GIS AND REMOTE SENSING TECHNIQUES APPLICATION TO THE SPATIO-TEMPORAL CLIMATE VARIABILITY ANALYSIS THE CASE OF ZIWAY DUGDA AND DODOTA WOREDA, ARSI ZONE, OROMIA REGION, ETHIOPIA

BY

ESUBALEW NEBEBE MEKONNEN

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirement for the Degree of Master of Arts in Geography and Environmental Studies Specialization in Geographic Information System (GIS), Remote Sensing (RS), and Digital Cartography

Addis Ababa University

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This is to certify that the thesis prepared by ESUBALEW NEBEBE MEKONNEN, entitled: GIS AND REMOTE TECHNIQUES APPLICATION On The SPATIO-TEMPORAL CLIMATE VARIABILITY ANALYSIS: THE CASE OF ZIWAY DUGDA AND DODOTA WOREDA, ARSI ZONE, OROMIA REGION, ETHIOPIA and submitted in partial fulfillment of the requirements for the Degree of Master of Arts in GIS, RS, and Digital Cartography complies with the regulations of the university and meets the accepted standards with respect to the originality and quality.

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Acronyms

AEZ	Agro-ecological Zone
CSA	Central Statistical Agency
CV	Coefficient of Variation
ESRI	Environmental System Research Institute
ETM^+	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
FEWS-NET	Famine and Early Warning System Network
GCS	Geographic Coordinate System
GIS	Geographical Information System
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
LULC	Land Use Land Cover
MODIS	Moderate Resolution Imaging Spectroradiometer
MSS	Multi Spectral Scanner
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NMA	National Meteorological Agency
NMSA	National Metrological Services Agency
NOAA	National Oceanic and Atmospheric Administration
NRGO	National Regional Government of Oromia
RMSE	Root Mean Square Error
SD	Standard Deviation
SPSS	Statistical Package for Social Sciences
TM	Thematic Mapper
UN	United Nations
UNDP	United Nations Development Program
USAID	United States Developmental Aid
USGS	United States Geological Survey
WGS	World Geodetic System
WMO	World Metrological Organization

Abstract

Climate change is the most complex and cross-cutting environmental problem facing the world today. Ethiopia has historically suffered from climate variability and extremes. The impact of climate variability is high in Ethiopia. The problem of climate change is broadly studied from various angles that emanates from solemnity of the problem. In this regard, the application of GIS and Remote Sensing technologies in analyzing climatic data is crucial. The study aimed at assessing GIS and Remote Sensing Techniques Application on the Spatio-Temporal Climate Variability Analysis: The Case of Ziway Dugda and Dodota woreda of Arsi Zone, Oromia Region, Ethiopia using GIS and Remote Sensing Techniques. In this study, gridded time series data of both rainfall and temperature ranging from 1983-2012 were employed as a principal data source. Auxiliary data from NASA's LANDSAT satellite images of three sets of time 1984^{TM}, 1995^{TM} and 2013^{ETM+} with row 54, 55 and path 168 have been used. In addition, Normalized Difference Vegetation Index [NDVI] data from National Aeronautics and Space Administration [NASA] of Moderate Resolution Imaging Spectrordadiometer [MODIS] terra sensor also utilized. Moreover, a survey was also carried out in the study site. This was made in order to complement the analysis output obtained from gridded data with the survey result. Due to the homogenous nature of the population a total of 40 sample respondents and four key informants: two agricultural extension officers and two Disaster Prevention Preparedness Commission officials, one from each 'woreda' were involved in the study. Both the sample respondents and key informants were carefully selected on the basis of purposive sampling technique. Direct narration and Simple descriptive statistics were used to analyze the data obtained from sample respondents. The temporal and spatial distribution of temperature, precipitation, land use land cover and NDVI have been analyzed in detailed and presented in annual and seasonal basis for different periods using the data obtained from 50 gridded meteorological stations, satellite images and MODIS data for the study site. The study revealed that long term recorded rainfall data showed an increasing trend during the observation period between 1983 and 2012, with an overall mounting rate of 78.8 mm, except inter annual fluctuation and the mean maximum total rainfall analysis output of the same period lacks consistent pattern. Furthermore, late onset and early cessation of rainfall has also characterized the study area. On the other hand, it is found that in the period from 1981 to 2010, the analysis result has shown that the maximum temperature increased by 0.23^0C per decade with an overall rise of 0.7^0C in thirty years period. While the minimum temperature is in a constant rate it did not show significant change in the observation time. Investigations indicate that climate variability is persistent particularly in the small rainy season 'belg', there was a decline in the amount of rainfall and affected vegetation condition and crop production. Statistical correlation analyses shows that there is moderate positive correlation between NDVI and mean annual rainfall in most cases and 'meher' season whereas a strong correlation found between rainfall and NDVI in 'belg' season. On the opposite, negative correlation was found between temperature and NDVI. Lastly, pertaining with the land use land cover classification the result denoted that the proportion of forest coverage is significantly decreasing from time to time. The forest coverage has been reduced to 12258.4 ha (7.5%) by 2013 from that of 1984 having a total forest coverage of 19140.4ha (11.7%). Generally, the time series analysis result reflected that rainfall, minimum temperature and maximum temperature observed in the study area have shown a clear spatial and temporal variation which contributed for the present climate dynamics in the locality.

Keywords: Climate Variability, GIS, Remote Sensing, Spatial, Temporal.

CHAPTER ONE

1.1. Background

Climate change is global in nature, but potential changes are not expected to be globally uniform; rather, there may be dramatic regional differences (Mullugojjam and Ferede, 2012). Climate change is real and happening now. In the present time, climate variability has changed and unseasoned rainfall is often observed (Conway *et al*., 2005). The basic climatic elements such as rainfall and temperature show seasonal and annual variation somewhat different from normally expected climatic conditions. The average global surface temperature has warmed by 0.8°C in the past century and 0.6°C in the past three decades (Hansen *et al*., 2006).

One region of the world where the effects of climate change are being felt particularly hard is Africa. Because of the lack of economic development and institutional capacity African countries are among the most vulnerable to the impacts of climate change (IPCC, 2001). In addition, IPCC (2007) in its report declared that the region will be hard-hit by changing climate because of lack of economic development and institutional capacity to deal with it. As the region strives to achieve sustainable development, national governments are immensely grappling with difficult trade-off and opportunity costs with regard to climate change (Muller *et al*., 2011). Climate change impacts have the potential to undermine and even, undo progress made in improving the socio-economic well-being of East Africans (Ayalew *et al*., 2012).

Ethiopia is one of the developing nations which enjoy an extremely diversified climatic conditions that ranges from semi-arid and desert to humid and warm types across its different parts (NMSA, 2001). To this end, there are different ways of classifying the country's climate systems into a number of agro-ecological zones (AEZs). Across its AEZs, there is a wide variation in mean annual rainfall and temperature (NMA, 2007). Besides, the county's climate is also characterized by a history of climate extremes, changing trends in temperature and precipitation patterns. The trend is that average annual maximum and minimum temperature levels have also been increasing in the country (NMA, 2007).

In a nutshell, currently the world climate is unpresedently changing in a manner that seriously affecting the welfare of people in every corner of the planet; particularly the situation becomes more adverse in developing countries. Ethiopia is one of the developing nations most vulnerable to the impacts of climate change with limited capacity to cope with short-term climatic shocks or adapt to longer-term trends (Conway, 2009).

In Ethiopian context, many studies were made on the issue of climate change and variability in different parts of the country. A study made by Woldamlak and Conway (2007) focusing on temporal and spatial variability of rainfall in the drought-prone Amhara region of Ethiopia and another study carried out by Mikias (2014) emphasizing on the effect of climate change and variability on the livelihoods of local communities the case of central rift valley region of Ethiopia can be mentioned. Nonetheless, from GIS and Remote Sensing perspective the area is little touched. Therefore, as an attempt of unveiling the indispensability of GIS and Remote Sensing in analyzing and portraying critical facts pertinent to climate change and variability, and in doing so, to contribute to the effort of mitigating the negative impact of climate change and variability in a given part of the planet, this study focused on spatio-temporal climate variability analysis the case of Ziway Dugda and Dodota Woredas, west Arsi Zone, Oromia Region, Ethiopia.

1.1. Statement of the Problem

Climate change is rapidly emerging as one of the most serious threats that humanity may ever face. Hence, it has recently become a pressing issue in various development, environment, and political forums at the national, regional, and international levels (Mikias, 2014). There is a substantial concern over the global problem of climate change and it is described as the most universal and irreversible environmental problem facing the planet Earth (IPCC, 2001).

Due attention is given to this issue because of occurrences of damage it might bring to the world following the change. For the world as a whole, the issue of climate change has been studied from different angles using various types of evidence in the last 30 years. It has become clear that not only have there been worldwide climate changes occurring in the last 100,000 years which have undoubtedly affected the distribution of crops and livestock, but also that recent short term climatic change may be affecting agricultural distribution (Guy, 2003 cited in Getnet, 2010).

Arguably, one of the most widespread and potentially devastating impacts of climate change in East Africa had been changes in the frequency, intensity, and predictability of precipitation and Temperature (Mullugojjam and Ferede, 2012). The same source further elucidated that changes in regional precipitation will ultimately affect water availability and may lead to decreased agricultural production and potentially widespread food shortages. Supporting this idea, Hulme *et al*., (2001) point out that changes in rainfall pattern will ultimately affect crop production and potentially widespread food shortages.

In addition, IPCC (2001) report and Woldeamlak and Conway (2007) indicated that the amount and temporal distribution of rainfall is thus the single most important determinant of national crop production levels from year to year, and rainfall in much of the country is often erratic and unreliable. Likewise, rainfall in much of the country is often erratic and unreliable; rainfall variability and associated droughts have historically been major causes of food shortages and famines (Wood, 1977; Pankhurst and Johnson, 1988 drawn in the works of Ayalew *et al*., 2012).

Climate variability in Ethiopia is not new. In relation with this, Bishaw *et al*., (2013) argued that Ethiopia is especially vulnerable to climate variability and change because large segments of the population are poor and depend on agricultural income, which is highly sensitive to rainfall variability. Its diverse agro-ecological zones are characterized by a dazzling variety of micro-climates and corresponding weather patterns.

The climate of Ethiopia is mainly controlled by the seasonal migration of the Inter-tropical Convergence Zone (ITCZ), which follows the position of the sun relative to the earth and the associated atmospheric circulation in conjunction with the complex topography of the country (NMSA, 2001). On the other hand, NMA (2007) indicated that the mean annual minimum temperature and annual rainfall variability and trend observed over the country in the period 1951-2006. The result reveals that there has been a warming trend in the annual minimum temperature over the past 55 years. It has been increasing by about 0.37^0C every ten years. The trend analysis of annual rainfall shows that rainfall remained more or less constant when averaged over the whole country. The same source also made climate projection that the mean annual temperature will increase in the range of 0.9^0C -1.1 ^{0}C by 2030, in the range of 1.7 - 2.1^0C by 2050 and in the range of 2.7-3.4 ^{0}C by 2080 over Ethiopia compared to the 1961-1990 normal.

Different researches had been conducted to assess the spatial and temporal patter of climate elements in different parts of the country. A recent study was made by Taye *et al*., (2013) focusing on spatiao-temporal variability and trend of rainfall and temperature in western Amhara region from GIS and remote sensing perspective. The study revealed that the contribution of *kiremt* rainfall to the annual total rainfall was very high in all study stations. Variations of minimum and maximum temperatures were found in every month. Similarly, another research carried out by Ayalew *et al*., (2012) examines variability of rainfall and its current trend in the same region. The study has found out that long term movements of rainfall in a time series did not show any increasing or decreasing trend of rainfall.

Hence, in this study an attempt was made to analyze the spatio-temporal variability of climate elements the case of Ziway Dugda and Dodota Woreda, Arsi zone, Oromia Region. As to the knowledge of the researcher no similar study was carried out in the study area. Basically, the investigator was necessitated to conduct this research primarily to fill the discrepancy that is not treated by previous researchers and provide a cumulative knowledge in the area by incorporating the issue of GIS within the whole package of climate change driving variables. Therefore, this study would be a remarkable piece of work which clearly portrays the prevailing situation.

1.2. Objectives of the Study

Above all, this study conceptualizes spatio-temporal analyses of climate variables in the essence from different angles.

1.2.1. General Objective

- To analyze climate change driving variables across time and space on the selected study site using GIS and RS methods.

1.2.2. Specific Objectives

- To analyze the trend of rainfall and temperature pattern both in space and time using time series data to reveal the dynamism of climate;
- To examine the effect of climate variability on the vegetation particularly on the size of forest cover using land use/land cover change detection analysis;
- To comprehend how far the outputs of gridded climate data correlated with Normalized Difference Vegetation Index value (NDVI);
- Explore the trend of November rain performance using time series data and its effect on the local people;

1.3. Significance of the Study

The issue of climate variability and change is widely studied in the world. The impact of the climate brings serious damage especially in developing countries. Ethiopia currently faces various problems resulted from climate variation even though the degree of the climate change is not clearly identified. In light of the situation and profile of the project area, analyzing major climate change elements will have some paramount importance on account of the following reasons.

- Analyzing the spatial-temporal trend of rainfall and understanding the subsequent trends of the change will have a vital importance to the present understanding of the dynamics of climate system in the locality.
- Very little was done on spatial-temporal climate variability study. Therefore, this study by far can be used as a benchmark for further studies.

1.4. Limitation of the Study

No research, per se, is complete and free from limitations. This paper is, therefore, constrained by the following.

- One of the drawbacks in this study was variation of time span coverage of basic climate data i.e. rainfall and temperature. The rainfall ranges between 1983 and 2012 while the temperature lasts from 1981 to 2010. But, it would have been better if both data has the same time span coverage. Nevertheless, the difference does not have a negative implication on the result of the study.
- The other serious problem was difficulty of downloading satellite images required to undertake the study. This is due to the big size (up to 1GB and above) of the satellite imagery and poor internet connectivity. In addition, the presence of cloud cover on some downloaded satellite images made the problem more adverse and interpretation difficult.

1.5. Delimitation of the Study

The project is mainly designed to analyze the spatial-temporal analyses of climate elements. Geographically, the scope of the study is confined to Ziway Dugda and Dodota Woreda found in west Arsi zone, Oromia region, Ethiopia where both the distribution of rainfall and temperature were highly erratic in nature. More specifically, among the various climate variables in this study particularly rainfall and temperature were thoroughly analyzed.

1.6. Organization of the Study

The project is organized in to five chapters. The first chapter contains introduction and statement of the problem. In addition, it briefs the basic questions, objectives, significance of the study, scope of the study, organization of the paper and definition of key terms.

The second chapter deals with review of related literature. This part addresses the relevant literature that is very much associated with the research topic. Hence, it is the background of the study, which is used as a springboard to sketch the direction of the study. It includes four main bodies; the various arguments on the concept of spatial and temporal variation of climatic elements, basic concepts on land use land cover change, normalized difference vegetation index, and empirical evidence made in the study area.

The third chapter explains the materials and methods. It clearly indicates the type of methodology used, data sources, and the different tools and software and finally a conceptual framework that helps to understand the spatial-temporal analysis of climate elements. The fourth chapter vastly concerned with analysis and interpretation, and presentation of the result. Finally, the fifth chapter covers conclusion and recommendations.

1.7. Operational Definition of Terminologies

Belg: the expression for the short rainy agricultural season in parts of Ethiopia.

Meher: expression for the long rainy season in parts of Ethiopia.

Dega: expression for one of the altitudinal agro-ecological belts in Ethiopia.

Kolla: expression for one of the altitudinal agro-ecological belts in Ethiopia.

Weyna Dega: expression for one of the altitudinal agro-ecological belts in Ethiopia.

Woreda: the smallest local administrative unit for a district.

District: is interchangeably used with woreda throughout the study to mean the same meaning.

CHAPTER TWO
REVIEW OF RELATED LITERATURE

2.1. The Concept of Climate and Climate Change

As drawn in the work of Yitea (2012) climate is described in terms of the variability of relevant atmospheric variables such as temperature, precipitation, wind, snowfall, humidity, clouds, including extreme or occasional ones over a long period in a particular region. The classical period for performing the statistics used to define climate corresponds to at least 3 decades, and it is designated by "climate normal period", as defined by the World Meteorological organization (WMO). As a result, the 30 year period proposed by the WMO should be considered more as an indicator than a norm that must be followed in all cases but other periods may be used depending on the purpose. This definition of the climate as representative of conditions over several decades should of course not mask the fact that climate can change rapidly. Climate can thus be viewed as a synthesis or aggregate of weather in a particular area for a long time (Goosse *et al*., 2010). The same source further underlined that the two most important factors determining an area's climate are air temperature and precipitation.

Basically, the term climate derived from ancient Greek *"klima"*, meaning *"inclination"* is commonly defined as the weather averaged over a long period of time. Different scholars explained the concept of climate in different perspectives in this regard Kadir *et al*., (2013) defined Climate generally as "average weather". It is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time. The same source further elucidated that global observations of temperature increases and changes in other climate variables provide unequivocal evidence that the climate is warming.

Sensoy and Demircan (2010) conceive climate in a narrow sense defined as the *"average weather,"* or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years whereas climate in a wider sense is the state, including a statistical description, of the climate system.

Consistently, the same study noted that climate is defined as the collective state of the atmosphere for a given place over a specified interval of time. On the same source it is indicated that there are three parts to this definition; the first deals with the state of the atmosphere. The collective state is classified based on some set of statistics. The most common statistic is the mean, or average. Climate descriptions are made from observations of the atmosphere and are described in terms of averages (or norms) and extremes of a variety of weather parameters, including temperature, precipitation, pressure and winds.

The second part of the climate definition deals with a location. It could be a climate the size of a cave, the Great Lakes region, or the world. In weather and climate studies we are most interested in micro-scale, regional, and global climates. The climate of a given place should be defined in terms of your purpose.

Time is the final aspect of the definition of climate. A time span is crucial to the description of a climate. Weather and climate both vary with time. Weather changes from day to day. Climate changes over much longer periods of time. Variations in climate are related to shifts in the energy budget and resulting changes in atmospheric circulation patterns. The difference between climate and weather is usefully summarized by the popular phrase "*Climate is what you expect, weather is what you get*."

Climate change is probably the most complex and challenging environmental problem facing the world today. In relation with this, Hegerl and Zwiers (2007) stated that climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. The climate change caused could be potentially due to internal processes and/or external forcings. Some external influences, such as changes in solar radiation and volcanism, occur naturally and contribute to the total natural variability of the climate system. Other external changes, such as the change in composition of the atmosphere that began with the industrial revolution, are the result of human activity.

In addition, International Panel on Climate Change [IPCC] (2007) having the same essence 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/or the variability of its properties and that persists for a prolonged period, typically decades or longer". The same source also explained that climate change may result from internal processes of the climate system and/or external forcing. Some external influences, such as changes in solar radiation and volcanism, occur naturally and contribute to the total natural variability of the climate system. Other external changes, such as the change in the composition of the atmosphere that began with the industrial revolution, are the result of human activity.

Moreover, Mukheibir and Ziervogel (2007) quoted in Getnet (2010) explained climate change as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change can also be defined as a trend in one or more climatic variables characterized by a fairly smooth continuous increase or decrease of the average value during the period of record. Furthermore, Changes in climate, which is generally defined as "average weather," is usually described in terms of the mean and variability of temperature, precipitation, and wind over a period of time. Changes in climate can be tracked 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 (IPCC, 2007). The climate system is affected by both its own internal dynamics and external factors. External factors ('forcing') include natural phenomena such as volcanic eruptions and solar variations, but human induced factors as well, such as the burning of fossil fuels and the clearing of forests, both of which lead to changes in the atmospheric composition.

Today, climate change and its consequences receive much attention in the public debate. It is the most complex and cross-cutting environmental problem which afflicts every corner of the world its impact is diverse and globally witnessed. In relation with this NMA (2007) in its report stated about the prominence of climate is that it is a key natural resource on which the others depend.

It influences food production, water and energy availability. It also sets the stage for the establishment of habitats, affects the pace of primary productivity, and influences species density and distribution.

In general, climate is the average state of the atmosphere and the underlying land or water, on time scales of seasons and longer. Climate is typically described by the statistics of a set of atmospheric and surface variables, such as temperature, precipitation, wind, humidity, cloudiness, soil moisture, sea surface temperature, and the concentration and thickness of sea ice. The statistics may be in terms of the long-term average, as well as other measures such as daily minimum temperature, length of the growing season, or frequency of floods. Although climate and climate change are usually presented in global mean terms, there may be large 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.

2.2. Major Attributes of Climate Change

2.2.1. 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 (IPCC, 2007). In this regard, rainfall and temperature are the two most prominent variable influences the climate of a region.

Precipitation is the general term for rainfall, snowfall and other forms of frozen or liquid water falling from clouds. A changing climate can directly influence precipitation amount, intensity, frequency and type. Large natural variability and strong geographic variations in these parameters are evident, substantially affected by atmospheric circulation patterns such as the El Niño Southern Oscillation. Increased warming accelerates evaporation and increases the amount of water vapor in the atmosphere, resulting in certain areas getting wetter and others getting drier. Widespread increases in heavy precipitation events have occurred even in places where total amounts have decreased (Kedir *et al*., 2013).

2.2.2. Rainfall and Temperature Trend

Quoting IPCC Ericson (2008) cited on Getnet (2010) wrote that annual rainfall is likely to decrease throughout most of the African region, with the exception of Eastern Africa, where annual rainfall is projected to increase. Trend analysis of annual rainfall in Ethiopia shows that rainfall remained more or less constant when averaged over the whole country while a declining trend has been observed over the Northern half of the country and Southwestern Ethiopia. On the other hand, recent climate trends based on UNDP climate data indicate change in temperature and rainfall. There is a clear and observable positive trend in temperature. Ethiopia shows a consistent warming trend, with observation of increasing minimum and maximum temperature over the past fifth years (McSweemy, *et al*., 2010 drawn in the work of Abaddi *et al*., 2013).

Surface of the Earth has warmed between 0.4^{o}C and 0.8^{o}C 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 rise in greenhouse gas concentrations would suggest that any greenhouse-induced warming should have been steady over the past 100 years. A research by various authors indicates that there is an increase of temperature over all of the country. Earliest climatological station of Gondar prior to 1993 had an anomaly of -4^{o}C while the result is abruptly increased to 4^{o}C in the preceding years since 2006 (Getnet, 2010).

Mikias (2014) indicated that the trend of climate change and variability in the rift valley area were gradually changing. The rainfall is highly variable both in amount and distribution across regions and seasons. The study area has experienced frequent climatic shocks, extended drought and delay in the onset of rain, erratic and low precipitation, and heavy and un-seasonal rainfalls these are some of the indicators of climate change and variability. As shown in the intensity, duration, frequency and distribution of rainfall decreased from time to time, whereas the temperature is increasing at an alarming rate. According to Negele Metrology Station recorded data (1981-2010), the precipitation trend of the area has shown dramatic decline, and the annual average temperature has shown an alarming rate of increase from (1981-2009).

2.3. Climate System in Ethiopia

According to NMA (2007) Climate is often described by the statistical interpretation of precipitation and temperature data recorded over a long period of time for a given region or location. Mean annual rainfall distribution over the country is characterized by large spatial variation which ranges from about 2000 mm over some pocket areas in the Southwest to less than 250 mm over the Afar and Ogaden low lands.

Regarding rainfall during the year occurs in different seasons. Unlike most of the tropics where two seasons are common (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 extends from (February to May), and Kiremt (long rain season) which extends from June to September (NMSA, 2001)

Temperatures are also very much modified by the varied altitude of the country. In general, the country experiences mild temperatures for its tropical latitude because of topography. Mean annual temperature distribution over the country varies from about 10^0 c cover the highlands of northwest, central and southeast to about 35^0c over north-eastern lowlands.

2.3.1. Agro Ecological Features of Ethiopia

There are many different regional climates across the world. To make sense of this variability we devise classification schemes in which important characteristics of a phenomenon are grouped into classes that have issues in common. The goal of classification is to identify and group together things that have similar characteristics. Climate classifications describe the world's climates. The problem with classifying climates is that there are few sharp dividing lines between different climates. There are gradual transitions from one climate to another.

A challenge in designing a climate classification scheme is that climates fluctuates and transition zones often exist between two very different climate regions, making sharp boundaries difficult to establish. One of the simplest climate classification schemes is based on solar illumination. This approach does have sharp boundaries.

Temperature and precipitation are two important climate variables. These two parameters typically define the type of vegetation that can grow in the region. It is therefore useful to classify climate according to these variables (Sensoy and Demircan, 2010).

The climate of Ethiopia is mainly controlled by the seasonal migration of the Inter-tropical Convergence Zone (ITCZ), which follows the position of the sun relative to the earth and the associated atmospheric circulation, in conjunction with the complex topography of the country (NMSA, 2001). There are different ways of classifying the climatic systems of Ethiopia, including the traditional, then Koppen's, the Throthwaite's, the rainfall regimes, and the agro-climatic zone classification systems (Temesgen *et al*., 2010).

The strongly varying topography of Ethiopia leads to three distinct climate zones across the country; namely, Dega (cool zone), Weyna-Dega (temperate zone) and Kolla (hot zone); Within each climatic zone, seasonal variations and changing atmospheric pressure systems contribute to the creation 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 crosscutting the western and eastern section of the high plateaus above 2400 up to 4620 meters above mean sea level, a temperate zone between 1,500 and 2,400 m.a.s.l, and the hot lowlands below 1,500 m. Mean annual temperature varies from less than 7-12ºC in the cool zone to over 25ºC in the hot lowlands (NMSA, 2001).

In general, the climate of Ethiopia varies from humid to semiarid (Kim *et al*., 2009). It is typically tropical in the south-eastern and north-eastern lowlands regions, but cooler in the large central highland regions of the country. Mean annul temperatures are around 15-20^{0}C in these high altitude regions, whilst 25-30^{0}C in the lowlands. The climate trend of Ethiopia over the last decades is such that the temperature has been increasing with about 0.2^{0}C per decade. However, the increase in minimum temperatures is more pronounced with roughly 0.4^{0}C per decade. The averaged precipitation over the country, on the other hand, has remained fairly stable over the last 50 years when averaged over the country (Keller, 2009).

There are different types of climate classification systems depending on the climatic element used. The most widely used is Koppen Climate Classification System (Pidwirny, 2006). Its classification is based on the annual and monthly averages of temperature and precipitation characteristics (Yitea, 2012).

The most commonly used climate classification systems are the traditional and the agro ecological zones (AEZs). According to the traditional classification system, which mainly relies on altitude and temperature, based on this classification Ethiopia has five climatic zones.

Table 1: Traditional climatic zones and their physical characteristics

Zone	**Altitude (meters a.s.l)**	**Rainfall (mm/year)**	**Average annual temperature (^{o}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)	1,500 – 2,300	800 – 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).

2.4. 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 several scholars. The problem of climate change is broadly studied from various angles that emanate due to the seriousness of the problem. Among those, the most recent is the application of satellite images which is used to analyze through Remote Sensing and GIS techniques that is developed with the development of Earth Observing satellites.

Reducing the risks caused by climate change is an immense challenge. Scientists, policy makers, developers, engineers, and many others have used geographic information system (GIS) technology to better understand a complex situation and offer some tangible solutions.

A GIS based framework helps us to gain a scientific understanding of earth systems at a truly global scale and leads to more thoughtful, informed decision making. GIS users represent a vast reservoir of knowledge, 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 explained that the key 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 merge them together in a single system. GIS creates a new framework for studying global climate change by allowing users to inventory and display large, complex spatial data sets. They can also analyze the potential interplay between various 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 crucial in the world today both in developed and developing countries. Epidemiological studies also possible by integrating of spatial data with malaria as attribute data (Cracknel, 2001).

2.5. Land Use/Land Cover Change Implication on Climate Change

Land use refers to man's activities and the varied uses which are carried on over land and land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others noticed on the land (NRSA, 1989).

Land Cover, defined as the assemblage of biotic and a biotic components on the earth's surface is one of the most crucial properties of the earth system. Land cover is that which covers the surface of the earth and land use describes how the land cover is modified. Land cover includes: water, snow, grassland, forest, and bare Soil. Land Use includes agricultural land, built up land, recreation area, wildlife management area etc.

Land surface is an important part of the climate system. The interaction between land surface and the atmosphere involves multiple processes and feedbacks; all of which may vary simultaneously. It is frequently stressed that the changes of vegetation type can modify the characteristics of the regional atmospheric circulation and the large-scale external moisture fluxes. So that Changes in surface energy budgets resulting from land surface change can have a profound influence on the Earth's climate (WMO, 2005).

The Earth system is composed of a number of biogeochemical cycles, all powered by the sun's energy. These global cycles include the circulation of certain elements, or nutrients, upon which life and the earth's climate depend. Then, through these cycles, all components of the environment are interrelated and greatly affect each other. Apart from these effects, the presences of drought and hydrological feedbacks associated with land-use change locally or through tele-connections, have a direct impact on the source/sink capabilities of the terrestrial ecosystem. These feedbacks, along with other climate forcing and feedbacks, makes climate prediction difficult problem, on time-scales of years. Therefore, the biogeochemistry has a significant role within the climate system (Netsanet, 2007).

