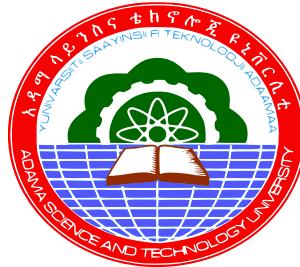


ANALYZING SPATIO-TEMPORAL CLIMATE VARIABILITY USING
GEOSPATIAL TECHNOLOGY: A CASE OF NORTH SHEWA, OROMIA,
ETHIOPIA



Adamu Dessalegn Taddesse

A Thesis Submitted to

The Department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's
of Science in Geo-Informatics

Office of Graduate Studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

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APPROVAL PAGE OF M.SC. THESIS

We, the advisor(s) of this thesis, hereby certify that we have read the revised version of the thesis entitled “Analyzing Spatio-Temporal Climate variability using Geospatial Technology: A case of North Shewa, Oromia, Ethiopia” and developed by Adamu Dessalegn Tadesse, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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CANDIDATE’S DECLARATION

I hereby declare that this Master Thesis entitled “Analyzing Spatio-Temporal Climate variability using Geospatial Technology: A case of North Shewa, Oromia, Ethiopia” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that used for this thesis have been accordingly acknowledged through citation.

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RECOMMENDATION

I/We, the advisor(s) of this thesis, hereby certify that we have read the revised version of the thesis entitled “Analyzing Spatio-Temporal Climate variability using Geospatial Technology: A case of North Shewa, Oromia, Ethiopia” prepared under our guidance by Adamu Dessalegn Taddesse Id. No. PGR/18283/11 submitted in partial fulfillment of the requirements for the degree of Master’s of Science in Geo-Informatics Engineering, the Graduate Program of the Department of Geomatics Engineering .

Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

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LIST OF ACRONYMS

AEZs	Agro Ecological Zones
CSA	Central Statistical Agency
DN	Digital Number
ENVI	Environment for Visualization of Image
ERDAS	Earth Resources Data Analysis System
ETM+	Enhanced Thematic Mapper plus
GIS	Geographic Information System
MSI	Moisture Stress Index
NDVI	Normalized Difference Vegetation Index
OLI	Operational Land Imager
RS	Remote Sensing
RSCCI	Remote Sensing Climate Compound Index
SAVI	Adjusted-Soil Vegetation Index
SPSS	Statistical Package for Social Sciences
TM	Thematic Mapper
TNDVI	Transformation Normalized Difference Vegetation Index
USGS	United States Geological Survey
WMO	World Meteorological Organization

ABSTRACT

Climate change has been one of the most environmental problems facing the world today. Many studies were made on the issue of climate change in different parts of the countries, based on rainfall and temperature data. There was still a wide zone variation among the study area and some lapse in it. Hence, this study aims at analyzing climate variability based on temperature, rainfall and satellite image. Gridded rainfall and temperature data, and satellite image for 30 years, were used for analysis. The overall average rainfall in the last 30 years was 1036.50 mm with standard deviation of + 27.27 mm and coefficient of variation 2.63 %. The annual rainfall and pattern show a considerable fluctuation, one year there is a slight positive anomaly and on the other year shows negative anomalies. Based on drought index classification, the statistical result revealed that in the area extremely dry was observed in 2002- 2004. In the year 2000,2001 and 2011 severely dry was observed. Moderate drought was occurred in 2005 and 2015. No drought (nearly normal) that was observed in the rest observation. The total average rainfall of Kiremt season between 1990 and 2020 was found to be 762.28 mm with +18.74 mm standard deviation and coefficient of variation 2.46%. The mean maximum temperature of the study area over thirty years' time ranging from 1990 to 2020 was 26.03⁰C with standard deviation +1.25⁰C and coefficient of variation 4.80%. From the result, there was linear correlation between mean annual rainfall and calculated NDVI value. The r^2 value was 0.8749. Regarding to the graph there was negative correlation (-0.88 correlation coefficient) of mean annual temperature and mean annual NDVI value of the year 1990 to 2020, with 0.766 value of r^2 . From the RSCCI, in thirty years observation there was 0.013% decrement in area of dega region from 1990 to 2020, and increment of woinadega and kola by 0.004% and 0.01% respectively. The highest proportion of the area falls within dega (49.93%) of the total area. The second highest (30.54%) area falls within woinadega and kola occupied small portion (19.53%) of the study area. Based on the finding of this study, possible to predict that the study area climate would project to dega (49.53%), woinadega (30.66%) and kola (19.81%) agro-ecology for the next thirty years (2050).

Keywords: *Climate Variability, Spatial, Temporal, Remote Sensing Climatic Compound Index.*

CHAPTER I: INTRODUCTION

1.1. Background

Climate is an average weather condition over years in a narrow sense or as the statistical description in terms of average and variability of relevant quantities a time ranging from months to millions of years. Climate change has been one of the most talked issues, particularly since the start of the twenty centuries. The most important climate quantities are most often surface variables such as temperature, precipitation and wind. The classical period for averaging these variables is 30 years (WMO,2019). The climate in a wider sense is the state that includes a statistical description of the climatic system (Kanwal, 2019).

According to World Meteorological Organization (WMO), over a long period, more than several years, the climate is the statistical description in terms of the mean and variability of relevant quantities, and it is the duration over years and decades, usually over 30 years. Forming a classification system of climate is a very tough and hard job. Many climatologists gave different climatic classifications based on their own experiences and criteria. Climatic classification is a system of arranging various climatic parameters either singly or grouped into ranks or sets, so, as both simplify the mass of data and to identify analogies (J. F. Griffith,1978, as cited in Kanwal, 2019).

According to many previous studies, the climate parameters and the normalized difference vegetation index (NDVI) have a positive relation in some region (Yitea, 2012); while it was negative in other regions depending on geographical position, geomorphology, vegetation type, climatic condition and other factors (Yitea, 2012). Precipitation is much more variable in both time and space than other climatic factors.

Ethiopia is one of the developing nations which enjoy diversified climatic conditions that range from semi-arid and desert to humid and warm types across its different parts (NMSA, 2001, as cited in Esubalew, 2014). To this end, there are different ways of classifying the country's climate systems into several agro-ecological zones (AEZs). Across its AEZs, there was a wide variation in mean annual rainfall and temperature (Esubalew, 2014). Besides, the county's climate was also characterized by a history of climate extremes, changing trends in temperature and precipitation patterns.

The trend was that the average annual maximum and minimum temperature levels have also been increasing in the country (Esubalew, 2014).

In the 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, as cited in Esubalew, 2014) 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 the effect of climate change variability on the livelihoods of local communities the case of central rift valley region of Ethiopia can be mentioned. Nonetheless, from a GIS and Remote Sensing perspective, the area is little touched. Therefore, as an effort 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 was focus on spatio-temporal climate variability analysis the case of North Shewa Zone, Oromia Region, Ethiopia.

Many studies were made on the issue of climate change and variability in different parts of the countries, based on rainfall and temperature data. There was still a wide zone variation among study area in mean annual rainfall and temperature since the system was done based on interpolation. Therefore, there was some lapse in it (Kanwal ,2019). This has been an era of information and technology which makes accessibility of spatial data for scientists and researchers on a broad scale. Access to aerial and satellite imagery is very helpful to study the climatic condition of an area.

Hence, this study was attempted to analyze the spatio-temporal variability of climate of North Shewa zone by using satellite image. No similar research was carried out in the study area. Basically, this study aims primarily to fill the gaps that is not treated by previous researchers and provide a cumulative knowledge in the area by incorporating the issue of Geospatial technology within the whole package of climate change driving variables. Therefore, this study was a remarkable piece of work which clearly portrays the prevailing situation taking into consideration relevant climatic factors such as, rainfall, temperature and satellite images.

1.2.Statement of the Problem

Climate change is rapidly occurring as one of the most serious vulnerable that human being may ever face. According to the IPCC (2007) report stated that global temperature is on the rise, with massive consequences, such as rising sea levels, drought, high winds, cyclones, and extreme temperatures, that could pose significant challenge to the lives and livelihood of the farming based society. Recently it has become a pressing issue in various development, environment, and political forums at the national, regional, and international levels (Mikias, 2014).

For the world as a whole, the issue of climate change and variability has been studied from different angles using various types of evidence in the last 30 years (Guy, 2003, as cited in Getnet, 2010). The impact of the climate has brought serious damage especially in developing countries. Ethiopia currently has faced various problems resulted from climate variation even though the degree of the climate change is not clearly identified (Esubalew, 2014).

Arguably, one of the most widespread and potentially devastating effects of climate change in East Africa had been changes in the frequency, intensity, and predictability of precipitation and Temperature (Esubalew, 2014). The same source further elucidated those changes in regional precipitation was ultimately affect water availability and may lead to decreased agricultural production and potentially widespread food shortages.

Administrative Zone of the Oromia National Regional State represents one of the localities within Ethiopia where trends in climate parameters remain largely unexamined and hence, only scanty of information is available here and there in bits and pieces(Ashenafi et al,2013).A number of factors has contributed and continue to account for this state of affairs, including hostile policy environments, weak production infrastructures, lack of modern farming techniques and more significantly, the changing of global climatic conditions.

North Shewa zone has faced various problems resulted from climate change. Study done by Ashenafi et al (2013), denoted that an upward trend of $0.07^{\circ}\text{C}/\text{annum}$ in mean annual maximum temperature at Kola AEZ. It also showed an upward trend of $0.06/\text{year}$ for both Dega and Woinadega AEZs. Mean annual minimum temperature exhibited an upward trend of $0.03^{\circ}\text{C}/\text{year}$ at Kola, Woinadega, and Dega, signifying a 1.05°C increase between 1979 and 2013. The reduced precipitation and rise in temperature could trigger wide-ranging influences on agricultural practices and crop production of smallholder farmers.

1.3. Objectives of the Study

1.3.1. General objective of the study

The general objective of the study was to analysis the spatio-temporal climate variability change of the study area by using Geospatial technology.

1.3.2. Specific objective of the study

The specific objective of the study was to:

- Analyze the patterns and trends of the spatio-temporal climate variability.
- Produce Climate Thematic map of study area.

1.4. Research Question

- 1) How to analyze the patterns and trend of spatio-temporal climate variability?
- 2) How to produce the climate Thematic map of study area?

1.5. Significance of the Study

This research is mainly designed to carry out the climate change of study area to provide better understanding of spatio-temporal climate change to all the stake holders like policymakers, scientists, agrarian (for obtaining maximum crop yield), drought and environmental monitors. Not only this but also used for integrating uptodate information into climate models that will be used by concerned authorities to make any developmental plans and implement policies and programs.

Also, the result of this study is expected to have the following significances.

- ✓ As a baseline for further studies related to analysis and modeling climate change using Geospatial technology.
- ✓ As a guide line for decision makers to improve the existing climate classification system and factors consider during classification.

1.6. Limitation of the Study

No research, has complete and free from limitations. One of the drawbacks in this study was the widely spaced distribution of meteorological stations which results in missing of some point data of basic climate data such as, rainfall and temperature. However, the difference does not have a negative implication on the result of the study. The other problem was difficulty of downloading satellite images required to undertake this study.

This was due to the large size (up to 1GB and above) of the satellite imagery and weak internet connection. In addition, the presence of strips of Landsat-7 image (gap) and cloud

cover on some downloaded satellite images made the problem more adverse and interpretation difficult.

1.7. Scope of the Study

This study has conducted in North Shewa. Research on climate analysis and modeling requires a wide scale study and climatic factors in different areas of the countries. Because of available time and resources in order to make the study more thorough manageable and due to severity of climate variability, extent of the study is limited to North Shewa, Oromia.

1.8. Organization of the Study

The study has organized in to five chapters. The first chapter contains brief description of introduction (background, statement of the problem, research questions, objectives, significance of the study, scope of the study, organization of the paper and definition of key terms. The second chapter deals with literature review. This part addresses the relevant literature that was very much associated with the research topic.

The third chapter has described the materials and methods. It clearly shows 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 was concerned with results and discussion of the study. Finally, the fifth chapter covers the conclusion and recommendations.

1.9. Operational Definition of Terminologies

Bega: expression for the dry season in Ethiopia.

Belg: The Short rainy season in Ethiopia.

Kiremt: The long rainy season in Ethiopia.

Dega: The cool zone climate zones /altitudinal agro-ecological in Ethiopia.

Kola: The hot zone climate zones /altitudinal agro-ecological in Ethiopia.

Woinadega: The temperate zone climate zones /altitudinal agro-ecological in Ethiopia.

CHAPTER II: LITERATURE REVIEW

2.1. The Concept of Climate Change

Today, global climate change and its consequences receive much attention within the debate. It is the foremost complex and cross-cutting environmental problem which afflicts every corner of the planet its impact is diverse and globally witnessed. With this NMA (2007, as cited in Esubalew,2014) in its report stated about the prominence of climate is that it is a key natural resource on which the others depend.

Climate was usually described by the statistics of a group of atmospheric and surface variables, like temperature, precipitation, wind, humidity, cloudiness, soil moisture, sea surface temperature, and therefore the concentration and thickness of sea ice.

2.2. Factors of climate change

2.2.1. Precipitation and Temperature

The climate of a given location has 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 changes that occurred representing climate variability (IPCC, 2007). Precipitation has the general terms for rainfall, snowfall, and other forms of frozen or liquid water falling from clouds.

A changing and variability of climate can directly influence precipitation amount, intensity, frequency, and type. Increased warming accelerates evaporation and increases the amount of water vapor in the atmosphere, has resulted in certain areas getting wetter and others getting drier. Widespread increases in heavy rainfalls 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 in Getnet (2010) wrote that annual rainfall is likely to decrease throughout most of the African region, except for Eastern Africa, where annual rainfall is projected to increase. Trend analysis of annual rainfalls in Ethiopia has shown that rainfalls 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 South western Ethiopia. On the other hand, recent climate trends has based on United nations development programme climate data indicate a change in temperature and rainfall.

There was a clear and observable positive trend in temperature. Ethiopia shows a consistent warming trend, with the observation of increasing minimum and maximum temperature over the past fifty years (Abaddi et al., 2013).

Research by various authors indicated that there was an increase in temperature over all of the country. Study done by Mikias (2014) indicated that the trend of climate change and variability in the rift valley area were gradually changing.

2.3. Climate System in Ethiopia

According to NMA (2007), Climate has often described by the statistical interpretation of rainfall and temperature data recorded over a long period of time for a given region or location.

There has been three seasons known in Ethiopia, namely Bega (dry season) which extends from October to January, Belg (short rainy season) which extends from (February to May), and Kiremt (long rainy season) which extends from June to September (NMSA, 2001, as cited in Esubalew, 2014).

Temperatures has very much modified by the varied altitude of the country. In general, the country experienced mild temperatures for its tropical latitude because of topography. Mean annual temperature distribution over the country varies from about 10⁰c cover the highlands of northwest, central and southeast to about 35⁰c over north-eastern lowlands (Esubalew , 2014).

2.3.1. Agro Ecological Features of Ethiopia

The goal of classification has to identify and group together things that have similar characteristics. Climate classifications describe the world's climates. A great challenge faced in designing a climate classification system was that climates fluctuates and transition zones often exist between two very different climate regions, making sharp boundaries difficult to establish. There are different ways of classifying the climatic systems of Ethiopia, including the traditional, Koppen's, the Throthwaite's, the rainfall regimes, and the agro-climatic zone classification systems (Temesgen et al., 2010).

The varying topography of Ethiopia leads to three distinct climate zones across the country; namely, Dega (cool zone), Woinadega (temperate zone) and Kolla (hot zone). Within each agro-ecologica 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).

In general, the climate of Ethiopia varies from humid to semiarid (Esubalew, 2014). It has typically tropical in the south-eastern and north-eastern lowlands regions, but cooler in the large central highland regions of the country. Mean annual temperatures are around 15-20°C in these high altitude regions, whilst 25-30°C in the lowlands. The most commonly used climate classification systems were 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 (°C)
Wurch (upper highlands)	3200 plus	900 – 2200	<11.5
Dega (cool zone)	2,300 – 3,200	900 – 1,200	17.5/16.0–11.5
Woinadega (temperate zone)	1,500 – 2,300	800 – 1,200	20.0–17.5/16.0
Kola (tropical zone)	500 – 1,500	200 – 800	27.5 – 20.0
Berha (desert)	below 500	below 250	>27.5

Source: MoA (2000).

2.4. Applications of GIS and Remote Sensing in Climate Change

The issue of climate change is currently an important concept that attracts the attention of several scholars. The problem of climate change has 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.

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 have enough 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 different sources and combine them together in a single system. GIS creates a new framework for studying global climate variability and change by allowing GIS users to inventory and display large, complex spatial data sets. They can also analyze the potential interplay between different factors, getting us closer to a true understanding of how our dynamic climate may change in the coming decades and centuries (ESRI, 2008).

Applications of scientific principles such as GIS and Remote Sensing equipped with GPS in detecting climatic variation is 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 Variability

Land use refers to man's activities and the varied uses which are carried on over land and it includes agricultural land, built up land, recreation area, wildlife management area etc.. Land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others noticed on the land (NRSA, 1989). It is the assemblage of biotic and a biotic components on the earth's surface is one of the most crucial properties of the earth system. The interaction between the land surface and the atmosphere involves multiple processes and feedbacks; all of which may changes simultaneously. It has frequently stressed that the changes of vegetation type can modify the characteristics of the regional atmospheric circulation systems and the large-scale external moisture fluxes. Therefore, Changes in surface energy budgets resulting from land surface change can have a profound influence on the Earth's climate (WMO, 2005).

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

2.6. Implication of Remote sensing Index on Climate Change

2.6.1. Normalized Difference Vegetation Index

Change in biophysical parameter of vegetation canopy implies a change in climate, accordingly vegetation are used as the most key inputs into climate change models (Ogunbadewa, 2013). Consequently, climate variability is one of the most important factors affecting vegetation condition. In this regard, remote sensing plays a crucial role to detect

and characterize vegetation dynamics that suffering from climate variability. The Normalized Difference Vegetation Index (NDVI) is related to the amount of photo synthetically absorbed radiation. It is a measure of the quantity and vigor of vegetation on the land surface.

According to USAID (2006),the 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 starting from sparse vegetation (0.1 - 0.5) to dense green vegetation (0.6 and above). Green and healthy vegetation reflects much less radiation within the visible part of the spectrum compared to those in the near-infrared part. More importantly, when vegetation is under stress, visible values may increase and near-infrared values may decrease (Esubalew ,2014). The Normalized Difference Vegetation Index is a method used to analyze the vegetation cover of an area. NDVI is calculated from reflectance measured within the visible and near-infrared channels from satellite-based remote sensing. NDVI shows the temporal and spatial change of Vegetation cover (Seleshi et al,2007).

As indicated in Greenland (1994) study, TNDVI is an integrated function of photosynthesis, leaf area, and evapotranspiration. It is a symbol of vegetation biomass, and it's a ratio between near-IR and red reflection. The total amount of biomass has an indirect and direct relation with surface energy balance; the surface temperature is consistent with the interference of sunlight, canopy cover ratio, and evapotranspiration cooling effect (Kanwal, 2019).

2.6.2. Land Surface Temperature

Land surface temperature is one of the most important variables measured by using the thermal bands of sensors. Sensors such as moderate resolution imaging spectroradiometer, AVHRR, Landsat-5 TM, Landsat-7 ETM+ and Landsat-8 are providing global thermal data. Land Surface Temperature (LST) is the radiative land surface skin temperature which plays crucial role in the physics of land surface through the process of energy and water exchanges between land surface and atmosphere (Gebrekidan , 2016).Digital numbers (DN) acquired from the United States Geological Survey (USGS) of the image were calculated and their average was taken out.

2.6.3. Adjusted-Soil Vegetation Index

Adjusted-Soil Vegetation Index is used to correct normalized difference vegetation index for the influence of soil brightness in areas where vegetative cover is low. The value of L varies based on the amount or cover of green vegetation: in very high vegetation regions, $L=0$; and in areas with no green vegetation, $L=1$. Generally, an $L=0.5$ works well in most situations and is the default value used (Rondeaux et al. 1996; Huete 1988).

2.6.4. Moisture stress index

Moisture Stress Index has used for canopy stress analysis, productivity prediction and biophysical modeling. It was proposed by Hunt, et al (1989) who first used the index to detect changes in leaf water content using the near- and middle infrared reflection ratio. Interpretation of the MSI values is inverted relative to other water vegetation indices; thus, higher values of the index indicate greater plant water stress and in inference, less soil moisture content.

