prevalence of climate variability in your locality?
2. How do you rate it its occurrence in the last twenty/ thirty years?

3. What are the impacts of climate change on the livelihood of the people particularly this premature rain effects on crop production of the local people?
4. What is your role in prevention of socio-economic disaster caused by climate change and variability before and after the disaster? How?
5. What should be done to adopt climate variability climate variability in your locality?

Annex-four

IV. Inter View Checklist for Key Information (KII) Name__________

Age________________ Sex__________ Education _________

AEZs: ______________

1. Do you feel climate variability in your AEZs?

2. How can you describe the climate change in your AEZs?

3 What is your perception on the general trend of temperature and rain fall pattern; the magnitude /intensity, frequency and its distribution of rain fall; the duration of rain fall (onset and cessation) and period in which rain start and end falling?

5. What are the major impacts of the climate variability?

6. Are there alternative livelihood system / practices as adaptation strategy to cope with climate change in general climate variability in particular?

Check list for Field Observation

The researcher focus on the following points during field survey

1. Dominant livelihood in the study area

2. Crop production and livestock ranching in different Agro ecological zone

3. Government and farmers activities on environmental conservation

4. Streams and other water sources condition

5. Soil and water conservation techniques

Annex-Two

	m2			sm2			sm3			m3			sm4			District		
Month	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**
January	11.9	4.1	34.3	11.9	3.9	33.0	10.9	3.6	33.4	11.3	4.2	37.2	11.3	4.2	37.2	11.6	4.0	34.1
February	17.9	12.0	67.1	18.4	12.3	66.8	18.8	12.1	64.1	20.9	13.2	63.3	20.9	13.2	63.3	18.8	12.2	65.0
March	40.3	22.6	56.2	46.9	25.4	54.1	57.7	28.1	48.7	69.6	32.5	46.7	69.6	32.5	46.7	52.0	26.5	51.0

April	53.0	20.8	39.2	60.4	25.0	41.3	76.2	28.0	36.7	88.8	33.5	37.7	88.8	33.5	37.7	66.9	25.5	38.1
May	67.7	38.4	56.7	69.9	39.9	57.1	83.0	40.3	48.5	87.0	47.1	54.2	87.0	47.1	54.2	75.2	40.6	54.0
June	65.6	28.0	42.7	67.6	30.2	44.6	79.9	31.2	39.1	80.1	39.4	49.3	80.1	39.4	49.3	71.6	31.2	43.6
July	244.0	66.5	27.3	261.1	71.8	27.5	286.4	77.3	27.0	323.7	95.1	29.4	323.7	95.1	29.4	274.4	76.2	27.8
August	224.9	39.1	17.4	242.3	42.2	17.4	273.4	44.5	16.3	299.7	56.1	18.7	299.7	56.1	18.7	255.1	44.2	17.3
September	88.1	23.5	26.7	93.4	25.6	27.4	114.9	28.7	24.9	120.7	31.8	26.3	120.7	31.8	26.3	101.4	26.1	25.7
October	27.6	18.8	68.3	29.4	20.2	68.8	43.8	21.3	48.6	44.5	24.4	54.8	44.5	24.4	54.8	34.4	20.4	59.3
November	17.7	11.7	66.1	16.4	11.3	68.8	14.8	9.4	63.2	13.8	9.7	69.9	13.8	9.7	69.9	15.9	10.5	65.9
December	10.0	5.6	56.2	10.2	5.7	55.8	10.0	5.9	59.0	11.5	7.6	66.4	11.5	7.6	66.4	10.4	6.1	58.4
Annual	868.4	100.7	11.6	927.8	313.3	33.8	1069.7	115.4	10.8	1171.4	143.0	12.2	1171.4	143.0	12.2	987.7	113.7	11.5
Kiremt(JJAS)	622.6	104.8	16.8	664.3	113.2	17.0	754.6	121.5	16.1	824.1	147.8	17.9	824.1	147.8	17.9	702.5	119.1	16.9
Belg(MAM)	160.9	49.9	31.0	177.1	54.7	30.9	216.9	58.7	27.1	245.3	70.1	28.6	245.3	70.1	28.6	194.0	56.5	29.1