Nevertheless, studies of tropical deforestation are inconclusive on its effects on local or global climate. Deforestation has been found to warm the Amazon basin, and in central Argentina. The effect of vegetation cover is to lower the surface temperature due to increased evapotranspiration. However several authors have found that tropical deforestation is likely to induce changes in atmospheric circulation, and that these changes may have consequences on precipitation and temperature patterns on a global scale (Gibbard *et al.,* 2005).

Many studies have revealed the extent to which changes in the land surface have affected local and regional climates and it is increasingly clear that some changes in the land surface can have significant impacts on the climate in distant parts of the Earth (Marland *et al*., 2003 cited in Netsanet, 2007).

2.6. Implication Normalized Difference Vegetation Index (NDVI) on Climate Change

Climate plays a major role in vegetation phonological cycles. Vegetation growth is functionally dependent on climate. Consequently, a change in biophysical parameter of vegetation canopy implies a change in climate, accordingly vegetation are used as key inputs into climate change models (Ogunbadewa, 2013). Climate variability is one of the most important factors affecting vegetation condition. In this regard, remote sensing plays an important role to detect and characterize vegetation dynamics that affected by climate variability.

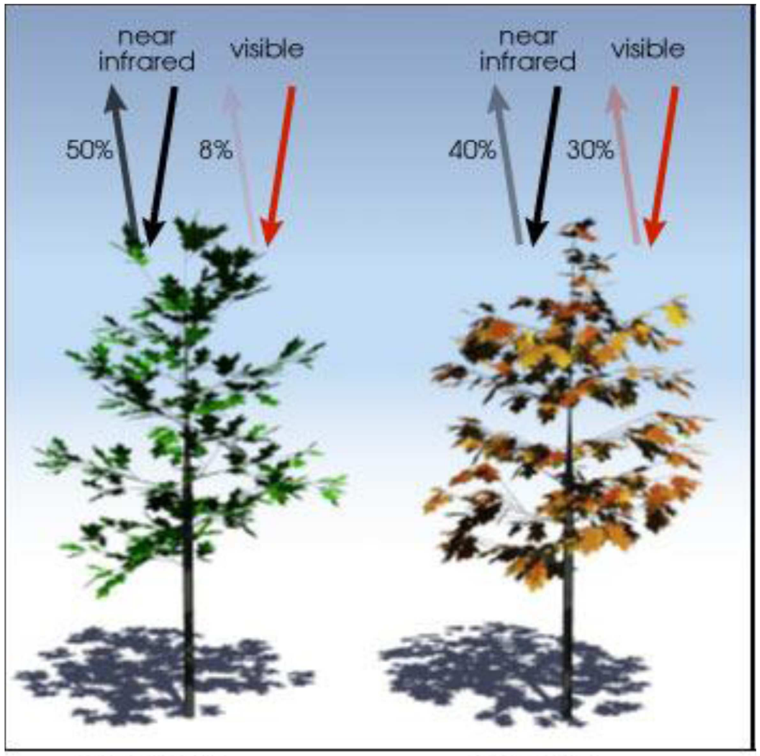
The Normalized Difference Vegetation Index (NDVI) is related to the quantity of photo-synthetically absorbed radiation. It is a measure of the amount and vigor of vegetation on the land surface. In general, NDVI values range from -1 to 1.0, with negative values indicating clouds and water, positive values near zero indicating bare soil, and higher positive values of NDVI ranging from sparse vegetation (0.1 - 0.5) to dense green vegetation (0.6 and above) (USAID, 2006).

Green and healthy vegetation reflects much less solar radiation in the visible part of electromagnetic spectrum compared to those in near-infrared part. More importantly, when vegetation is under stress, visible values may increase and near infrared values may decrease. The NDVI is calculated from two channels, the near infrared (NIR) and among the visible part the red portion of electromagnetic spectrum using the following algorithm:

$$\text{NDVI} = \lambda NIR - \lambda RED / \lambda NIR + \lambda RED$$

Where, λRED is red portion of electromagnetic spectrum (0.6-07μm) and λNIR =near infrared portion of electromagnetic spectrum (0.75-1.5μm).

The Normalized Difference Vegetation Index (NDVI) is a method used to analyze the vegetation cover of an area. NDVI is calculated from reflectance measured in the visible and near infrared channels from satellite-based remote sensing. NDVI shows the temporal and spatial change of Vegetation cover. Pertaining with this the vegetation tool sees the entire landscape every day because of its huge field of view and is an important tool for studies worldwide vegetation (Baret *et al*., 2006 quoted in Tinebebe, 2012).



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

Computation of NDVI
Source: FEWS-NET (2007)

2.7. Empirical Evidence

Climate change is probably the greatest long-term challenge facing the human race. Humanity everywhere in the world is being haunted by multitudes of problems and challenges; and in effect, climate change is one of humanity's most devastating problems. Different researches had been conducted to assess the spatial and temporal patterns climate in different parts of the country. Particularly a few studies have been conducted on the issue of climate variability both in space and time. In this regard, 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 denoted that temperature is getting increased by 0.37^{o}C in the rift valley and 0.48^{o}C in highland and by 0.4^{o}C in whole areas per 12 years and rain is constant and shows insignificant rise.

In addition, another recent study carried out by Mulugojjam 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 revealed that the contribution of *kiremit* rainfall to the annual total rainfall was very high in all study stations. Variations of minimum and maximum temperatures were found in every month. The long term recorded rainfall data indicated an increasing trend during 1995-2008 and decreasing trend during 1979-1994, except, inter-annual fluctuation. Further, late onset and early cessation of rainfall was noted in all study stations in recent years. The spatiotemporal variability of rainfall, minimum temperature and maximum temperatures observed in the study stations are alarming.

On the other hand, Dereje *et al*., (2012) studied variability of rainfall and its current trend in Amhara region, Ethiopia. For this purpose, 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 varied from 850 to 1485 mm. Belg ("small rainfall" in March – 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 growing period due to early cessation of rainfall had been observed in recent years.

CHAPTER THREE
MATERIALS AND METHODS

The main objective of the study is to examine the spatio-temporal climate variability analyses of climate elements the case of Ziway Dugda and Dodota Woreda, Arsi zone, Oromia Region, Ethiopia. The rational for the selection of Ziway Dugda and Dodota Woreda as research site is due to the prevalence and harshness of the problem. In addition, the assessment made on Arsi zone by Piguet (2003) and [NRGO] National Regional Government of Oromia (2011) indicated that all the 22 Woredas found in the Arsi zone are afflicted by prolonged drought and climate variability. Among those, the most vulnerable Woredas were Dodota Sire and Ziway Dugda. Furthermore, according to the socio-economic activity and geo-ecological location criteria made by Thornton *et al*., (2006) and Morton (2007), the zone is categorized as a hotspot for climate change impacts. Many of the districts are located in the central Rift Valley of Ethiopia. As a result, the area is highly prone to climate variability indices.

3.1. Data Sources

The main sources of the data in this study were both primary and secondary sources. To obtain information on spatio-temporal climate variability analysis, empirical data were collected. Accordingly, the first-hand information was collected from the National Meteorological Agency of Ethiopia, farmers found in the two woredas, Agricultural Extension office of Dodota and Ziway Dugda Woreda and Disaster Prevention and Preparedness Commission [DPPC] of East Shewa Arsi Zone Dodota and Ziway Dugda Woredas. Different secondary sources of data were used to derive the required information for this study. This includes pertinent documents like; available recorded documents in the two Woredas, previous literatures, and review of relevant published and unpublished documents, journals, and reports which are written on the subject under investigation were consulted and important ideas were taken and included in this study.

3.2. Sampling Techniques

A total of fourty farmers, two agricultural extension officers and two disaster prevention preparedness commission officials; one expert from each Woredas have participated in this study. The basic reason the researcher has taken only forty samples was mainly due to the homogenous nature of the respondents. Only peasants who have lived long time in the study area and had detail information about the past and present situations of the area, mostly elder peoples, were included in the study. This was done in order to obtain in-depth information about the issue under investigation. Purposive sampling was used to select both sample respondents and key informants to get the general information. Purposive sampling was mainly used because this type of data collection technique is a rational methodology. It helps to clearly explore target groups and to generate the desired information. In this respect, Dolores and Tongco (2007) noted that purposive sampling may also be used with both qualitative and quantitative research techniques. The inherent bias of the method contributes to its efficiency, and the method stays robust even when tested against random probability sampling.

3.3. Data Collection Method and Instruments

Both primary and secondary sources of data were used to get reliable information for the study. The primary information was collected through questionnaire and personal interview. A self-administered questionnaire was carried out with peasants to capture the reality on the ground and an in-depth interview was held with heads of Dodota and Ziway Dugda Woreda agricultural extension officers and respective DPPC heads. Secondary data was also employed which was obtained from the two administrative Woredas which revealed crop performance record of the two districts in the past years.

3.3.1. Questionnaire

Questionnaire is the major instrument chosen by the researcher to collect data from the selected sample farmers regarding their livelihood source, opinion on the present climate change in the past decades and the amount and distribution of rainfall in the locality. Clarification and direction was given by the researcher assistant by translating the questionnaire into their local language Oromifa to the sample respondents. The structure of questionnaires consists of both structured and semi-structured. As suggested by Bryman (2008) semi-structured questionnaire was found to be an appropriate strategy for the study because questions that were not included in the interview guide were asked and new questions were raised as ideas emerge through the process.

The advantage of this type of question over the unstructured (“open- ended,”) question is its greater reliability. It is a more reliable (consistent and stable) question because subjects are given specific responses from which to choose. The data from this type of question are more easily analyzed than data from open-ended items (Yount, 2006). The open-ended item, however, increases the likelihood that subjects will respond incorrectly (that is, in a way not planned by the researcher). Supporting this idea Henn *et al*., (2006) indicated that open questions may be long and complex, and when written by the respondent, they may be hard to read. For these reasons, open questions may be difficult to code and analyze. Due to this reason, the study used semi-structured question.

3.3.2. In-Depth Interview

An in -depth interview is one of the most important qualitative research method employed by the researcher. 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 being inclusive of all varieties of participants; it became comprehensive and capture most realities. The researcher used 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 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 using a tape recorder in parallel with a back-up note was also taken and the interview was transcribed while the interviewer memory was still fresh.

3.4. Major Data Types and Sources

3.4.1. Meteorological Data

This study largely depends on the data obtained from National Metrological Agency. This consists of basic climatic elements of rainfall and temperature record of the past thirty years. The rainfall data extends from 1983 to 2012, while the temperature data lasts from 1981 to 2010. The presence of time span variation between rainfall and temperature data was not intentionally done by the researcher rather it is the only available data obtained from the National Metrological

Agency (NMA). In line with this, as noted in [WMO] World Metrological Organization (2005), the classical period to study climate related issues is 30 years. In this regard, it is possible to note that the study satisfies the basic criteria set by World Metrological Organization. A total of 50 gridded metrology stations were involved in this study each is situated with 10 km interval. Among those, 16 stations are completely found within the study area. The remaining 34 neighboring stations were used for interpolation purpose in order to convert the point data into a continuous raster surfaces and to make the result more reliable and consistent (Figure 1).

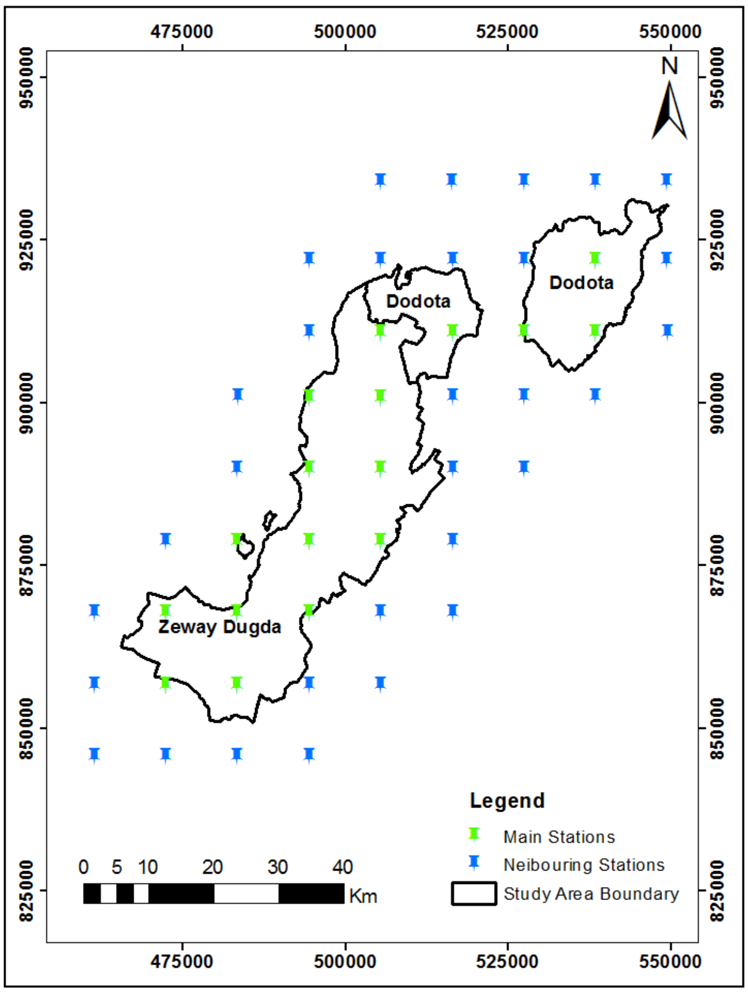


Figure 1: Gridded Meteorological stations distribution in the study area

The Long term (30 years) records of monthly rainfall, maximum and minimum temperature gridded data used for the study was obtained from the National Meteorological Agency (NMA) of Ethiopia. Initially the researcher used the gauge data. However, due to the presence of limited stations within the study site, the output was unrealistic. As a result, it is found imperative to use the grid data. In addition, the gauge data has many limitations; missing data for the particular observation was one of the most serious problems. Moreover, the meteorological stations were irregularly distributed over the study area i.e. does not cover the intended area as desired. To this end, it is found extremely important to use gridded data for this study.

3.4.2. Satellite Image Data

The satellite imageries used were that of the United States Geological Survey [USGS] Land Sat of three point of time for the year 1984, 1995 and 2013 with 168 paths, and 54 & 55 rows. The spectral characteristics of the images are described below.

Table 2: Spectral Characteristics of satellite images

Sensor	Number of spectral bands	Spatial Resolution (m)	Date of acquisition
TM (Land sat_5)	6	30m	December 21, 1984
TM (Land sat_5)	6	30m	January 15, 1995
ETM^+ (Land sat_7)	7	30m	December 21, 2013

The TM instrument on Land sat 5 and ETM^+ instrument on Land sat 7 observe the Earth with 7 different filters or "*bands*". Bands 1, 2, 3, 4, 5, and 7 on both instruments are sensitive to light energy from the sun reflected by the surface of the earth. Each band is sensitive to a different part of the reflected solar energy. The parts of the reflected energy are defined by the length of light waves. Thus, band 1 of the TM and ETM+ instruments records reflected light energy only in the range of 0.45 microns (µm - a micron is one millionth of a meter long) to 0.52 µm.

The human eye sees reflected light in that band of wavelengths as the color blue; hence, band 1 is sometimes referred to as the blue band. In a similar manner, bands 2 and 3 of the TM and ETM+ instruments record reflected green and red light, respectively. TM and ETM+ bands 4, 5, and 7 record reflected light in wavelengths that human eyes cannot detect. These bands are referred to as near infrared (NIR, band 4) and short wave infrared (SWIR, bands 5 and 7). Band

6 of the TM and ETM+ instruments is different from all the other bands because it does not record reflected light energy, but rather heat energy emitted by the Earth's surface. It is sometimes called the thermal infrared band (TIR band) or just the thermal band.

3.4.3. Gridded Datasets Derived from Satellite Platform

The multi-temporal images used (Table 6) were acquired from the NASA Terra (AM-1) satellite's Moderate Resolution Imaging Spectroradiometer [MODIS] sensor. The MODIS 500m NDVI product (MOD13A1) 16 day composites provided the needed vegetation phenology data. The MODIS re-projection tool was used to convert HDF file to Geotif and images were resampled using the nearest neighbor operator from their native sinusoidal projection to geographic projection with datum WGS 84. The monthly NDVI raster map and others such as maximum, minimum and mean NDVI values were extracted by averaging the 16-composite.

The normalized difference vegetation index (NDVI) is related to quantity of photo-synthetically absorbed radiation. It is a measure of amount and vigor of vegetation on the land surface. In general, NDVI values range from -1.0 to 1.0, with negative values indicate clouds and water, positive values near zero indicate bare soil, and higher positive values of NDVI ranging from sparse vegetation (0.1-0.5) to dense vegetation (0.6 and above) (USAID, 2006).

Likewise, although the Normalize difference vegetation index (NDVI) value classification is not specific, depending on previous some studies, the vegetation condition of the region is classified as high vegetation (values above 0.5), medium vegetation (from 0.29 - 0.5), low vegetation (0.166- 0.292), no vegetation (from 0.1 -0.166) and water body (USGS, 2011).

Table 3: Spectral Characteristics of Satellite Image

Satellite system	Sensor	Spatial resolution	Temporal resolution	Time-period/ Acquisition date
NASA	MODIS Terra	MOD13A1 500m NDVI	16 day composite	From 2000 -2012

Generally, the first step was to adjust the NDVI value between -1 and 1. This was done on ArcGIS environment using raster calculator by multiplying the input data with "0.0001" and make the data permanent using tiff image format. Afterwards, after all the data sequentially arranged, visually inspected, the data was aggregated in to seasonal (Kiremt and Belg) and annual basis. Followed by, subset the area of interest (AOI) using extract by mask tool available in spatial analyst. After doing so, subsequently, average NDVI value was calculated for the seasonal and annual ones. This was carried out by simply summing all the input data and dividing the sum by N (number of input data).

3.4.4. Field Observation

The field trip was arranged for a week. The trip covered the main parts of the study area extends from Tero kebele of Dodota Woreda to Ogolecho town. During the field trip, ground truths point data were collected using GPS, X and Y coordinates of climate stations were also coded and registered. Climatic situation of the study area and Land use land cover patterns are also partially identified.

3.4.5. Tools and Software's

Different software was utilized in this study in order to analyze spatial-temporal climate variability analysis. ERIDAS IMAGINE 9.2, ArcGIS10.1, GLOBAL MAPPER, GOOGLE EARTH, EASY GPS, ENVI, VISO, JMP (statistical software version 11) and SPSS software were used for data processing, analyzing and interpreting the result.

3.4.6. Base Cartographic Datasets

There are other relevant dataset that are used in this study, like shape file which is developed for 2007 population and housing census obtained from Central Statistical Agency (CSA). The shape file was basically 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 projected to the geographic coordinate system WGS_1984. This was made to ensure consistency between the datasets.

3.5. Method of Data Analysis

The rainfall, minimum and maximum temperature data were captured into Microsoft excel, 2010 spreadsheet on monthly basis. Data quality control was done by careful inspection of the completeness, spatial and temporal consistency of the rainfall, and temperature records in the study areas.

The next step was data preparation, at this stage, all the datasets was organized and arranged in a desired order to make ready for the analysis. For every climate variables a total of 56161 records of temperature (maximum and minimum) and rainfall data were gleaned from metrology agency in a softcopy. Every data was carefully filtered. Then, both the rainfall and temperature data aggregated in to seasonal and annual ones. Time series annual rainfall and temperature datasets were subjected to detailed analyses of using sequences of statistical packages available on Arc GIS environment and mapped. In addition, seasonal rainfall variability of the study stations was analyzed and mapped using Arc GIS 10.1 software. Coefficient of variation (CV) was calculated as the ratio of standard deviation to the mean (NMSA, 1996 quoted in Taye *et al*., 2013).

3.5.1. Geo-statistical Methods

Sample data can provide valuable information, but due to many constraints, it is difficult to get the whole region sample data. So that, geo-statistics models predicts the value in un-sampled location and quantifies the uncertainty of the prediction. Meteorological stations are located in sparse and in the places which are often not of interest for different human activities. The value of climate elements cannot be measured in all point of the region, but only in sample points. In this respect, spatial interpolation may be used to estimate the values in such areas where there is no measurement (Yang *et al*., 2004).

Spatial interpolation can be used to estimate climatological variables at other locations. Although there are several methods to perform this, it can be difficult to determine which one best reproduces actual condition. Generally, commonly used interpolation methods in ArcGIS can be categorized either deterministic or stochastic. Deterministic methods do not use probability theory (e.g. proximal) or on indication of extent of possible errors, whereas stochastic methods provide probabilistic estimate or incorporate the concept of randomness. Spline and Inverse Distance Weighting (IDW) are assessed as deterministic interpolation methods, whereas Kriging is stochastic, which mostly used in ArcGIS (Burrough and McDonnell, 1998 drawn in the works of Yitea, 2012). Moreover, spline and Inverse Distance Weighting (IDW) are exact types of deterministic interpolation methods while kriging is an exact type of stochastic interpolation methods.

Kriging allows for interpolated cells to exceed the boundaries of the sample range (Chehayeb 2011). In addition, kriging methods are successful in the spatial interpolation of meteorological elements such as temperature and rainfall (Zhou *et al*., 2005 drawn in the works of Yitea, 2012). Different interpolation methods were tried in order to increase the prediction accuracy such as inverse distance weighting (IDW), simple kriging, Universal kriging and ordinary kriging. Ordinary kriging method was the best for this study and all raster maps of seasonal precipitation and temperature for the study region were constructed using the geo-statistical interpolation method known as ordinary kriging.

Ordinary kriging relies on the spatial correlation structure of the data to determine the weighting values instead of weighting nearby data points by some power of their inverted distance. Ordinary kriging is an effective spatial interpolation and mapping tool because it honors data locations provides unbiased estimates at un-sampled locations, and provides for minimum estimation variance, i.e. the best linear unbiased estimator (Jantakat and Ongsomwang, 2011).

During interpolating the different datasets of both temperature and rainfall, the researcher has used a spherical model and the number of lags was 12 with the cell size (X, Y) 0.0032, 0.0032 for every raster outputs.

3.5.2. Inter-annual Fluctuation of Rainfall

As indicated in Agnew and Chappel (1999) quoted in Mullugojjam and Ferede (2012), the standardized rainfall anomalies were calculated and graphically presented to evaluate inter annual fluctuations of rainfall in the study area over the period of observation, described as:

$$SRA = (Pt - Pm)/\sigma$$

Where: SRA is standardized rainfall anomaly,

Pt : is annual rainfall in a given year (in the year "t" from 1983 to 2013)

Pm : is long term mean annual rainfall over a period of observation i.e. 1983 to 2013 and

σ : is standard deviation of each year annual rainfall over the period of observation (1983 to 2013)

On the same source, drought severity classes can also be categorized as extreme drought (SRA<-1.65), severe drought (-1.28>SRA>-1.65), moderate drought (-0.84>SRA> -1.28), and no drought (SRA>-0.84).

3.5.3. Temperature Anomalies

Temperatures are also very much modified by the varied altitude of the country. In general, the country experiences mild temperatures because of its topography although it is located in the tropics. Mean annual temperature distribution over the country varies from about 10^0C over the highlands of northwest, central and southeast to about 35^0C over north-eastern lowlands (NMA, 2007).

Time series mean annual maximum and minimum temperature anomalies of the study area were scrutinized based on the following equation;

$$STA = (Tt - Tm)/\sigma$$

Where: STA is standardized temperature anomaly, Tt : is annual maximum/minimum temperature in year t,

Tm : is long term mean annual maximum/minimum temperature over a period of observation and

σ : is standard deviation of maximum/minimum annual temperature over the period of observation.

3.5.4. Land Use Land Cover Analysis

Present and past information on land cover and land use change for the study area was generated from remotely sensed data. Satellite image from Land sat for 1984^{TM}, 1995^{TM} and 2013 $^{ETM+}$ with spectral resolution 30m were analyzed to calculate land use land cover change over the study area. It is believed that the time gap of ten years between the three satellite imagery is wide enough to show changes and trends in Land Use and Land Cover in the study area.

Image processing was done using false color composite of bands 4, 3, and 2 in RGB transformation and visual interpretation. This is because vegetation cover reflects more at infrared region than visible band. At true color composite only green band will be reflected and the other bands will be absorbed for photosynthesis by chlorophyll. Detailed digital image processing and visual interpretation of satellite images were made using ERDAS Imagine 9.2 and ENVI 4.2 software. Since the acquired satellite image was already geo-referenced, there is no need of geo-referencing the acquired satellite image. Then, the original satellite image was subset using ERDAS Imagine 9.2 to fit the study area boundary.

The LU/LC classification was done on the basis of reflectance characteristics of the different land use land cover types by using false color composites. For this study a supervised classification scheme with maximum likelihood classifier decision rule was used following assigning training sites for each land use classes (more than 50 training samples were taken in order to increase accuracy and to minimize errors of the classification).

After classification, recoding technique was used in order to avoid minor fragmented classification errors on the output map. Then after, the final analysis output was imported in to

ArcGIS environment for map preparation. It was also here the change detection analysis was performed and the difference map was produced. From visual and digital interpretations of the satellite imagery, different LU/LC classes were distinguished these include: Forest, Farm land, Shrub Land, water body, built-up area, and bare land.

Basically satellite images are used to analyze land use land cover change with particular emphasis on forest cover change which has direct rapport with climate change

3.5.5. Normalized Difference Vegetation Index (NDVI)

The first task in the NDVI analysis was removing below zero NDVI value. This was basically done in order to avoid confusion negative NDVI with negative values. This was performed in ArcGIS environment on raster calculator using the following equation, [input data < = 1] & [input data > = 0] and define the output new value as "1", then reclassify the output value as "No data" for "0"and "1" for all others and finally multiply the original data with reclassified data and make the data permanent.

Since the MODIS data presented in 16 days composite. Initially, it is imperative to convert the data into monthly as well annual ones. Afterwards, time series biomass (NDVI) value was analyzed using statistical algorithm. The overall average annual biomass coverage for the observation period between 2000 and 2012 was calculated by adding all yearly average value and dividing the sum by the number of observation on ArcGIS environment using raster calculator available in spatial analyst tool. Statistically, this can be expressed using the following equation:

$$Yi = \sum_{i=2000}^{2012} \frac{\mathrm{xi}}{\mathrm{N}}$$

Where, Yi = overall mean NDVI

xi = is the average NDVI value of a given year

N = total observation years

The basic objective is to assess the NDVI dynamics over time. I.e. whether there is a decline or increment in natural vegetation index over time.

The yearly average NDVI value for *Kiremt* season (June to September) was calculated by adding all the NDVI data found within the defined period (from day 152 or June1st to end of September or day 273) and divided by the number of observation. This was analyzed in ArcGIS environment using raster calculator, which is available in spatial analysis tool. The equation can be formulated as follows:

$$xi = [\sum_{k=June}^{\mathrm{September}} (\mathrm{x}^{\mathrm{k}})] / \mathrm{n}$$

Where, xi = is mean NDVI for *kiremt* season of a given year

x^{k} = number of NDVI data for *kiremt* season

n = is number of observation in a year

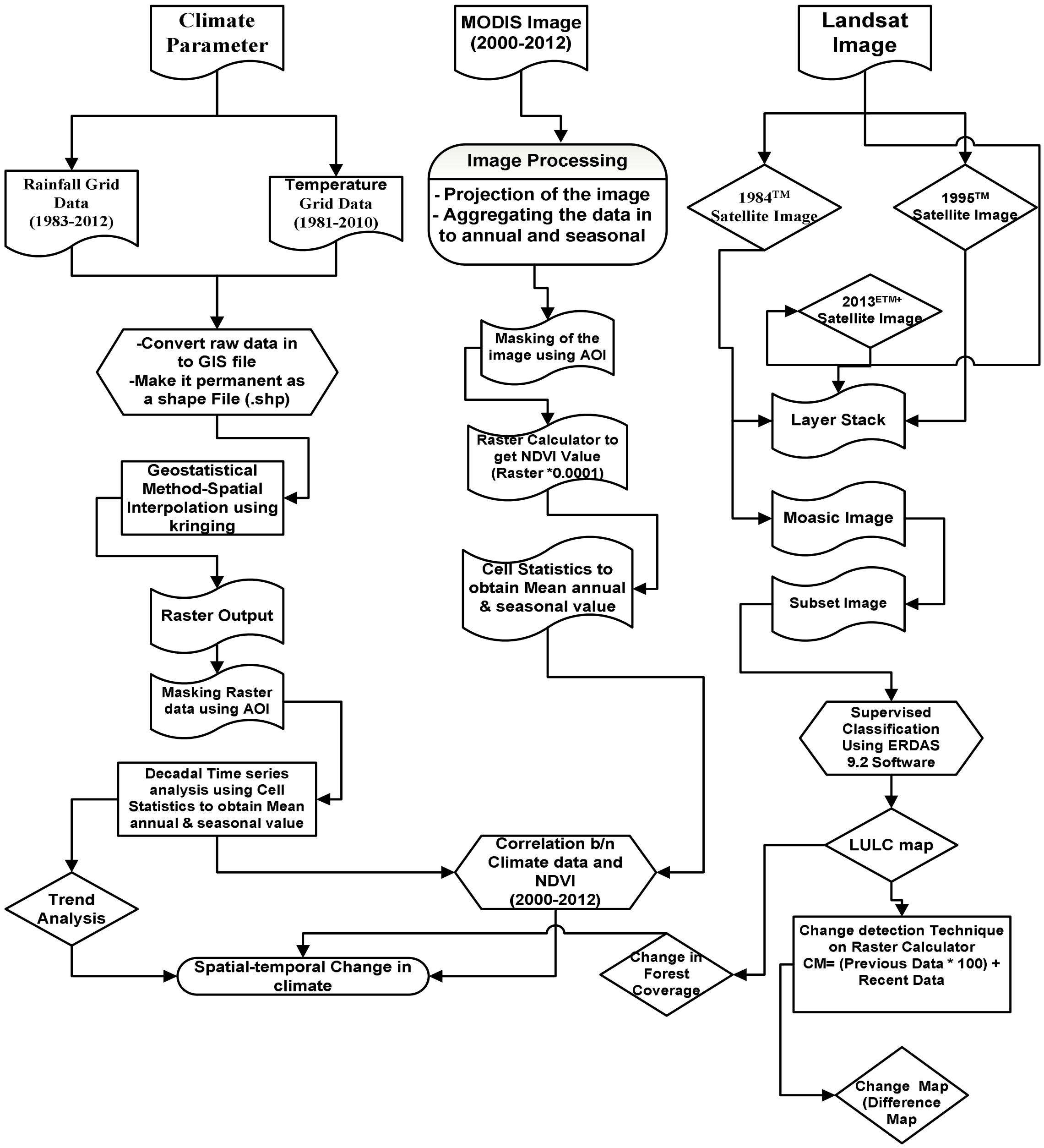


Figure 2: Analytical framework for understanding spatio-temporal climate variability analysis.