2.6.5. Remote sensing climatic compound index

Remote sensing climatic compound index is a new climatic compound index which is introduced for a new climatic classification study area, based on some parameters which include temperature, vegetation, evapotranspiration, snow, water and soil moisture because, the climate is mainly affected by these factors naturally. Land surface temperature is highly accelerated by the loss of vegetation, soil moisture content and increased temperature and is activated by anthropogenic activities (Kang et al. 2010).

2.7. Empirical Evidence

Different researches have been conducted to assess the spatial and temporal patterns of climate in different parts of the country. In this regard, a study done 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 was getting increased by 0.37°C in the rift valley and 0.48°C in highland and by 0.40°C in whole areas per twelve years and rain was constant and shows insignificant rise.

In addition, another recent study made 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 five meteorological stations with thirty years of daily rainfall, maximum and minimum temperatures data were used (1979-2008).

The study showed that the contribution of kiremit rainfall to the total annual rainfall was very high in all study stations. The long term recorded rainfall data revealed an increasing trend during 1995-2008 and decreasing trend during 1979-1994, except, inter-annual fluctuation.

On the other hand, study conducted by Dereje et al., (2012) on variability of rainfall and its current trend in Amhara region, Ethiopia. For this purpose, ten meteorological stations with thirty years of daily rainfall data have been used. The spatial distribution of annual rainfall was varied from 850mm to 1485 mm.

2.8. Theoretical Review of climate classification

According to World Meteorological Organization, over a long period of time, more than several years, climate has the statistical description in terms of the mean and variability of relevant quantities, and it is duration over years and decades, usually over thirty(30) years. The dissimilar pattern of climate distinguishes from similar ones by using such classification of climate (Walter ,2011).

Many climatologists have given different climatic classification on the basis of their own experiences and criteria. Climatic classification has been merely a method of arranging various climatic parameters either singly or grouped into ranks or sets, so, to as both simplify the mass of data and to identify analogies (Grifths, 1978).

Koppen classification was temperature based and developed by climate indices, despite zone variation among themselves. Globally, therefore, there was some lapse in it (Kanwal ,2019). In 1948, Thornthwaite had introduced a climate classification based on rainfall and potential evapotranspiration. This approach was adopted by various regions of the world for classification (Kanwal ,2019).

2.9. Conceptual Framework of the Study

The conceptual framework illustrated in fig 2.1 below is demonstrates the climate change and it's the most driving factors. Variability and change in the climate state, or climate dynamics, is a key driver of change in social and biogeophysical environments and is modulated by the inherent dynamics of these systems.

The occurrence of a climate hazard is altered by a change in the climate state and has measurable impacts on physical and social systems. The results can be complex, resulting from direct and indirect effects of several climate and non-climate factors. The level of

impact is modulated by the sensitivity and vulnerability of the impacted systems to climate variability and change, and the risk involved is determined by the probability that hazard occur. Social and environmental vulnerability to climate change is a function of the degree of exposure, the sensitivity of the system, and the capacity for adaptation.

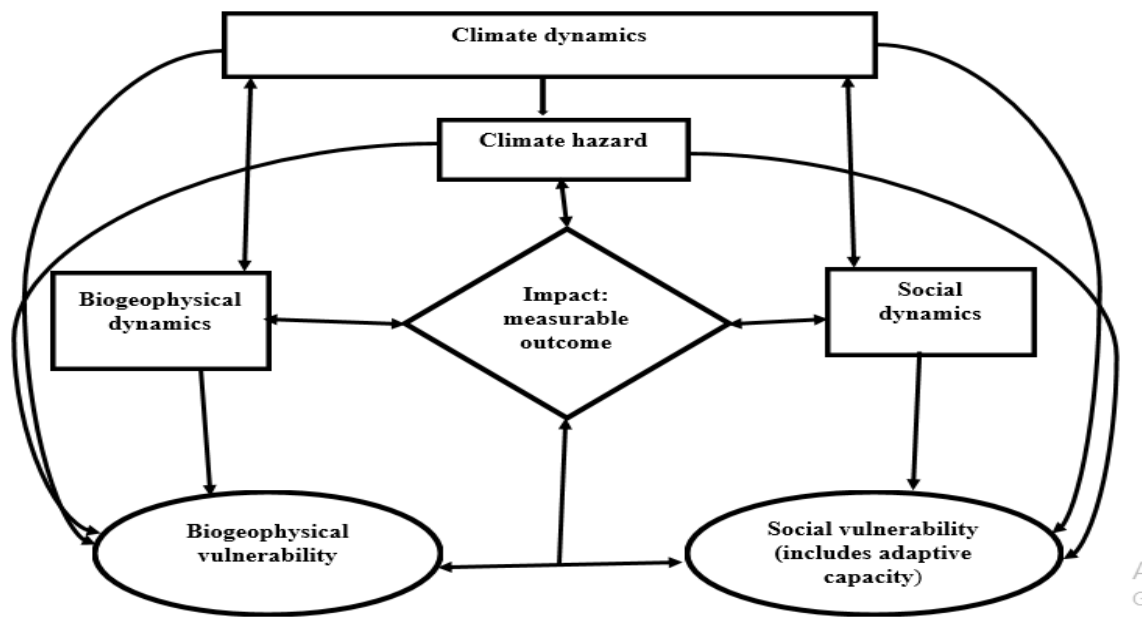


Figure 1: The conceptual framework of the study

2.9.1. Climate dynamics

Climate dynamics is defined as the variability and change of the climate system. It includes changes in temperature, rainfall, solar radiation and cloud cover, large-scale circulation patterns, wind strength and direction

2.9.2. Climate hazard

A hazard is commonly defined as a phenomenon that has the potential to cause risks. In terms of climate change, a climate hazard may be any event or change in climate, such as a single extreme event that exceeds a critical temperature threshold, or a complex combination of changes involving multiple climate variables and resulting in multiple impacts.

To determine the impact involved with a particular hazard, it is necessary to consider the likelihood or probability of its occurrence. The risks of climate climate hazards are highly defined by criteria (usually thresholds) that link the impacts of climate change to their potential outcomes (Carter et al., 2007). These thresholds can be defined through research

or through stakeholder consultation, and they contribute to the development of a vulnerability framework (Conde and Lonsdale, 2005).

2.9.3. Impacts

Impacts are measurable results of (or system responses to) climate dynamics and climate hazards, and are typically modulated by changes in biogeophysical and social systems.

2.9.4. Biogeophysical dynamics

Biogeophysical dynamics define changes and variability of the biological, geochemical, and physical environmental systems.

2.9.5. Social dynamics

Social dynamics defines changes in social, economic and political systems. It includes changes in population structures, technological developments, changes in financial institutions and regulation bodies.

2.9.6. Vulnerability

The concept that vulnerability is a function of the exposure and sensitivity of a system to a climate hazard, and the ability to adapt to the effects of the hazard. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007). Adger et al (2004) form a distinction between biogeophysical vulnerability and social vulnerability.

2.9.7. Biogeophysical vulnerability

Indicators of biogeophysical vulnerability to climate change include Soil quality, Water quality, Sea level change, Coastal, Salinization, atmospheric; freshwater; marine pollution, and biodiversity.

2.9.8. Social vulnerability

Indicators of social vulnerability include health and nutrition (calorie intake; access to health care), physical infrastructure (resilience to severe storms, floods, kilometer of roads), Institutions, governance, conflict, and social capital, geographical and demographic factors (population density / growth), dependence on climate sensitive economic sectors such as agriculture, forestry, tourism (% employment by sector), access to natural resources and ecosystems (e.g., water resources per capita), technical capacity, and level of education.

CHAPTER III: MATERIALS AND METHODS

3.1. Study Area Description

3.1.1. Geographic Location

North Shewa Administrative Zone is located in the Oromia National Regional State of Ethiopia. Its latitudinal and longitudinal locations extend from 9°08'52"-10°35'17"N and 37°56'13"-39°34'47"E, respectively. North Shewa Zone is bordered on the south by Oromia Special Zone Surrounding Finfinne, on the southwest by West Shewa, on the north by the Amhara Region, and on the southeast by East Shewa.

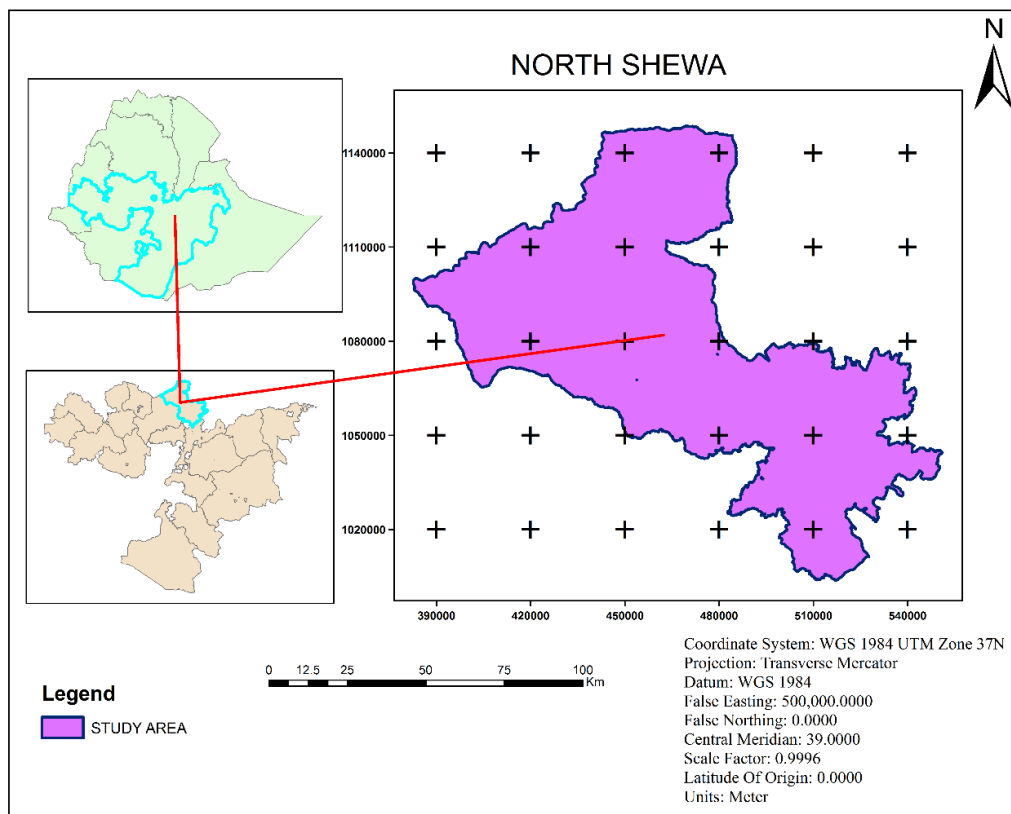


Figure 2: Location of Study Area

3.1.2. Population

Based on Census conducted by the Central Statistical Agency of Ethiopia (CSA,2007), North Shewa Zone has a total population of 1,431,305, of whom 717,552 are men and 713,753 women; within an area of 9,306.91 square kilometers, North Shewa has a population density of 138.66. While 146,758 or 10.25% are urban dwellers, a further 9 individuals are pastoralists. A total of 314,089 households were counted in this area, which results in an average of 4.56 persons to a household, and 303,609 housing units.

3.1.3. Topography

The topography is typically ragged terrain with some mountains. It is divided into 3 agroecologies, namely, 15% Highland, 40% Midland and 45% Lowland (CSA, 2007). It has dissected by high plateaus and mountains associated with hills, valleys and gorges. The altitude of North shewa zonev extends from about 1000 m.a.s.l., located in Abay gorge in Wara Jarso district to over 3500 m.a.s.l., located in Degem district (Asaminew and Diriba 2015).

3.2. Major Data Types and Sources

3.2.1. Data Source

The main sources of the data in this study were both primary and secondary sources. To obtained information on Spatio-temporal climate variability analysis, empirical data was collected. Collected accurate and reliable data was the most determinant factor for any research as it determines the quality of the research. In this particular research, the first steps was to identify the relevant climate factors to be consider for analysis and modeling climate followed by setting criterion based on international and local rules. Accordingly, the necessary data was collected from the respective sources.

Table 2: Data source

No	Data required	Source	Data type	Year	Data format
1	Rainfall	National Metrological Agency	Secondary	1990-2020	Csv
2	Temperature	National Metrological Agency	Secondary	1990-2020	Csv
3	Satellite image	USGS	Secondary	1990-2020	TIFF

3.2.2. Meteorological Data

This study largely depends on the information/data obtained from National Metrological Agency. This consists of basic climatic elements of rainfall and temperature record of the past thirty years. In line with this, as noted in World Metrological Organization (2005), the classical period to study climate related issues is 30 years. In this regard, it's possible to notice that the study satisfies the essential criteria set by World Metrological Organization. A total of 46 gridded metrology stations were involved in this study. Among those, 16 stations are completely found within the study area. The remaining 30 neighboring stations were used for interpolation purpose so as to convert the point data into a continual raster surfaces and to make the result of the study more reliable and consistent.

The 30 years records of monthly and annually 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's found imperative to use the grid data. In addition, the gauge data has many limitations; missing data for the actual 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's found extremely important to use gridded data for this study.

3.2.3. 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 2000, 2010 and 2020 with 168 and 169 paths, and 53 & 54 rows. The spectral characteristics of the images are described below.

Table 3: Spectral Characteristics of satellite images

Sensor	Number of spectral Bands	Spatial Resolution (m)	Date of acquisition
TM (Land sat_5)	7	30m	2000/12/18
ETM+ (Land sat_7)	7	30m	2010/12/30
Landsat 8	11	30m	2020/12/20

The TM and ETM+ instrument on Landsat 5 and 7 observe the Earth with 7 different filters or bands. Bands 1, 2, 3, 4, 5, and 7 on TM and ETM+ 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 electromagnetic energy. The parts of the reflected energy are defined by the length of energy waves.

The human eye sees reflected light in that band of wavelengths as the color blue, green and red; hence, band one is usually observed as the blue band. In a similar manner, bands two and three of the TM and ETM+ instruments record reflected green and red light, respectively. TM and ETM+ bands four, five, and seven record reflected light in wavelengths that human eyes cannot detect. The band 4 referred to as near infrared, bands 5 and 7 referred to as short wave infrared. Band 6 of the TM and ETM+ instruments is different from all the other bands because it doesn't record reflected light energy, but rather energy emitted by the Earth's surface. It is sometimes called as the thermal infrared band (TIR band) or just the thermal band.

3.2.4. Field Observation

The field trip was arranged for a week. The trip covered the main parts of the study area extends from Wara Jarso Woreda to Chanco 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.

3.2.5. Base Cartographic Datasets

The other relevant dataset that was 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.

3.3. Tools and Softwares

Software are programs which are used for collection, organization, analysis, interpretation and presentation of data. Different software was utilized in this study to analyze spatial-temporal climate variability analysis. In order to achieve the objective of the study Arc GIS, SPSS, ENVI 5.3 and ERDAS IMAGINE software used.

Arc GIS is a software application developed by ESRI for working with maps and geographic information. It is used for creating maps and model, compiling geographic data, analyzing spatial information, sharing geographic information and managing geographic information

in geo database. ERDAS IMAGINE is an image processing software package that allows users to process both geospatial and other imagery as well as vector data. List of software and their purpose summarize in table 4.

Table 4: List of software

No	Software	Version	Purpose
1	Arc GIS	10.8	Storing, managing, and analyzing spatial information and produce map
2	ERDAS IMAGINE	2015	Processing and analyzing satellite images
3	SPSS	22	Management and statistical analysis of data
4	ENVI	5.3	Processing and analyzing satellite images

3.4. Method of Data Analysis

The rainfall, minimum and maximum temperature data were captured into Microsoft excel, 2016 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 within the study areas.

All the datasets was organized and arranged in a desired order to form ready for the analysis. For every climate variable record of temperature (maximum and minimum) and rainfall data were gleaned from metrology agency in a softcopy. every data was carefully filtered. Then, 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 in software. In addition, seasonal rainfall variability of the study stations was analyzed and mapped using Arc GIS 10.8 software. Coefficient of variation (CV) was calculated as the ratio of standard deviation to the mean (Taye et al., 2013).

3.4.1. Geo-statistical Methods

The value of climate elements cannot be directly measured in all point of the region, but only in sample points. According to Yang et al (2004) spatial interpolation may be used to estimate the values in such areas where there is no measurement.

Interpolation predicts values for cells in a raster from a number of sample points data. It can be used to predict unknown values for any geographic point data, such as elevation, rainfall, temperature, and so on. Commonly used interpolation methods in ArcGIS software package

can be categorized either deterministic or stochastic. Deterministic methods do not use probability theory 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 are assessed as deterministic interpolation methods, whereas Kriging is stochastic, which mostly used in ArcGIS (Yitea, 2012). Moreover, spline and Inverse Distance Weighting are exact types of deterministic interpolation methods while kriging is an exact type of stochastic interpolation methods.

Kriging methods are successful in the spatial interpolation of meteorological elements such as temperature and rainfall and allows for interpolated cells to exceed the boundaries of the sample range (Esubalew, 2014).

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 (Esubalew, 2014).

3.4.2. Inter-annual Fluctuation of Rainfall

As indicated in Agnew and Chappel (1999) quoted in Esubalew (2014), 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:

$$SRA = \frac{R_t - R_m}{\sigma} \quad (1)$$

Where: SRA is standardized rainfall anomaly,

R_t : is annual rainfall in a given year (in the year "t" from 1990 to 2020)

R_m : is long term mean annual rainfall over a period of observation i.e., 1990 to 2020 and σ : is standard deviation of each year annual rainfall over the period of observation (1990 to 2020).

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 ($SRA > -0.84$).

3.4.3. Coefficient of Variation (CV)

Coefficient of Variation is a statistical measure of how the individual data value varies from the mean value. A greater value of CV is the indicator of higher spatial variability, and vice versa (Chakraborty et al. 2013). It is computed using the following equation:

$$CV = \frac{\sigma}{x} * 100 \quad (2)$$

Where, CV is the coefficient of variation, σ is the standard deviation (SD) and x is the mean. Accordingly, CV values < 20% denotes less variable, between 20% and 30% denotes moderately variable and >30% denotes high variability of rainfall.

Precipitation Concentration Index: - is a measure of relative distribution. It is a means to represent spatial variability of rainfall patterns. PCI indicate rainfall concentration in terms of distribution and variability and is computed on annual and seasonal scale using the following equations, respectively.

$$PCI_{Annual} = \frac{\sum_{l=1}^{12} PI^2}{(\sum_{l=1}^{12} PI)^2} * 100 \quad (3)$$

$$PCI_{Seasonal} = \frac{\sum_{i=1}^{12} pi^2}{(\sum_{i=1}^4 pi)^2} * 100 \quad (4)$$

Where, pi is the monthly precipitation in month i

According to scholars' categorization, PCI values of less than 10 signify a uniform precipitation distribution (low precipitation concentration); PCI values between 11 and 15 signify a moderate precipitation concentration; values from 16 to 20 indicates irregular distribution and values greater than 20 signify a strong irregularity (high precipitation concentration) of precipitation distribution (De Luis et al. 2011; Valli et al. 2013; Al-Shamarti 2016).

3.4.3. Temperature Anomalies

Mean annual temperature distribution over the country varies from about 10°C over the highlands of northwest, central and southeast to about 35°C over north-eastern lowlands (NMA, 2007). According Esubalew (2014) time series mean annual maximum and minimum temperature anomalies of the study area were analyzed based on the following equation;

$$STA = \frac{T_t - T_m}{\sigma} \quad (5)$$

Where: STA is standardized temperature anomaly, T_t is annual maximum/minimum temperature in year t, T_m 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.

3.4.4. Land Surface Temperature

Sensor radiances measured at a wavelength region is generally stored in digital numbers converted using a quantification system for the convenience of data storage. The land surface temperature can be calculated using the Landsat 5,7 and 8 thermal bands. It simply requires applying a set of equations through a raster image calculator (ENVI 5.3, ArcMap, ArcGIS Pro, QGIS). Retrieval of LST for Landsat Landsat-5/TM and Landsat-7/ETM+.

In the first step, the digital number of the image is converted into spectral radiance by using Eq.

$$L_\lambda = L_{min} + (L_{max} - L_{min}) * \frac{DN}{255} \quad (6)$$

Where, L_λ =Spectral radiance, L_{min} is the minimum radiance (Watts/ (m².srad.μm), L_{max} is the maximum radiance (Watts/ (m².srad.μm)

In the second step, spectral radiance is converted into sensor radiance value by using Eq.

$$TOA = \frac{L_{max\lambda} - L_{min\lambda}}{Q_{calmax} - Q_{calmin}} * (Q_{cal} - Q_{calmin}) + L_{min\lambda} \quad (7)$$

Where, T_{OA} = Top of atmospheric, Q_{cal} is the DN value of pixel, Q_{calmax} is the maximum DN value of pixels, Q_{calmin} is the minimum DN value of pixels.