Borena average Temperature

Year	jun	Feb	Mar	AP	may	June	July	August	Sep	Oct	Nov	Dce
1961	18.95	18.15	19.17	19.45	20.37	18.94	15.49	15.16	16.60	16.71	15.78	15.75
1962	16.78	18.22	19.84	19.42	19.87	18.78	16.70	15.23	16.15	16.57	17.15	17.03
1963	17.88	18.94	19.92	19.21	19.07	19.17	16.66	16.36	17.22	17.80	17.40	16.73
1964	17.37	17.73	20.03	19.86	19.90	18.99	15.99	15.88	16.89	16.40	16.27	15.63
1965	17.25	18.39	19.35	19.41	20.71	19.72	17.14	16.39	17.39	17.10	16.79	16.77
1966	18.10	18.17	19.27	19.60	20.02	19.25	17.33	17.02	17.30	17.50	16.87	16.79
1967	17.45	18.87	19.15	19.17	19.38	19.04	16.04	15.85	16.91	16.56	16.06	16.16
1968	17.17	16.86	18.67	18.61	19.54	18.44	16.28	16.68	17.32	17.50	17.17	17.38
1969	17.92	17.86	19.94	20.00	20.15	19.86	17.17	16.54	17.54	17.53	17.92	17.62
1970	17.71	19.34	18.80	20.15	20.50	20.52	17.17	16.45	17.32	17.33	16.53	16.43
1971	17.27	18.66	19.37	19.74	19.16	19.05	16.67	16.39	16.90	17.29	16.65	15.77
1972	17.96	17.85	19.50	19.53	19.80	19.00	17.34	16.98	17.32	17.80	17.53	17.46
1973	18.53	20.19	21.16	21.43	19.93	19.93	17.35	16.65	17.37	17.45	17.14	16.52
1974	17.90	18.95	18.53	20.71	19.26	18.93	16.50	16.42	16.72	17.68	16.66	16.89
1975	17.76	20.09	20.03	20.05	20.26	18.89	16.67	15.61	16.68	17.45	17.01	16.56
1976	17.85	19.05	19.90	19.74	19.44	19.76	16.75	16.59	17.68	17.68	17.30	18.03
1977	18.07	18.81	19.76	20.71	20.14	19.50	17.29	16.75	17.72	17.21	17.20	17.39
1978	18.18	19.10	19.55	20.74	20.57	20.04	16.59	16.84	17.54	17.58	17.06	17.37
1979	17.78	19.16	19.70	20.71	19.75	19.67	17.47	17.14	17.92	18.10	17.77	17.77
1980	18.68	19.87	20.65	20.61	20.74	20.05	17.27	16.95	17.94	18.49	18.20	17.68
1981	18.10	18.64	19.11	19.38	19.91	19.93	16.82	16.85	16.96	17.06	16.65	16.49
1982	17.94	18.42	19.23	19.42	19.76	20.00	17.82	16.92	17.74	16.92	17.20	17.24
1983	16.97	18.42	19.70	20.20	20.48	20.11	18.15	17.50	18.11	17.72	17.31	16.76
1984	17.16	18.45	20.32	20.96	19.66	19.40	17.25	17.34	17.17	17.76	16.93	17.92
1985	17.89	19.01	19.51	19.32	19.19	17.39	16.78	17.52	18.12	18.01	16.88	17.75
1986	17.87	19.66	19.10	20.44	19.58	18.06	17.24	17.52	18.04	17.79	17.27	17.52
1987	18.19	18.88	19.87	19.33	19.51	18.51	17.72	18.70	18.74	18.45	17.63	17.95
1988	18.57	20.65	20.11	20.48	19.98	17.70	17.18	17.60	18.18	17.78	16.71	16.64