CHAPTER FOUR

DATA PRESENTATION, INTERPRETATION AND ANALYSIS

4.1. Description of the Study Area

The study was conducted on two administrative Woredas of Ziway Dugda and Dodota Woreda found in Arsi zone, Oromia Region, Ethiopia. Ziway Dugda is one of the 26 woredas of Arsi Zone. The name of the district is derived from Lake Ziway that borders the district from the west. The district has 29 kebele administrative units of which 28 are rural Peasant Associations while one is town. Ogolcho is the capital town of the district which is located at 222 km from Capital City Addis Ababa and 47km from zonal capital Assella Town.

Considering its absolute location, the study area is located between 7^{0}27'00'N-8^{0}00'34''N Latitude and 38^{0}45'00''E-39^{0}03'13''E Longitude. Relatively, the district shares a boundary line with Tiyo district in the south, east and south east, Munessa District in the south west, Hetosa-district in the East, Dodota district in the north and north east and East Shewa zone in the north, north west, west and south west direction. The district has a total area of 1247 km^2 which accounts for about 5.935% of the total area of the zone.

On the other hand, Dodota is also one of the administrative units of Arsi Zone. Astronomically, the capital town Dera is found just on 8^{o}20'N Latitude and 39^{o}17'E Longitude. Relatively; Dodota District is found North West of Lode Hetossa District, west of Sire district, South of East shoa Zone (Adama District) District, north of Hetosaa district and East Ziway Dugda district with the total area of 511.9 Km^2. Dodota is 125 km away from the capital city of the country Addis Ababa, 25 km from Adama and 50 km from the zone capital, Asella.

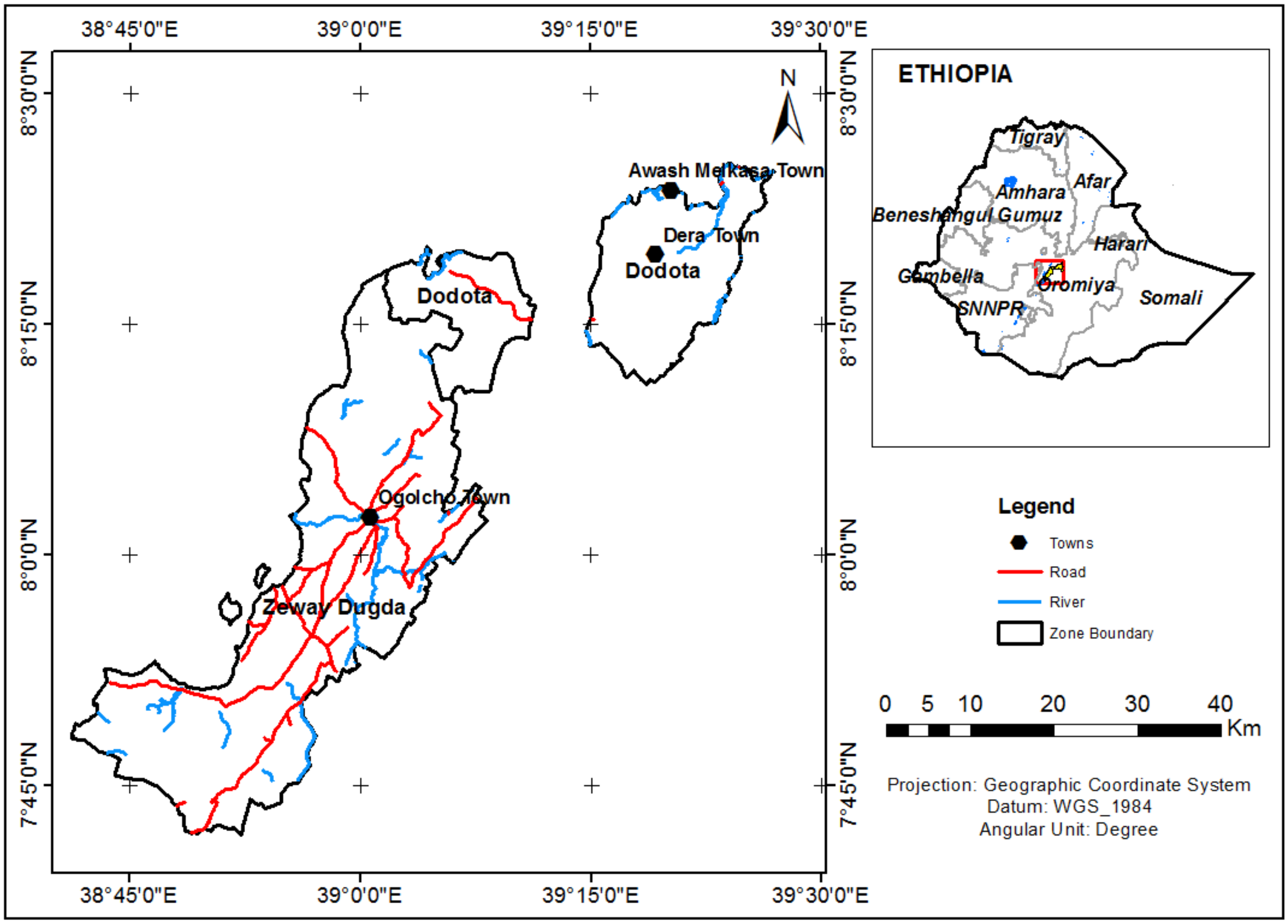


Figure 3: Location Map of the study area

4.2. Physical Characteristics

4.2.1. Topography of the study area

Based on elevation and rainfall, the study area generally falls within two ecological zones. These include:

Woina Dega: (Temperate): extends from 1500 to 2300 meters,

where annual rainfall ranges from 800 to 1200-mm.

Kolla: (Tropical): areas between 500 and 1500 meters with annual rainfall ranges from 200 to 800 mm. The areas fall within these agro-ecological zones are shown in figure 4.

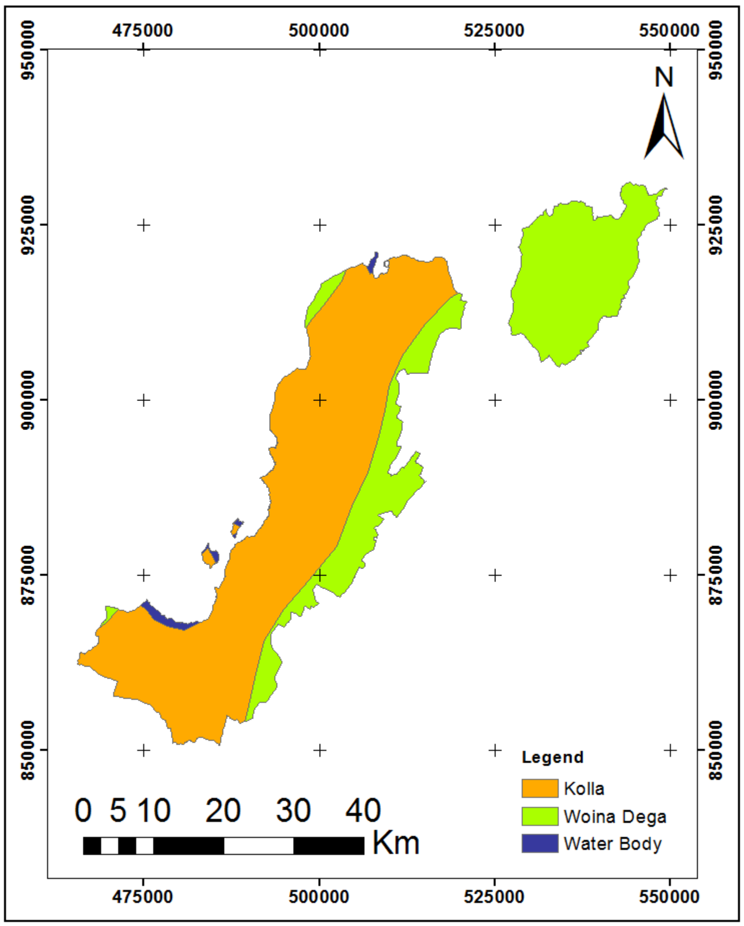


Figure 4: Agro-ecological zone of study site

4.2.2. Land use Land Cover

The false color composite of satellite image of the study area from which land use/land cover classes derived is shown in Figure 5 with a band combination of 4, 3, and 2.

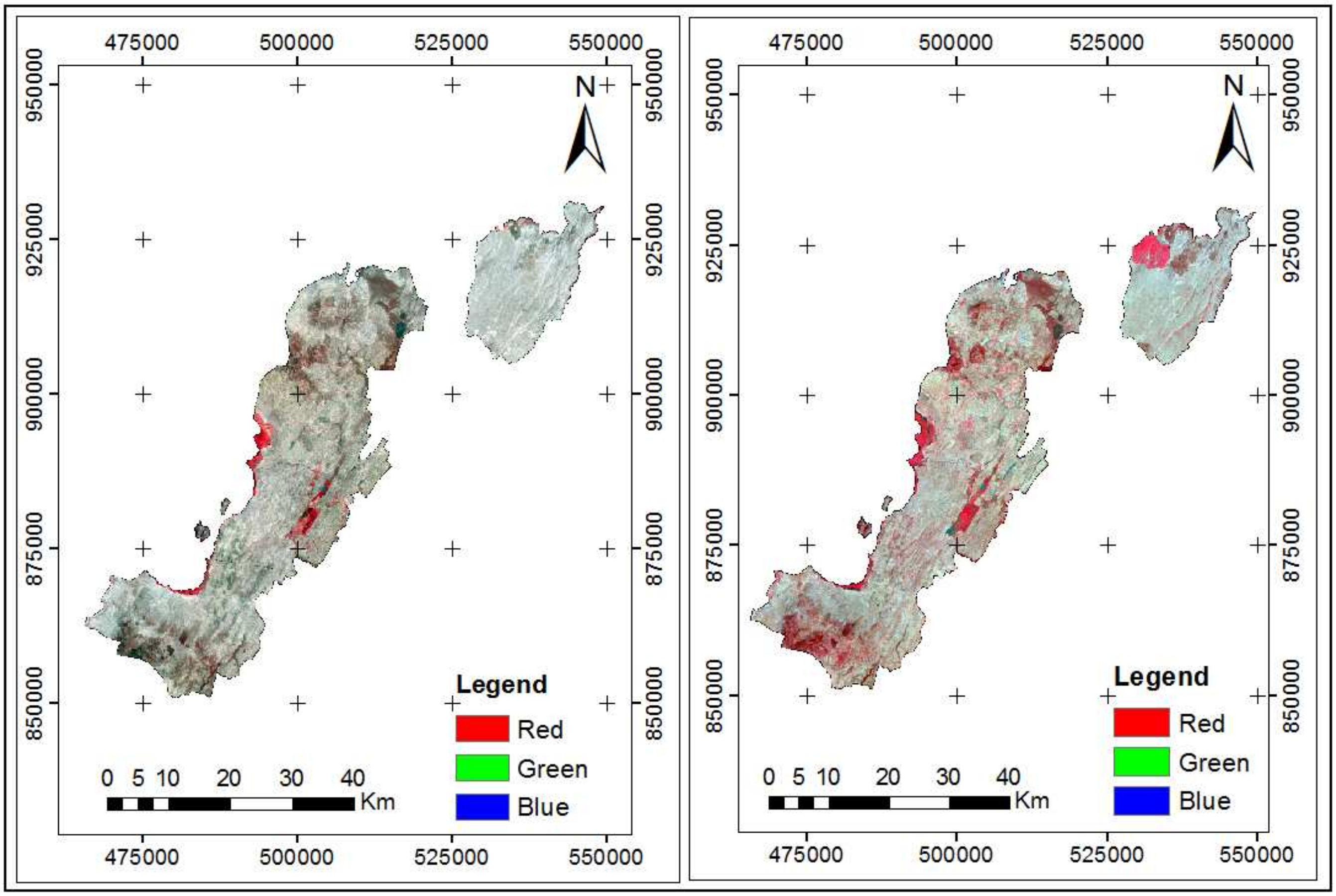


Figure 5: False Color Composite of satellite images (1984^{TM} to the right and 2013^{ETM+} to the left)

4.2.3. Temperature

Due to its altitudinal location, the climatic conditions of the two districts are dominantly moderately warm which has a temperature ranging from 20^{o}C to 25^{o}C. This type of climate covers 95 % of the total area of the district. The remaining ones are moderately cool and account for 5 %. Hence, the dominant type of climatic condition of the district is moderately warm (hot) agro-ecological zone. According to NMA, monthly maximum temperature time series reconstructed from station observations and remote sensing and other proxies for the year 1981-2010 is shown in figure 6.

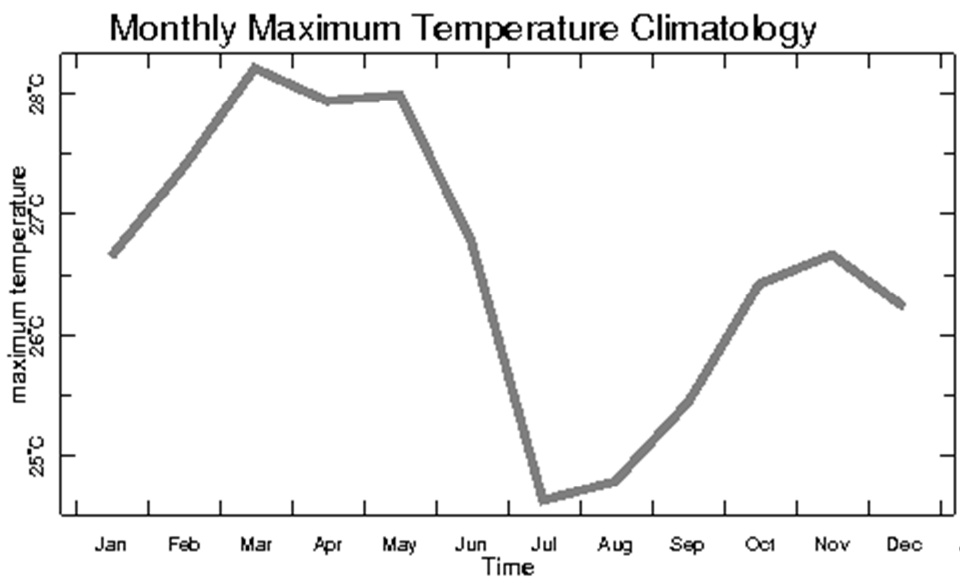


Figure 6: Maximum temperature of the study area (1981-2010)

4.2.4. Rainfall

The mean annual rainfall of the two *woredas* ranges between 800 to 1000 mm. The rainfall pattern is uni-modal, representing the *Meher* season (from June to end of September) as shown in figure 7.

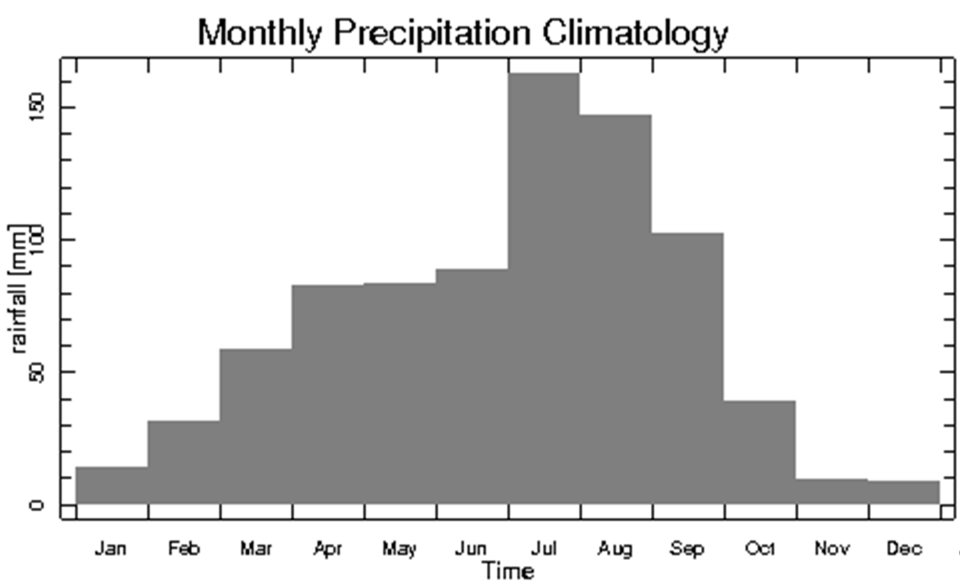


Figure 7: Mean monthly rainfall for the year 1983 - 2010

4.2.5. Vegetation

Regarding the vegetation cover, various species of acacia trees, bushes, woodlands, swampy and marsh lands, forest, shrubs and grass lands are the major vegetation types in the district. Among those mentioned shrub is the most dominant vegetation type in the study area.

4.2.6. Relief and Drainage

The relief structure of the two districts is dominated by plain areas except few areas dissected by small hill and cannons of gulley erosion. The altitude of the Ziway Dugda district ranges between 1619m to 2380m above the sea level. The lowest place is found in the shore areas of Lake Ziway while the highest place is located on the Achena Mountain (2380m). Similarly, the altitude of the Dodota district ranges between 1343 and 2271 meters above sea level. The lowest place is found in Awash Bishola area (1343m) while the highest place is located in Aminia Dabaso, 2271m. The district has the major permanent rivers like Ketar and Chufa rivers. On the other hand, Dodota has low network of river systems. However; there are two major permanent rivers in the district. These are Awash River and Keleta River. Generally, in the case of Ziway Dugda the district has a potential for both traditional and modern irrigation particularly along Ketar river which can be used to increase agricultural productivity if utilized efficiently. The same is true for Dodota along Awash River and Keleta River.

4.2.7. Geology and Soil

The two districts are found in the Great East African Rift Valley which was formed during Cenozoic era as a result of faulting and volcanic activities within different epoch of quaternary period. Its most eastern part and western part along the border of Ziway Dugda district are covered by alluvial and Lacustrine deposits NRGO (2011). Furthermore, explained that the northern and south eastern half of the district is covered by Dino formation while its southern central part is covered by Alkaline Olivine basalt. Its most western most part and south western tip along Hetosa district is covered by Rhyolitic volcanic creator.

In the case of Dodota, the major types of soil that are found in the district are Chromic Luvisols, Mollic Andosols and Vitric Andosols. In addition, Dystric Nitosols, Eutric Fluvisols and Orthic Acrisols are found in pocket areas of the district. In addition, Dystric Nitosols, Eutric Fluvisols and Orthic Acrisols are found in pocket areas of the district. The major types of soil found in the Ziway Dugda are Chromic Luvisols, Mollic Andosols and Vitric Andosols.

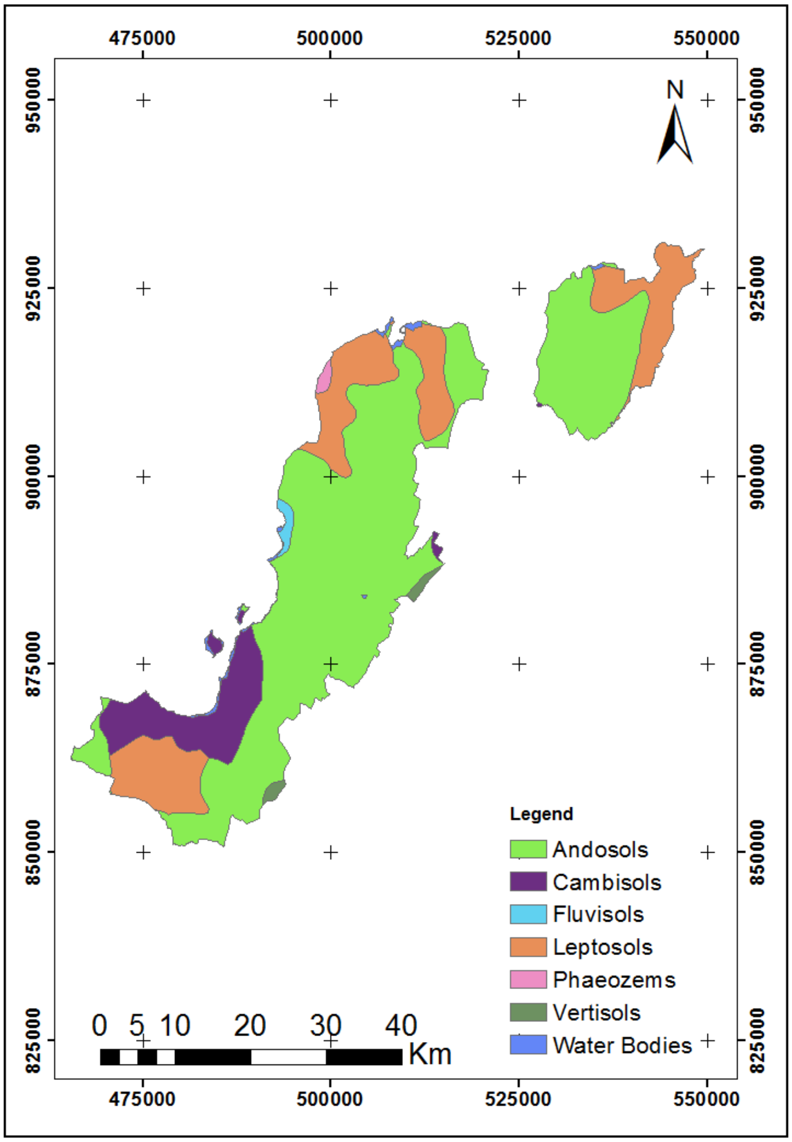


Figure 9: Soil map of the study area

Source: FAO (1998)

4.2.8. Population

Based on the 2007 Population and Housing Census conducted by Central Statistics Agency of Ethiopia CSA (2007), the counted population of Dodota district was 63302, of which 30.1% are urban dweller and the remaining are rural inhabitants. From the total population of the district, 49.7% are females and 50.3% are males. The population of Ziway Dugda Woreda is 120987, of which urban population constitute only 3.9%. This indicates that most of the population of the district are rural dwellers. From the total population of the district, 50.1% are females and the remaining 49.9% are males. The population density of Ziway Dugda is 94 persons per km^2 while crude population density for Dodota is 141 persons per km^2.

4.3. Socio-Demographic Characteristics of the Respondents

4.3.1. Demographic Characteristics of the Respondents

In this section, demographic characteristics of the respondents would be described in detail. Cross tabulation counts obtained from the relevant variables were presented and interpreted.

The age-categorization was made on the basis of considering the minimal and maximum age level. Based on the classification, the majority of the respondents were males.

Table 4: Age and sex distribution of the respondents

		Age Group						
Description		18_25	26_35 year	36_45 year	46_55 year	56 & above	Total	Total (%)
Sex	Male	0	1	4	22	0	27	67.5
	Female	0	5	2	6	0	13	32.5
Total		0	6	6	28	0	40	100
Total %)		0	15	15	70	0	100	100

Source: Cross tabulation result, 2014

On the result indicated in the above table 4, 27 (67.5%) of the respondents are males while the remaining are females. Regarding the age group, 28 (70%) of peasants were found between the age group of 46 and 55. The age group between 26 up to 35 and 35 to 45 each constitutes 15%. This clearly shows that the large majority of the respondents were adults. This fact abetted a lot to obtain the intended information as desired.

4.3.2. Marital Status and Educational Level of the Respondents

Marital status is the other correlate which reflects the well-being of a household. In this study, the married households takes the largest lion share which is 38 (95%) of the samples. On the other hand, only 5 % respondents were found to be widowed.

As shown in table 5, out of the total number of respondents, 16 (40%) were illiterate and the same number of the respondents were primary school incomplete. While 7.5% and 12.5% of the study population were primary school completed and secondary school incomplete respectively. This indicates the vast majority the selected sample populations were did not get the chance to go to school and those who obtained the chance withdraw from schooling early due to various reasons.

The implication here is that due to lack of awareness about the importance of their environment, they might be involved in different ecological destructive activities which contribute in accelerating microclimate deterioration.

Table 5: Marital Status and Educational level of Respondents

Educational Level							
		Primary School Complete	Primary School Incomplete	Secondary School Incomplete	Illiterate	Total	Total %
	Single	0	0	0	0	0	0
Marital Status	Married	3	15	5	15	38	95
	Divorced	0	0	0	0	0	0
	Widowed	0	1	0	1	2	5
Total		3	16	5	16	40	100
Total %		7.5	40	12.5	40		100

Source: Field survey result, 2014

4.3.3. Households Livelihood Sources

In the field survey questions regarding the presence of household, livelihood sources other than agriculture were forwarded to the selected sample respondents. The large majority 37 (92.5%) of the sample population answered that agriculture is the sole source of living. The remaining 3 (7.5%) reflected that they also engaged in off-farm activities in order to complement household income and food in case of adverse conditions in agriculture. From this, it is possible to conclude that almost all the respondents were highly dependent on their subsistence agricultural to support their family.

4.4. RESULT AND DISCUSSIONS

This section presents a detailed description of the results obtained from the analysis of temporal and spatial rainfall and temperature variability over Dodota and Ziway Dugda Woreda of Arsi zone. This research focuses on characterization of rainfall and temperature variations in the study area.

4.4.1. Farmers Perception on Climate Variability

The climate has changed, is changing, and will continue to change regardless of what investments in mitigation are made (Belaineh *et al*., 2013). Rainfall and temperature variability is the most important indicators of climate change (Mikias, 2014). In this regard, the farmers' perception on climate change indicated that all the respondents 40 (100%) perceived that there is a climate change in the locality in the past decades i.e. all the respondents feel that there is an increase in temperature and decrease of rainfall over the years in the area.

On top of that, the outcome of the key informants also goes in line with the results obtained from the sample respondents. Both the Disaster Prevention Preparedness Commission (DPPC) and agricultural extension officers in the two woredas confirmed the presence of climate change in the vicinity. They stated that *"In the past four or five years the amount of rainfall is decreasing. On the contrary, temperature is increasing. In simple terms increased temperature and low or erratic rainfall was the key issues explained"*.

The suggestion is that all sample respondents in the study area noticed that there have been changes in climate. This is emanated from the existence of widespread covariate risks in the area as a direct result of climate variability and change. One of the possible explanations is that a shift from idiosyncratic risk to covariate risk due to climate change might have led to a unified local perception.

4.4.2. Results from Climate Parameters

4.4.2.1. Onset time, Cessation and Duration of Rainfall

Regarding information about the distribution, onset time, end time and duration of rainfall is very crucial; particularly in areas their activities are dependent on rainfall. According to National Regional Government of Oromia [NRGO] (2011) report the rainfall pattern in the study area exhibits a bimodal nature i.e. long rain during *kiremt* season and small rain in *Belg* season. With respect to this, the interview held with the local agricultural officers in both Woredas indicated that "the area used to get bimodal rainfall maximum rainfall in Meher and small rain in Belg season, but in the past few years, the rainfall in the *belg* season has greatly decreased in its amount. Usually, the farmers plough their land and wait for the coming of *belg* rain, but for one thing the rain does not come on time. Besides, the amount is getting low from time to time".

The main rainy season of the study area is summer, i.e. June, July, August and September. Regarding the onset time and end dates of rainfall in the main season in the study area. The overwhelming majority, (39) 97.5% of the respondents replied that there is a shift in rainfall pattern in the main (*kiremt*) season usually the rain comes late than the normal time. The field survey result denoted on table 6, shows that there is a variation in rainfall starting time in the study area.

Pertaining with the rainfall cessation time of *kiremt* season, the dominant (38) 95% of the respondents reported that there is an early withdrawal of rainfall than the expected time. This directly linked with crop productivity due to late onset and early cessation of rainfall. The concentration of rainfall was fell down. Consequently, crops suffered from rainfall shortage. As a result crops dry before they reach flowering stage.