In step 3, sensor effective radiance is converted into sensor brightness value by using Eq.

$$BT = \frac{K2}{\ln(\frac{K1}{TOA} + 1)} \quad (8)$$

Where, B_T refers to the effective at satellite brightness temperature in Kelvin, $K1$ (Watts/(m².srad.μm))and $K2$ (Kelvin) are the calibration constants and T_{OA} is the spectral radiance. The values of the constants ($K1$ and $K2$) were presented in table 3.4 since they change from sensor to sensor.

To obtain the results in Celsius, the radiant temperature is adjusted by adding the absolute zero (approx. -273.15°C). This is the final step in the LST calculation.

$$T^{\circ}C = T(K) - 273.15 \quad (9)$$

Table 5: Thermal band calibration constants for Landsat satellites.

SATELLITE	K1	K2
Landsat-5/TM (Band6)	607.76	1260.56
Landsat-7/ETM+ (Band6)	666.09	1282.71
Landsat-8 OLI (Band10)	774.89	1321.08
Landsat 8 (Band11)	480.89	1201.14

The first to retrieve LST for Landsat 8 OLI band data, are converted to radiance using the radiance rescaling factors provided in the metadata file by using Eq.

$$L_{\lambda} = ML * Q_{cal} + AL \quad (10)$$

Where, L_{λ} temperature of atmosphere spectral radiance

ML band-specific multiplicative rescaling factor from the metadata (radiance multi band X where X is the band number), AL band-specific additive rescaling factor from the metadata (radiance_add_band_X, where X is the band number), Q_{cal} quantized and calibrated standard product pixel values (DN).

In the second step, conversion of OLI band data from spectral radiance to brightness temperature using the thermal constants provided in the metadata file using Eq.

$$BT = \frac{K2}{\ln\left(\frac{K1}{L_{\lambda}} + 1\right)} \quad (11)$$

Where, BT at satellite brightness temperature (K), L_{λ} temperature of atmosphere spectral radiance, K1 and K2 band-specific thermal conversion constants from the metadata.

For obtaining the results in Celsius, the radiant temperature is revised using eq.

$$T^{\circ}C = T(K) - 273.15 \quad (12)$$

In the third step, calculate the NDVI

$$NDVI = Float \frac{(Band\ 5 - Band\ 4)}{Float(Band\ 5 + Band\ 4)} \quad (13)$$

In the fourth step compute the proportion of vegetation P_v :

$$P_v = Square \left(\frac{(NDVI - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} \right) \quad (14)$$

Fifth step, calculate Emissivity: Surface emissivity stands for the surface ability that transforms heat energy into radiant energy (Sobrino,2001). Depending on the fractional vegetation cover (FVC) for a given pixel. The land surface emissivity (ϵ) is calculated using Eq (15) as proposed by Sobrino et al. (2004).

$$\epsilon = 0.004 * P_v + 0.986 \quad (15)$$

Final step, calculate the land surface temperature using mono window algorithm. A comparative analysis has been done to assess land surface temperature.

$$LST = \frac{BT}{(1 + W * \left(\frac{BT}{P}\right) * \ln(\epsilon))} \quad (16)$$

Where, B_T brightness (at-satellite temperature), W wavelength of emitted radiance (11.5 μ m),

$P = 14,380$ (constant)

3.4.5. Normalized Difference Vegetation Index

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:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (17)$$

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(Esubalew,2014). The overall average annual NDVI coverage for the observation period between 1990 and 2020 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:

$$Y_i = \sum_{i=1990}^{2020} \frac{X_i}{N} \quad (18)$$

Where, Y_i = overall mean NDVI

X_i = is the average NDVI value of a given year

N = total observation year

3.4.6. Adjusted-Soil Vegetation Index

Adjusted-Soil Vegetation Index is used to correct Normalized Difference Vegetation Index for the influence of soil brightness in areas where vegetative cover is low. Generally, $L = 0.5$ works well in most scenarios and is used as default value (Rondeaux et al. 1996; Huete 1988,as cited Kanwal,2019).

$$SAVI = \left(\frac{NIR - R}{(NIR + R)} + L \right) * (1 + L) \quad (19)$$

Where, NIR is the reflectance value of the near infrared band, RED is reflectance of the red band, and L is the soil brightness correction factor.

3.4.7. Moisture stress index

Moisture Stress Index (MSI) is a water ratio index that finds the water content in vegetation or leaf relative. Soil moisture plays a significant part in growing vegetation from the roots rather than precipitation (Soni et al. 2017, as cited Kanwal,2019). It is normally estimated from satellite data that uses SWIR band instead of MIR because of band's sensitivity to moisture. The ratio between SWIR and MIR reduces scattering effect and dominates water variation in vegetation (Zhang et al. 2013, as cited Kanwal,2019). Interpretation of the MSI is inverted relative to other water vegetation indices; thus, higher values of the index indicate greater plant water stress and in inference, less soil moisture content.

$$MSI = \frac{RSWIR}{NIR} \quad (20)$$

Where, RSWIR Remote sensing short wave infrared, NIR near infrared.

3.4.8. Transformed normalized difference vegetation

According to Greenland (1994, as cited Kanwal,2019), TNDVI is an integrated function of photosynthesis, leaf area and evapotranspiration. It is a symbol of vegetation biomass, and it is a ratio between near-IR and red reflection.

$$TNDVI = \sqrt{\frac{NIR - RED}{NIR + RED}} + 0.5 \quad (21)$$

3.4.9. Regression Analysis

Linear regression finds the line of best fit through a set of data. The linear correlation coefficient computed from the sample data measures the strength and direction of a linear relationship between two quantitative variables. The symbol for the sample correlation coefficient is r . The range of the linear correlation coefficient is from -1 to +1. If there is a strong positive linear relationship between the variables, the value of r will be close to +1. If there is a strong negative linear relationship between the variables, the value of r will be close to -1. When there is no linear relationship between the variables or only a weak relationship, the value of r will be close to 0.

$$r = \frac{n \sum(xy) - (\sum x)(\sum y)}{\sqrt{[n \sum(x^2) - (\sum x)^2][n \sum(y^2) - (\sum y)^2]}} \quad (22)$$

Where, n is the number of data pairs.

Coefficient of Determination(r^2): The coefficient of determination is the square of the linear correlation coefficient. The coefficient of determination is a measure of the variation of the dependent variable that is explained by the regression line and the independent variable. The symbol for the coefficient of determination is r^2 and has value between 0 and 1. If it is near to 1 then most of the variation is explained by the regression line, there is little unexplained variation and the line is a good fit of the data. If the value is near to 0 then most of the variation is unexplained and the line is not a good fit.

3.4.10. Remote sensing climatic compound index (RSCCI)

Is a new climatic compound index which is introduced for a new climatic classification study area, based on some parameters which include land surface temperature, vegetation, evapotranspiration/precipitation, water and soil moisture of study area because the climate is mainly affected by these factors naturally.

$$RSCCI = \frac{LST + NDVI + SAVI + MSI + TNDVI}{5} \quad (23)$$

The overall process performed to analysis climate change was illustrated by the following general work flow.

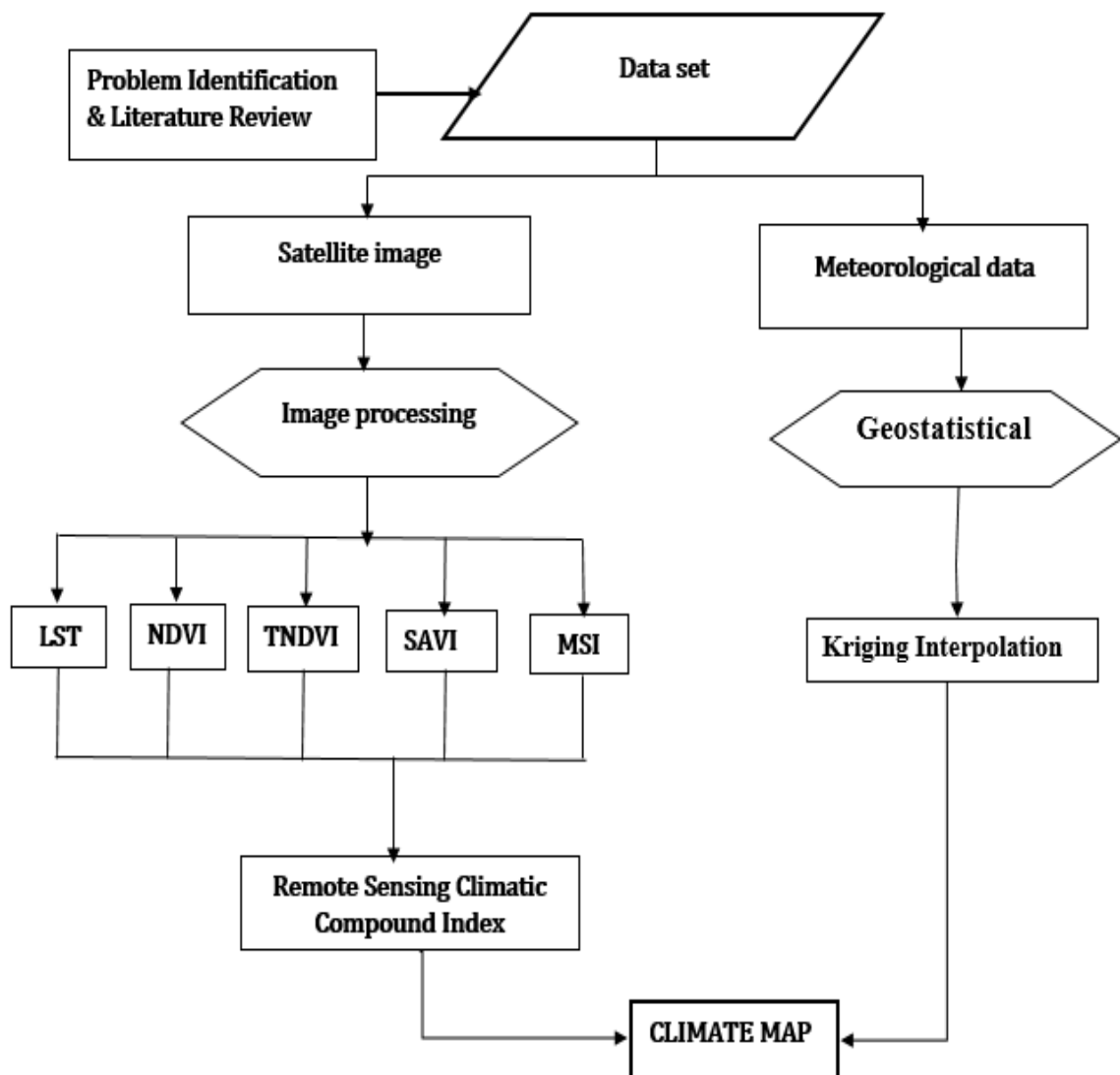


Figure 3: Methodological Scheme of the Study

CHAPTER IV: RESULT AND DISCUSSION

This section presents a detailed description of the results obtained from the analysis of temporal and spatial climate variability over North Shewa zone. This research focused on characterization of satellite image, rainfall and temperature variations in the study area.

4.1. 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 Sixteen stations which have long record of rainfall the zone received the mean annual rainfall between 1990 and 2000, 1096.75mm was, with standard deviation of +18.00mm and 2% coefficient of variation. The mean annual rainfall observation between 2000 and 2010 was 872.48 mm, with standard deviation of +27.31 mm and 3.13% coefficient of variation. The mean annual rainfall of the last decade found to be 1134.26 mm, with +30.38 mm standard deviation and 2.68% coefficient of variation. Generally, the result showed that the mean annual rainfall distribution across all the three observation varies both in space and time.

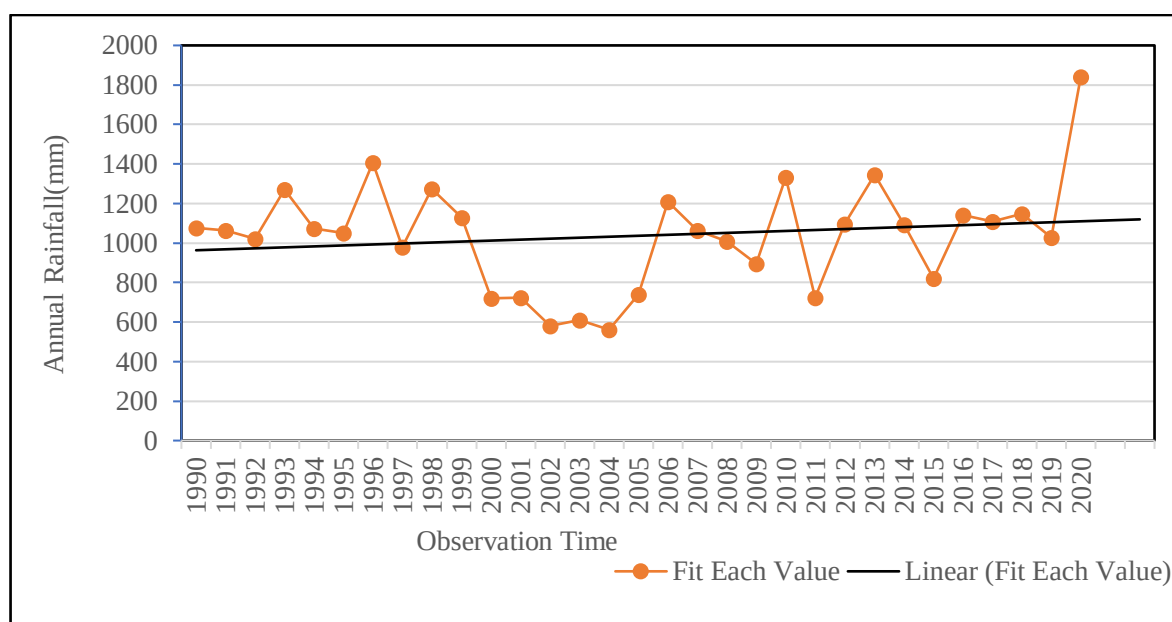


Figure 4: Total mean annual rainfall trends in the study area between 1990 and 2020

Figure 4, demonstrates that in the study area heavy rainfall was registered in 2020 with annual rainfall of 1842.5 mm and the minimum rainfall occurred in the year 2004 with annual rainfall of 561.15 mm. The overall average rainfall in the last 30 years' time was 1036.50 mm with a standard deviation of + 27.27 mm and coefficient of variation of 2.63 %.

Generally, as figure 4 depicts, the annual rainfall pattern shows a considerable fluctuation, one year there is a slight positive anomaly and on the other year shows negative anomalies. Thus, it is possible to deduce that rainfall is highly irregular in nature for all the observation times (1990-2020).

Table 6: Annual mean rainfall(mm), SD (mm) and CV (%)

Year	Maximum	Minimum	Mean	SD	CV (%)
1990-2000	1405.63	720.27	1096.75	18.00	2
2000-2010	1333.83	561.15	872.48	27.31	3.13
2010-2020	1842.5	722.33	1134.26	30.38	2.68

4.2. Interannual Fluctuation of Rainfall

Based on drought index classification, the statistical result revealed that in the area extremely dry was observed if $SRA < -1.65$, and this was observed in 2002, 2003 and 2004. In the category of $-1.28 > SRA > -1.65$, which gives clue to severely dry, in the year 2000, 2001 and 2011 severely dry was observed. If the outcome falls between $-0.84 > SRA > -1.28$, moderate drought would be the case which occurred in 2005 and 2015. In the rest observation, drought was not prevailed in the area (nearly normal).

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 5 & 6) shows lack of annual total rainfall trends for the period from 1990 to 2020.

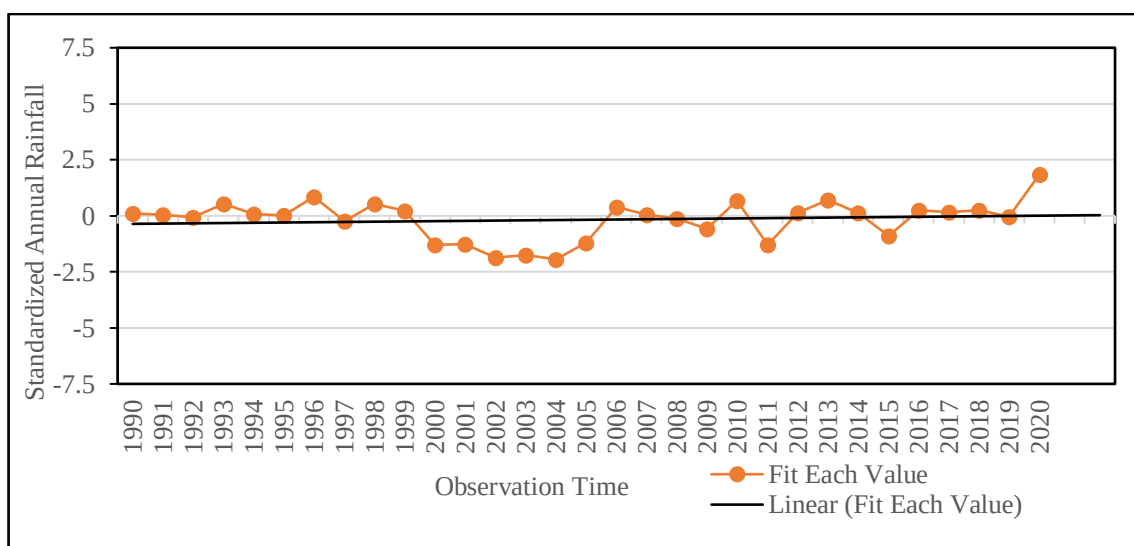


Figure 5: Standardized annual rainfall anomaly in the study site during the observation year b/n 1990 and 2020

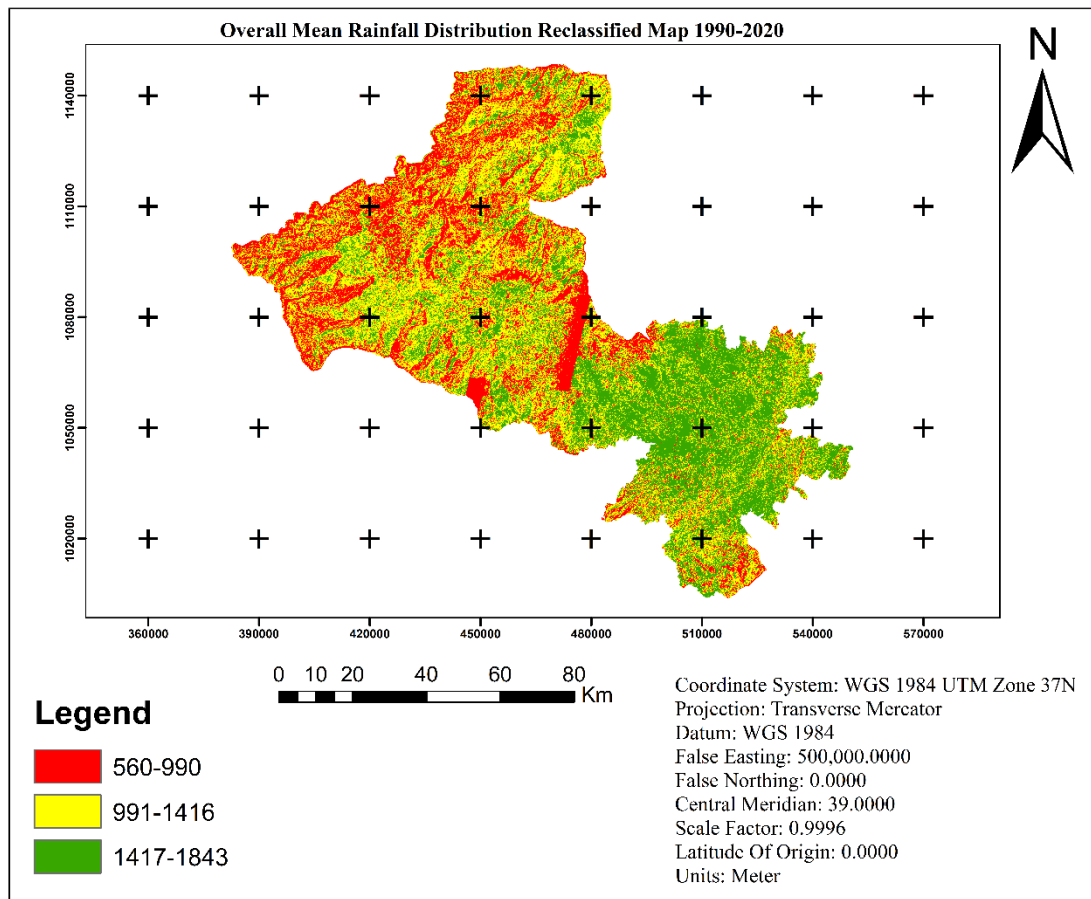


Figure 6: The Overall Mean Rainfall Distribution Reclassified Map 1990-2020

The result of standardized rainfall anomalies indicated that the interannual variability of rainfall (Fig 5& 6) shows lack of annual total rainfall trends for the period from 1990-2020. 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 66.67% of the study area showed below average rainfall record while the remaining 33.33% showed above average rainfall amount. As portrayed in fig 6, the overall mean rainfall of the study site was 1036.5 mm. The mean maximum and minimum rainfall of the same period found to be 1842.5 mm and 561.15 mm respectively.