1989	16.87	18.25	18.42	19.41	19.11	17.41	17.28	17.34	18.03	17.69	16.49	17.82
1990	17.76	18.33	18.89	19.80	20.89	20.15	17.50	17.32	18.04	17.72	17.84	17.66
1991	18.44	19.70	19.69	20.65	20.17	20.05	17.57	17.09	17.93	17.48	17.16	16.67
1992	16.86	16.76	19.52	20.41	20.73	20.07	17.57	16.77	17.20	17.60	17.04	16.97
1993	17.78	17.86	20.13	19.53	19.98	19.76	17.41	17.21	17.84	17.48	18.42	15.99
1994	18.07	18.94	18.85	20.91	20.43	20.07	17.37	16.99	17.03	17.37	17.17	17.14
1995	18.05	18.51	19.62	20.20	20.29	19.08	17.10	17.40	17.81	18.12	17.41	18.07
1996	18.46	19.87	20.16	20.84	19.65	19.14	17.69	17.06	18.12	17.81	16.81	17.32
1997	18.50	18.27	20.27	20.04	20.05	20.00	17.90	17.29	18.50	17.87	18.01	17.86
1998	18.66	19.36	20.07	21.69	20.97	21.07	17.86	16.95	17.63	17.76	17.28	17.20
1999	18.06	19.54	19.34	20.71	20.47	19.96	16.99	16.09	17.22	16.50	16.78	17.50
2000	18.04	19.17	19.60	20.79	20.31	20.56	17.76	17.19	17.81	17.28	18.26	17.26
2001	18.15	18.95	19.97	21.60	20.23	19.56	17.40	16.78	17.85	18.18	17.60	18.07
2002	17.65	19.94	20.27	21.44	21.53	20.67	18.77	17.95	18.21	17.82	18.61	17.87
2003	18.51	20.02	20.64	21.11	21.36	19.95	17.27	17.30	17.48	17.84	17.85	17.49
2004	18.85	19.08	20.14	20.54	21.05	19.94	17.87	17.75	17.93	17.60	17.77	17.76
2005	18.05	20.87	20.68	21.20	20.67	19.77	17.60	17.85	18.34	17.87	17.50	17.26
2006	18.95	20.15	19.87	20.43	20.47	20.18	18.09	17.18	17.65	18.08	17.63	16.56
2007	17.69	19.15	20.25	20.54	20.98	19.84	17.38	17.16	18.11	17.71	18.09	17.35
2008	18.45	18.94	19.81	20.16	20.53	19.81	17.69	17.30	18.16	17.95	17.48	17.53
2009	18.48	20.24	20.37	21.72	21.33	21.27	17.88	17.88	19.04	18.37	18.20	18.09
2010	19.08	20.06	20.15	22.04	21.69	20.23	17.50	17.16	17.85	18.39	18.62	18.25
2011	18.18	19.84	19.99	21.40	20.54	21.16	18.77	17.57	18.21	17.69	18.46	17.70
2012	18.34	20.24	20.36	20.85	21.33	19.96	17.37	16.89	18.35	18.43	18.08	18.07
2013	18.98	20.22	20.89	21.33	21.41	20.48	18.33	17.20	18.43	18.23	18.11	17.07
2014	18.26	18.84	20.74	20.49	20.34	20.84	18.37	17.48	18.15	18.07	18.15	18.06
2015	17.76	20.17	21.44	21.04	20.96	20.54	19.37	18.09	19.10	19.11	18.56	17.74
2016	18.56	20.15	22.61	21.31	20.57	20.44	18.20	17.67	18.53	18.68	18.11	17.99
2017	18.88	19.61	21.03	20.91	20.67	20.69	18.56	17.70	18.52	18.47	17.99	17.73
2018	17.45	20.69	20.85	20.51	20.67	19.51	17.61	17.05	17.83	18.09	17.50	17.90

Lt												
Mean	18.02	19.11	19.89	20.38	20.28	19.67	17.39	17.01	17.73	17.70	17.41	17.28
SD	0.56	0.91	0.75	0.78	0.65	0.85	0.70	0.67	0.61	0.55	0.66	0.66
CV	3.13	4.78	3.78	3.82	3.21	4.32	4.04	3.91	3.44	3.09	3.80	3.82