Generally, the findings of the study revealed that there is a fluctuation of onset and end time of rainfall relatively as compared to previous times.

4.4.2.2. Annual Patterns of Rainfall

The annual total rainfall of the study area varies temporally and spatially. The values are averaged from the gridded data of fifty stations which have long record of rainfall. Both Dodota and Ziway Dugda Woredas received the mean annual rainfall between 1983 and 1992 was 800mm, with standard deviation of ±15.8 mm and 0.02 (1.97%) coefficient of variation. The mean annual rainfall observation between 1993 and 2002 was 854.4 mm, with standard deviation of ±39.3 mm and 0.05 (4.6%) coefficient of variation. The mean annual rainfall of the last decade found to be 878.5mm, with ±14.8mm standard deviation and 0.02 (1.68%) coefficient of variation. Generally, the result showed that the mean annual rainfall distribution across all the three observation varies both in space and time. The mean decadal rainfall trend designate that there is an increase of rainfall amount from time to time with small variation. Supporting this idea, NMA (2007) report designate that the temperature across the country could rise by between 0.9 and 1.1 ^{0}C by 2030, whereas precipitation is expected to show some increase.

In line with this, Conway (2009) in his discussion paper stated that Northern and Southern Africa will also become much drier (precipitation falling by 15% or more) over the next century. In addition, NMSA (2001) also stated that an increasing trend in annual rainfall has been observed in central Ethiopia.

Table 7: Mean decadal maximum, minimum rainfall, standard deviation (mm) and coefficient of variation (in percent), 1983-2012.

Decade	Mean Maximum (mm)	Mean Minimum (mm)	SD	CV	CV (%)
^{1st} 1983-1992	846.3	762.1	15.7	0.02	2.1
^{2nd} 1993-2002	946.7	779.3	39.2	0.05	5.0
^{3rd} 2003-2012	903.8	839.5	14.2	0.02	1.75

Source: cell statistics result on ArcGIS Environs, 2014

The ten years average maximum and minimum precipitation distribution reflects that the rainfall pattern across the three decades showed a different trend. As table 7 shows, the mean maximum rainfall on the second decade of the observation, the intensity of rainfall increased by 100.4 mm, with standard deviation of ±4.3 mm and coefficient of variation of -0.02 as compared to the first decade of the observation time. However, in the last decade the rainfall amount was reduced by 42.3 mm, with standard deviation ±32.2 mm and coefficient of variation -0.03. In this respect, the result obtained from the field survey revealed that all the respondents 40 (100%) reflected that there is a reduction in rainfall amount from time to time. This implies that there is a linear relationship between the outputs of the gridded data with the primary information obtained from the field.

The mean decadal minimum rainfall record shows that there is an increasing in the rainfall trend across the decades. In the first observation, the mean annual minimum rainfall was found to be 762.1 mm with standard deviation of ±15.7 mm and 0.02 coefficient of variation, while in the second observation time, the rainfall showed a slight increment which is 779.3 mm, with ±39.2 mm standard deviation and 0.05 coefficient of variation, and in the last decade the rainfall reached to 839.5 mm, having a standard deviation of ±14.2 mm and 0.02 coefficient of variation.
The time series analysis of total annual rainfall was done to reveal the general trends of rainfall amounts over the study area. The result of standardized rainfall anomalies indicated that the inter annual variability of rainfall and (Figure 10) shows lack of annual total rainfall trends for the period from 1983 to 2012 in the study area.

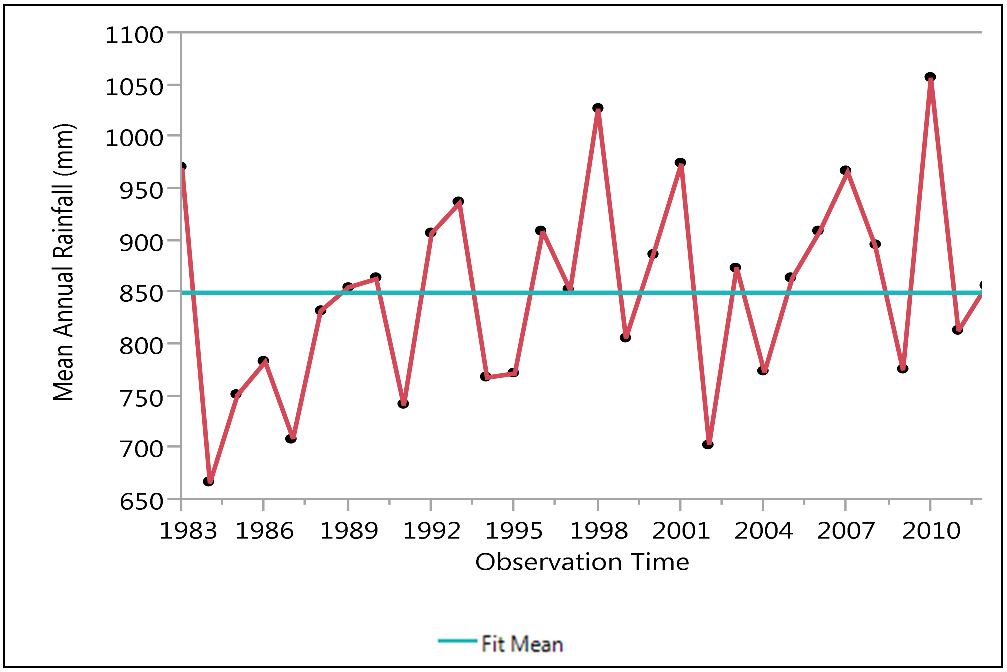


Figure 10: Total mean annual rainfall trends in the study area between 1983 and 2012.

The above figure demonstrates that in the study area heavy rainfall was registered in 2010 with annual rainfall of 1056.7 mm and the minimum rainfall occurred in the year 1984 with annual rainfall of 665.8 mm. The overall average rainfall in the last 30 years time is 850 mm with a standard deviation of ±21 mm and coefficient of variation of 2.48%.

Generally, as figure 10 depicts, the annual rainfall pattern shows a considerable fluctuation, one year there is a slight positive anomalies and on the other year shows negative anomalies. Thus, it is possible to deduce that rainfall is highly irregular in nature for all the three observation times (1983-2012). Nevertheless, substantial positive anomalies occurred in the study area during 1998 and 2010.

4.4.2.3. Inter-annual Fluctuation of Rainfall

Based on drought index classification, the statistical result revealed that in the area extreme drought was observed if SRA<-1.65 and this was observed in 1984, 1987, 1991, 1994, 1995, 2002, 2009 and 2011. In the category of -1.28>SRA>-1.65, which gives clue to severe drought, only in the year 1985 severe drought was observed. If the outcome falls between -0.84>SRA> -1.28, moderate drought would be the case which occurred in two point of time i.e. 1986 and 2004. In the rest observations, drought was not prevailed in the area.

The time series analysis of total annual rainfall was done to reveal the general trends of rainfall amounts over the study area. The result of standardized rainfall anomalies indicated that the inter-annual variability of rainfall (Figure 11 & 12) shows lack of annual total rainfall trends for the period from 1983 to 2012.

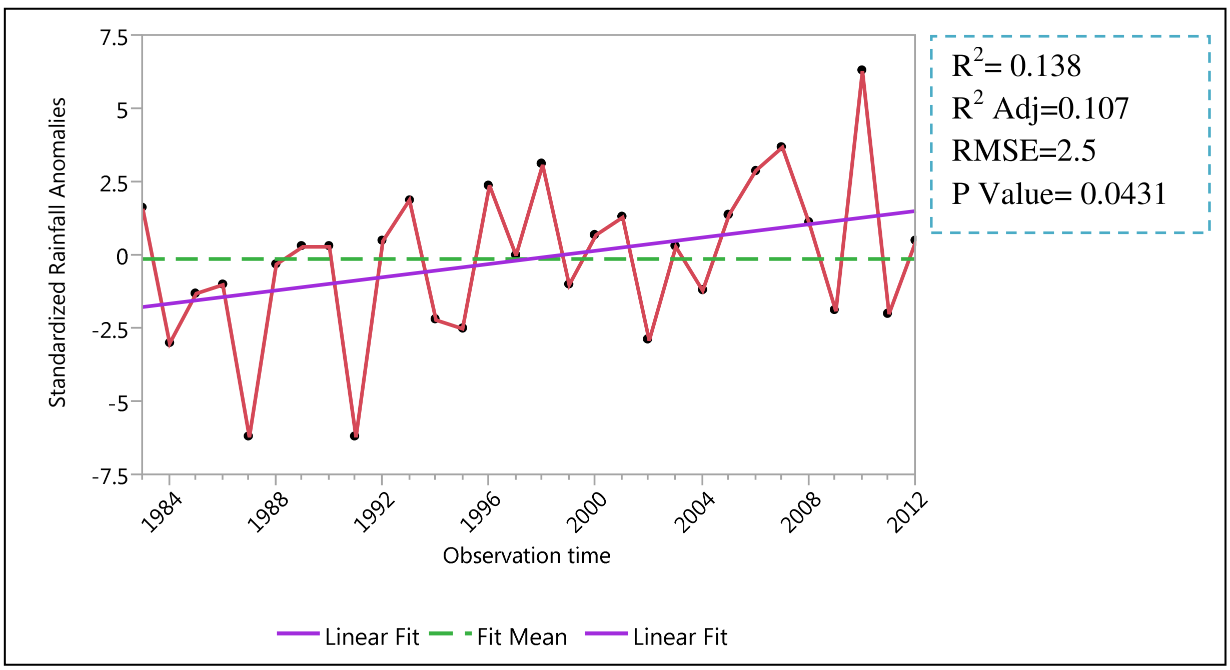


Figure 11: Standardized annual rainfall anomaly in the study site during the observation year b/n 1983 and 2012.

In general, rainfall in the study area shows significant decadal variability. This means a year with a positive anomaly tends to be followed by another year with a negative anomaly. Regarding the annual rainfall anomaly, more than 67% of the study area showed below average rainfall record while the remaining 33% showed above average rainfall amount. As portrayed in figure 12, the overall mean rainfall of the study site was 850 mm. The mean maximum and minimum rainfall of the same period found to be 892.8 mm and 795.5 mm respectively

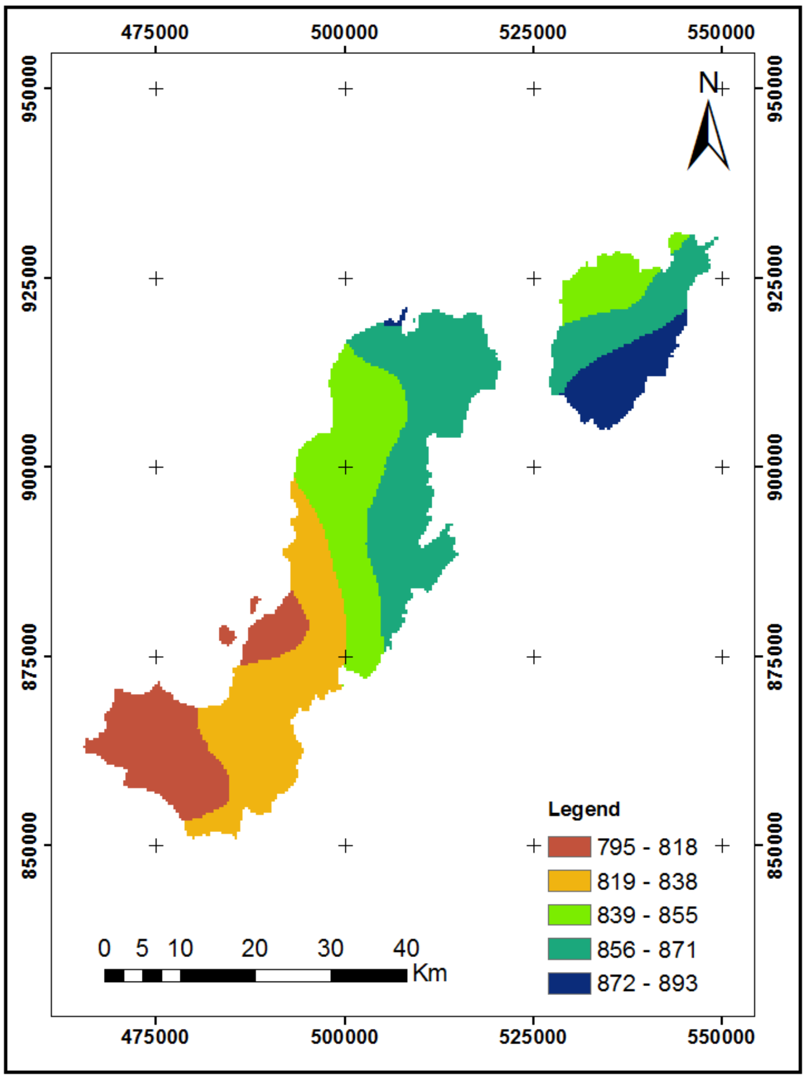


Figure 12: The overall mean rainfall distribution reclassified map (1983-2012)

4.4.2.4. Rainfall Trend at Decadal Level

4.4.2.4.1. First Decadal observation (1983-1992)

Figure 13 reveals the rainfall distribution between 1983 and 1992. In this period, the minimum rainfall was recorded in 1984 with 666 mm and the maximum rainfall was 969.6 mm that was registered in 1983 and the average rainfall in the period was found to be 800 mm.

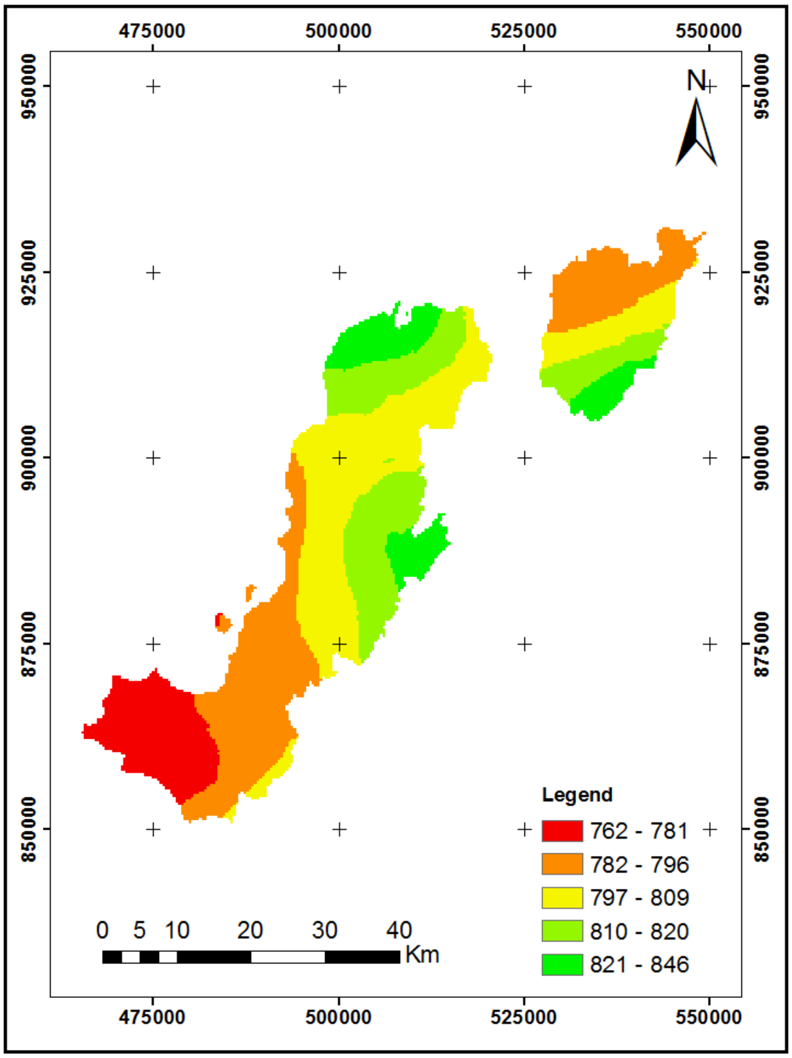


Figure 13: Reclassified mean decadal rainfall map from 1983 to 1992

4.4.2.4.2. Second Decadal observation (1993-2002)

The average total annual rainfall between 1993 and 2002 was 854.3 mm. For the observation time, the maximum rainfall was 1026.7 mm recorded in 1998 and the minimum was 703.4 mm registered in 2002.

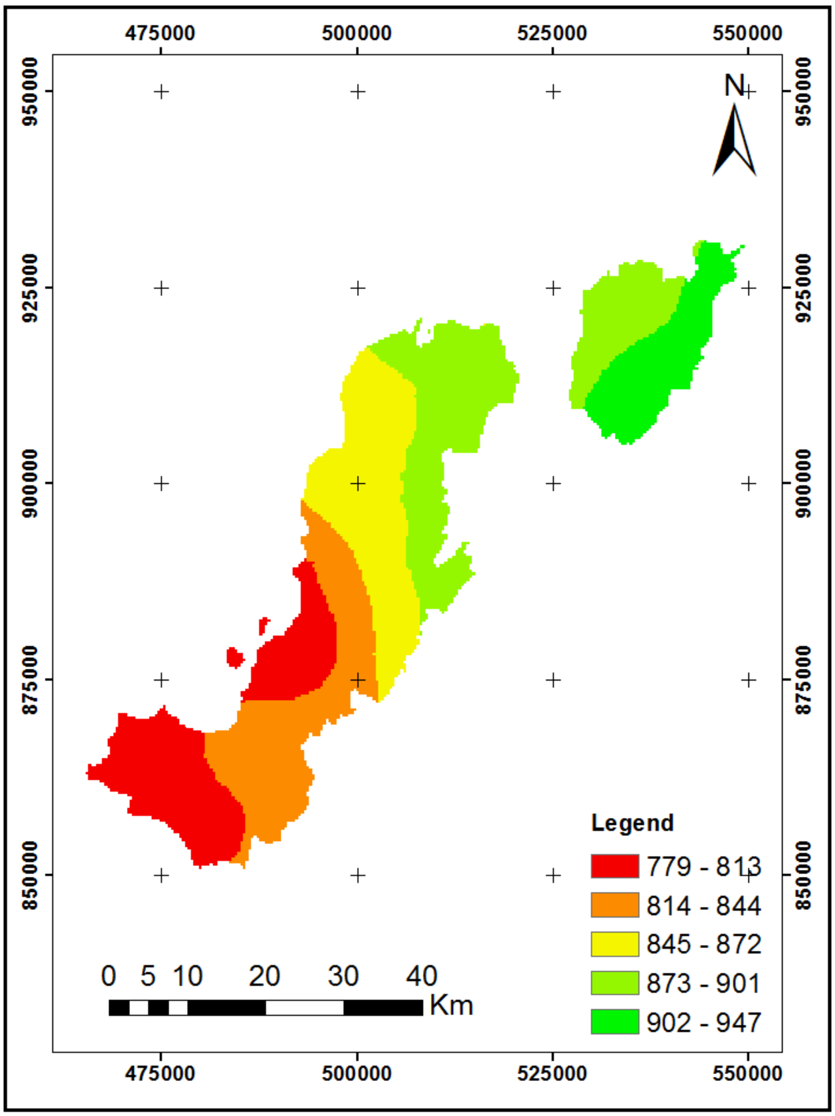


Figure 14: Reclassified mean decadal rainfall map between 1993 and 2002

4.4.2.4.3. Third Decadal Observation (2003-2012)

The average total annual rainfall from 2003 to 2012 was 878 mm, with standard deviation of ±82.3 mm and 9.4% coefficient of variation. The maximum rainfall was 1056.7 mm recorded in 2010 and the minimum was 772.7 mm manifested in 2004.

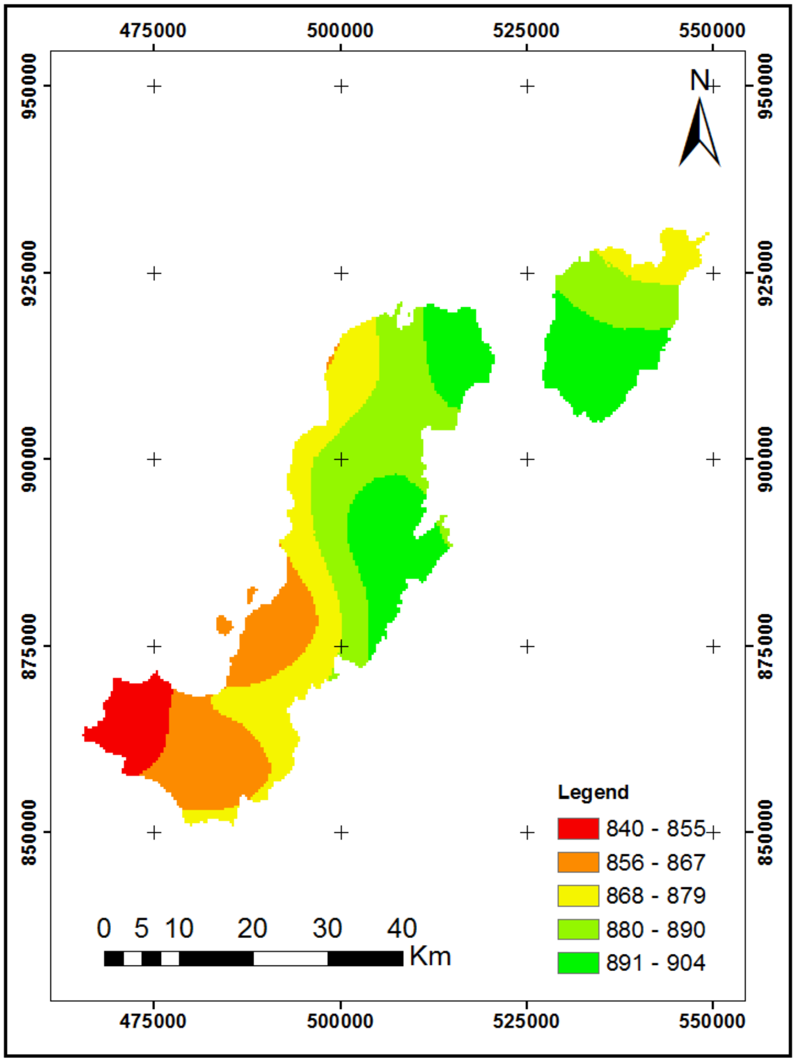


Figure 15: Reclassified mean decadal rainfall map between 2003 and 2012.

4.4.2.5. Meher Season Rainfall

Kiremt rain has great significance over life of Ethiopian farmers. Since the total economic activity is based on Kiremt rain, the variations occurred in each moment which later lead to climate change can affect the maturity and development of crop. Rainfall during the year occurs in different seasons. There are three seasons in Ethiopia, namely, a dry season which is referred as *bega* (October to January), a short rain season which locally termed as *belg* (extend from February to May), and a long rain season called Kiremt (June to September). Generally, the gridded data showed the rainfall trend across the observation in kiremt season started in June and continued increasing in intensity until August then after began to decline in September.

In addition, Seleshi and Zanke (2004) indicated that the kiremt season starts in July, lasts for about three to four months as a result of convergence in low-pressure systems, and impact of the Inter Tropical Convergence Zone (ITCZ). The study area received its maximum rainfall during *Meher* season that extends from June to September. As depicted in figure 16, the total average rainfall of *Kiremt* season in the period of observation between 1983 and 2012 was found to be 528.2 mm with $\pm$32.7 mm standard deviation and coefficient of variation 0.06 (6.2%). In the study area, the maximum kiremt rainfall was recorded in 2010 which is 666 mm and the minimum was 300 mm apparent in 1987. The general trend of *Meher* season rainfall showed an increasing trend as shown in table 8 and figure 16.

In relation to *meher* season rainfall distribution, the main problem lies on the late onset of and early withdrawal of rainfall at this time. Pertaining with this, the interview held with key informants reflected that "The farmers' life is dependent on *meher* rainfall crops like Corn, Maize, Teff, Wheat, Sorghum and Barley. These are the staple food crops in the locality. But, due to the frequent delay of *meher* season rainfall and its seasonal variation causes reduction of crop production".

This indicates that due to the variation in climate the farming community was identified as the most vulnerable because of its dependence on agricultural production for its livelihood.

Table 8: seasonal mean *Kiremt* rainfall, standard deviation (mm), coefficient of variation, 1983- 2012

Decades	*kiremt* season Mean Rainfall (mm)	SD	CV
1983-1992	493.7	28.7	0.06
1993-2002	522.1	50.4	0.10
2003-2012	568.8	21.5	0.04

Source: analysis result on ArcGIS environs, 2014

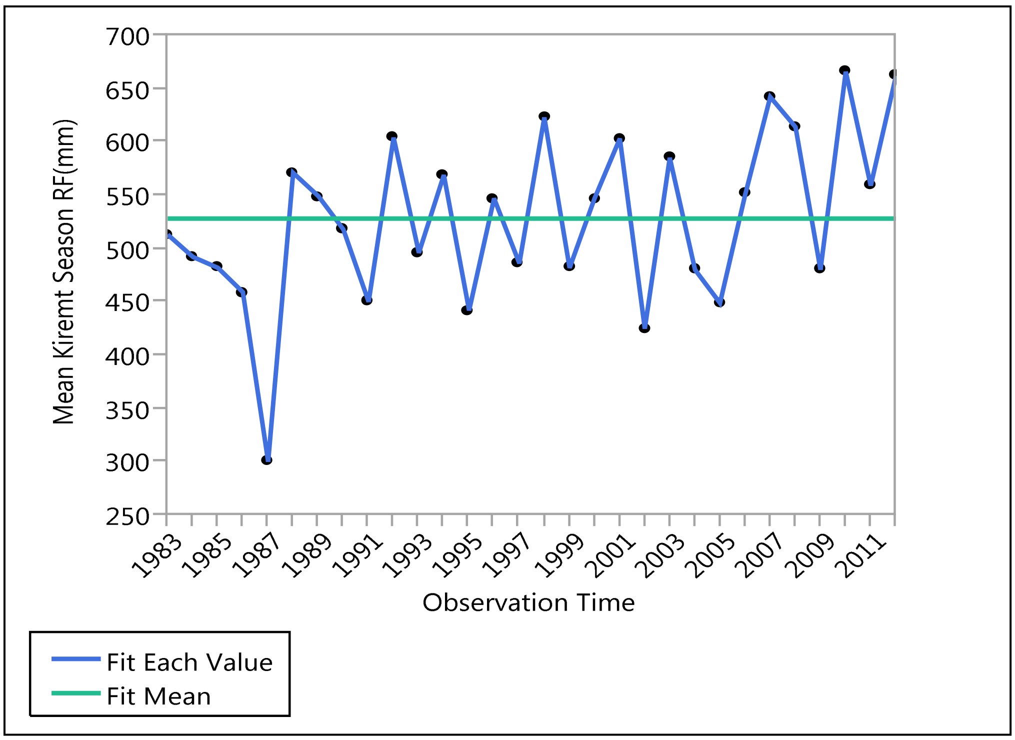


Figure 16: trend of rainfall during *meher (kiremt)* season b/n 1983 and 2012.

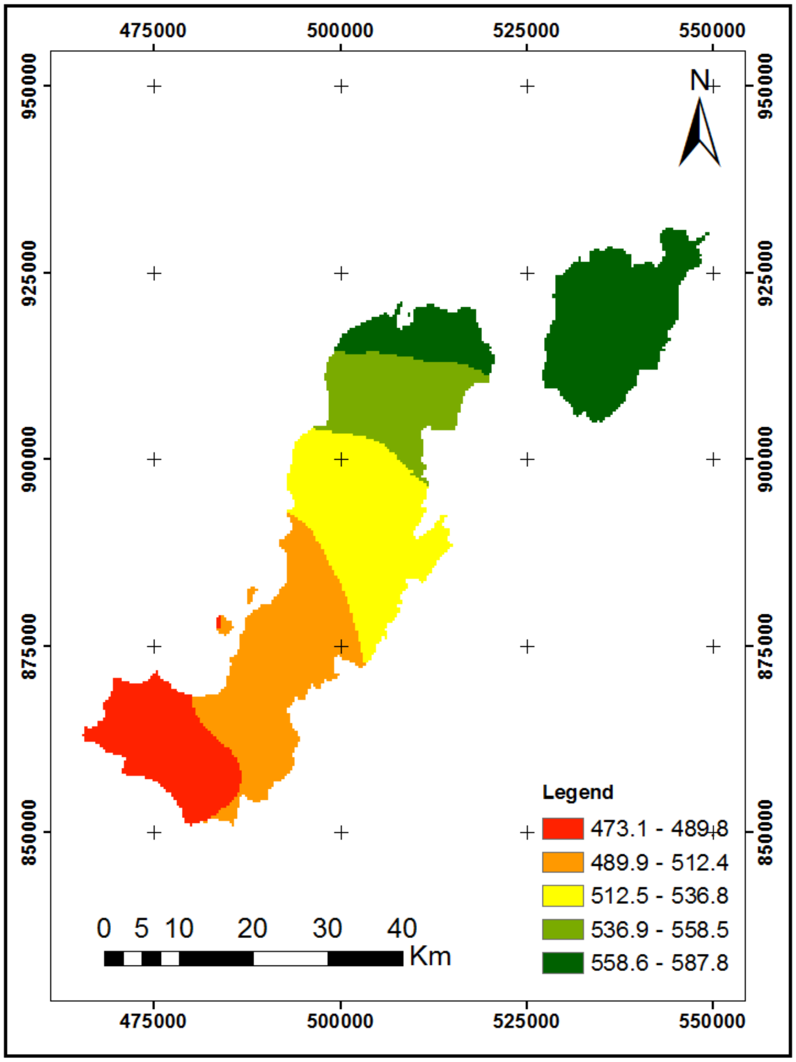


Figure 17: Mean Annual Kiremt/Meher season Rainfall distribution Map from 1983 to 2012

4.4.2.6. Belg Season Rainfall

In Ethiopia, there are seasonal rainfall patterns that vary in number, intensity, duration, and timing, depending on location. The *belg* season is particularly is important for the production of fast growing crops. According to NMSA (2001) the *belg* season lasts February through May, which is a short rainy season. The result of the analysis across the observation (1983-2012) demonstrated that the study area received a mean rainfall of 246 mm during the *belg* season having a standard deviation of ±13.9 mm and coefficient of variation 0.06 (5.6%) (Figure, 18).