4.2.1. First Decadal observation (1990-2000)

Figure 4.4 reveals the rainfall distribution between 1990 and 2000. In this period, the minimum rainfall was recorded in 2000 with 720.27mm and the maximum rainfall was 1405.63 mm that was registered in 1996 and the average rainfall in the period was found to be 1096.75mm.

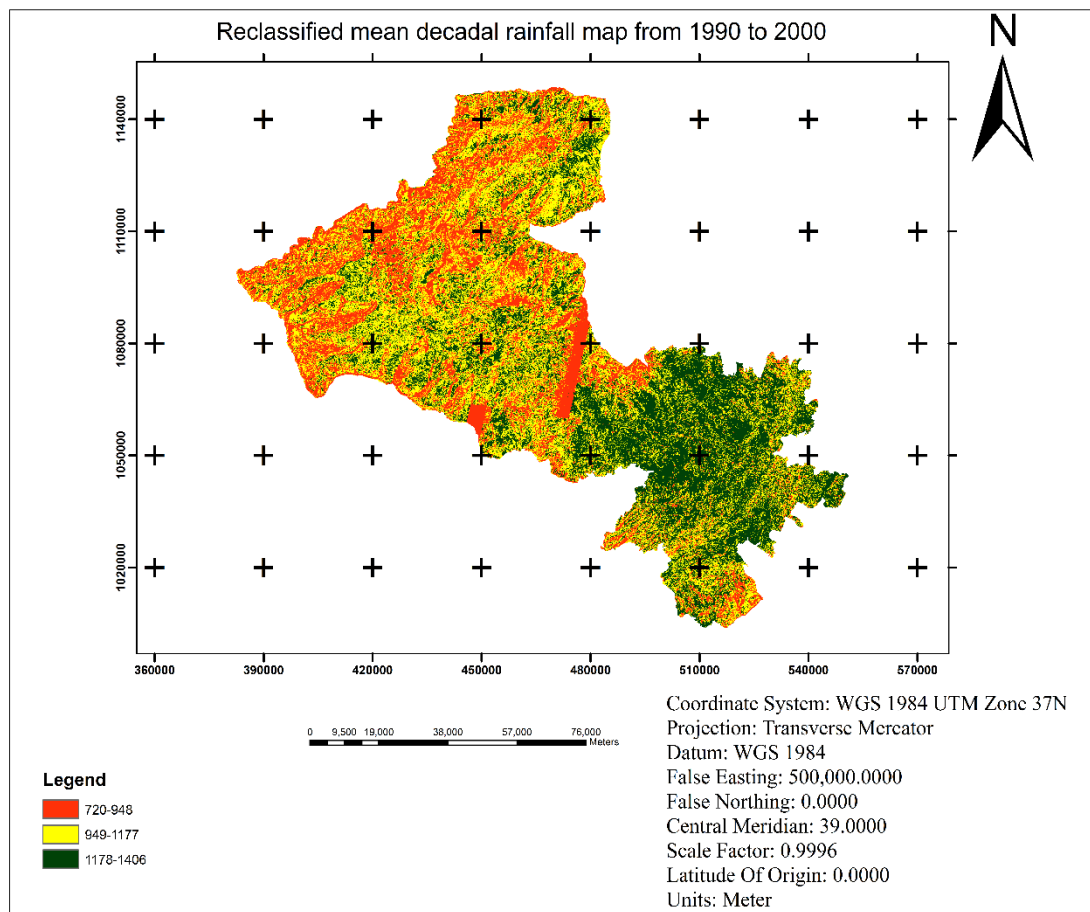


Figure 7: Reclassified mean decadal rainfall map from 1990 to 2000

4.2.2. Second Decadal observation (2000-2010)

The average total annual rainfall between 2000 and 2010 was 872.476 mm. For the observation time, the maximum rainfall was 1333.83 mm recorded in 2010 and the minimum was 561.15 mm registered in 2004.

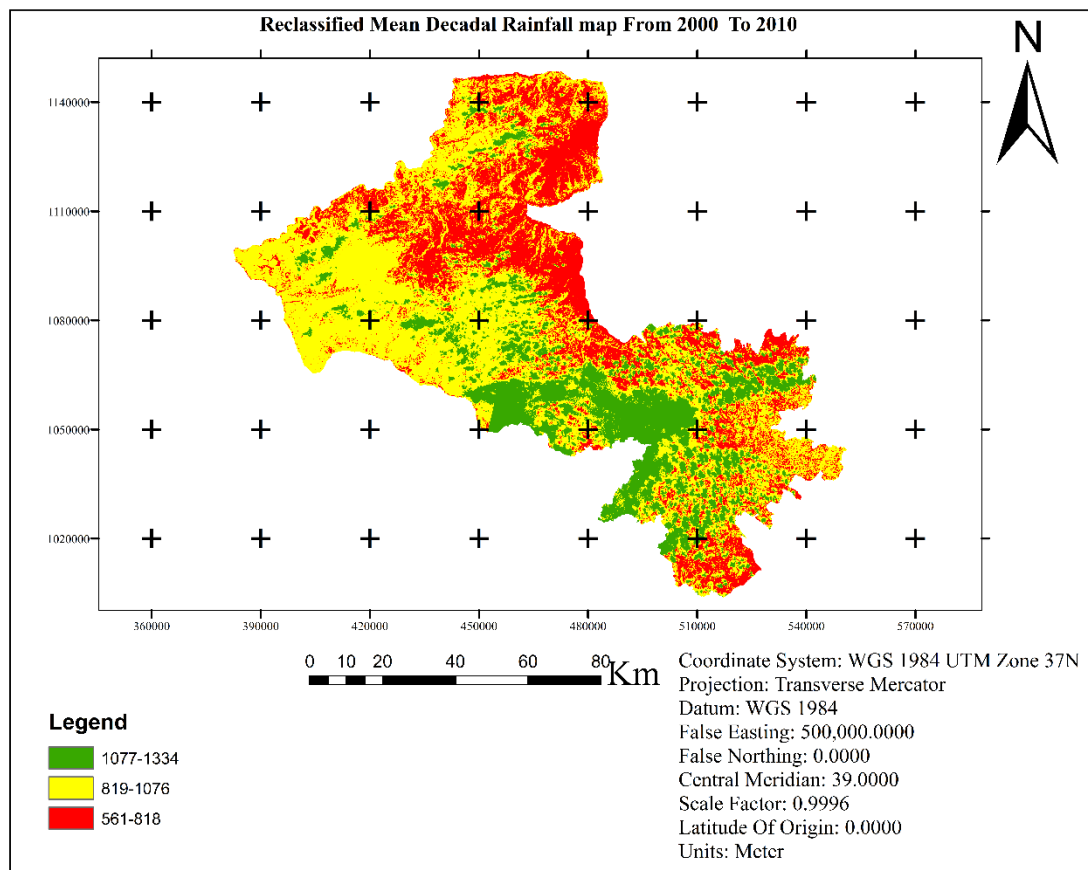


Figure 8: Reclassified mean decadal rainfall map between 2000 and 2010

4.2.3. Third Decadal Observation (2010-2020)

The average total annual rainfall from 2010 to 2020 was 1134.26 mm, with standard deviation of +30.38 mm and 2.68 % coefficient of variation. The maximum rainfall was 1842.5 mm recorded in 2020 and the minimum was 722.33 mm manifested in 2011.

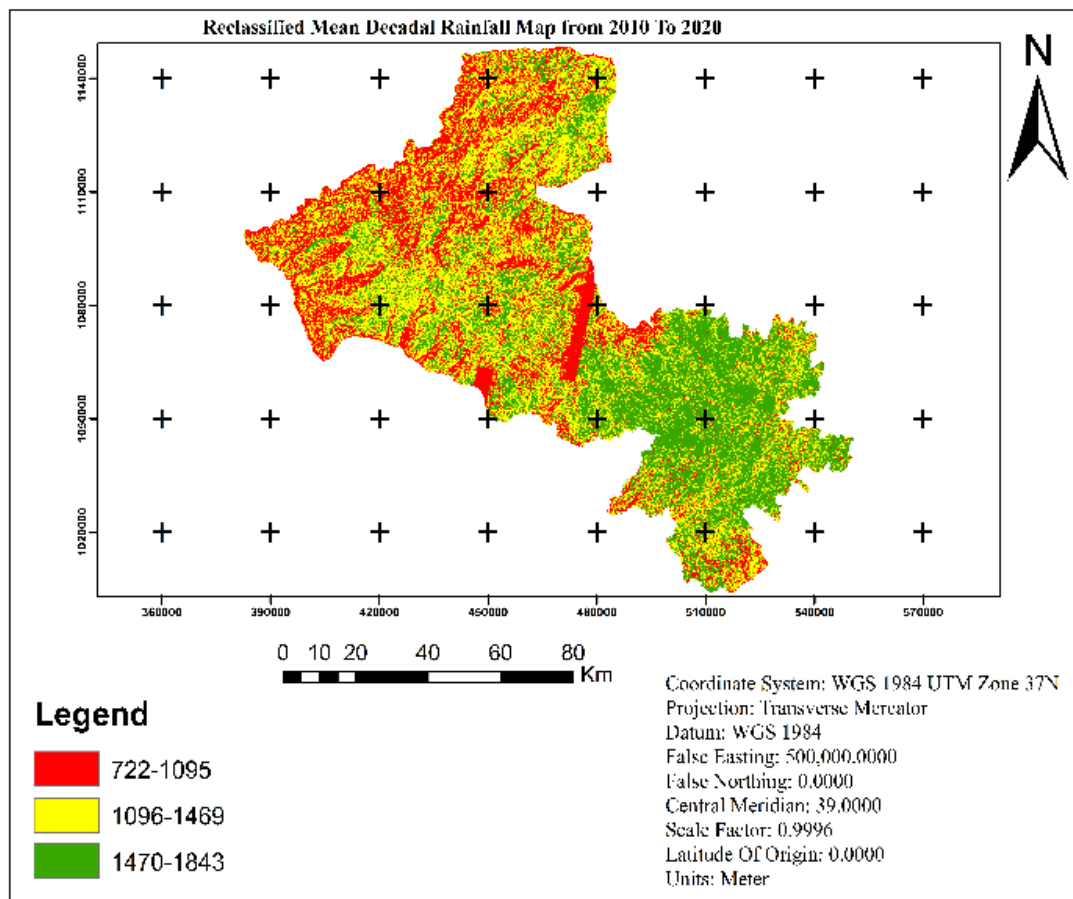


Figure 9: Reclassified mean decadal rainfall map between 2010 and 2020

4.2.4. Kiremt 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) (Esubalew ,2014). 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.

The study area received its maximum rainfall during kiremt season that extends from June to September. As depicted in figure 10, the total average rainfall of Kiremt season in the period of observation between 1990 and 2020 was found to be 762.28 mm with +18.74 mm standard deviation and coefficient of variation 2.46%. In the study area, the maximum

kiremt rainfall was recorded in 2020 which is 1063.3 mm and the minimum was 404.46 mm apparent in 2004. The general trend of kiremt season rainfall showed an increasing trend as shown in table 7 and figure 10.

Table 7: Kiremt season mean rainfall(mm), SD (mm) and CV (%)

Decades	Mean Rainfall (mm)	SD	CV
1990-2000	814.60	12.50	0.015344
2000-2010	643.61	21.37	0.0332
2010-2020	823.40	17.59	0.021359

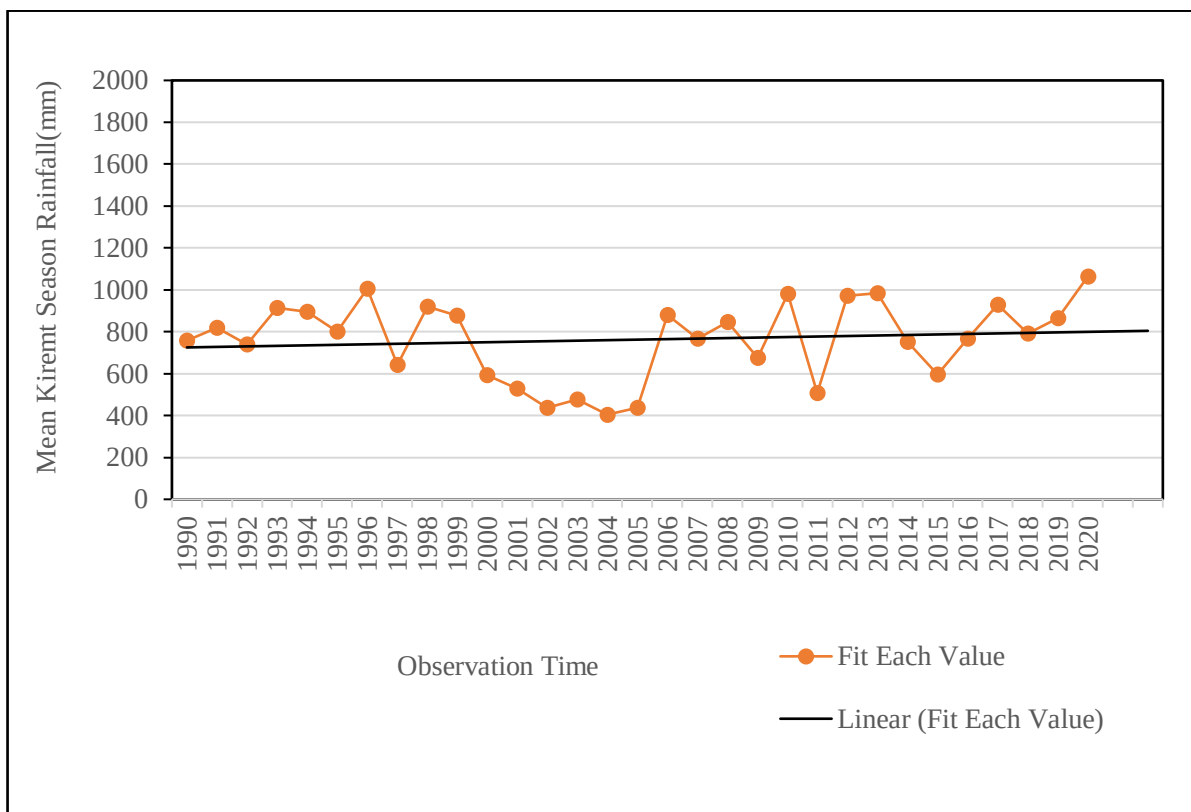


Figure 10: Trend of rainfall during kiremt season b/n 1990 and 2020

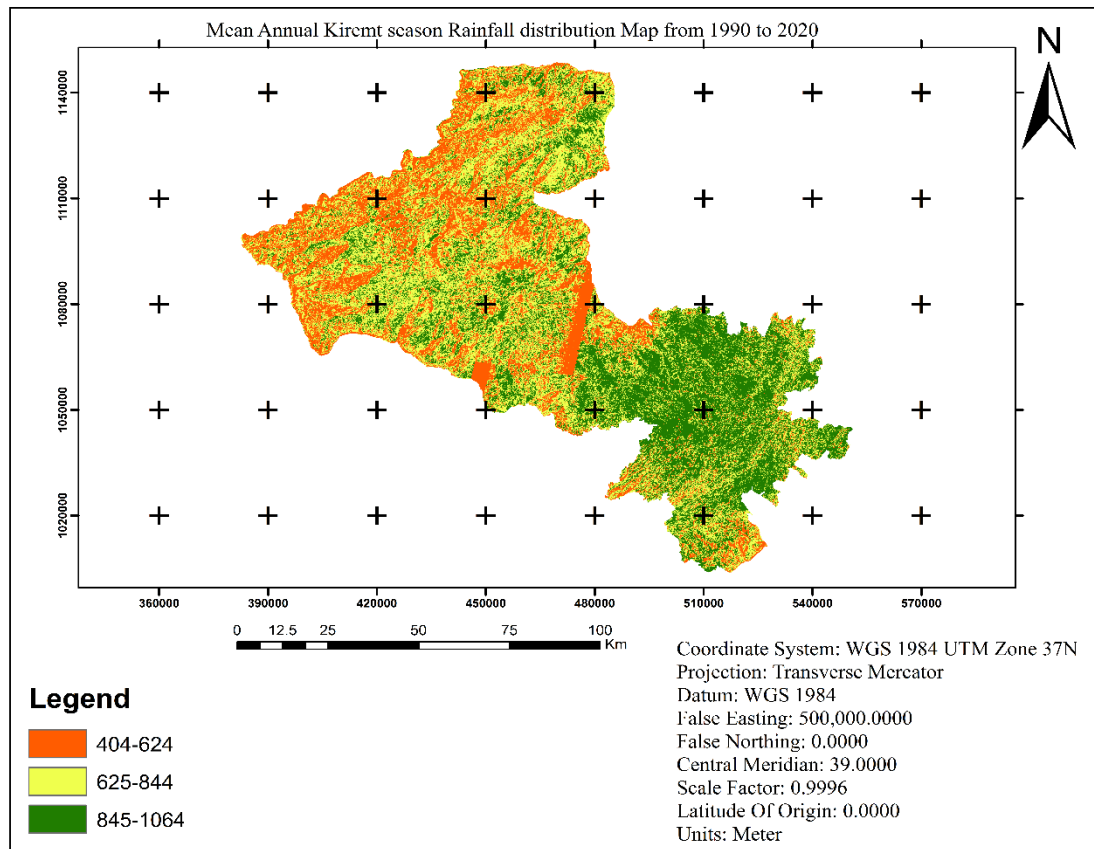


Figure 11: Mean Annual Kiremt season Rainfall distribution from 1990 to 2020

4.2.5. 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 important for the production of fast growing crops. According to NMSA (2001, as cited Esubalew, 2014) the belg season lasts February through May, which is a short rainy season. The result of the analysis across the observation (1990-2020) demonstrated that the study area received a mean rainfall of 206.61 mm during the belg season having a standard deviation of +11.94 mm and coefficient of variation 0.06 (5.78%) (Figure 12).