Year	Jan	Feb	Mar	Apri	May	June	July	Augu	Sep	Oct	Nov	Dec
1981	6.0	9.5	117.1	78.3	27.5	30.6	296.3	290.8	120.4	24.0	9.3	9.5
1982	22.2	35.2	48.5	68.4	84.9	38.4	177.4	248.8	111.2	57.2	43.9	8.9
1983	8.2	19.4	40.1	70.2	146.5	54.5	197.5	266.9	104.2	36.5	16.5	6.0
1984	7.1	13.9	38.0	23.6	134.3	104.9	169.6	148.3	107.9	9.6	18.2	8.4
1985	16.2	7.7	30.5	104.6	69.7	44.5	279.5	248.7	102.9	24.6	10.9	7.6
1986	7.2	28.9	40.7	100.2	59.6	149.9	233.6	237.2	133.1	25.7	7.8	7.9
1987	9.3	21.0	97.3	67.4	151.6	47.7	116.8	227.8	63.9	31.8	9.3	13.6
1988	11.5	34.0	23.0	53.3	25.3	56.9	459.3	288.6	188.0	43.2	7.1	5.9
1989	12.4	29.0	109.9	103.6	30.4	49.3	235.0	262.5	89.1	32.3	8.1	39.5
1990	10.3	68.8	42.7	61.9	36.3	47.4	269.8	212.1	131.6	13.7	9.5	6.8
1991	10.9	16.2	36.1	28.7	65.0	84.5	238.1	203.0	90.9	29.1	8.4	18.9
1992	14.1	32.0	55.9	63.6	46.2	41.3	149.4	260.0	90.1	37.7	24.0	14.7
1993	9.9	25.6	45.9	144.9	93.5	46.2	252.9	160.1	144.4	49.2	8.1	5.9
1994	7.4	13.9	42.7	45.7	57.2	56.1	325.9	253.8	125.2	14.0	10.7	6.3
1995	7.0	14.2	38.0	74.8	84.0	52.0	238.0	276.7	67.2	15.6	7.7	14.9
1996	19.5	10.2	115.4	94.6	117.3	117.6	254.2	239.5	71.2	15.1	25.9	7.6
1997	17.9	8.5	60.6	85.1	60.9	125.7	259.4	190.2	99.0	81.5	30.7	7.5
1998	13.9	12.8	72.0	40.2	113.9	53.0	380.0	327.1	95.9	73.5	12.1	5.8
1999	15.6	8.1	13.9	42.4	32.6	65.5	359.9	274.7	83.5	91.0	7.3	9.2
2000	6.8	8.3	21.6	121.6	62.4	53.8	386.1	320.9	94.0	50.3	34.6	12.8
2001	6.8	17.9	67.2	43.7	63.1	72.8	357.1	295.5	78.2	19.7	8.6	9.7
2002	19.9	16.4	59.8	55.5	26.6	55.0	254.3	248.4	71.0	14.7	7.7	16.7

2003	13.2	37.0	71.0	38.1	22.9	74.9	247.2	261.9	95.4	17.5	12.5	12.9
2004	15.1	12.3	46.6	79.1	26.5	81.8	240.9	235.1	73.3	30.3	10.4	8.7
2005	12.9	8.1	81.1	71.8	95.3	66.2	300.5	207.3	104.0	31.1	18.7	6.0
2006	9.4	10.9	91.3	75.3	49.7	53.3	317.1	301.8	118.9	38.6	11.3	16.9
2007	13.5	29.6	40.5	52.3	77.5	117.7	300.1	267.3	148.7	30.0	8.1	6.2
2008	13.2	8.5	13.5	47.4	104.7	88.8	309.3	238.6	102.8	34.0	38.9	6.6
2009	11.5	11.8	46.9	42.2	30.9	50.9	294.2	275.3	64.9	63.5	8.5	16.7
2010	10.7	16.7	34.8	87.3	108.8	56.3	370.6	307.5	86.3	14.0	11.3	11.3
2011	13.6	8.3	51.5	63.1	87.0	84.2	246.5	250.1	86.5	14.3	42.4	6.0
2012	7.3	8.0	64.3	48.8	34.5	94.1	343.5	277.8	103.6	25.2	13.2	10.0
2013	10.2	8.9	26.7	56.3	37.5	113.9	358.3	301.6	80.8	65.6	14.5	6.6
2014	10.6	14.0	49.2	77.8	133.0	53.8	204.3	203.9	127.9	57.7	9.2	11.5
2015	10.4	19.3	39.1	46.9	114.3	54.1	104.9	202.9	76.1	15.5	22.2	10.3
2016	9.9	14.1	31.4	55.7	160.9	87.5	308.1	305.8	112.6	22.8	13.7	6.8
2017	8.9	25.7	40.5	68.0	125.2	41.5	269.5	341.8	105.7	21.4	13.0	7.4
2018	9.8	30.6	29.6	59.2	59.6	155.4	321.4	232.4	104.0	36.7	31.1	7.9

Annex Three