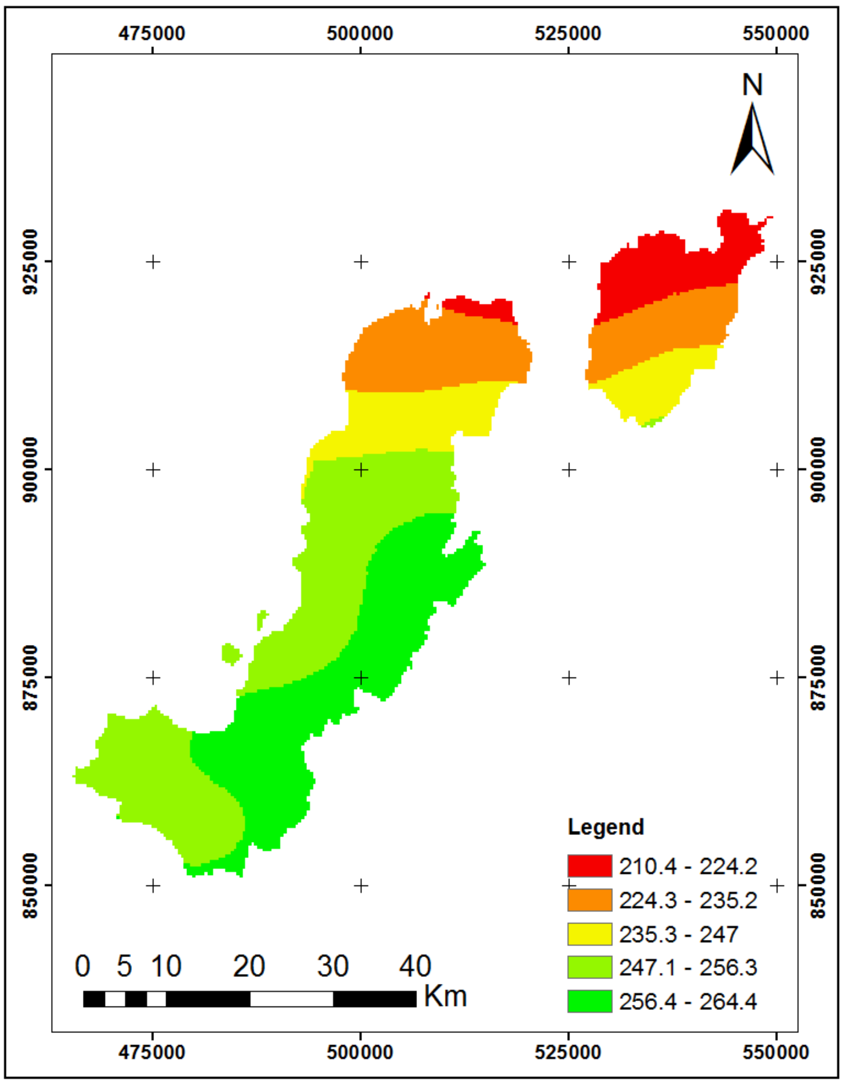


Figure 18: Portray mean annual *Bulg* season rainfall distribution between 1983 and 2012

In thirty years period of *Bulg* rainfall distribution, the maximum rain was recorded in 1983 which is 426 mm with high standard deviation of ±47 mm in the period and 10.9% coefficient of variation. whereas the minimum rainfall was 120 mm which happened in 2009, with ±17 mm standard deviation and 14.4% coefficient of variation.

From this, it is possible to note that *Belg* rainfall has significant contribution to the annual total rainfall in the locality. However, as figure 19 and table 9 clearly show that the amount of *Belg* rainfall was decreasing. Supporting this idea, the information obtained from key informants suggested that the amount of *Belg* rainfall was declining from time to time.

Table 9: Average contribution of the *belg* seasons to the annual average precipitation, Standard deviation (mm), coefficient of variation, 1983-2012

Decades	*Belg* season	SD	CV
	Mean Rainfall (mm)		
1983-1992	267	15.3	0.06
1993-2002	238	16	0.07
2003-2012	231	10.9	0.05

Source: computation on ArcGIS environs, 2014

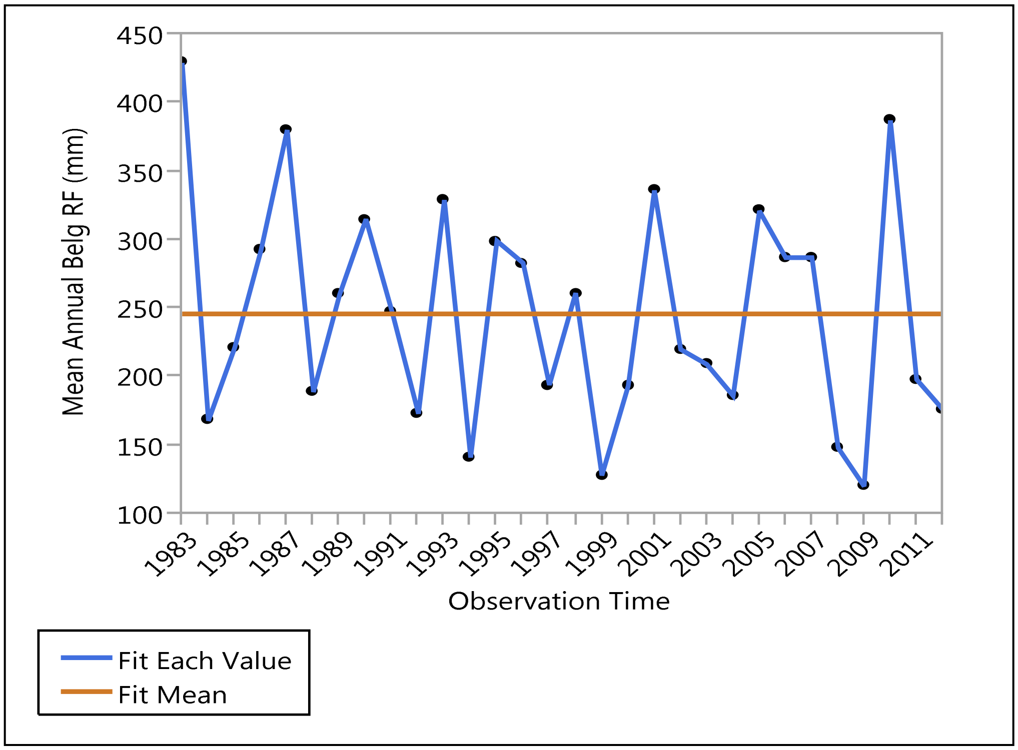


Figure 19: shows trend of rainfall distribution in *belg* season from 1983 to 2012.

4.4.2.7. November Rain Performance

The result indicated that the area received mean monthly November rain of 10.8 mm with standard deviation ±0.7 mm and 0.06 coefficient of variation. The maximum amount of November rain was received in 2008, which was 72.3 mm, while the minimum was zero (Figure 20). In relation with this, a question raised regarding the occurrence of untimely November rain to the key informants and they stated that "They rarely faced this unexpected November rain for instance in the year 2001 due to the prevalence of November rain in the Woreda affected crop production specially this is the time of crop harvesting and the damage at that time was significant".

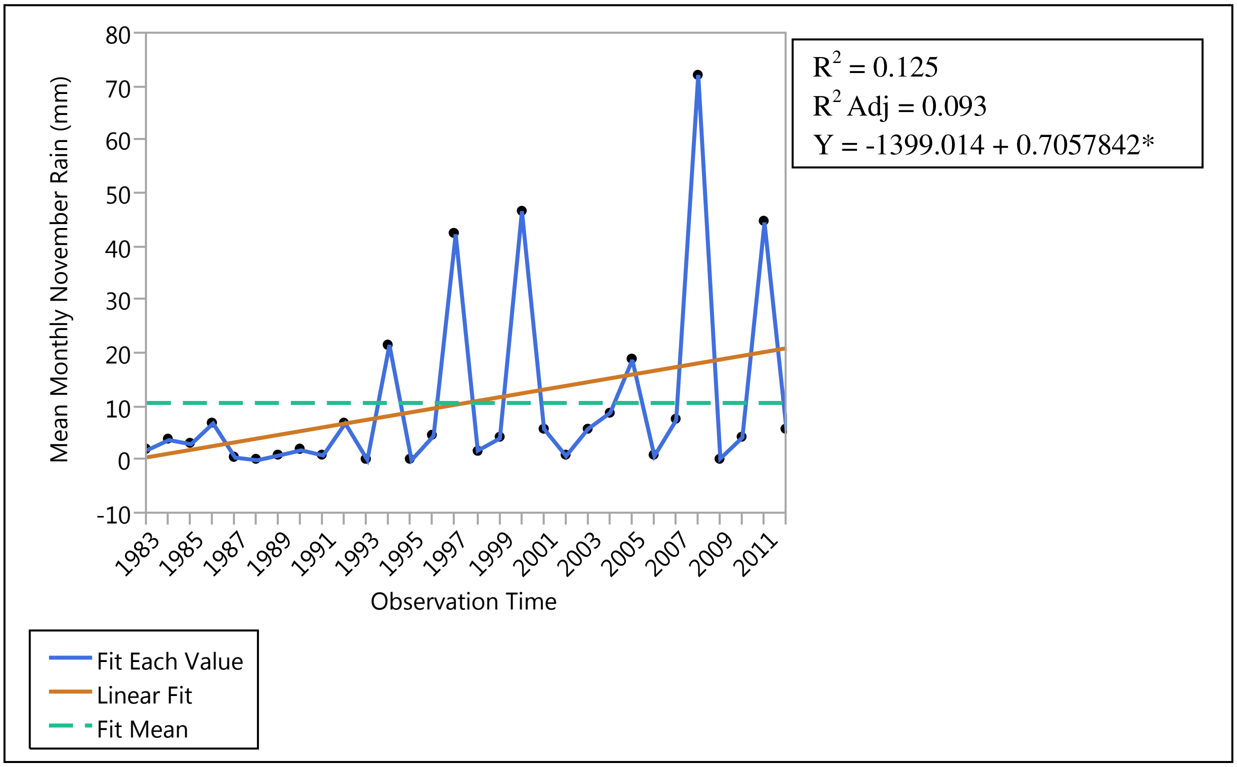


Figure 20: shows trend of November rain b/n 1983 and 2012.

On the other hand, all the 40 (100%) sample respondents noted that they have faced untimely November rain; nevertheless, the impact on their crop production varies. The substantial number of the informants encountered a partial production loss due to the pervasiveness of untimely November rain. Thus, the study revealed that the occurrence of November rain is relatively increasing from time to time as shown clearly in figure 20 and 21. The rate of incidence this is intensifying. This is particularly the case in the eastern periphery of Dodota Woreda which is very much affected by this unexpected November rain.

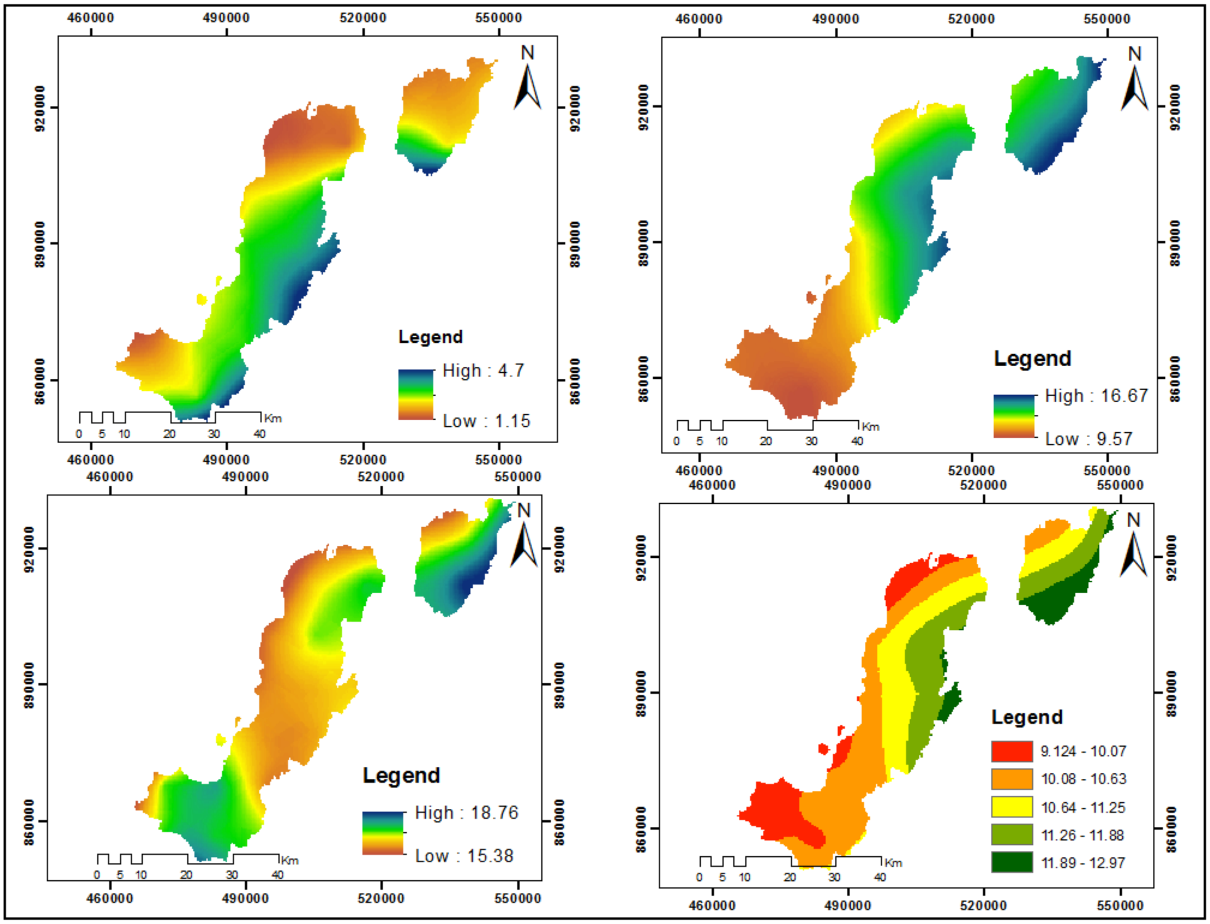


Figure 21: Demonstrates November rainfall distribution at decadal level (at the top right 1983-1993, 1994-2003 top left, 2004-2012 bottom right & 1983-2012 mean November rain bottom left)

4.4.2.8. Temperature Variability

Temperature is the most widely reported direct observation of changes in climate (Kadir *et al*., 2013). It is a key indicator amongst whole climatic elements to show whether the terrestrial or water surfaces are getting hot or cool. It is due to observable changes recognized in mean temperature in the world that significant emphasis is given to the issue of climate change.

Annual temperatures can be examined for the occurrence of average, low or high temperature extremes. Further characterizing and quantifying temperature data has various advantages: such as, to help make decisions about how crop are grown and managed, to estimate yields to help government and incorporate decision about buying and selling products and to improve understanding and suggest new or improved management methods (Mulugojam and Ferede, 2012).

4.4.2.8.1. Spatial and Temporal Variability of Maximum and Minimum Temperature

To show temperature variability of Ziway Dugda and Dodota Woreda, obtained monthly minimum and maximum gridded data was obtained from the National Meteorology. The analysis revealed that the mean maximum temperature of the study area over thirty years period varies from time to time. The mean maximum annual temperature value from 1981 to 1990 was 26.6^{0}C with standard deviation $\pm$1.1^{0}C and coefficient of variation 4.1% while mean temperature for the year 1991-2000 was 26.8^{0}C with the same standard deviation and coefficient of variation with the previous decade. Mean maximum temperature for the observation between 2001 and 2010 was 27.3^{0}C with standard deviation of $\pm$1.2^{0}C and coefficient of variation 4.4%. The mean maximum temperature of the study area over thirty years time ranging from 1981 to 2010 was 27^{0}C with standard deviation $\pm$1.14^{0}C and coefficient of variation 4.2% as depicted in figure 22 below.

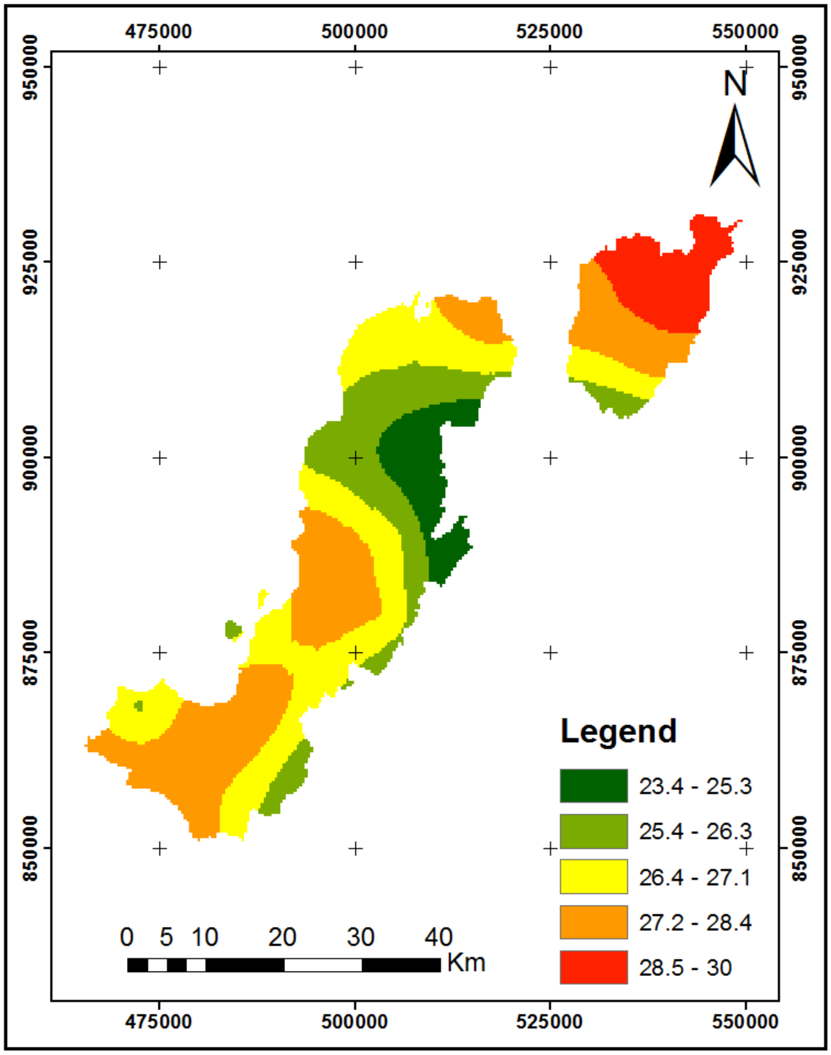


Figure 22: Reclassified average maximum temperature between 1981 and 2010

In relation with this, the survey conducted by UNEP (1984) for the stations found within the study area since their establishment to 1984 shows that the highest mean temperature was 24.6 ^{0}C and the lowest was 14.1^{o}C. To this effect, the result of the study shows that there was an escalation in the amount of mean maximum temperature in the first two decades with a difference of 0.2^{0}C while in the last 2001 to 2010 observation the mean annual maximum temperature doubled, increased by 0.5^{0}C.

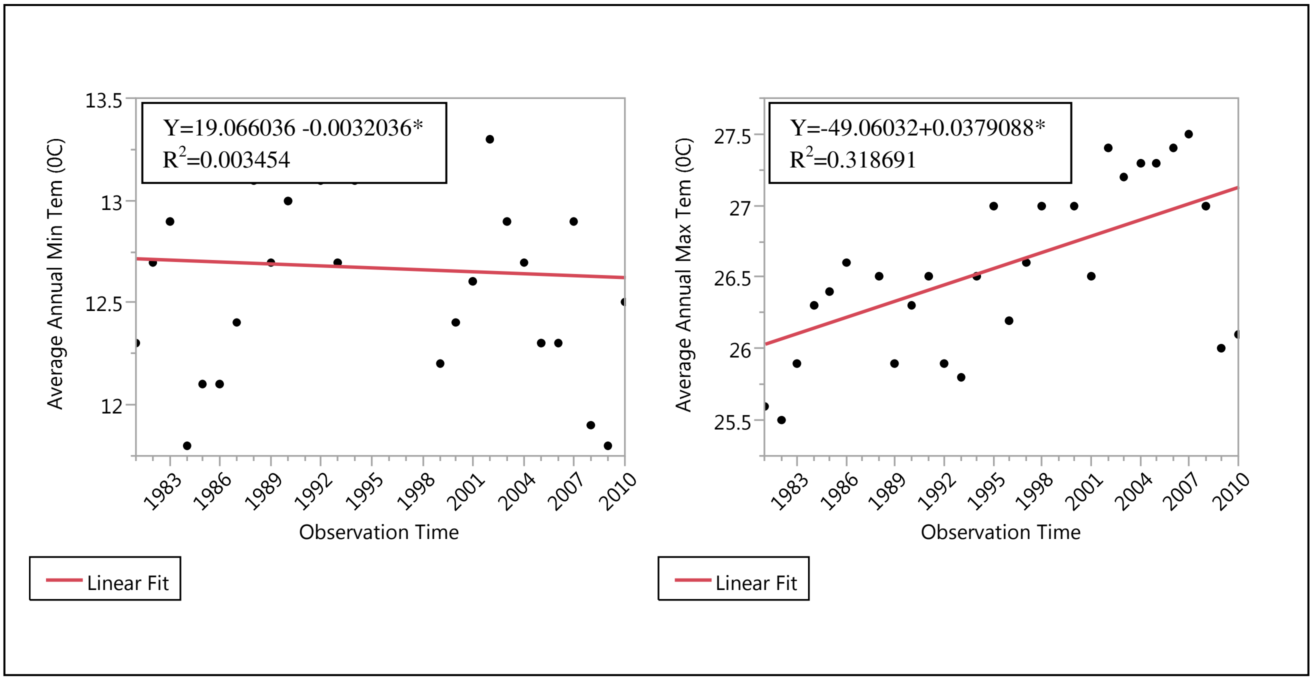


Figure 23: Depicts Mean Annual Min & Max Temperature Trend of the study area between (1981-2010)

As indicated in the table 9, the highest average annual minimum temperature was 13^{0}C which was recorded in the second decade of the observation time (1991 to 2000) with $\pm$1.1 ^{0}C standard deviation and 0.06 of coefficient variation. The lowest average annual minimum temperature was 12.5^{0}C with coefficient of variation of 0.9 for the first and last decades. The coefficient variation is much higher for minimum temperature than maximum temperature. On the other hand, the area experienced sharp rise of mean annual maximum temperature was detected in the last decade of the study period with an increase of 0.5^{0}C. The mean annual minimum temperature shows that in the first two decades there was an augmentation of 0.5^{0}C. Nevertheless in the last decade there was a decline in the mean annual minimum temperature with 0.5^{0}C as stipulated in the table 10. Thus, it is interesting to note that the average annual maximum temperature is increasing faster than the average annual minimum temperature.

Table 10: Decadal mean minimum and mean maximum temperature (^{O}C) and SD and CV (%), 1981-2010

Year Observation (Decades)	Mean		SD		CV		CV (%)	
	Max T^o	Min T^o	Max T^o	Min T^o	Max T^o	Min T^o	Max T^o	Min T^o
1981-1990	26.6	12.5	1.1	1.1	0.04	0.09	4.1	8.8
1991-2000	26.8	13	1.1	0.76	0.04	0.06	4.1	5.8
2001-2010	27.3	12.5	1.2	1.15	0.04	0.09	4.4	9.2

Source: Cell Statistics result on ArcGIS, 2014

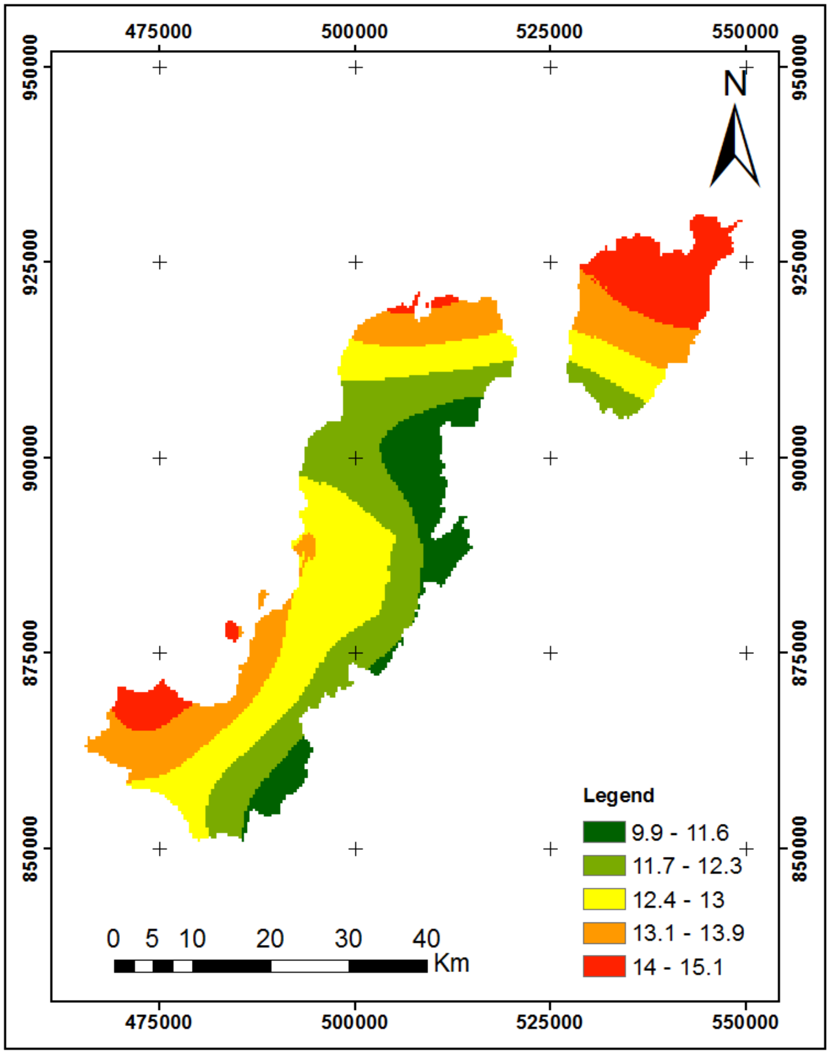


Figure 24: Reclassified time series average minimum temperature from 1981 to 2010

In the study area, the mean annual maximum temperature reached its highest level 27.9^{0}C in the year 2002 and 2007. But, the lowest temperature was found to be 25.9^{0}C registered in 2009. The areal average annual maximum temperature of the study area in all the three decades shows relatively increasing trend while the mean minimum temperature record shows declining trend.

Regarding people's observation opinion on the temperature condition of the past decades collected from the field, it shows that the temperature is very much increasing, especially in the recent past.

Regarding the issue of whether the temperature of the area is changing or not, all respondents replied that there is an increment in temperature situation. The respondent also added that there is a rise in temperature status as compared to the past. This implies that the analysis result of the mean maximum temperature is positively correlated with the information obtained from the field survey.

4.4.2.8.2. Extreme high and low Temperature event

The occurrence and magnitude of extreme temperature across time and space which depend on latitude and altitude of location, and other factors which affect the climatic condition of an area, such as distance from the sea, ocean current etc. In the case of Ziway Dugda and Dodota Woreda, the minimum and maximum temperature records were found in the range of >9.4^0C and <30.7^0C, respectively. Hence, the study takes 9.4^0C, 10.5^0C, and 9.7^0C and 29.4^0C, 29.8^0C, and 30.7^0C as minimum and maximum extremes, respectively (table 11 and figure 25).