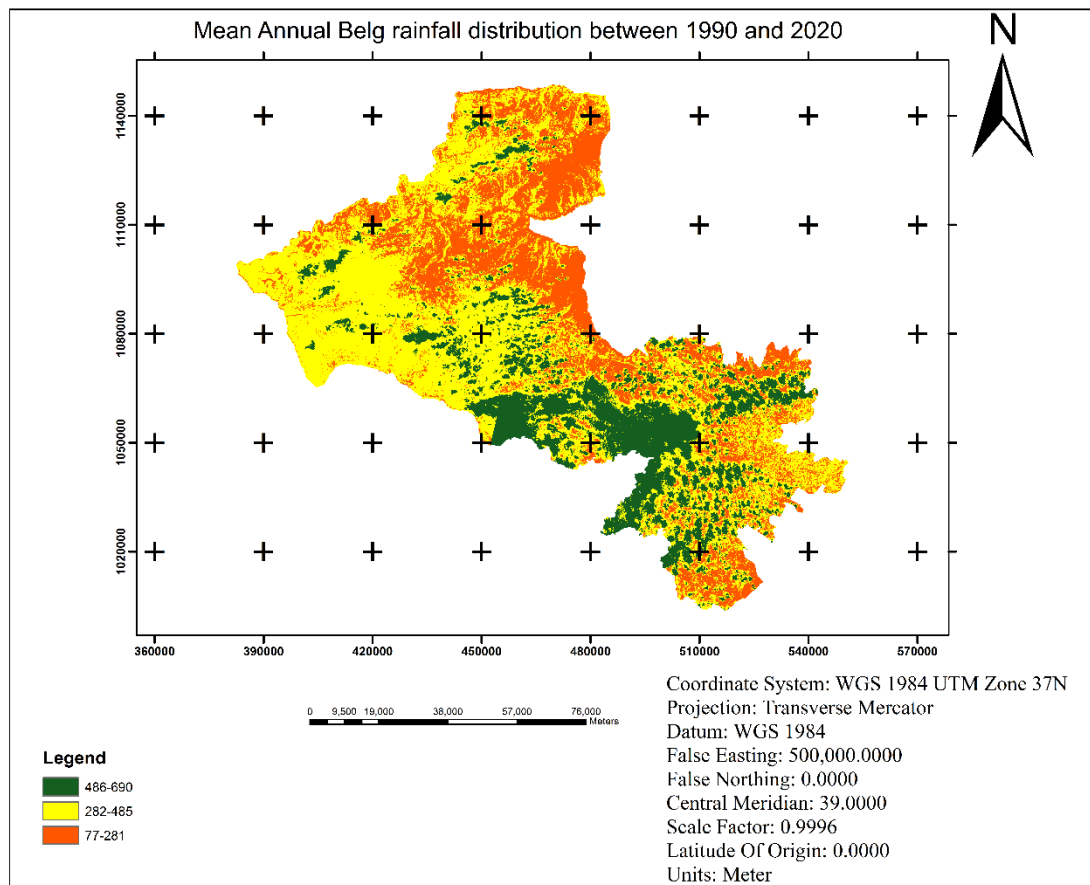


Figure 12: Portray mean annual Belg rainfall distribution between 1990 and 2020

In thirty years period of Belg rainfall distribution, the maximum rain was recorded in 2020 which is 689.7mm, whereas the minimum rainfall was 77.48mm which happened in 2009.

Table 8: Belg season mean rainfall(mm), SD (mm) and CV (%)

Decades	Mean Rainfall (mm)	SD	CV
1990-2000	201.48	7.33	0.04
2000-2010	171.94	9.00	0.05
2010-2020	246.95	17.40	0.07

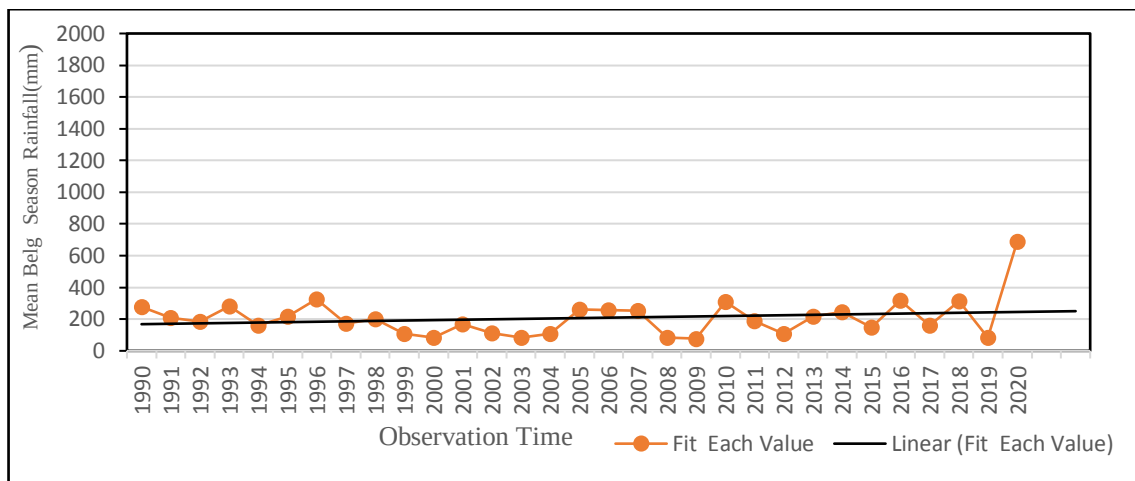


Figure 13: Shows trend of rainfall distribution in belg season from 1990 to 2020

4.2.6. Bega Season Rainfall

The bega season lasts October through January, which is a no rainy season (Esubalew, 2014). The result of the analysis across the observation (1990-2020) demonstrated that the study area received a mean rainfall of 67.90 mm during the beg a season having a standard deviation of +4.27 mm and coefficient of variation 0.062876 (6.29%) (Figure 14).

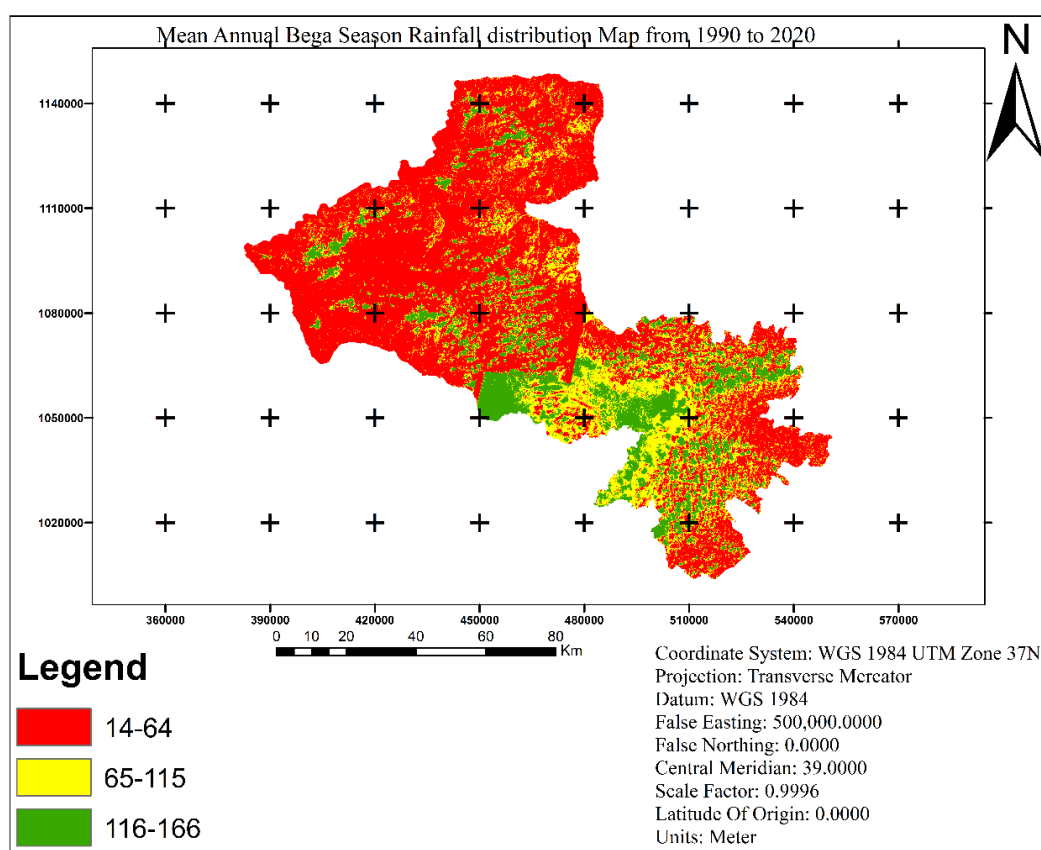


Figure 14: Mean annual Bega season rainfall distribution between 1990 and 2020

In thirty years, period of Bega rainfall distribution, the maximum rain was recorded in 1997 which is 165.17 mm, whereas the mean minimum rainfall was 14.85 mm which happened in 2012.

Table 9: Bega season mean rainfall(mm), SD(mm) and CV(%)

Decades	Mean Rainfall (mm)	SD	CV
1990-2000	80.67	5.23	0.06
2000-2010	56.93	3.38	0.06
2010-2020	64.81	3.93	0.06

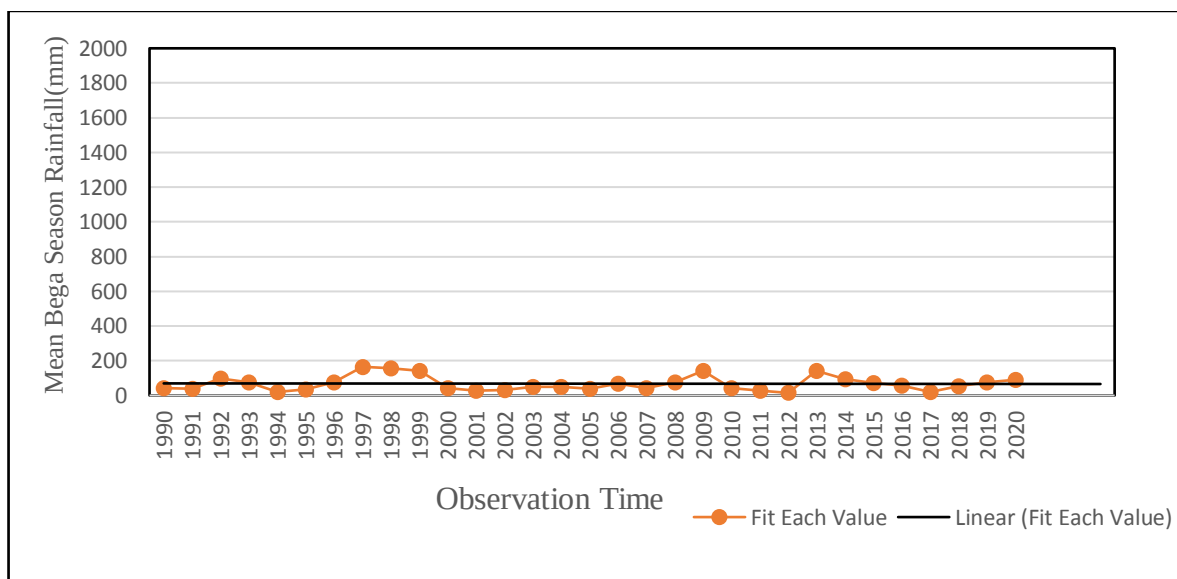


Figure 15: Shows trend of rainfall distribution in Bega season from 1990 to 2020

Table 10: Annual and seasonal PCI values of rainfall distribution pattern (1990-2020)

PCI	Annual (%)	Kiremt (%)	Belg (%)	Bega (%)
<10	-	64.52	19.35	16.13
10 - 15	38.71	22.58	54.84	19.35
16 - 20	61.29	12.90	19.35	22.58
>20	38.71		6.45	41.94

Table 10, depicts frequency and percentage of annual and seasonal PCI values rainfall distribution for the years ranging from 1990 to 2020. It shows irregular distributions in the

annual rainfall pattern. While higher frequency of irregular distributions in the annual rainfall pattern (61.29%), moderate rainfall distribution (38.71%) and more strong irregularity was observed (38.71%) and it was illustrating a more or less uniform and moderate pattern in Kiremt rainfall. It further shows that uniform precipitation distribution (16.13%), moderate (19.35%), irregular distribution (22.58%) and strong irregularity (41.94%) of bega rainfall pattern. Also, it revealed that uniform precipitation distribution (19.35%), moderate (54.84%), irregular distribution (19.35%) and strong irregularity (6.45%) of belg rainfall pattern.

4.3. Spatial and Temporal Variability of Maximum and Minimum Temperature

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 1990 to 2000 was 25.71°C with standard deviation $+1.03^{\circ}\text{C}$ and coefficient of variation 4% while mean temperature for the year 2001-2010 was 25.86°C with standard deviation $+1.26^{\circ}\text{C}$ and coefficient of variation 4.86 %. Mean maximum temperature for the observation between 2011 and 2020 was 26.55°C with standard deviation of $+1.41^{\circ}\text{C}$ and coefficient of variation 5.32%. The mean maximum temperature of the study area over thirty years time ranging from 1990 to 2020 was 26.03°C with standard deviation $+1.25^{\circ}\text{C}$ and coefficient of variation 4.80% as depicted in figure 4.13 below. 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 0.15°C while in the last 2010 to 2020 observation the mean annual maximum temperature was increased by 0.69°C .

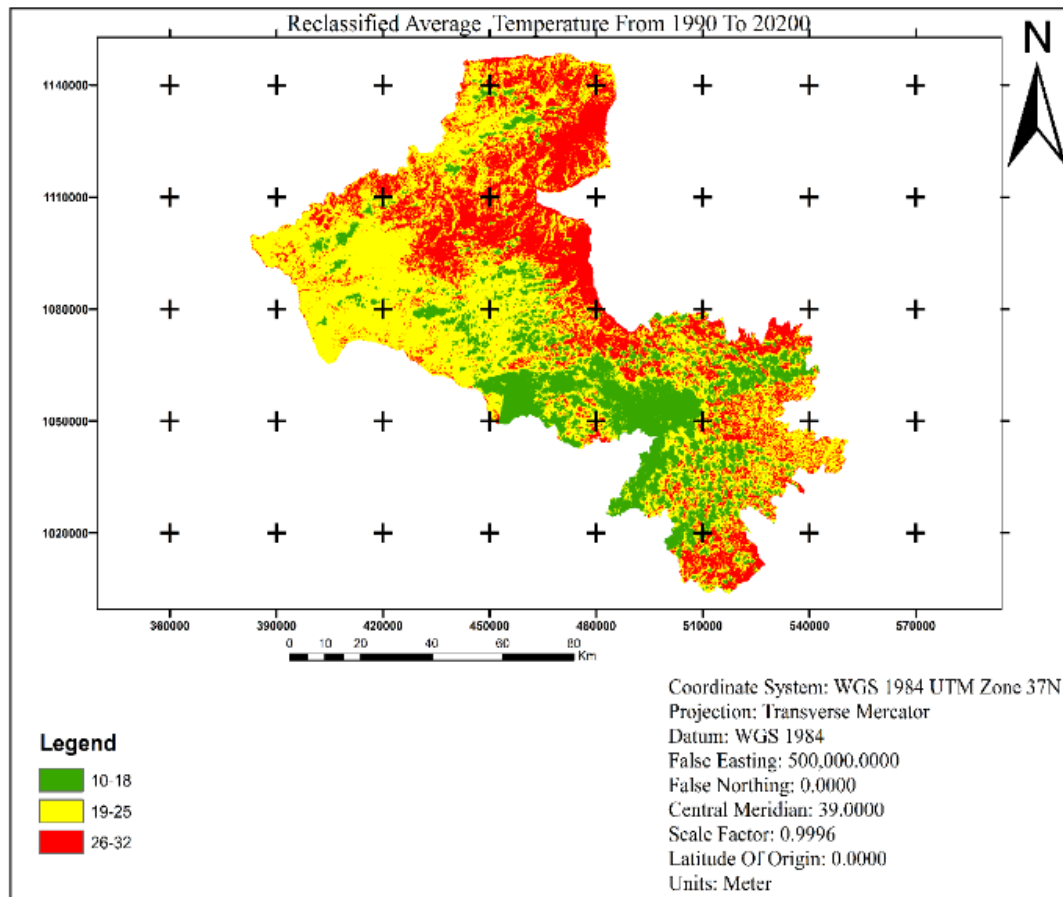


Figure 16: Reclassified average temperature between 1990 and 2020

Table 11: Decadal mean minimum and mean maximum temperature, SD and CV

Year	Mean ($^{\circ}\text{C}$)		SD($^{\circ}\text{C}$)		CV (%)	
	Max	Min	Max	Min	Max	Min
1990-2000	25.71	11.69	1.03	0.38	4	3.23
2001-2010	25.86	11.94	1.26	0.40	4.86	3.33
2011-2020	26.55	11.84	1.41	0.32	5.32	2.68

In the study area, the mean annual maximum temperature reached its highest level 27.66°C , 27.2°C , 27.12°C in the year 2002, 2003 and 2004 respectively. But the lowest temperature was found to be 11.69°C registered in 1996. The areal average annual maximum and minimum temperature of the study area in all the three decades shows relatively increasing and declining trend.

4.3.1. Inter-annual Temperature Fluctuation

Inter-annual/annual variation of maximum and minimum temperatures expressed in terms of normalized temperature anomalies averaged. Figure (17 and 18) clearly exhibits that there has been a warming trend in the mean annual maximum temperature over the past 30 years and it has increased by 0.84°C . This clearly shows that there has been a relatively increasing and declining trend in the mean.

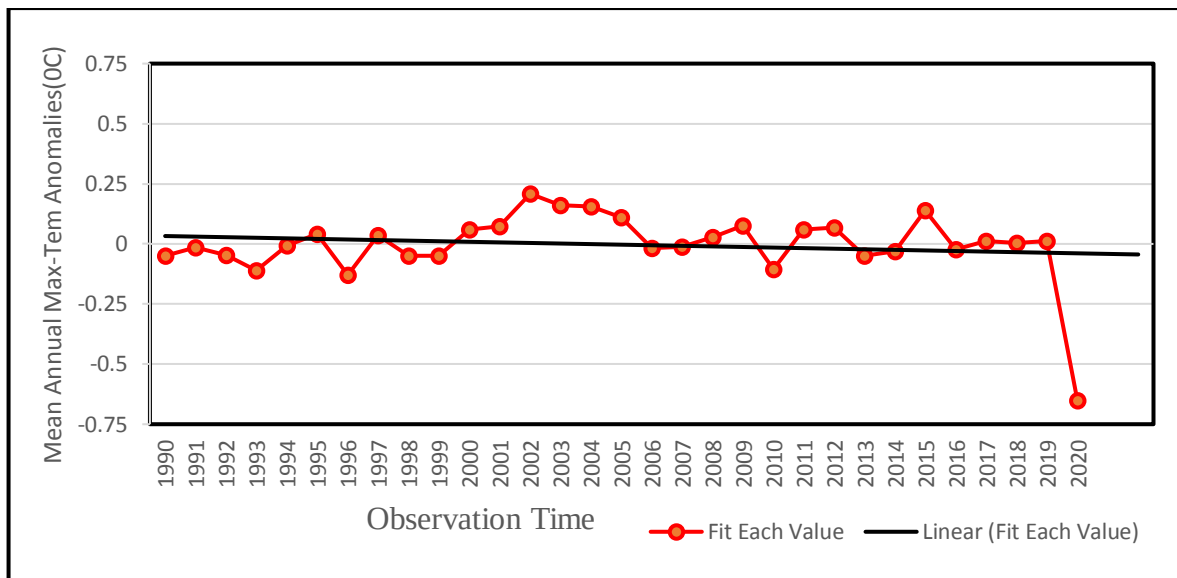


Figure 17: Mean maximum temperature variability and trend over the study area

On the other hand, as depicted in figure 18, the mean annual minimum temperature over the past thirty years demonstrated that there has been a slight rise and decline unlike the average annual maximum temperature.

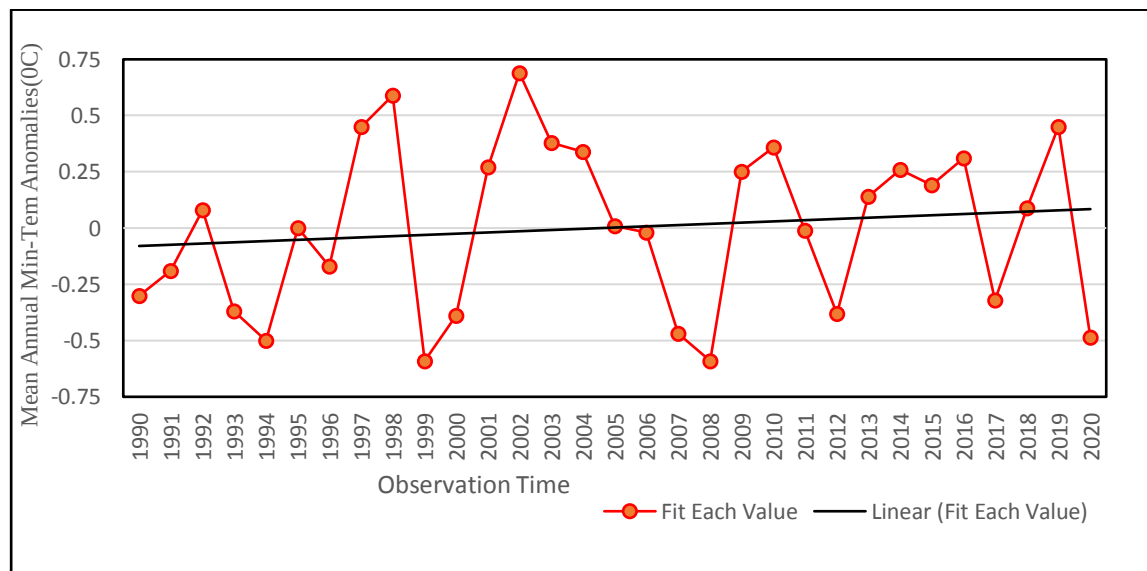


Figure 18: Mean minimum temperature variability and trend over the study area

4.3.2. Correlation between mean annual NDVI and average annual Rainfall

Rainfall data from meteorological stations and greenness of vegetation derived from NDVI were correlated using linear regression equation to develop a climate change model (Ogunbadewa, 2013). The study in this section observed the correlation of rainfall and NDVI for the year 1990 to 2020 have been thoroughly analyzed on both annual and seasonal basis.