Table 11: Extreme minimum and maximum temperature event during 1st (1981-1990), 2nd (1991-2000), 3rd (2001-2010) decades

Event	Temperature (T^0c)	Year of observation (decades)
Min T^0c	9.4	1981-1990
	10.5	1991-2000
	9.7	2001-2010
Max T^0c	29.4	1981-1990
	29.8	1991-2000
	30.7	2001-2010

Source: statistical analysis result on ArcGIS environs, 2014

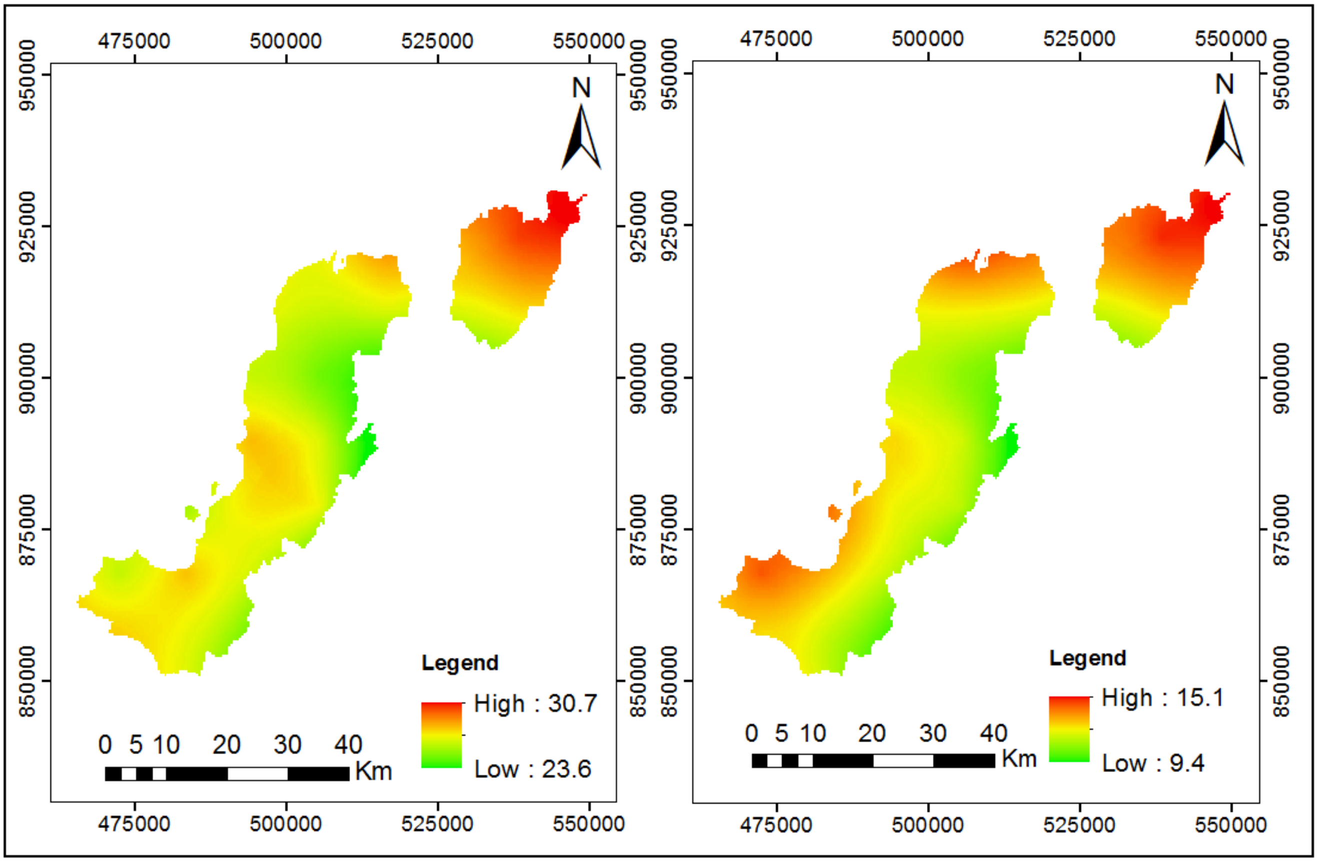


Figure 25: Reclassified extremely maximum and minimum temperature (2001-2010 right & 1981-1990 left) respectively

In a nutshell, the existence and frequencies of extreme minimum and maximum temperature events have a warming effect on climatic condition of the study area. The observed data reveals that the extreme maximum and minimum temperature were 30.7^{0}c and 9.4^{0}c correspondingly occurred in the first and the last decades of the observation.

4.4.2.9. Inter-annual Temperature Fluctuation

4.4.2.9.1. Mean Annual Maximum and Minimum Temperature Anomalies

Inter-annual/Annual variation of maximum and minimum temperatures expressed in terms of normalized temperature anomalies averaged. Figure 26 clearly exhibits that there has been a warming trend in the mean annual maximum temperature over the past 30 years and it has been increasing by about 0.7^{0}C. This clearly shows that there has been a warming trend in the mean annual maximum temperature in the study area. In line with this, the UNDP Climate Change Profile for Ethiopia (UNDP 2007/08) report also shows that the mean annual temperature has increased by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade

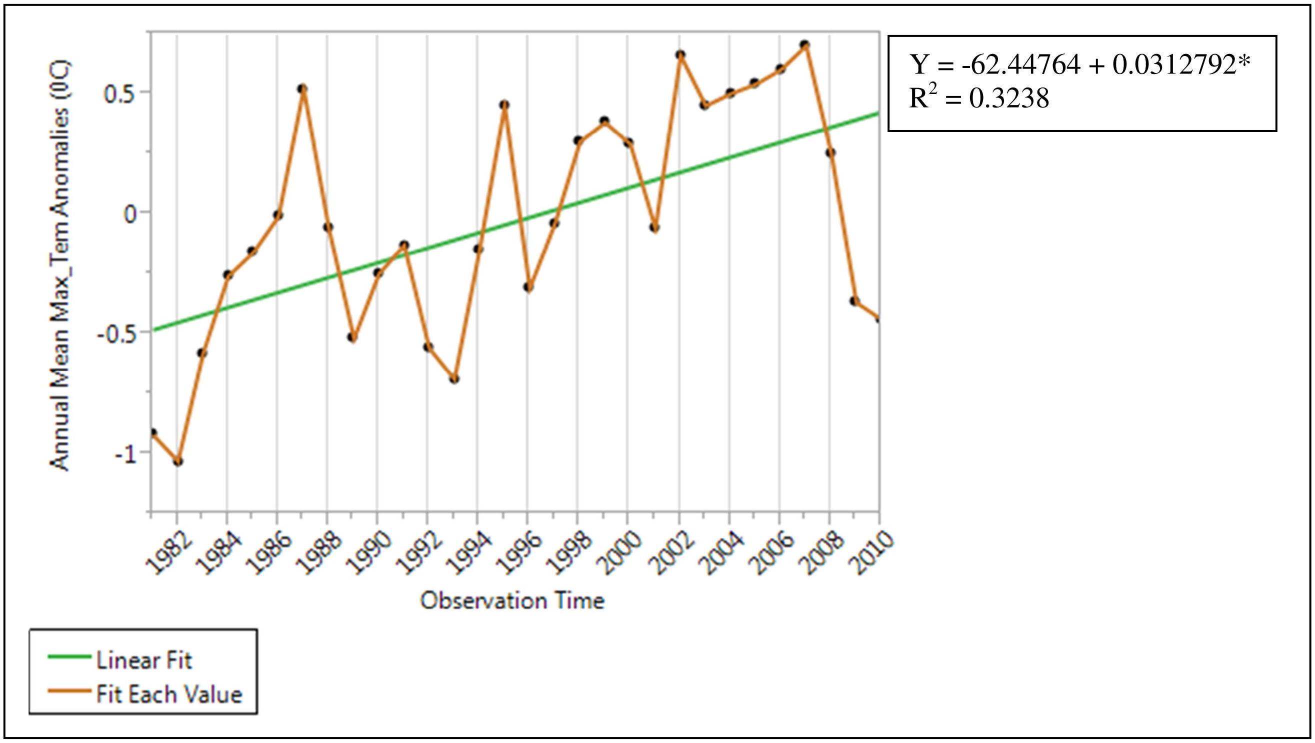


Figure 26: year to year annual mean maximum temperature variability and trend over the study area (1981-2010).

In addition, projected climate change over Ethiopia made by NMA (2007) emphasize that the mean annual temperature of the country will increase in the range of 0.9 to 1.1 °C by 2030. The same report points out that regarding the past trend, it clearly reveals that there has been a warming trend in the annual minimum temperature over the past 55 years i.e. 1951 to 2006. It has been increasing by about 0.37 ^{0}C every ten years. This goes with the result obtained from the analysis because in the last three decades, the mean maximum temperature exacerbated by 0.7^{0}C i.e. on average per decade 0.23^{0}C which means if the temperature increment continued with this rate in the year 2030, it will reach to the projected level.

On the other hand, as depicted in figure 27, the mean annual minimum temperature over the past thirty years demonstrated that there has been a slight decline unlike the average annual maximum temperature.

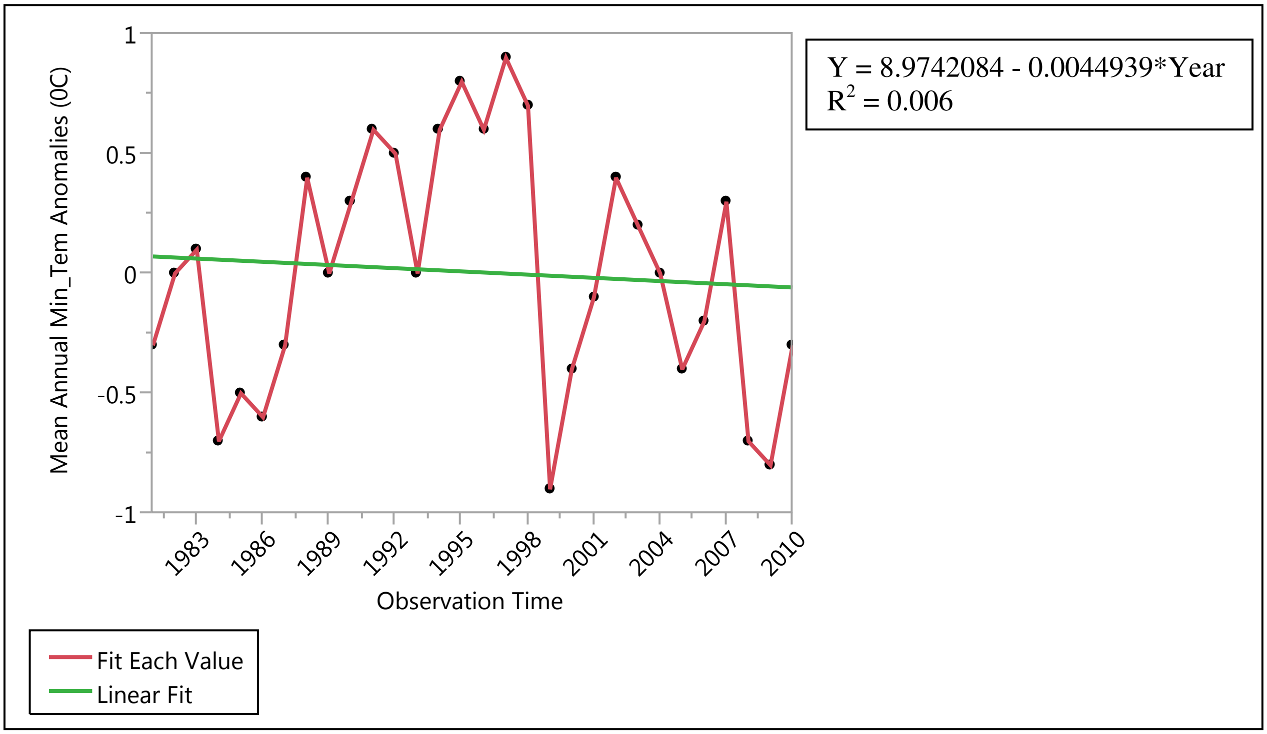


Figure 27: year to year annual mean minimum temperature variability and trend over the study area (1981-2010).

4.4.2.10. Social Consequences of Climate Change

4.4.2.10.1. Climate Change Impact on the community

Climate variability and change over the past century have already had measurable effects on ecosystems, societies, economies, and health (Oxfam, 2010). The vulnerability of Ethiopia to climate change impact is a function of several biophysical and socioeconomic factors [ORS] Oromia Regional State Government (2004).

Table 12 illustrates the effect of climate change and variability on various social groups in the study area. On average, 60% of the respondents suggested youths are the most vulnerable to climate shocks. In addition to that, of the remaining 30%, respondents reflected that all farmers of the community are disproportionately affected by the consequences of climate change. Respondent reported that adult women, adult men and girls are highly susceptible to climatic impacts which accounts 5%, 2.5% and 2.5% respectively. In general, it is possible to infer that relatively youths are more vulnerable as compared with other social groups because they have low adaptability capacity and little resistance when they are exposed for climate change impacts.

Table 12: Who is more affected by the climate change impacts?

Vulnerable group	Adult Man	Adult Women	Girls	Boys	Youths	all are affected	Total
No of respondents	1	2	1	0	24	12	40
No of respondents in %	2.5	5	2.5	0	60	30	100

Source: survey result. 2014

4.4.2.10.2. Crop Cultivation

Climate change has impact on Ethiopian agriculture. Erratic rainfall and increasing amount of temperature are influencing the agricultural system of the country. Many regions have been severely affected by climate changes (NMA, 2007).

Many researchers confirmed that, in Ethiopia, climate change poses particular risks to poor farmers and pastoralists who have an immediate daily dependence on climate sensitive livelihoods and natural resources (Mikias, 2014).

Table 14 designates the magnitude of agricultural damages occurred on agricultural land within the study area. The major cause for production loss was due to excess amount of rain fall or rain shortage or other effects of climate related causes. Basically, long record of agricultural damage was included in this study simply to show the level of climate variability effect could have on crop production as one important driving factor.

The aggregated damage is increasing from time to time and in certain year's extreme damage occurred. In the year 2004 and 2010 extreme damage was recorded as shown on table 13.

Table 13: Agricultural damage in hectare in the districts within the study area

Year	Dodota-Sire	Ziway Dugda
1994	11,785	5,995
1995	8,792	9478
1996	3904	NA
1997	2,463	2463
1998	4,016	4450
1999	17,145	44,906
2000	14,218	4331
2001	3,927	5444
2002	4,880	1853
2003	40,826	22,280

2004	1,044	6689
2005	1,339	5380
2006	18,690	16,496
2008	2,921	NA
2010	20,948	42,404
Averaged Damage (He)	10,928	13,244
Averaged cultivated land	46,990	31,799
% of damage	23.3	41.6

Source: Arsi Zone DPPC Office, 2010

4.4.2.10.3. Changing of Land Use/Cover

4.4.2.10.3.1. Land Use Land Cover Classification of 1984 image

The study area has been defined to have six land use land cover categories, which are: Bare land, built-up area, farm land, forest, shrub and bush land, and water body. The result of the land use land cover classification for 1984 showed on the table 14 and figure 28 below that the overriding share of the study area was covered by shrub land, farm land and bare land which accounts for 56170.9 ha (34.4%), 54485.8 ha (33.3%) and 28970 ha (17.7%) respectively. Built-up area, forest and water body covered the remaining. Water body takes the smallest proportion in this respect, 272.5 ha (0.17%). The proportion of forest coverage was 11.85% (19424.6 ha).

Table 14: LU/LC classes, their corresponding areas for the year 1984.

Land Cover Type	Hectares	Percentages
Bare land	28970.0	17.7
Built-up area	4205.6	2.6
Farm land	54485.8	33.3
Forest	19123.9	11.7
Shrub land	56170.9	34.4
Water Body	434.8	0.3
Total	163391	100

Source: statistical analysis result on ERDAS Imagine, 2014

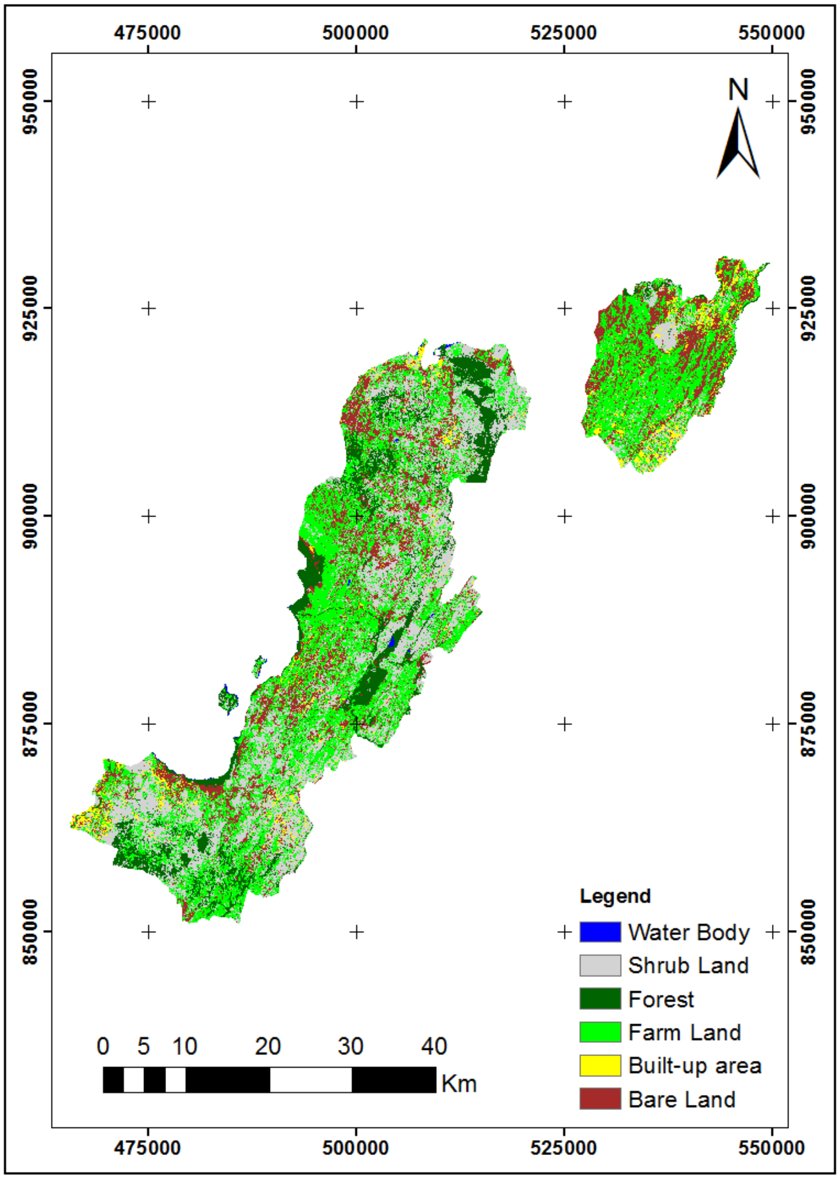


Figure 28: Land use land cover classification map for 1984

4.4.2.10.3.2. Land Use Land Cover Classification of 1995

The land use land cover for the year 1995, given on figure 29, reveals that farm-land, shrub land and built-up area accounted the dominant land use, which account for 51262.8 ha (31.3%), 47039.2 ha (28.7%) and 25168.7 ha (15.4%) respectively. Likewise, here the least type was water body which constitutes for 2102.6 ha (1.3%). The forest land, reduced to 10052.5 ha (6.1%) as compared to the 1984 classification.

Table 15: LULC classes, their corresponding areas for the year 1995

Land Cover Type	Hectares	Percentage
Bare land	27850.9	17.0
Built-up area	25168.7	15.4
Farm land	51262.8	31.3
Forest	10052.5	6.1
Shrub and bush	47039.2	28.7
Water Body	2102.6	1.3
Total	163476.7	100

Source: statistical analysis result on ArcGIS Environs, 2014

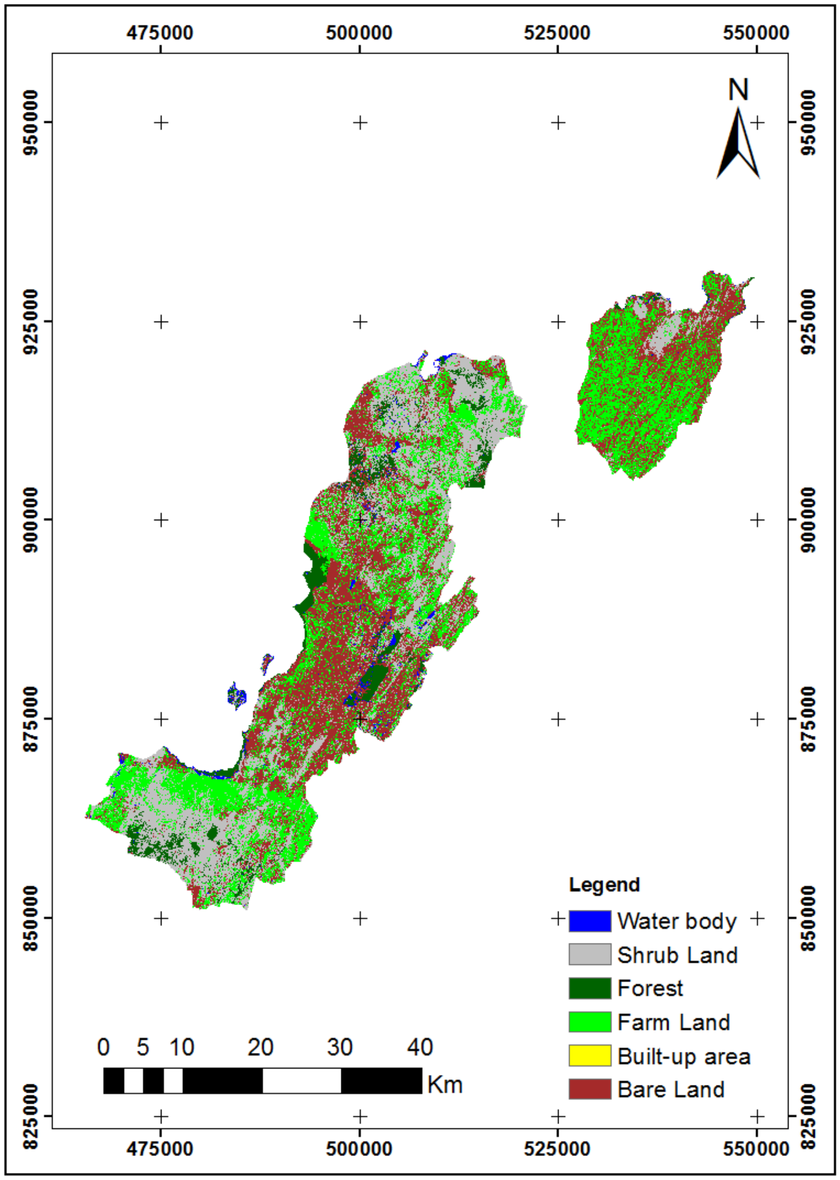


Figure 29: Land use land cover classification map of 1995

4.4.2.10.3.3. Spatial Correlation between the Land use/Cover classes of 1984 and 1995

The land use Conversion matrix in table 17 indicates the dynamics of the land use /cover change of the study area from 1984 to 1995. The column shows the land use categories of the year 1984. The rows indicate the land use categories in 1995. The highlighted diagonal values are the unchanged values of each land use class.

The change detection matrix result on table 16 and figure 30 shows that compared to 1984, the proportion of forest and shrub land was reduced dramatically in 1995. Of the total land use forest and shrub land 6992.1 ha (4.3%) and 16002 ha (9.8%) was converted in to shrub land and farm land respectively. Both land use classes underwent a series of changes in ten years' time. The size of forest coverage was reduced by 9059.8 ha (5.5%) and at the same time shrub land dropped by 9145.6 ha (5.6%). On the contrary, built-up area and water body were increased. Particularly the built-up area augmented significantly by 20941.5 ha (12.8%). In this regard, forest accounts 1364.6 ha (0.8%), farm land constitutes 10052 ha (6.2%), shrub land 6681.9 ha (4.1%) and bare land 6303.7 ha (3.9%) was transformed in to built-up area between 1984 and 1995. Likewise, land use of water body also increased initially. It was found to be 434.8ha (0.3%). However, in the course of time, it was raised by 1628 ha (1%). Pertaining with this 891.8 ha (0.5%), 265.6 ha (0.2%) and 383.9 ha (0.2%) of forest, farm land and shrub land correspondingly contributed for the change. The rest land use classes decreased in land use coverage. In this respect, bare land declined by 1113.7 ha (0.7%) and in the same way, the farm land also diminished by 3250.6 ha (2.0%).

Table 16: Change Detection Matrix for 1984 and 1995

Change Detection Matrix result of 1984 and 1995															
Year	Land Use Land Cover class for 1995														
	LU/LC Type	**Forest**		**Farm Land**		**Shrub Land**		**Water Body**		**Built-up area**		**Bare Land**		**Class Total**	
		Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	**Area (ha)**	**%**
Land Use Land Cover class for 1984	**Forest**	9235.7	5.7	166.9	0.1	6992.1	4.3	891.8	0.5	1364.6	0.8	472.8	0.3	19123.9	11.7
	Farm Land	339.6	0.2	24195.0	14.8	10262.7	6.3	265.6	0.2	10052.0	6.2	9370.9	5.7	54485.8	33.3
	Shrub Land	321.7	0.2	16002.0	9.8	25710.3	15.7	383.9	0.2	6681.9	4.1	7071.0	4.3	56170.9	34.4
	Water Body	31.4	0.0	6.1	0.0	44.5	0.0	301.0	0.2	28.4	0.0	23.5	0.0	434.8	0.3
	Built-up area	0.5	0.0	1992.5	1.2	561.2	0.3	19.6	0.0	716.6	0.4	915.2	0.6	4205.6	2.6
	Bare Land	135.2	0.1	8872.7	5.4	3454.6	2.1	201.1	0.1	6303.7	3.9	10002.9	6.1	28970.0	17.7
	Class Total	**10064.1**	**6.2**	**51235.2**	**31.4**	**47025.3**	**28.8**	**2062.8**	**1.3**	**25147.1**	**15.4**	**27856.3**	**17.0**	**163391**	**100**
	Image Difference	**-9059.8**	**-5.5**	**-3250.6**	**-2.0**	**-9145.6**	**5.6**	**1628.0**	**1.0**	**20941.5**	**12.8**	**-1113.7**	**-0.7**		

Source: change detection analysis result on Arc GIS environs, 2014.

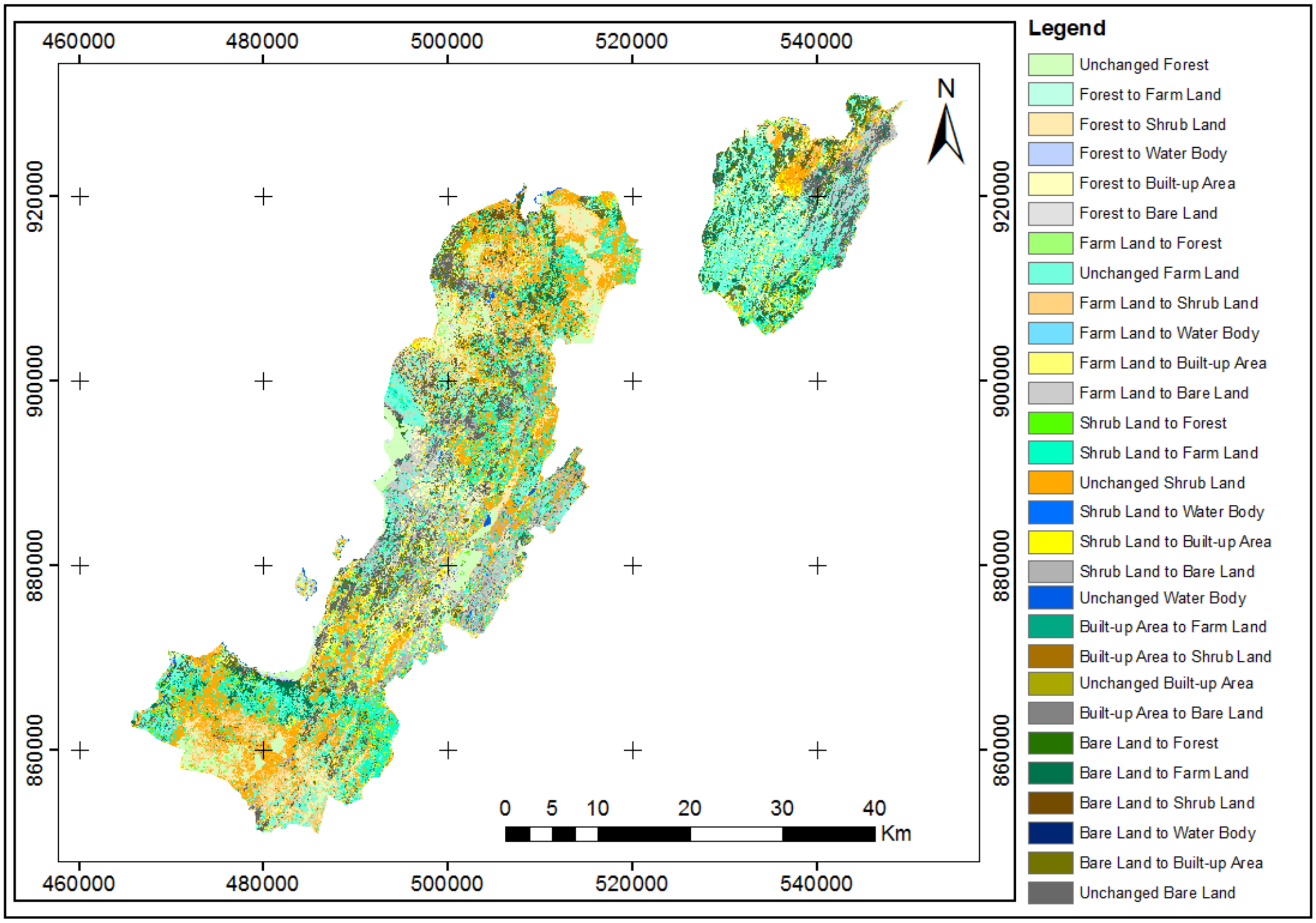


Figure 30: Change Map of the study area b/n 1984 and 1995

4.4.2.10.3.4. Land Use Land Cover Classification of 2013

In this land use land classification the result demonstrated that water body made up the least coverage, which is 890.9 ha (0.5%), whereas farm land and shrub land takes the largest proportion, 66247.4 ha (40.6%) and 59264.2 ha (36.3%) respectively. Nevertheless, significant negative change was observed in the built-up land use type in this land use was reduced by half.