From annual quantitative analysis of vegetation coverage, both the highest and the lowest vegetation coverage were manifested in the year 1990 and 2004 which is 21.30% and 5.29% respectively as shown in table 12. 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,as cited Esubalew,2014).

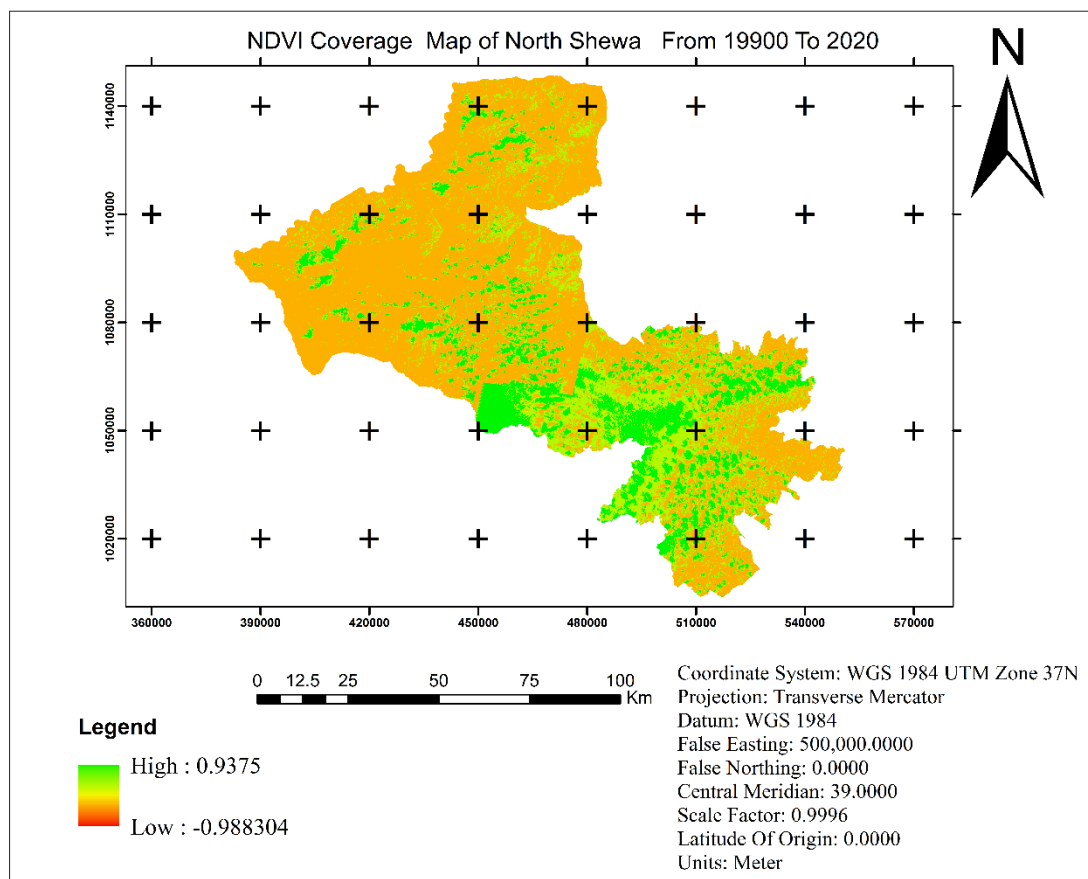


Figure 19: Depicts the overall average annual NDVI distribution 1990 to 2020

Table 12: Vegetation Coverage and Coefficient of Variation

Vegetation Coverage per decade			
Decade	1990-2000	2001-2010	2011-2020
CV	0.05-0.17	0.17- 0.21	0.12 -0.17
Vegetation Coverage (%)	5.29-16.60	16.60-21.30	11.72 -16.55

According to Gamo et al. (2013, as cited Kanwal,2019), the value range of an NDVI is -1 to 1. Negative values of NDVI (values approaching -1) correspond to water. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values (>0.6) indicate dense vegetation. As shown in table 12, 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 0.05-0.21 coefficients of variation.

From the result, it was possible to deduced that there was linear correlation between mean annual rainfall and calculated NDVI value. The r^2 value was 0.8749 r^2 adjusted is 0.871, and the P value is significant at 0.002 since the threshold for statistical significance level is 0.05. The high value of r^2 shows that the time-series NDVI datasets derived from satellite image was a way forward in the direction of advancement in data availability.

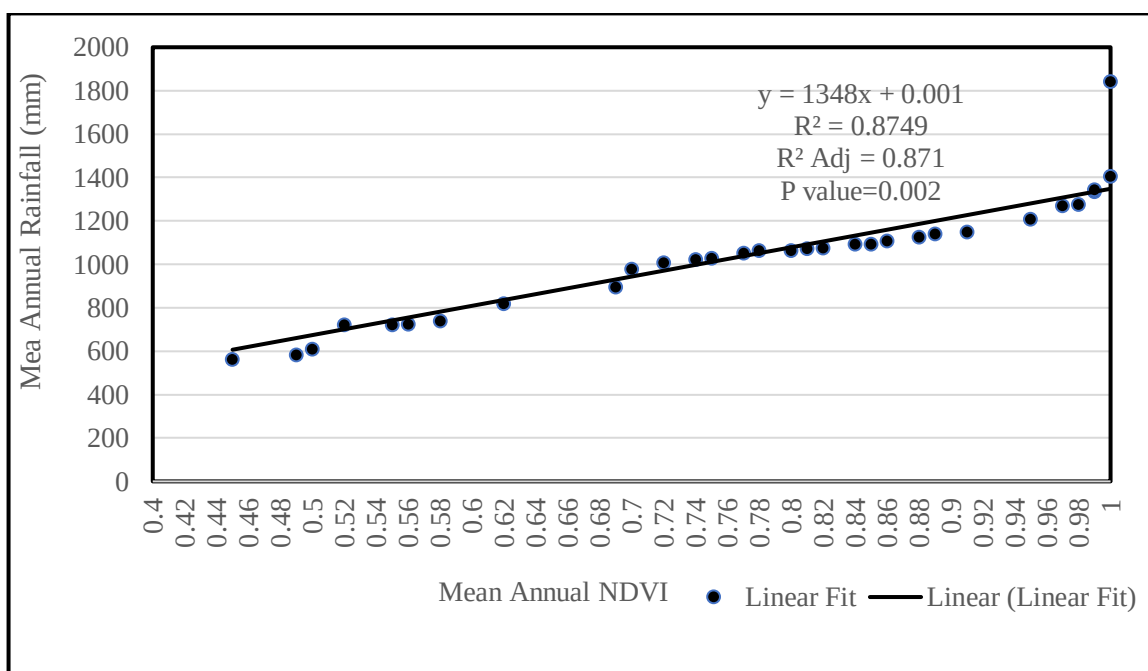


Figure 20: Shows the correlation b/n mean annual rainfall and mean annual NDVI

4.3.3. Correlation between mean annual NDVI and average annual temperature

Regarding to the graph (figure 21), the correlation of mean annual temperature and mean annual NDVI value of the year 1990 to 2020, the result explained that mean annual temperature is negatively correlated (-0.88 correlation coefficient) with NDVI values of the area, which is 0.766 value of r^2 . Increase in temperature was not coincides with an increase in NDVI. This implied that temperature is also a very important climatic element for vegetation growth depending on the type of vegetation and climatic zone.

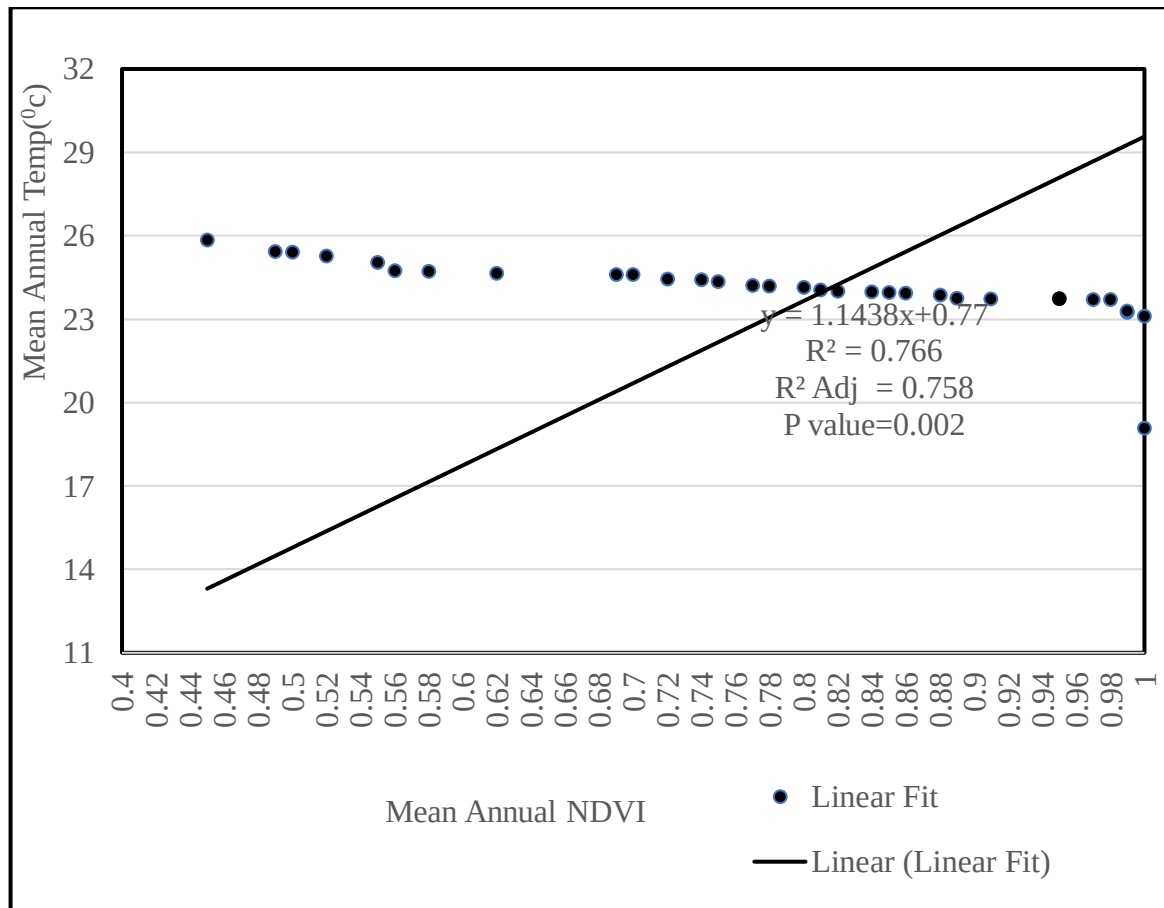


Figure 21: Shows the correlation b/n mean temperature and mean NDVI

4.3.4. Traditional Agroecological climatic classification of Study area using RSCCI

North Shewa zone has been classified into three agro-ecological climatic zones as, dega, woinadega and kola. Area of dega, woinadega and kola agro-ecological climatic classification of North Shewa calculated from RSCCI for the year 1990 was 468379.6, 283120.8 and 179190.21 hectares.

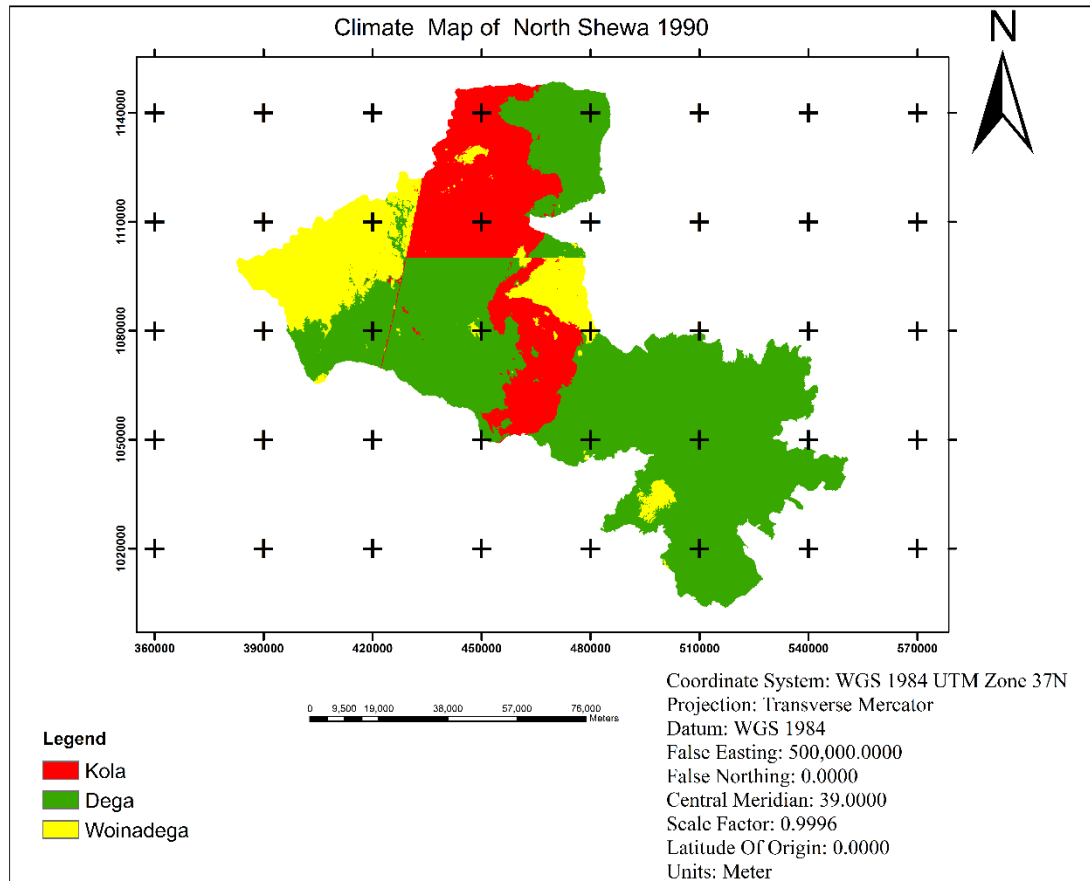


Figure 22: The climatic classification using RSCCI for year 1990

Area of dega, woinadega and kola agro-ecological climatic classification of study area calculated from RSCCI for the year 2000 was 335034.4 ,373688 and 221968.2 hectares.

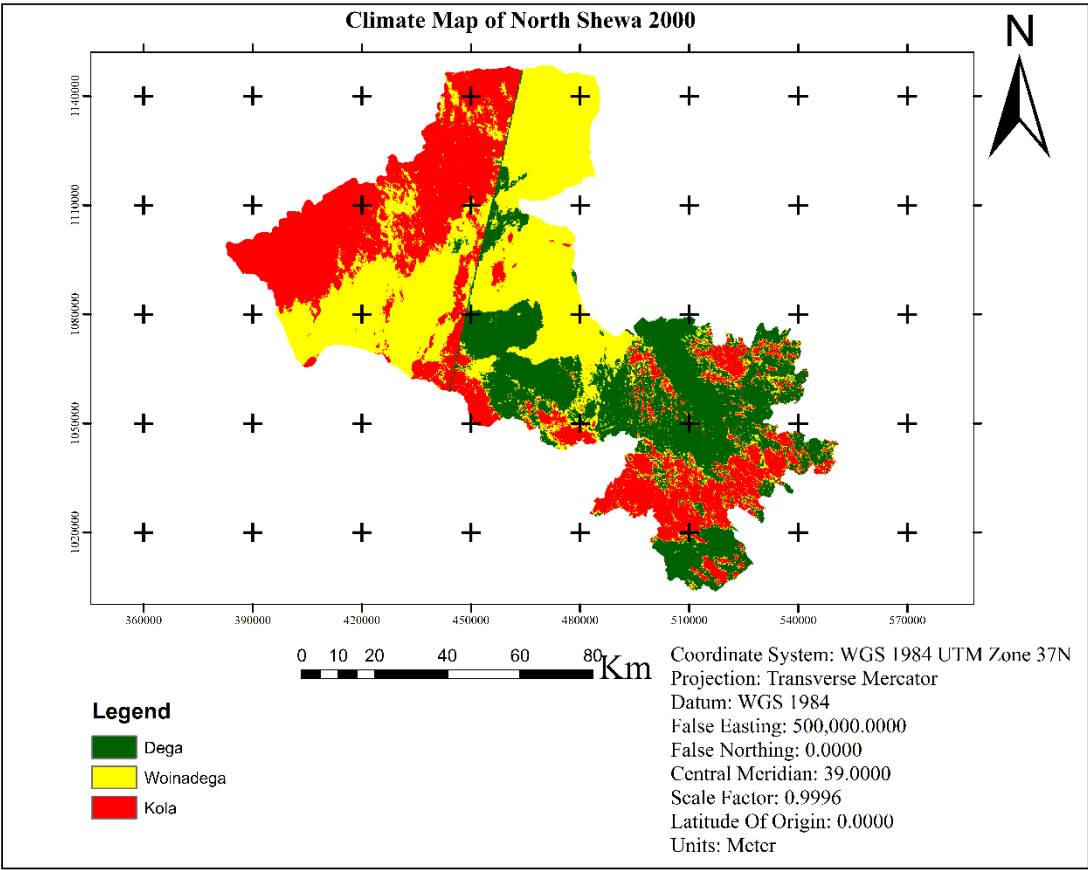


Figure 23: The climatic classification using RSCCI for year 2000

As shown in figure below (24), the regions which was shown with green color, yellow and red in the legend of figures are classified as dega (baddaa), woinadega (baddaa daree) and kola(gammoojjii) respectively. The highest proportion of the area falls within highland (Dega) agro-ecology 38.14% of the total area. The second highest proportion of the area falls within midland (Woinadega) agro-ecology 38.14% of the total area of the zone. Kola occupies small portion of the study area.

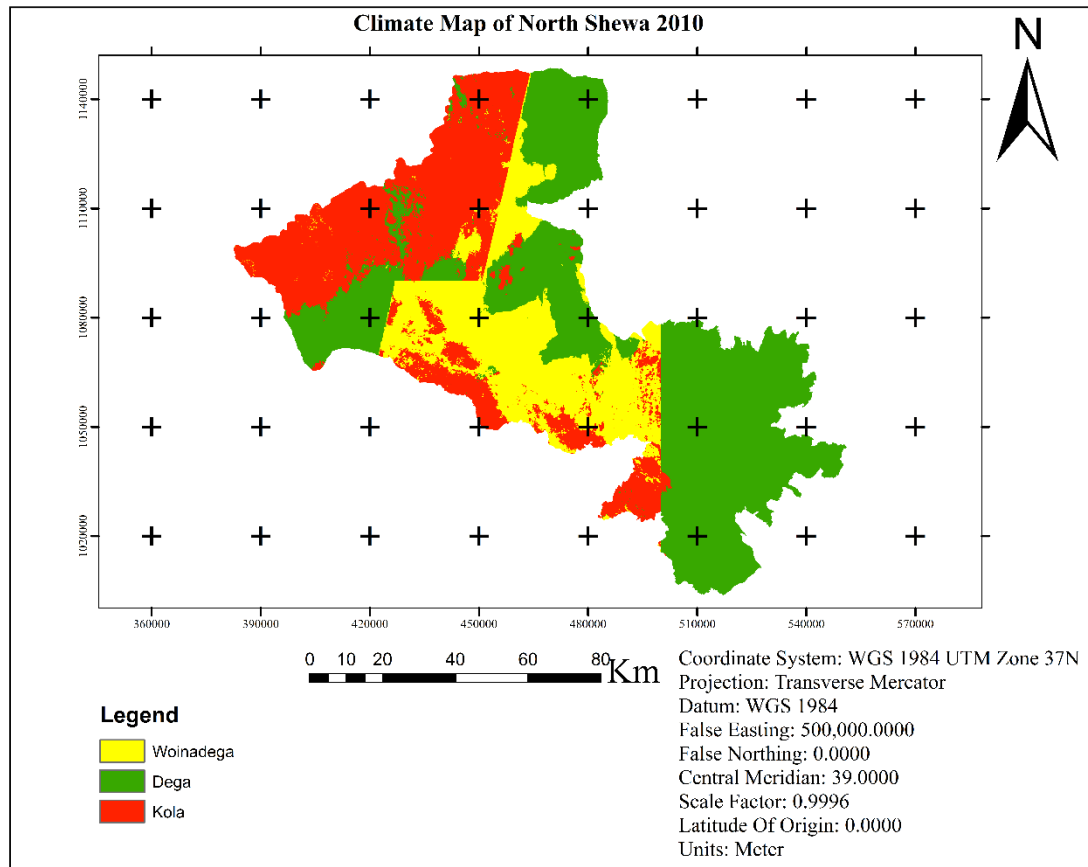


Figure 24: The climatic classification by using RSCCI for year 2010

As the figure (25) shows, dega was occupy over 49.93% of the total area of the zone. The second highest proportion of the area falls within temperate (woinadega) agro-ecology. Kolla occupies small portion of the study area with 19.53%.