Table 17: LULC types, their corresponding for the year 2013

Land Cover Type	Hectares	Percentage
Bare land	16574.4	10.1
Built-up area	13419.3	8.2
Farm land	66247.4	40.6
Forest	6882.1	4.2
Shrub land	59264.2	36.3
Water Body	890.9	0.5
Total	163655	100

Source: statistical analysis result on ArcGIS Environs, 2014

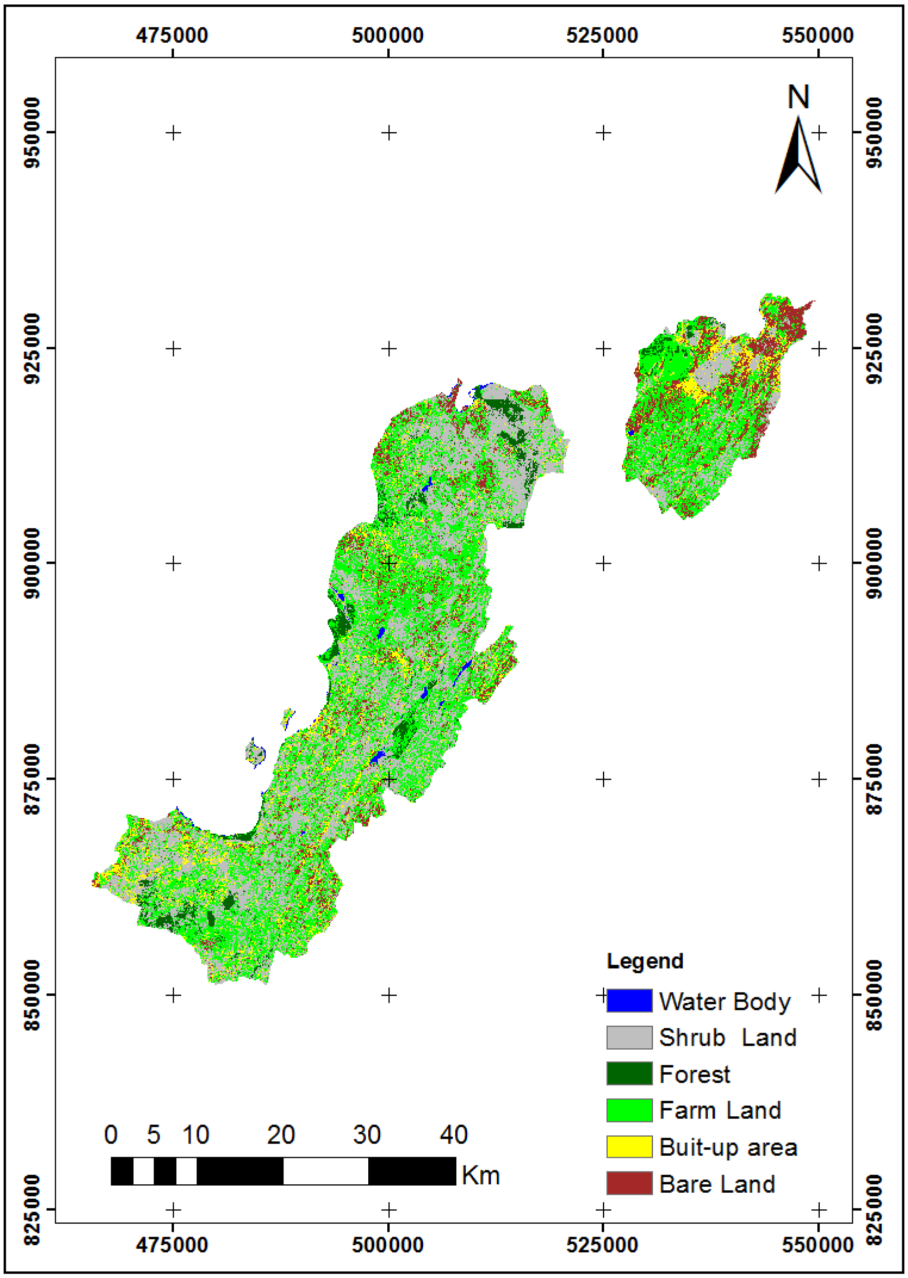


Figure 31: Land use land cover classification for 2013

In this category, as the change detection matrix shows on table 18, the bare land, built-up area, forest and water body underwent through negative change. Shrub and farm land resulted in a positive change. The bare land and built-up area were reduced by 11286.7 ha (6.9%) and 7680.2 ha (4.7%) respectively between the year 1995 and 2013. At the same time, forest and water body also declined by 3878.4 ha (2.4%) and 1240.8ha (0.8%) consecutively. A large portion of the forest, 2868.7 ha (1.7%), 2408.2 ha (1.5%) and 602.2 ha (0.4%) was transformed to farm land, shrub land and built-up area accordingly. On the other hand, shrub land increased by 7125.5 ha (4.3%) and farm land 16960.5 ha (10.3%).

In this comparison, tremendous land use/land cover change was observed in the built-up class which is 11708 ha (7.1%) and 6851.4 ha (4.2%) of the built-up area changed to farm land and shrub land respectively. The smallest change occurred in the water body.

Table 18: Change Detection Matrix of 1995 and 2013

	Change Detection Matrix of 1995 to 2013 in (Ha & %)														
Year	Land Use Land Cover class for 2013														
Land Use Land Cover class for 1995	**LULC Type**	**Forest**		**Farm Land**		**Shrub Land**		**Water Body**		**Built-up area**		**Bare Land**		**Class Total**	
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (ha)	%
	Forest	3976.4	2.4	2868.7	1.7	2408.2	1.5	160.2	0.1	602.2	0.4	36.9	0.0	10052.5	6.1
	Farm Land	285.6	0.2	25600.0	15.6	12913.6	7.9	39.6	0.0	5479.3	3.3	6944.7	4.2	51262.8	31.3
	Shrub Land	1454.7	0.9	14741.9	9.0	23898.3	14.6	60.1	0.0	4896.7	3.0	1987.4	1.2	47039.2	28.7
	Water Body	119.1	0.1	711.1	0.4	574.3	0.4	437.0	0.3	218.4	0.1	42.6	0.0	2102.6	1.3
	Built-up area	262.2	0.2	11708.0	7.1	6851.4	4.2	75.1	0.0	3329.2	2.0	2942.8	1.8	25168.7	15.4
	Bare Land	76.1	0.0	12593.5	7.7	7519.0	4.6	89.7	0.1	2962.7	1.8	4609.8	2.8	27850.9	17.0
	Class Total	**6174.1**	**3.8**	**68223.2**	**41.6**	**54164.8**	**33.0**	**861.8**	**0.5**	**17488.6**	**10.7**	**16564.2**	**10.1**	163476.7	100
	Image Difference	**-3878.4**	**-2.4**	**16960.5**	**10.3**	**7125.5**	**4.3**	**-1240.8**	**-0.8**	**-7680.2**	**-4.7**	**- 11286.7**	**-6.9**		

Source: change detection result on ArcGIS environs, 2014.

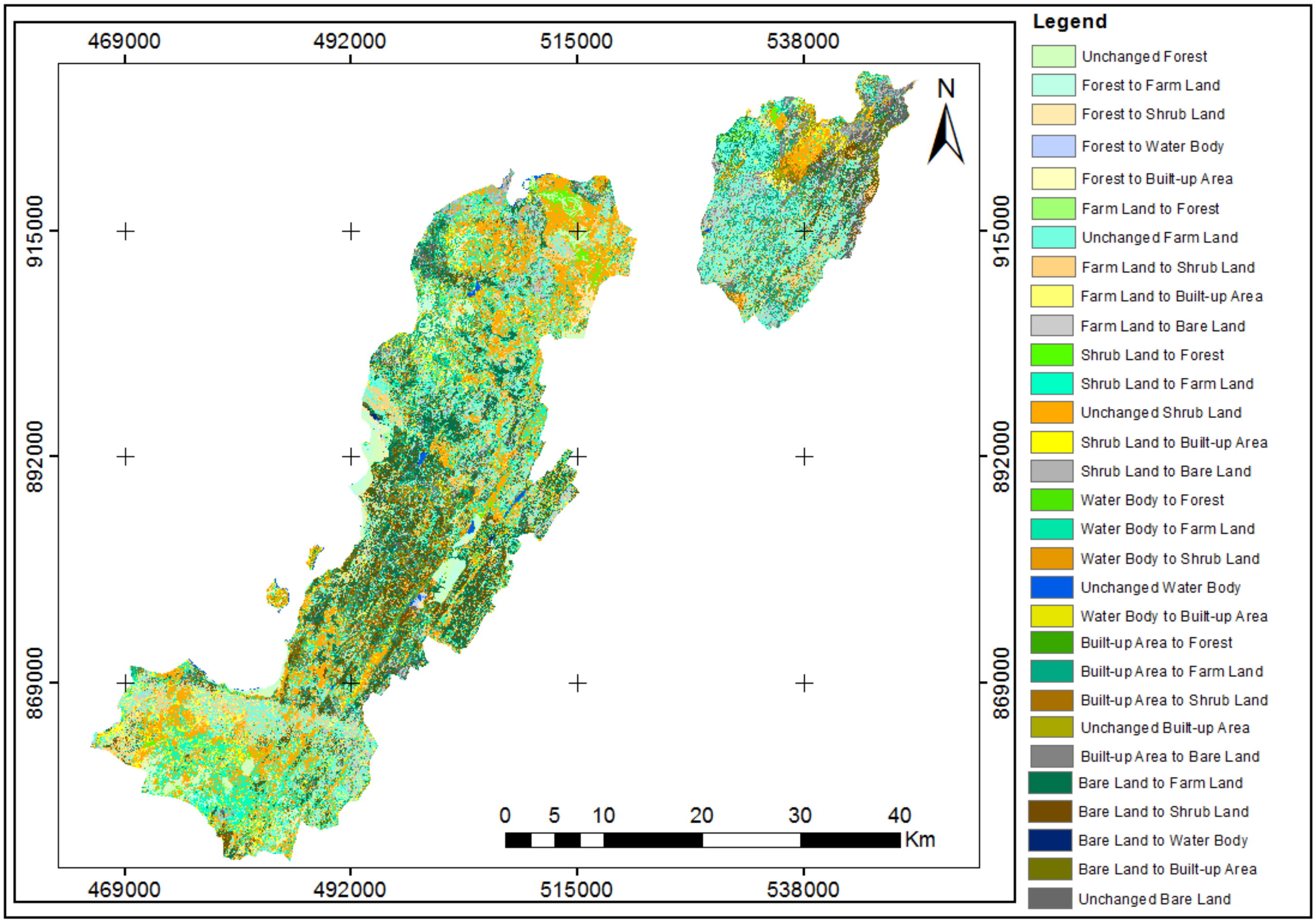


Figure 32: Change Map of the study area b/n 1995 and 2013

Spatial Correlation between the Land use/Cover classes of 1984 and 1995

This section tried to interpret the change detection matrix result obtained between the year 1984 and 2013 as stipulated in the change detection matrix on table 19.

Forest Coverage

The 1984^{TM} satellite image LU/LC classification showed that the total land use of forest in 1984 was 19140.4 ha (11.7%) of the total study area. However, it has reduced to 6882.1 ha (4.2%) in the year 2013 LU/LC classification. This implied that in three decades times, 12258.4 ha (7.5%) of forest coverage has been deforested. Based on the change detection matrix result exhibited in table 19, most of the forest was converted into shrub land, farm land and built-up area which constitutes 6791.3 ha (4.2%), 5621.9 ha (3.4%) and 696.7 ha (0.4%) respectively.

Farm Land

The area of land that was occupied by agriculture in 1984 was 54430.2 ha (33.3%) and it escalated to 66247.4 ha (40.6%) in 2013. In this regard, most 20341.6 ha (12.5%) of shrub land, 13297.4 ha (8.1%) of bare land and 5621.9 ha (3.4%) of forest contributed to the rise of agricultural land between 1984 and 2013. The increase of agricultural land is purely population induced. The amount of increase in agricultural land during the 1984 and 2013 periods was 11817.2 ha (7.2%).

Shrub Land

At the initial stage, this LU/LC category covered a total area of 56088.6 ha (34.3%). In the course of time, the shrub land increased to 59264.2 ha (36.3%) in 2013. The rate of increase of the shrub land during 1984 to 2013 was 3175.6 ha (1.9%). This LU/LC category has increased at the expense of farm land, forest and bare land which accounts to 16970.3 ha (10.4%), 6791.3 ha (4.2%) and 6515.8 ha (4%) respectively.

Water Body

The 1984 LU/LC classification result showed that the total land use of water body was 431.8 ha (0.3%). Of the total study area in the year 2013, the size of water body slightly increased to 890.9 ha (0.5%). The magnitude of water body increased by 459.1 ha (0.2%) in thirty years period.

Built-up Area

The area occupied by built-up area in 1984 was 4211.9 ha (2.6%) and increased to 13419.3 ha (8.2%) in 2013. The land use of built-up area increased by 9207.4 ha (5.6%) in three decades time. In this regard, except water body all land use types contributed for the increase of the land use of built-up area. About 5357.3 ha (3.3%) of farm land, 3690.1 ha (2.3%) of shrub land, 2768.2 ha (1.7%) of bare land and 696.7 ha (0.4%) of forest have been converted to built-up area (see table 19).

Bare Land

The change detection matrix result as shown on table 20, the proportion of bare land was greatly reduced by 11286.7 ha (6.9%). In this respect, 13297.4 ha (8.1%), 6515.8 ha (4%) and 2768.2 ha (1.7%) were transformed to farm land, shrub land and built-up area respectively.

Table 19: Change Detection Matrix of 1984 and 2013

	Change Detection Matrix of 1984 to 2013 in (Ha & %)														
Year	Land Use Land Cover class for 2013														
Land Use class of 1984	**LULC Type**	**Forest**		**Farm Land**		**Shrub Land**		**Water Body**		**Built-up area**		**Bare Land**		**Class Total**	
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (ha)	%
	Forest	5643.1	3.5	5621.9	3.4	6791.3	4.2	268.3	0.2	696.7	0.4	119.1	0.1	19140.4	11.7
	Farm Land	562.6	0.3	25642.6	15.7	16970.3	10.4	133.1	0.1	5357.3	3.3	5764.3	3.5	54430.2	33.3
	Shrub Land	454.2	0.3	20341.6	12.5	28162.7	17.2	133.0	0.1	3690.1	2.3	3307.0	2.0	56088.6	34.3
	Water Body	15.5	0.0	53.1	0.0	59.6	0.0	242.2	0.1	57.7	0.0	3.7	0.0	431.8	0.3
	Built-up area	4.4	0.0	1290.9	0.8	764.4	0.5	11.7	0.0	849.3	0.5	1291.2	0.8	4211.9	2.6
	Bare Land	202.3	0.1	13297.4	8.1	6515.8	4.0	102.6	0.1	2768.2	1.7	6089.1	3.7	28975.4	17.7
	Class Total	**6882.1**	**4.2**	**66247.4**	**40.6**	**59264.2**	**36.3**	**890.9**	**0.5**	**13419.3**	**8.2**	**16574.4**	**10.1**	**163278.3**	
	Image Difference	**-12258.4**	**-7.5**	**11817.2**	**7.2**	**3175.6**	**1.9**	**459.1**	**0.3**	**9207.4**	**5.6**	**-12401.0**	**-7.6**		

Source: change detection analysis result on Arc GIS environs, 2014

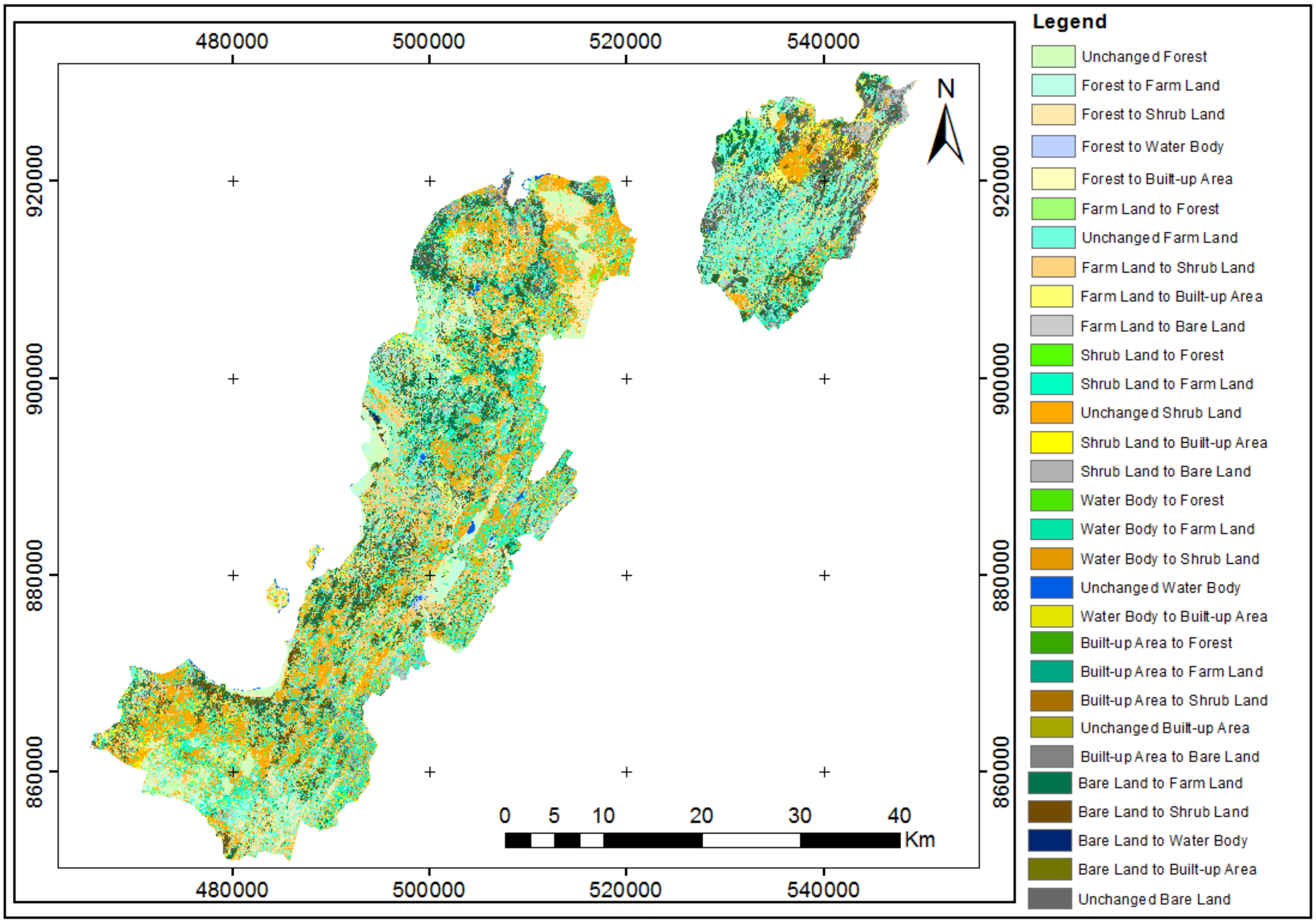


Figure 33: Change Map of the study area b/n 1984 and 2013

In general, in the land use land cover change detection analysis particular interest was given to the vegetation aspect i.e. forest coverage. The land use land cover classification result of the study area pointed out that the proportion of forest coverage decreased from time to time. In the year 1984, the forest coverage was 19140.4 ha (11.7%) of the total study area (see table 20). However, in the subsequent years, in 1995 and 2013 it was considerably reduced to 10052.5 ha (6.1%) and 6882.1 ha (4.2%) respectively. This implies the forest coverage has fallen down by 12258.4 ha (7.5%) of the entire area in thirty years' time.

Different explanation could be given for the deterioration of the forest resource in the area. In this regard, as it is well explained in the works of Netsanet (2007), the most important causality of all human induced causes for land cover change which are critical and currently increasing at alarming rate; which can be categorized into two broad divisions: proximate and driving causes. In Ethiopia, the proximate causes of land cover change, particularly natural forest destruction for agricultural expansion, the demand for increasing amounts of construction material, fuel wood and charcoal are the major factors for the increasing destruction of forest resources in the study area in particular and the country in general which have a far reaching implication changing the climatic condition of a given locality (Kahsay, 2004).

In addition, Climate variability and change can contribute to land degradation by making current land use practices unsustainable and induce more rapid conversion of land to unsustainable uses. The combined effects of rising temperatures and reduction of rainfall in the study area can cause further drying and reduction of forest and other vegetative resources (Mikias, 2014).

Moreover, UNEP (2002) in its report stated that forest ecosystems play multiple roles at global as well as local levels as providers of environmental services to nature in general, humans in particular, and as source of economically valued products. The same source further described that forests especially natural forests are used for various ecological and economic purposes. They could maintain local climate, regulates hydraulic cycle, used as wild life habitats and reduce runoff and soil erosion.

4.4.2.11. Spatial and temporal variation of mean annual NDVI coverage

The study in this section observed the correlation of rainfall and NDVI for the year 2000 to 2012 have been thoroughly analyzed on both annual and seasonal basis and presented in detail as follows.

From annual quantitative analysis of vegetation coverage, both the highest and the lowest vegetation coverage were manifested in the year 2009 and 2001 which is 20.7% and 17.3% respectively as shown in table 22. Pertaining with this, various studies report that the spatial and temporal differences in the NDVI are closely related to climate in many environments. In fact, temporal variations in the NDVI may be representative of the vegetation response to climate variability. Thus, the vegetation biomass has been widely used to monitor ecosystem dynamics and to detect the spatial extent and temporal variability of land degradation (Tucker and Choudhury, 1987; Groten and Ocatre, 2002 drawn in the works of Velk *et al*., 2008).

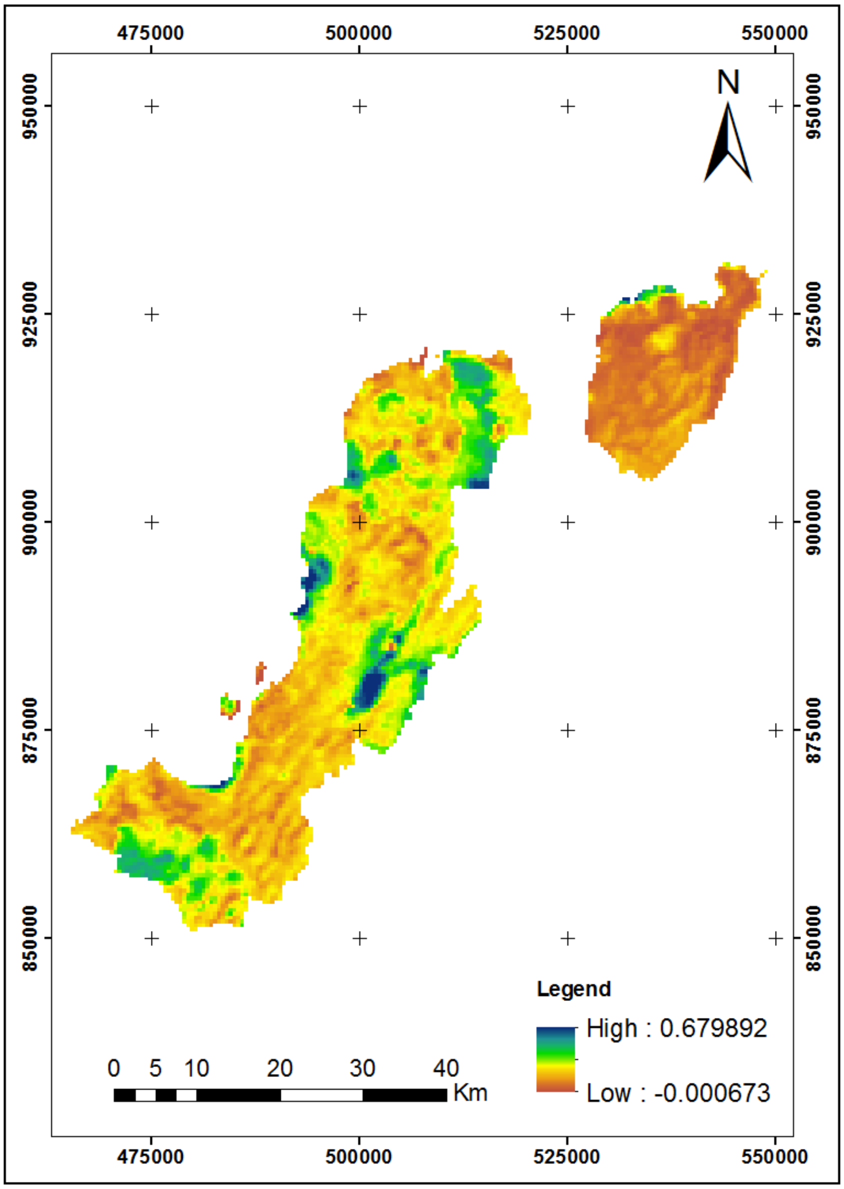


Figure 34: Depicts the overall average annual NDVI distribution b/n 2000 and 2012.

Table 20: Annual Quantitative Vegetation Coverage, Coefficient of Variation and Vegetation Type.

Vegetation Coverage Per year													
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CV	0.18	0.17	0.22	0.20	0.20	0.19	0.19	0.20	0.18	0.21	0.18	0.18	0.18
Low Vegetation (%)	17.6	17.34	21.5	20.41	20.16	18.81	19.29	20.04	17.67	20.66	18.4	18.3	17.6

Source: ArcGIS statistical analysis result, 2014

Based on USAID (2006) the vegetation condition of a region can be classified as high vegetation (values above 0.5), medium vegetation (from 0.292 - 0.5), low vegetation (0.166- 0.292), no vegetation (from 0.1 -0.166) and water body. As shown in table 21, the quantitative analyses of vegetation coverage shows relatively similar pattern. As a result the study area can be categorized under low vegetation coverage that ranges between 0.17-0.22 coefficients of variation.

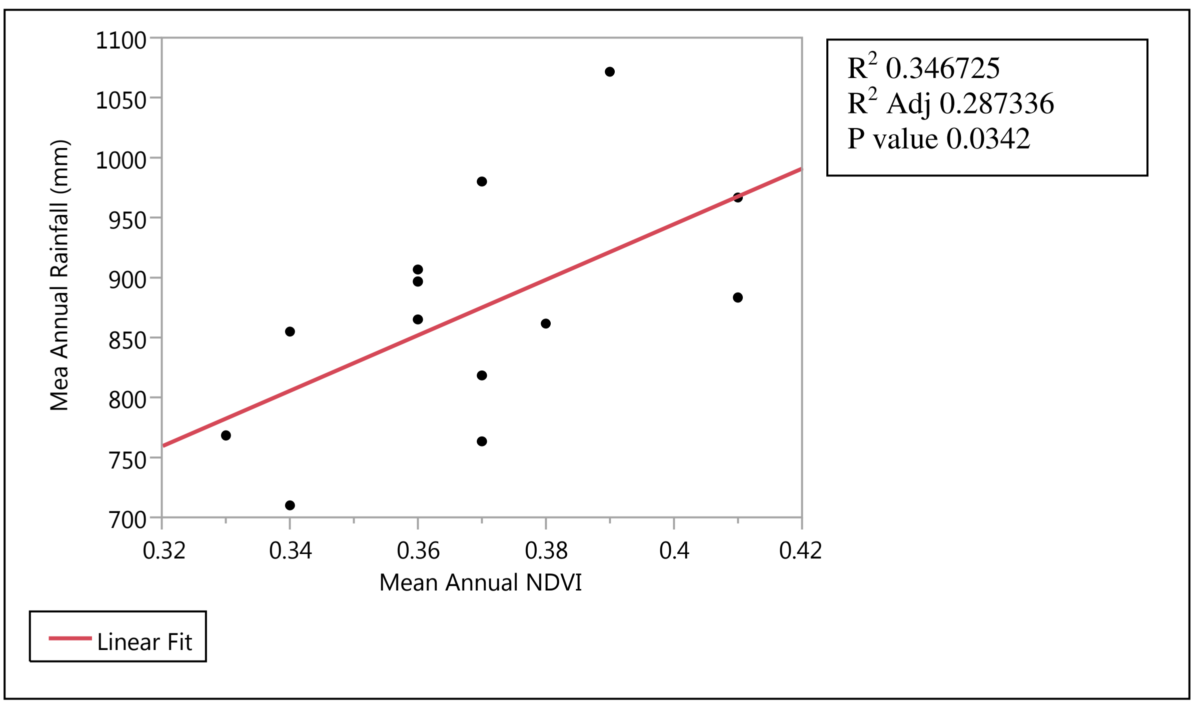


Figure 35: Graph shows the correlation b/n mean annual rainfall and mean annual NDVI between 2000 and 2012.