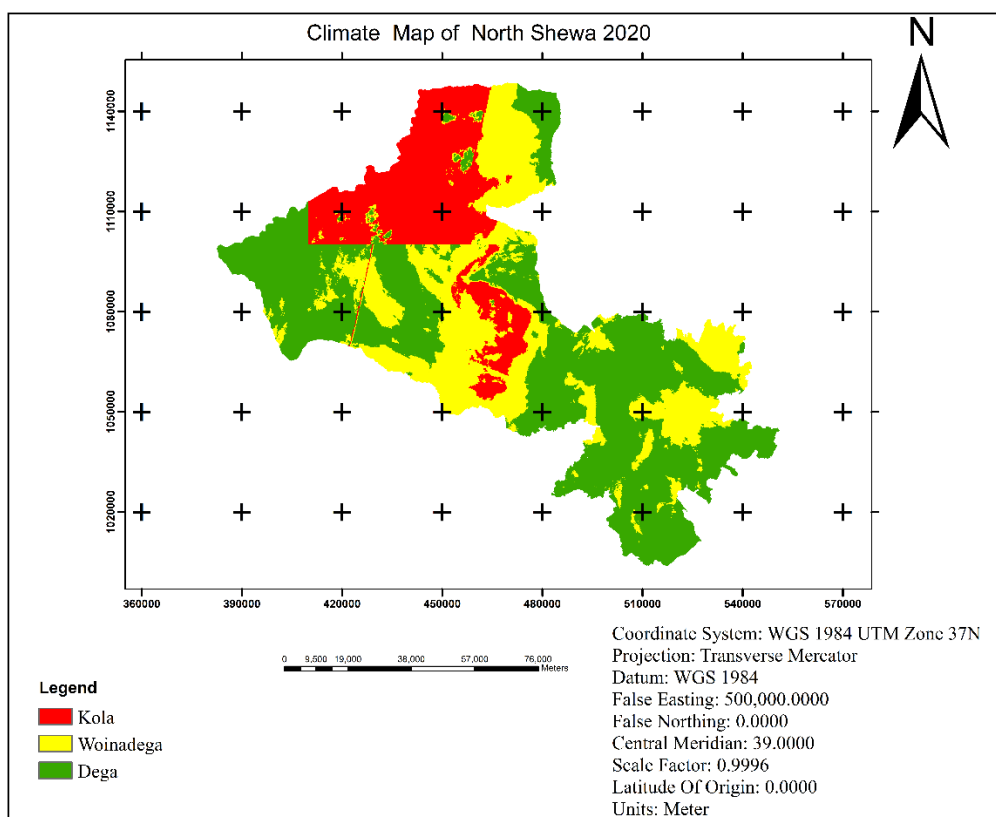


Figure 25: The climatic classification using RSCCI for year 2020

Table 13: Area of agro-ecological climatic classification calculated from RSCCI

Classes	1990		2000		2010		2020	
	Area (hectare)	%	Area (hectare)	%	Area (hectare)	%	Area (hectare)	%
Dega	468379.6	50.33	335034.4	36.00	373688	40.15	464659.6	49.93
Woina- dega	283120.8	30.42	373688	40.15	355003.8	38.14	284270.7	30.54
Kola	179190.21	19.25	221968.2	23.85	201998.8	21.70	181760.3	19.53

Figures 22,23,24 and 25 and table 13 shows the climatic classification of North Shewa zone by using remotely sensed images collaborated with compound indices mentioned in equation (24). In this index, the study area was divided into three agro-ecological climatic zone, shown in figs. 22,23,24 and 25, through different colors such as yellow, green and red which predict the climate regions of North Shewa zone from 1990 to 2020. The regions which are shown

with green color, yellow and red in the legend of figures were classified as Dega(highland), woinadega and kola regions respectively.

The highest proportion of the area falls within highland (Dega) agro-ecology 49.93% of the total area. The second highest proportion of the area falls within midland (Woinadega) agro-ecology 30.54% of the total area of the zone. Kola occupies small portion (19.53%) of the study area.

4.4. Discussion

The aim of study was attempted to analyze the spatio-temporal climate variability of study area (1990-2020) using satellite image, temperature and rainfall. The time series analysis of total annual rainfall was done to reveal the general trends of rainfall amounts over the study area. The overall average rainfall in the last 30 years' time was 1036.50 mm with a standard deviation of + 27.27 mm and coefficient of variation of 2.63 %. The statistical result revealed that in the area extremely dry was observed in 2002, 2003 and 2004. The study area received its maximum rainfall during kiremt season that extends from June to September. The results obtained PCI, shows high uniform (64.52%) rainfall distribution during kiremt season than other seasons and annual. Supporting this finding research conducted by Ashenafi et al (2013) shows 81.6% and 14.2% of the total rainfall was gained in kiremt and belg season respectively in the study area.

The mean maximum temperature in the first two decades was increased by 0.15 °C while in the last (2010-2020) it was increased by 0.69 °C. There has been a warming trend in the mean annual maximum temperature over the past 30 years and it has increased by 0.84 °C. Results obtained by Esubalew (2014); the mean annual maximum temperature showed 0.5°C increase per decade (1981- 2010).

There was linear correlation between mean annual rainfall and calculated NDVI value, and negative correlation with temperature. Similarly, Esubalew (2014), report shows linear correlation between mean annual rainfall and calculated NDVI value ($r^2 = 0.35$).

The highest proportion of the area falls within highland (Dega) of the total area. In agreement with the present study, earlier studies have shown, Ashenafi et al (2013) report designate that the Dega occupies over 50% of the total area of the zone.

5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

It was concluded from the results of this research that distinguished climatic change has been observed within the boundaries of north Shewa zone in a time span of thirty years from 1990 to 2020. The result shows there was a considerable spatial variation of rainfall and temperature in the study area. The findings of the study revealed that there is a fluctuation of rainfall and temperature in the study area.

The mean annual total rainfall of the study area varied from 561.15 mm to 1842.5 mm between 1990 and 2020. The overall average rainfall in the last 30 years' time is 1036.50 mm with a standard deviation of + 27.27 mm and coefficient of variation of 2.63 %. The time series analysis result, which was made at decadal level, designates that there is a positive anomaly in the trend of rainfall. With regard to the mean decadal maximum rainfall distribution in the past three decades was lacks a consistent trend. This study has shown that there are significant inter-annual variations of rainfall. Moreover, differences in rainfall amount and trend have been observed.

The magnitude of mean annual maximum temperature increased by 0.15°C ,0.69°C and 0.84°C from 1990 to 2000, 2000 to 2010, and 2010 to 2020 respectively. In thirty years, observation there was 0.028°C increment in mean annual maximum temperature in the study area from 1990 to 2020. Furthermore, variation in inter-annual minimum and maximum temperature patterns have been also noted in the study area.

This study also aimed at investigating the statistical relationship between climate parameters, normalized difference vegetation indices and surface temperature. The analysis was based on time series of vegetation indices and climate elements of thirteen years (1990 to 2020). From the result, it was possible to deduced that there was linear correlation between mean annual rainfall and calculated NDVI value. The r^2 value was 0.8749 r^2 adjusted is 0.871, and the P value is significant at 0.002 since the threshold for statistical significance level is 0.05. The high value of r^2 shows that the time-series NDVI datasets derived from satellite image was a way forward in the direction of advancement in data availability.

The correlation of mean annual temperature and mean annual NDVI value of the year 1990 to 2020, explained that mean annual temperature is negatively correlated (-0.88 of correlation coefficient) with NDVI values of the area, which is 0.766 value of r^2 . Increase in

temperature was not coincides with an increase in NDVI. This implied that temperature is also a very important climatic element for vegetation growth depending on the type of vegetation and climatic zone.

From the Remote Sensing Climatic Compound Index model there was 14.33% and 4.15% reduction and increased in area of dega region from 1990 to 2000, and from 2000 to 2010 respectively. There was 9.78% increment in area of dega region from 2010 to 2020. In thirty years observation there was 0.013% decrement in area of dega region from 1990 to 2020 and increment of Woinadega and kola by 0.004% and 0.01% respectively.

Based on the finding of this study, possible to predict that the study area climate would projected to dega (49.53%), woinadega (30.66%) and kola (19.81%) agro-ecology for the next thirty years (2050).

5.2. Recommendations

On the basis of the findings in this study, the researcher makes the following recommendations.

-  Strengthen of further research on the impact of climate change and variability on different socio-economic activities of the societies is very essential.
-  Creation of awareness and public participation on:
 - adverse effects climate elements,
 - climate change policies,
 - environmental and drought monitoring systems and improve the disaster related risk reduction capacity (adaptation and mitigation Mechanisms).

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APPENDIX

Appendix 1: Average Rainfall(mm) of study area

Year	Lat	Lon	El	RF(mm)	Lat	Lon	El	RF(mm)
1990	9.67	38.67	2833	1076.74	10.17	38.67	2480	948.36
1991	9.67	38.67	2833	1064.15	10.17	38.67	2480	929.97
1992	9.67	38.67	2833	1022.09	10.17	38.67	2480	893.29
1993	9.67	38.67	2833	1271.42	10.17	38.67	2480	1149.23
1994	9.67	38.67	2833	1073.73	10.17	38.67	2480	1042
1995	9.67	38.67	2833	1050.77	10.17	38.67	2480	1009.31
1996	9.67	38.67	2833	1405.63	10.17	38.67	2480	1220.02
1997	9.67	38.67	2833	977.88	10.17	38.67	2480	847.56
1998	9.67	38.67	2833	1274.55	10.17	38.67	2480	1156.1
1999	9.67	38.67	2833	1126.98	10.17	38.67	2480	1144.61
2000	9.67	38.67	2833	720.27	10.17	38.67	2480	658.8
2001	9.67	38.67	2833	723.98	10.17	38.67	2480	640.76
2002	9.67	38.67	2833	581.57	10.17	38.67	2480	590.45
2003	9.67	38.67	2833	610.4	10.17	38.67	2480	542.6
2004	9.67	38.67	2833	561.15	10.17	38.67	2480	482.6
2005	9.67	38.67	2833	738.33	10.17	38.67	2480	641.44
2006	9.67	38.67	2833	1207.88	10.17	38.67	2480	1170.47
2007	9.67	38.67	2833	1063.91	10.17	38.67	2480	982.65
2008	9.67	38.67	2833	1007.8	10.17	38.67	2480	911.04
2009	9.67	38.67	2833	895.91	10.17	38.67	2480	927.46
2010	9.67	38.67	2833	1333.83	10.17	38.67	2480	1325.81
2011	9.67	38.67	2833	722.33	10.17	38.67	2480	670.09
2012	9.67	38.67	2833	1094.57	10.17	38.67	2480	958.79
2013	9.67	38.67	2833	1345.26	10.17	38.67	2480	1292.95
2014	9.67	38.67	2833	1092.9	10.17	38.67	2480	1116.48
2015	9.67	38.67	2833	818.97	10.17	38.67	2480	754.18
2016	9.67	38.67	2833	1140.24	10.17	38.67	2480	1153.17
2017	9.67	38.67	2833	1149.17	10.17	38.67	2480	1079.66
2018	9.67	38.67	2833	1215.96	10.17	38.67	2480	1187.64
2019	9.67	38.67	2833	1210.16	10.17	38.67	2480	1117.77
2020	9.67	38.67	2833	1842.5	10.17	38.67	2480	1192.77

Year	Lat	Lon	El	RF (mm)	Lat	Lon	El	RF(mm)
1990	9.5	39.25	2800	1102.71	9.19	39.15	2550	1122.56
1991	9.5	39.25	2800	1061.38	9.19	39.15	2550	1017.45
1992	9.5	39.25	2800	992.11	9.19	39.15	2550	994.66
1993	9.5	39.25	2800	1285.26	9.19	39.15	2550	1277.79
1994	9.5	39.25	2800	1016.26	9.19	39.15	2550	951.82
1995	9.5	39.25	2800	1043.98	9.19	39.15	2550	986.91
1996	9.5	39.25	2800	1427.8	9.19	39.15	2550	1431.99
1997	9.5	39.25	2800	1047.9	9.19	39.15	2550	1200.62
1998	9.5	39.25	2800	1194.67	9.19	39.15	2550	1168.59
1999	9.5	39.25	2800	963.33	9.19	39.15	2550	864.58
2000	9.5	39.25	2800	554.36	9.19	39.15	2550	541.18
2001	9.5	39.25	2800	631.32	9.19	39.15	2550	655.51
2002	9.5	39.25	2800	578.11	9.19	39.15	2550	536.75
2003	9.5	39.25	2800	530.46	9.19	39.15	2550	538.06
2004	9.5	39.25	2800	525.93	9.19	39.15	2550	527.87
2005	9.5	39.25	2800	660.8	9.19	39.15	2550	723.82
2006	9.5	39.25	2800	1055.2	9.19	39.15	2550	1068.17
2007	9.5	39.25	2800	921.16	9.19	39.15	2550	971.98
2008	9.5	39.25	2800	768.26	9.19	39.15	2550	798.81
2009	9.5	39.25	2800	749.11	9.19	39.15	2550	739.46
2010	9.5	39.25	2800	1181.15	9.19	39.15	2550	1144.65
2011	9.5	39.25	2800	551.31	9.19	39.15	2550	551.64
2012	9.5	39.25	2800	802.62	9.19	39.15	2550	778.29
2013	9.5	39.25	2800	1140.2	9.19	39.15	2550	1078.08
2014	9.5	39.25	2800	957.43	9.19	39.15	2550	940.51
2015	9.5	39.25	2800	757.42	9.19	39.15	2550	650.76
2016	9.5	39.25	2800	1258.67	9.19	39.15	2550	1047.85
2017	9.5	39.25	2800	1079.83	9.19	39.15	2550	990.98
2018	9.5	39.25	2800	1135.97	9.19	39.15	2550	1108.24
2019	9.5	39.25	2800	1292.44	9.19	39.15	2550	1234.43
2020	9.5	39.25	2800	1471.14	9.19	39.15	2550	1408.51

Year	Lat	Lon	El	RF(mm)	Lat	Lon	El	RF(mm))
1990	9.8	38.73	2781	1076.74	10.19	38.7	1860	808.31
1991	9.8	38.73	2781	1064.15	10.19	38.7	1860	810.29
1992	9.8	38.73	2781	1022.09	10.19	38.7	1860	742.5
1993	9.8	38.73	2781	1271.42	10.19	38.7	1860	851.79
1994	9.8	38.73	2781	1073.73	10.19	38.7	1860	946.36
1995	9.8	38.73	2781	1050.77	10.19	38.7	1860	879.4
1996	9.8	38.73	2781	1405.63	10.19	38.7	1860	1105.59
1997	9.8	38.73	2781	977.88	10.19	38.7	1860	1052.49
1998	9.8	38.73	2781	1274.55	10.19	38.7	1860	1026.02
1999	9.8	38.73	2781	1126.98	10.19	38.7	1860	889.35
2000	9.8	38.73	2781	720.27	10.19	38.7	1860	416.45
2001	9.8	38.73	2781	723.98	10.19	38.7	1860	486.23
2002	9.8	38.73	2781	581.57	10.19	38.7	1860	461.82
2003	9.8	38.73	2781	610.4	10.19	38.7	1860	595.25
2004	9.8	38.73	2781	561.15	10.19	38.7	1860	493.41
2005	9.8	38.73	2781	738.33	10.19	38.7	1860	636.24
2006	9.8	38.73	2781	1207.88	10.19	38.7	1860	783.27
2007	9.8	38.73	2781	1063.91	10.19	38.7	1860	719.55
2008	9.8	38.73	2781	1007.8	10.19	38.7	1860	748.7
2009	9.8	38.73	2781	895.91	10.19	38.7	1860	663.09
2010	9.8	38.73	2781	1333.83	10.19	38.7	1860	1076.21
2011	9.8	38.73	2781	722.33	10.19	38.7	1860	506.05
2012	9.8	38.73	2781	1094.57	10.19	38.7	1860	809.8
2013	9.8	38.73	2781	1345.26	10.19	38.7	1860	1092.01
2014	9.8	38.73	2781	1092.9	10.19	38.7	1860	833.7
2015	9.8	38.73	2781	818.97	10.19	38.7	1860	802.83
2016	9.8	38.73	2781	1140.24	10.19	38.7	1860	919.18
2017	9.8	38.73	2781	1149.17	10.19	38.7	1860	844.87
2018	9.8	38.73	2781	1215.96	10.19	38.7	1860	819.87
2019	9.8	38.73	2781	1210.16	10.19	38.7	1860	834.09
2020	9.8	38.73	2781	1842.5	10.19	38.7	1860	744.39

Year	Lat	Lon	El	RF(mm)	Lat	Lon	El	RF(mm)
1990	9.63	38.63	2566	808.31	9.67	38.67	2561	1076.74
1991	9.63	38.63	2566	810.29	9.67	38.67	2561	1064.15
1992	9.63	38.63	2566	742.5	9.67	38.67	2561	1022.09
1993	9.63	38.63	2566	851.79	9.67	38.67	2561	1271.42
1994	9.63	38.63	2566	946.36	9.67	38.67	2561	1073.73
1995	9.63	38.63	2566	879.4	9.67	38.67	2561	1050.77
1996	9.63	38.63	2566	1105.59	9.67	38.67	2561	1405.63
1997	9.63	38.63	2566	1052.49	9.67	38.67	2561	977.88
1998	9.63	38.63	2566	1026.02	9.67	38.67	2561	1274.55
1999	9.63	38.63	2566	889.35	9.67	38.67	2561	1126.98
2000	9.63	38.63	2566	416.45	9.67	38.67	2561	720.27
2001	9.63	38.63	2566	486.23	9.67	38.67	2561	723.98
2002	9.63	38.63	2566	461.82	9.67	38.67	2561	581.57
2003	9.63	38.63	2566	595.25	9.67	38.67	2561	610.4
2004	9.63	38.63	2566	493.41	9.67	38.67	2561	561.15
2005	9.63	38.63	2566	636.24	9.67	38.67	2561	738.33
2006	9.63	38.63	2566	783.27	9.67	38.67	2561	1207.88
2007	9.63	38.63	2566	719.55	9.67	38.67	2561	1063.91
2008	9.63	38.63	2566	748.7	9.67	38.67	2561	1007.8
2009	9.63	38.63	2566	663.09	9.67	38.67	2561	895.91
2010	9.63	38.63	2566	1076.21	9.67	38.67	2561	1333.83
2011	9.63	38.63	2566	506.05	9.67	38.67	2561	722.33
2012	9.63	38.63	2566	809.8	9.67	38.67	2561	1094.57
2013	9.63	38.63	2566	1092.01	9.67	38.67	2561	1345.26
2014	9.63	38.63	2566	833.7	9.67	38.67	2561	1092.9
2015	9.63	38.63	2566	802.83	9.67	38.67	2561	818.97
2016	9.63	38.63	2566	919.18	9.67	38.67	2561	1140.24
2017	9.63	38.63	2566	844.87	9.67	38.67	2561	1149.17
2018	9.63	38.63	2566	1215.96	9.67	38.67	2561	1215.96
2019	9.63	38.63	2566	1210.16	9.67	38.67	2561	1210.16
2020	9.63	38.63	2566	744.39	9.67	38.67	2561	1310.87