From the result, it is possible to deduce that there is linear correlation between mean annual rainfall and calculated NDVI value. The r^2 value is 0.346725 and r^2 adjusted is 0.287336, and the P value is significant at 0.0342 since the threshold for statistical significance level is 0.05.

4.4.2.12. Correlation between Meher season NDVI and Meher season Rainfall

The correlation described the degree of the relationship between the two variables (i.e. rainfall and the vegetation index). The analyses were performed at 95% confidence level. As figure 36 shows, that all the values were significant at P value of 0.18. Generally, the results showed moderate correlation found between rainfall and NDVI. This could indicate that NDVI results could potentially be influenced by other factors rather than precipitation alone.

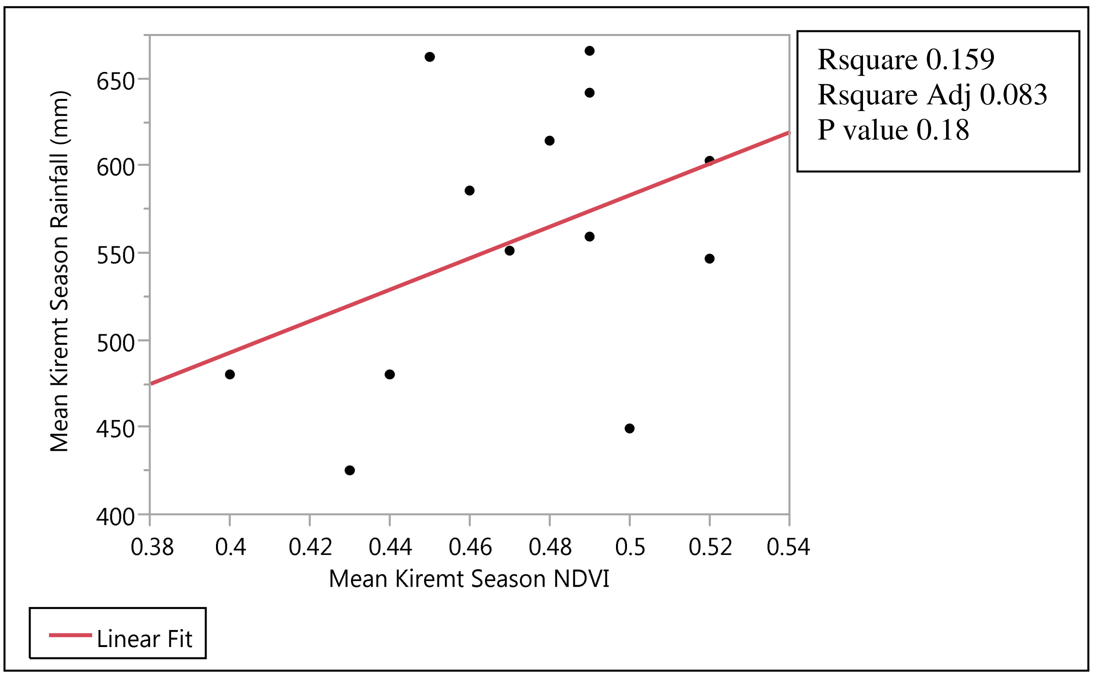


Figure 36: Graph shows correlation b/n mean kiremt season rainfall and mean kiremt season NDVI (2000-2012).

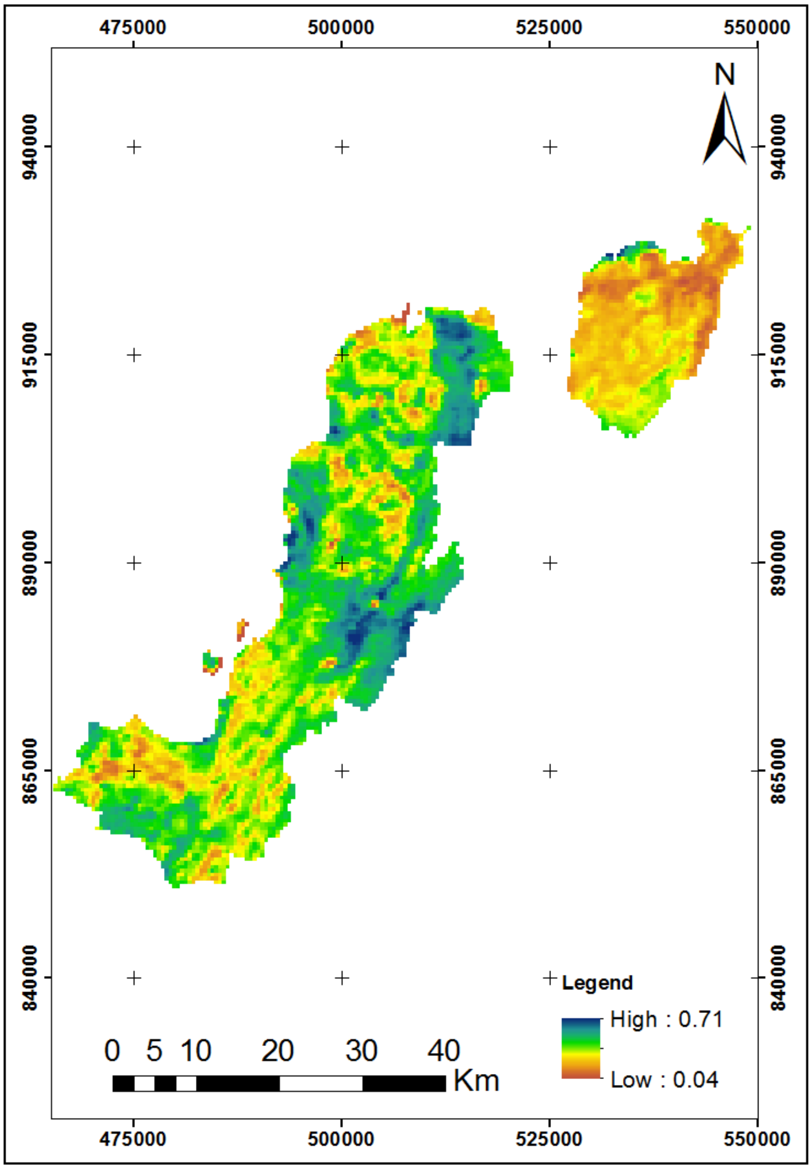


Figure 37: Depicts the overall mean annual kiremt season NDVI distribution (2000-2012).

4.4.2.13. Correlation between Belg Season NDVI and Belg Season Rainfall (2000-2012).

Generally, there was high vegetation coverage in Kiremt season (June, July, August and September) than Belg (February, March, April and May) from the period 2000 to 2012 due to presence of relatively good amount of rainfall which created favorable environment for plants or crop to grow. In the Belg season, the highest vegetation coverage class year is 2003 (27.3%) and lowest maximum vegetation coverage class year is 2001 (23.2%). The highest medium vegetation coverage class year is 2012 (25.6%). As shown in figure 10 during *Belg* season almost all parts of the study area was dry and there was no as such vegetation coverage. Only some parts was covered by vegetation.

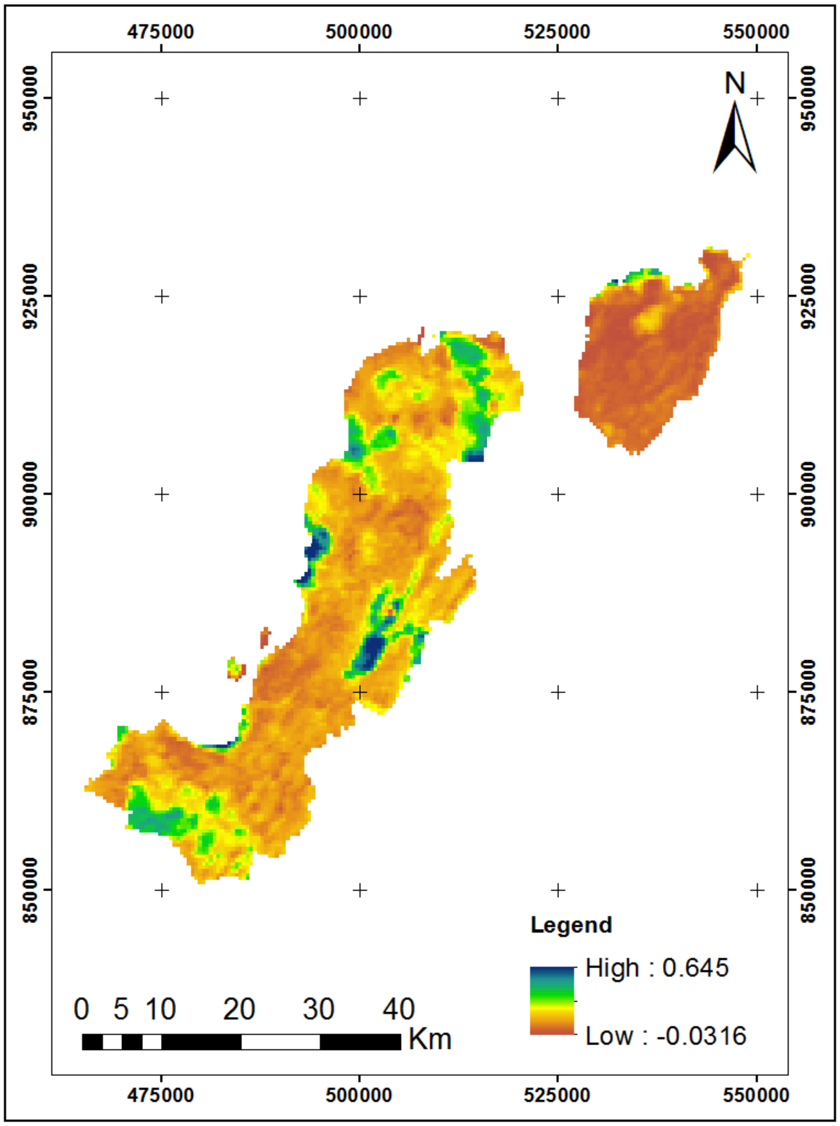


Figure 38: Illustration of time series analysis of mean *belg* Season NDVI b/n 2000 and 2012

The correlation result shows strong linear relationship between NDVI and rainfall in the area, which is 0.715 of r^2, P values of 0.0003. The scatter plot and map results indicated that the correlations between *belg* precipitation and NDVI are positive and exhibits a clear spatial pattern. In general, the correlation reflects that there is a decrease in vegetation coverage through time this is due to the fact precipitation and temperature directly influence water balance, causing changes in soil moisture regime which, in turn, influences plant growth.

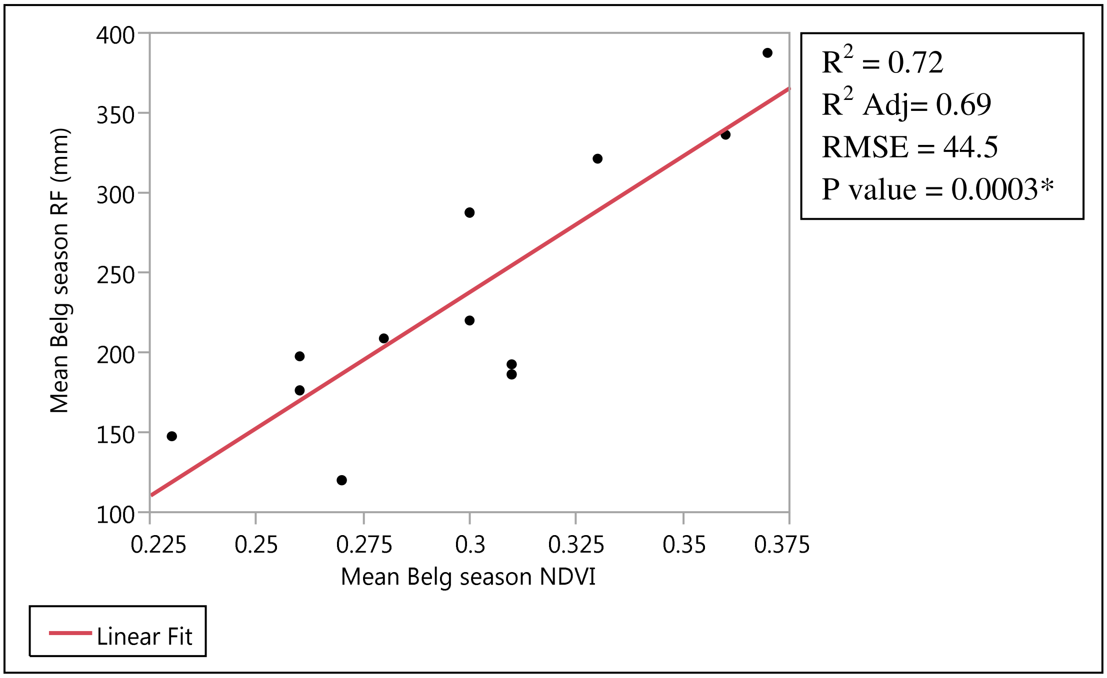


Figure 39: Graph shows correlation b/n mean *Bulg* season rainfall and mean *Bulg* season NDVI (2000-2012).

4.4.2.14. Correlation between mean annual NDVI and average annual temperature

Regarding, the scatter plot correlation of mean annual temperature and mean annual NDVI value of the year 2000 to 2010, the result explains that mean annual temperature is negatively correlated with NDVI values of the area, which is 0.0088 value of r^2, 0.78 values of p and residual standard error of 0.559. This implies implied that temperature is also a very important climatic element for vegetation growth depending on the type of vegetation and climatic zone.

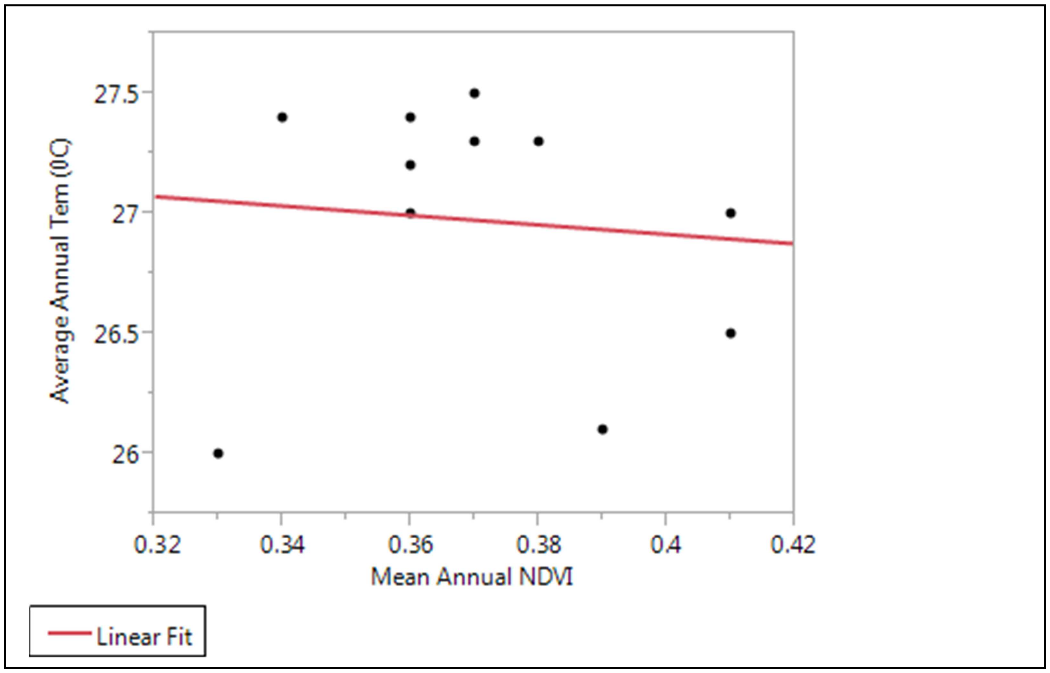


Figure 40: Graph shows correlation b/n mean annual Temperature and mean NDVI (2000-2010)

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary

This study deals with analyzing the spatio-temporal climate variability analysis of the area located within central rift valley, Ziway Dugda and Dodot Woreda. Basic climatic elements derived from 50 gridded stations for the last 30 years were carefully analyzed along with satellite images for the year 1984, 1995 and 2013, which mainly used to show climate variability influences in the land use land cover change over time. In this regard, particular interest was given to the forest coverage. The study also used MODIS data that ranges between 2000 and 2012. It has shown the correlation with rainfall and temperature data of the same period in annual and seasonal basis.

The result indicates that all climatic elements considerable variability is observed. The result shows there is a considerable spatial variation of rainfall and temperature in the study area. Among the different rainfall features considered during the study period, rainfall onset, end time and duration are found to be the variable ones. The overwhelming majority, (37) 92.5% of the respondents replied that there is a shift in rainfall pattern in the *Kiremt* by saying the rain usually comes later than the normal time. Pertaining with the rainfall cessation time in *Kiremt* season, the dominant (38) 95% of the respondents replied that there is an early withdrawal of rainfall than the normal time. Generally, the findings of the study revealed that there is a fluctuation on the onset of rainfall and cessation as well amount of rainfall in the main *Kiremt* season.

The mean annual total rainfall of the study area varied from 665.8 mm to 1056.7 mm between 1983 and 2012. The overall average rainfall in the last 30 years is 850 mm. The time series analysis result, which was made at decadal level, designates that there is a positive anomaly in the trend of rainfall. The mean annual rainfall increased by 78.8 mm in thirty years' period i.e. between 1983 and 2012. With regard to the mean decadal maximum rainfall distribution in the past three decades it lacks a consistent trend. Similarly, the mean Kiremt season rainfall also shows increasing trend. It is escalated by 75.1 mm of the same time span. Thus, the mean annual and mean Kiremt season rainfall shows the same pattern.

On the other hand, the *Belg* season rainfall record designated a negative anomaly. The amount of rainfall is reduced by 36 mm between 1983 and 2012. Pertinent with this fact, the result obtained from the key informants also reflects the same result i.e. the amount of *Belg* rainfall has been declining from time to time. The mean annual *Belg* season rainfall for the observation time was 246 mm.

On top of this, the occurrence of untimely November rain also examined the analysis of the study point out that the prevalence of November rain in the study area is increasing from time to time with a mean monthly rain of 10.8 mm. In a nutshell, the analysis of the study indicated that rainfall shows a significant variation both in space and time at seasonal and annual level.

Variance of maximum and minimum temperature occurred across the observation period (from 1981 to 2010). The magnitude of mean annual maximum temperature increased from time to time. The overall mean annual maximum temperature of the study area over the past 30 years was 27^0C while the overall mean annual minimum temperature was 12.67^0C. The mean annual maximum temperature generally augmented by 0.7^0C in the past three decades between 1981 and 2010. On average, the decadal maximum temperature rise by 0.23^0C. But, the average annual minimum temperature has shown a declining trend particularly this is true in the last decade of the observation time i.e. 2001 to 2010.

This study has shown that there are significant inter-annual variations of rainfall. Moreover, differences in rainfall amount and trend has been observed. Furthermore, variation in inter-annual minimum and maximum temperature patterns have been also noted in the study area. The study also found out that the size of forest coverage has decreased from time to time. Of the total land use, the lion share of forest was 19140.4 ha (11.7%) in the year 1984, but through time due to various extraneous factors, the forest coverage was reduced to 6882.1 ha (4.2%) in 2013. The forest coverage was declined by 64% in three decades period. In this respect, the possible explanation could be increasing of population resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forests for fuel wood, charcoal and construction materials (Bishaw, 2001).

This study also aimed at investigating the statistical relationship between climate parameters, normalized difference vegetation indices (NDVI) and surface temperature. The analysis was based on time series of vegetation indices and climate elements of thirteen years (2000 to 2012). The total temporal and spatial analyses of climatic elements and vegetation characteristics of the district show instability or variability of both climatic elements and vegetation coverage during the study period (2000 to 2012). Long year data analyses of climatic elements and vegetation coverage for the whole three seasons (Belg, Kiremt and Annual) and advanced statistical techniques would be important to understand the variability. The detail observation of the vegetation map clearly shows spatial and temporal variability of greenness occurs due to rainfall variability in the locality.

The correlation of *Belg* season precipitation with NDVI is positive and exhibits a clear spatial pattern. Similarly, the correlation of mean annual NDVI value with mean annual Meher season rainfall resulted in a moderate correlation. Lastly, in examining the correlation of NDVI and average annual temperature, the outcome designated a negative correlation. In comparison, the yearly correlation coefficients between NDVI and precipitation are very high while the correlation between NDVI and temperature are low. Within the period 2000 to 2012 there were a considerable seasonal or year to year variation in precipitation and NDVI throughout the study area. The total growing season analyses show that the general temporal and spatial distribution of NDVI in the whole study area correspond directly with the spatial pattern of average monthly or annual precipitation.

5.2. Conclusion

In this study an attempt has been made to analyze GIS and Remote Sensing application to the spatio-temporal climate variability analysis the case of Ziway Dugda and Dodota woredas, Arsi Zone, Oromia Region, Ethiopia. In light of the evidences that obtained from the study the following conclusions could be drawn;

The study revealed that there has been an increase of mean annual rainfall in the last three decades with a total amount of 78.8 mm. Nevertheless, there was an inter-annual fluctuation of rainfall. I.e. one year with a positive anomaly followed by another year with a negative anomaly. The average annual maximum temperature in the study area has shown an escalation in the observation period between 1981 and 2010. It is escalated by 0.7^0C. On average per decade 0.23^0C. On the other hand, the annual average minimum temperature designated a declining trend. Thus, as suggested by different scholars it is the maximum temperature which reflects the reality. This implies there is a warming trend in the study area. The temperature is increasing at alarming rate as compared to the past decades. In a nutshell, the analysis of the study indicated that rainfall shows a significant variation both in space and time at seasonal and annual level.

The findings of the study largely demonstrate that the proportion of forest has been deteriorated from time to time. Initially, in the year 1984 the size of forest coverage was 19140.4 ha (11.7%) However, in the subsequent years the proportion of forest resource was fallen down to 6882 ha (4.2%). This led us to the conclusion that high rate of deforestation is highly prevalent in the study area this is largely due anthropogenic factors.

The occurrence of untimely November rain also examined the analysis of the study point out that the prevalence of November rain in the study area is increasing from time to time with a mean monthly rain of 10.8 mm. This reveals that due to the frequent occurrence of this unexpected November rain in the study area the effect on the crop production is very significant; in effect the yield is very much meandering from time to time with negative implication.

Regarding the correlation between climate driving variables and NDVI value the study found out that except for *belg* season precipitation and NDVI value which shows strong linear correlation.

But, for the rest observation the result has shown that moderate correlation exists. On the contrary, negative correlation was found between the mean annual temperature and NDVI value for the observation period.

5.3. Recommendations

Based on the findings of the study, the following recommendations have been drawn.

- Public participation and awareness creation is highly needed in the field of climate variability and change. This could be done through educating the local community on how to intercede the problem from happening and developing various mechanisms on how to protect their environment and refrain from engaging in any destructive activities on the environment.
- Ensuring community participation especially those of women and youths, in both formulating climate change policies, environmental and drought monitoring systems and improve their disaster related risk reduction capacity.
- High rate of deforestation is highly prevalent in the study area. As a result, the size of forest is deteriorating from time to time. The implication is that the adaptive capacity undertaken to reduce human intervention in the locality is very low. Besides, the continued loss of forest makes people more vulnerable to the consequences of climate change even as deforestation and other environmental degradation continued to contribute to the problem. Thus, in order to recuperate the existing and restore the vanished forest resources due attention should be given by concerned jurisdiction to mitigate the problem by designing appropriate mechanisms which can be put in to action like trees transplanting and conducting large scale reforestation programs.
- The amount and prevalence of November rainfall in the observation period in the study area is significantly increasing from time to time. This is particularly true in the recent decade. As a result, the effect on the ground was visible because this is the time where crops are flourishing and crop harvesting is taking place. Therefore, in order to minimize its impact on the crop production the two woredas agricultural extension officials and disaster prevention preparedness commission officers should work hand in hand with the local peasant association. Thus, the responsible authorities should provide the necessary metrological information in advance before the time approaches so that the local community would collect the yield before it is seriously affected by the unseasoned November rainfall.

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Annex

Addis Ababa University

School of Graduate Studies

College of Social Sciences

Department of Geography and Environmental Studies

GIS, Remote Sensing, and Digital Cartography Stream

Questionnaire No: __________
Code number: _________

Date of interview: ___________

Locality: Lowlanders

Questionnaire items for the key informants

This is designed for the purpose of gathering information to assess GIS and Remote Sensing Techniques Application on the Spatio-Temporal Climate Variability Analysis: The Case of Ziway Dugda And Dodota Woreda, Arsi Zone, Oromia Region, Ethiopia. Your genuine response is greatly helps to the achievements of the objectives of the study. Please, feel free to respond, what you know about the issue under investigation. I would like to assure that your response will be kept confidential and all the information obtained from you will be used only for the purpose of the academic work.

I am full consented to participate on this interview questionnaire

Yes ☐ No ☐

If you are willing, we will continue. The validity of this study highly depends on your truthful and honest response to the item provided. Therefore, you are kindly requested to respond to the given item appropriately.

Thank you in advance for your unreserved cooperation.

I. Background information about the respondents

1. Sex: Male [ ] Female [ ]
2. Marital status: Married [ ] Single [ ] Divorced [ ] Widow [ ]

3. Age: A. 18-25 B. 26-35 C. 35-45 D. 46-55 E. 41 & above
4. What is your educational level?
   A. Illiterate B. Primary school incomplete C. Primary School complete D. Secondary school incomplete

II. Questions related to climate change influences on crop production

1. Do you or your family member have another source of livelihood other than agriculture? Yes/No, if yes please specify?____.
2. Do you think that there is a climate change in your locality in the past twenty/thirty years?
   A. Yes, there is a change B. No, there is no change C. I don’t know
3. Is there a noticeable change in the amount of rainfall in the main rainy season?
   A. Yes B. No C. I don’t know
4. What do you think the amount of rainfall in the last decade in the month November?
   A. Increased B. Decreased C. I don’t know
5. Do you think the timing of the onset of rain in the main season shifted?
   A. Yes B. No C. I don’t know
6. Has the rain started late than normal?
   A. Yes B. No C. I don’t know
7. Is rain of main season early withdrawal than normal?
   A. Yes B. No C. I don’t know
8. Have you faced untimely rain in the month November in the last decade?
   A. Yes B. No C. I don’t know
9. If there is, how do you rate the impact on crop production in terms of yield quintal/ha?
   ____.
10. Did you encounter complete/partial crop failure due to the unexpected November rain?
    A. Yes, very much B. Yes C. No, there is no D. I don’t know
11. Is your planting date changing due to change on the onset of rain?
    A. Yes B. No C. I don’t know
12. Do you feel temperature of the area changing?
    A. Yes, very much B. No C. I don’t know
13. Do you feel temperature is increasing?
    A. Yes, very much B. Yes, but is optimal C. No D. I don’t know

14. Who is more affected by the climate change problems?

15. A. Adult Man B. Adult Women C. Girls D. Boys E. Youths

III. Interview Questions: Disaster Prevention and Preparedness Commission (DPPC)

Qualification ____

Position/profession ___________________________________

1. How do you view the prevalence of November rain 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 are your major challenges in alleviation of the problem and what should be done?

IV. 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 ____ %

DECLARATION

I hereby declare that the thesis entitled: GIS AND REMOTE SENSING TECHNIQUES APPLICATION ON THE SPATIO-TEMPORAL CLIMATE VARIABILITY ANALYSIS: THE CASE OF ZIWAY DUGDA AND DODOTA WOREDA, ARSI ZONE, OROMIA REGION, ETHIOPIA has been carried out by me under the supervision of Dr. Ephrem Gebremariam Department of Geography and Environmental Studies, Addis Ababa University, Addis Ababa in the year 2014 as a part of Master of Arts program in Geographical Information System (GIS), Remote Sensing (RS), and Digital Cartography. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Esubalew Nebebe

Signature: ________________________

Addis Ababa University

Addis Ababa

Date: October, 2014

CERTIFICATE

This is certified that the thesis entitled: GIS AND REMOTE SENSING TECHNIQUES APPLICATION ON THE SPATIO-TEMPORAL CLIMATE VARIABILITY ANALYSIS: THE CASE OF ZIWAY DUGDA AND DODOTA WOREDA, ARSI ZONE, OROMIA REGION, ETHIOPIA is a bona-fide work carried out by Esubalew Nebebe under my guidance and supervision. This is the actual work done by Esubalew Nebebe for the partial fulfillment of the award of the Degree of Master of Arts in Geographical Information System (GIS), Remote Sensing (RS), and Digital Cartography from Addis Ababa University, Addis Ababa, Ethiopia.

Dr. Ephrem Gebremaiam

Assistant Professor

Signature: ________________________

Chair Holder of CAD and Geo-informatics in EiABC,

Addis Ababa University