Year	Lat	Lon	El	RF(mm)	Lat	Lon	El	RF(mm)
1990	10.12	38.25	2560	1090.1	9.83	38.5	2510	1076.74
1991	10.12	38.25	2560	1059.69	9.83	38.5	2510	1064.15
1992	10.12	38.25	2560	1052.56	9.83	38.5	2510	1022.09
1993	10.12	38.25	2560	1266.35	9.83	38.5	2510	1271.42
1994	10.12	38.25	2560	1106.13	9.83	38.5	2510	1073.73
1995	10.12	38.25	2560	1075.32	9.83	38.5	2510	1050.77
1996	10.12	38.25	2560	1409.75	9.83	38.5	2510	1405.63
1997	10.12	38.25	2560	976.67	9.83	38.5	2510	977.88
1998	10.12	38.25	2560	1280.13	9.83	38.5	2510	1274.55
1999	10.12	38.25	2560	1159.05	9.83	38.5	2510	1126.98
2000	10.12	38.25	2560	739.26	9.83	38.5	2510	720.27
2001	10.12	38.25	2560	709.38	9.83	38.5	2510	723.98
2002	10.12	38.25	2560	563.48	9.83	38.5	2510	581.57
2003	10.12	38.25	2560	623.25	9.83	38.5	2510	610.4
2004	10.12	38.25	2560	591.03	9.83	38.5	2510	561.15
2005	10.12	38.25	2560	765.21	9.83	38.5	2510	738.33
2006	10.12	38.25	2560	1222.81	9.83	38.5	2510	1207.88
2007	10.12	38.25	2560	1104	9.83	38.5	2510	1063.91
2008	10.12	38.25	2560	1082.2	9.83	38.5	2510	1007.8
2009	10.12	38.25	2560	950.79	9.83	38.5	2510	895.91
2010	10.12	38.25	2560	1400.16	9.83	38.5	2510	1333.83
2011	10.12	38.25	2560	771.41	9.83	38.5	2510	722.33
2012	10.12	38.25	2560	1159.54	9.83	38.5	2510	1094.57
2013	10.12	38.25	2560	1381.37	9.83	38.5	2510	1345.26
2014	10.12	38.25	2560	1154.07	9.83	38.5	2510	1092.9
2015	10.12	38.25	2560	848.21	9.83	38.5	2510	818.97
2016	10.12	38.25	2560	1126.93	9.83	38.5	2510	1140.24
2017	10.12	38.25	2560	1204.62	9.83	38.5	2510	1149.17
2018	10.12	38.25	2560	1449.76	9.83	38.5	2510	1215.96
2019	10.12	38.25	2560	1308.3	9.83	38.5	2510	1210.16
2020	10.12	38.25	2560	1324.63	9.83	38.5	2510	1310.87

Year	Lat	Lon	El	RF(mm)	Lat	Lon	El	RF(mm)
1990	9.34	38.75	2619	744.46	9.25	39.25	2655	1122.56
1991	9.34	38.75	2619	874.13	9.25	39.25	2655	1017.45
1992	9.34	38.75	2619	791.56	9.25	39.25	2655	994.66
1993	9.34	38.75	2619	934.43	9.25	39.25	2655	1277.79
1994	9.34	38.75	2619	1020.88	9.25	39.25	2655	951.82
1995	9.34	38.75	2619	1007.3	9.25	39.25	2655	986.91
1996	9.34	38.75	2619	1147.11	9.25	39.25	2655	1431.99
1997	9.34	38.75	2619	1160.02	9.25	39.25	2655	1200.62
1998	9.34	38.75	2619	908.98	9.25	39.25	2655	1168.59
1999	9.34	38.75	2619	983.67	9.25	39.25	2655	864.58
2000	9.34	38.75	2619	436.95	9.25	39.25	2655	541.18
2001	9.34	38.75	2619	524.18	9.25	39.25	2655	655.51
2002	9.34	38.75	2619	483.54	9.25	39.25	2655	536.75
2003	9.34	38.75	2619	792.8	9.25	39.25	2655	538.06
2004	9.34	38.75	2619	665.88	9.25	39.25	2655	527.87
2005	9.34	38.75	2619	791.16	9.25	39.25	2655	723.82
2006	9.34	38.75	2619	950.31	9.25	39.25	2655	1068.17
2007	9.34	38.75	2619	979.99	9.25	39.25	2655	971.98
2008	9.34	38.75	2619	935.91	9.25	39.25	2655	798.81
2009	9.34	38.75	2619	740.48	9.25	39.25	2655	739.46
2010	9.34	38.75	2619	1216.48	9.25	39.25	2655	1144.65
2011	9.34	38.75	2619	585.32	9.25	39.25	2655	551.64
2012	9.34	38.75	2619	777.04	9.25	39.25	2655	778.29
2013	9.34	38.75	2619	1252.75	9.25	39.25	2655	1078.08
2014	9.34	38.75	2619	1000.3	9.25	39.25	2655	940.51
2015	9.34	38.75	2619	739.22	9.25	39.25	2655	650.76
2016	9.34	38.75	2619	979.9	9.25	39.25	2655	1047.85
2017	9.34	38.75	2619	828.92	9.25	39.25	2655	990.98
2018	9.34	38.75	2619	875.76	9.25	39.25	2655	1108.24
2019	9.34	38.75	2619	906.8	9.25	39.25	2655	1234.43
2020	9.34	38.75	2619	916.12	9.25	39.25	2655	1408.51

Year	Lat	Lon	El	RF(mm)	Lat	Lon	El	RF(mm)
1990	9.8	38.4	2560	1090.1	9.9	38.35	2568	1090.1
1991	9.8	38.4	2560	1059.69	9.9	38.35	2568	1059.69
1992	9.8	38.4	2560	1052.56	9.9	38.35	2568	1052.56
1993	9.8	38.4	2560	1266.35	9.9	38.35	2568	1266.35
1994	9.8	38.4	2560	1106.13	9.9	38.35	2568	1106.13
1995	9.8	38.4	2560	1075.32	9.9	38.35	2568	1075.32
1996	9.8	38.4	2560	1409.75	9.9	38.35	2568	1409.75
1997	9.8	38.4	2560	976.67	9.9	38.35	2568	976.67
1998	9.8	38.4	2560	1280.13	9.9	38.35	2568	1280.13
1999	9.8	38.4	2560	1159.05	9.9	38.35	2568	1159.05
2000	9.8	38.4	2560	739.26	9.9	38.35	2568	739.26
2001	9.8	38.4	2560	709.38	9.9	38.35	2568	709.38
2002	9.8	38.4	2560	563.48	9.9	38.35	2568	563.48
2003	9.8	38.4	2560	623.25	9.9	38.35	2568	623.25
2004	9.8	38.4	2560	591.03	9.9	38.35	2568	591.03
2005	9.8	38.4	2560	765.21	9.9	38.35	2568	765.21
2006	9.8	38.4	2560	1222.81	9.9	38.35	2568	1222.81
2007	9.8	38.4	2560	1104	9.9	38.35	2568	1104
2008	9.8	38.4	2560	1082.2	9.9	38.35	2568	1082.2
2009	9.8	38.4	2560	950.79	9.9	38.35	2568	950.79
2010	9.8	38.4	2560	1400.16	9.9	38.35	2568	1400.16
2011	9.8	38.4	2560	771.41	9.9	38.35	2568	771.41
2012	9.8	38.4	2560	1159.54	9.9	38.35	2568	1159.54
2013	9.8	38.4	2560	1381.37	9.9	38.35	2568	1381.37
2014	9.8	38.4	2560	1154.07	9.9	38.35	2568	1154.07
2015	9.8	38.4	2560	848.21	9.9	38.35	2568	848.21
2016	9.8	38.4	2560	1126.93	9.9	38.35	2568	1126.93
2017	9.8	38.4	2560	1204.62	9.9	38.35	2568	1204.62
2018	9.8	38.4	2560	1247.78	9.9	38.35	2568	1247.78
2019	9.8	38.4	2560	1215.87	9.9	38.35	2568	1215.87
2020	9.8	38.4	2560	1324.63	9.9	38.35	2568	1324.63

Year	Lat	Lon	El	RF(mm)	Lat	Lon	El	RF(mm)
1990	9.55	38.88	2654	1217.6	9.5	38.67	2700	1217.6
1991	9.55	38.88	2654	1115.58	9.5	38.67	2700	1115.58
1992	9.55	38.88	2654	1088.02	9.5	38.67	2700	1088.02
1993	9.55	38.88	2654	1361.41	9.5	38.67	2700	1361.41
1994	9.55	38.88	2654	1073.8	9.5	38.67	2700	1073.8
1995	9.55	38.88	2654	1071.82	9.5	38.67	2700	1071.82
1996	9.55	38.88	2654	1527.5	9.5	38.67	2700	1527.5
1997	9.55	38.88	2654	1130.52	9.5	38.67	2700	1130.52
1998	9.55	38.88	2654	1374.44	9.5	38.67	2700	1374.44
1999	9.55	38.88	2654	1087.63	9.5	38.67	2700	1087.63
2000	9.55	38.88	2654	751.76	9.5	38.67	2700	751.76
2001	9.55	38.88	2654	768.71	9.5	38.67	2700	768.71
2002	9.55	38.88	2654	580.21	9.5	38.67	2700	580.21
2003	9.55	38.88	2654	659.75	9.5	38.67	2700	659.75
2004	9.55	38.88	2654	631.44	9.5	38.67	2700	631.44
2005	9.55	38.88	2654	836.47	9.5	38.67	2700	836.47
2006	9.55	38.88	2654	1246.01	9.5	38.67	2700	1246.01
2007	9.55	38.88	2654	1134.41	9.5	38.67	2700	1134.41
2008	9.55	38.88	2654	1050.58	9.5	38.67	2700	1050.58
2009	9.55	38.88	2654	879.49	9.5	38.67	2700	879.49
2010	9.55	38.88	2654	1322.59	9.5	38.67	2700	1322.59
2011	9.55	38.88	2654	744.64	9.5	38.67	2700	744.64
2012	9.55	38.88	2654	1123.12	9.5	38.67	2700	1123.12
2013	9.55	38.88	2654	1376.34	9.5	38.67	2700	1376.34
2014	9.55	38.88	2654	1101.46	9.5	38.67	2700	1101.46
2015	9.55	38.88	2654	943.68	9.5	38.67	2700	943.68
2016	9.55	38.88	2654	1230.1	9.5	38.67	2700	1230.1
2017	9.55	38.88	2654	1297.24	9.5	38.67	2700	1297.24
2018	9.55	38.88	2654	1241.21	9.5	38.67	2700	1215.96
2019	9.55	38.88	2654	1293.8	9.5	38.67	2700	1210.16
2020	9.55	38.88	2654	1356.87	9.5	38.67	2700	1356.87

Appendix 2: Average Temperature(°c) of study area

Year	Lat	Lon	El	Temp(°c)	Lat	Lon	El	Temp(°c)
1990	9.5	39.25	2800	21.1	9.19	39.15	2550	22.23
1991	9.5	39.25	2800	21.29	9.19	39.15	2550	22.55
1992	9.5	39.25	2800	21.07	9.19	39.15	2550	22.21
1993	9.5	39.25	2800	20.59	9.19	39.15	2550	21.71
1994	9.5	39.25	2800	21.39	9.19	39.15	2550	22.63
1995	9.5	39.25	2800	21.69	9.19	39.15	2550	22.88
1996	9.5	39.25	2800	20.37	9.19	39.15	2550	21.48
1997	9.5	39.25	2800	21.57	9.19	39.15	2550	22.28
1998	9.5	39.25	2800	21.18	9.19	39.15	2550	22.31
1999	9.5	39.25	2800	21.39	9.19	39.15	2550	22.71
2000	9.5	39.25	2800	22.38	9.19	39.15	2550	23.75
2001	9.5	39.25	2800	22.31	9.19	39.15	2550	23.6
2002	9.5	39.25	2800	23.07	9.19	39.15	2550	24.47
2003	9.5	39.25	2800	22.78	9.19	39.15	2550	24.13
2004	9.5	39.25	2800	22.8	9.19	39.15	2550	24.05
2005	9.5	39.25	2800	22.49	9.19	39.15	2550	23.62
2006	9.5	39.25	2800	21.61	9.19	39.15	2550	22.8
2007	9.5	39.25	2800	21.54	9.19	39.15	2550	22.68
2008	9.5	39.25	2800	22.07	9.19	39.15	2550	23.24
2009	9.5	39.25	2800	22.3	9.19	39.15	2550	23.54
2010	9.5	39.25	2800	21.05	9.19	39.15	2550	22.2
2011	9.5	39.25	2800	22.39	9.19	39.15	2550	23.7
2012	9.5	39.25	2800	22.32	9.19	39.15	2550	23.65
2013	9.5	39.25	2800	21.52	9.19	39.15	2550	22.66
2014	9.5	39.25	2800	21.49	9.19	39.15	2550	22.65
2015	9.5	39.25	2800	22.69	9.19	39.15	2550	24.06
2016	9.5	39.25	2800	21.34	9.19	39.15	2550	22.73
2017	9.5	39.25	2800	21.68	9.19	39.15	2550	23
2018	9.5	39.25	2800	21.63	9.19	39.15	2550	22.87
2019	9.5	39.25	2800	21.59	9.19	39.15	2550	22.81
2020	9.5	39.25	2800	20.7	9.19	39.15	2550	21.81

Year	Lat	Lon	El	Temp(⁰ c)	Lat	Lon	El	Temp(⁰ c)
1990	9.67	38.67	2833	23.73	10.17	38.67	2480	25.6
1991	9.67	38.67	2833	24	10.17	38.67	2480	25.81
1992	9.67	38.67	2833	23.75	10.17	38.67	2480	25.55
1993	9.67	38.67	2833	23.26	10.17	38.67	2480	24.98
1994	9.67	38.67	2833	24.05	10.17	38.67	2480	25.55
1995	9.67	38.67	2833	24.46	10.17	38.67	2480	26.06
1996	9.67	38.67	2833	23.12	10.17	38.67	2480	24.83
1997	9.67	38.67	2833	24.42	10.17	38.67	2480	26.31
1998	9.67	38.67	2833	23.72	10.17	38.67	2480	25.47
1999	9.67	38.67	2833	23.73	10.17	38.67	2480	25.31
2000	9.67	38.67	2833	24.62	10.17	38.67	2480	26.21
2001	9.67	38.67	2833	24.72	10.17	38.67	2480	26.35
2002	9.67	38.67	2833	25.85	10.17	38.67	2480	27.28
2003	9.67	38.67	2833	25.45	10.17	38.67	2480	27.06
2004	9.67	38.67	2833	25.41	10.17	38.67	2480	27.1
2005	9.67	38.67	2833	25.04	10.17	38.67	2480	26.75
2006	9.67	38.67	2833	23.97	10.17	38.67	2480	25.66
2007	9.67	38.67	2833	24.01	10.17	38.67	2480	25.78
2008	9.67	38.67	2833	24.35	10.17	38.67	2480	25.99
2009	9.67	38.67	2833	24.74	10.17	38.67	2480	26.36
2010	9.67	38.67	2833	23.29	10.17	38.67	2480	25.13
2011	9.67	38.67	2833	24.62	10.17	38.67	2480	26.25
2012	9.67	38.67	2833	24.67	10.17	38.67	2480	26.3
2013	9.67	38.67	2833	23.72	10.17	38.67	2480	25.51
2014	9.67	38.67	2833	23.88	10.17	38.67	2480	25.58
2015	9.67	38.67	2833	25.27	10.17	38.67	2480	27.01
2016	9.67	38.67	2833	23.94	10.17	38.67	2480	25.67
2017	9.67	38.67	2833	24.2	10.17	38.67	2480	25.98
2018	9.67	38.67	2833	24.15	10.17	38.67	2480	25.86
2019	9.67	38.67	2833	24.22	10.17	38.67	2480	25.98
2020	9.67	38.67	2833	23.52	10.17	38.67	2480	25.31

Year	Lat	Lon	El	Temp(⁰ c)	Lat	Lon	El	Temp(⁰ c)
1990	9.8	38.73	2781	23.73	10.19	38.7	1860	29.13
1991	9.8	38.73	2781	24	10.19	38.7	1860	29.02
1992	9.8	38.73	2781	23.75	10.19	38.7	1860	28.99
1993	9.8	38.73	2781	23.26	10.19	38.7	1860	28.59
1994	9.8	38.73	2781	24.05	10.19	38.7	1860	28.74
1995	9.8	38.73	2781	24.46	10.19	38.7	1860	28.75
1996	9.8	38.73	2781	23.12	10.19	38.7	1860	27.6
1997	9.8	38.73	2781	24.42	10.19	38.7	1860	28.32
1998	9.8	38.73	2781	23.72	10.19	38.7	1860	28.56
1999	9.8	38.73	2781	23.73	10.19	38.7	1860	28.51
2000	9.8	38.73	2781	24.62	10.19	38.7	1860	30.31
2001	9.8	38.73	2781	24.72	10.19	38.7	1860	30.19
2002	9.8	38.73	2781	25.85	10.19	38.7	1860	30.46
2003	9.8	38.73	2781	25.45	10.19	38.7	1860	30.19
2004	9.8	38.73	2781	25.41	10.19	38.7	1860	30.54
2005	9.8	38.73	2781	25.04	10.19	38.7	1860	29.64
2006	9.8	38.73	2781	23.97	10.19	38.7	1860	29.32
2007	9.8	38.73	2781	24.01	10.19	38.7	1860	29.44
2008	9.8	38.73	2781	24.35	10.19	38.7	1860	29.38
2009	9.8	38.73	2781	24.74	10.19	38.7	1860	29.79
2010	9.8	38.73	2781	23.29	10.19	38.7	1860	28.15
2011	9.8	38.73	2781	24.62	10.19	38.7	1860	30.01
2012	9.8	38.73	2781	24.67	10.19	38.7	1860	29.25
2013	9.8	38.73	2781	23.72	10.19	38.7	1860	27.91
2014	9.8	38.73	2781	23.88	10.19	38.7	1860	28.75
2015	9.8	38.73	2781	25.27	10.19	38.7	1860	29.61
2016	9.8	38.73	2781	23.94	10.19	38.7	1860	28.97
2017	9.8	38.73	2781	24.2	10.19	38.7	1860	29.27
2018	9.8	38.73	2781	24.15	10.19	38.7	1860	28.09
2019	9.8	38.73	2781	24.22	10.19	38.7	1860	29.25
2020	9.8	38.73	2781	23.52	10.19	38.7	1860	28.9

Year	Lat	Lon	El	Temp(0c)	Lat	Lon	El	Temp(0c)
1990	9.63	38.63	2566	23.73	9.67	38.67	2561	23.73
1991	9.63	38.63	2566	24	9.67	38.67	2561	24
1992	9.63	38.63	2566	23.75	9.67	38.67	2561	23.75
1993	9.63	38.63	2566	23.26	9.67	38.67	2561	23.26
1994	9.63	38.63	2566	24.05	9.67	38.67	2561	24.05
1995	9.63	38.63	2566	24.46	9.67	38.67	2561	24.46
1996	9.63	38.63	2566	23.12	9.67	38.67	2561	23.12
1997	9.63	38.63	2566	24.42	9.67	38.67	2561	24.42
1998	9.63	38.63	2566	23.72	9.67	38.67	2561	23.72
1999	9.63	38.63	2566	23.73	9.67	38.67	2561	23.73
2000	9.63	38.63	2566	24.62	9.67	38.67	2561	24.62
2001	9.63	38.63	2566	24.72	9.67	38.67	2561	24.72
2002	9.63	38.63	2566	25.85	9.67	38.67	2561	25.85
2003	9.63	38.63	2566	25.45	9.67	38.67	2561	25.45
2004	9.63	38.63	2566	25.41	9.67	38.67	2561	25.41
2005	9.63	38.63	2566	25.04	9.67	38.67	2561	25.04
2006	9.63	38.63	2566	23.97	9.67	38.67	2561	23.97
2007	9.63	38.63	2566	24.01	9.67	38.67	2561	24.01
2008	9.63	38.63	2566	24.35	9.67	38.67	2561	24.35
2009	9.63	38.63	2566	24.74	9.67	38.67	2561	24.74
2010	9.63	38.63	2566	23.29	9.67	38.67	2561	23.29
2011	9.63	38.63	2566	24.62	9.67	38.67	2561	24.62
2012	9.63	38.63	2566	24.67	9.67	38.67	2561	24.67
2013	9.63	38.63	2566	23.72	9.67	38.67	2561	23.72
2014	9.63	38.63	2566	23.88	9.67	38.67	2561	23.88
2015	9.63	38.63	2566	25.27	9.67	38.67	2561	25.27
2016	9.63	38.63	2566	23.94	9.67	38.67	2561	23.94
2017	9.63	38.63	2566	24.2	9.67	38.67	2561	24.2
2018	9.63	38.63	2566	24.15	9.67	38.67	2561	24.15
2019	9.63	38.63	2566	24.22	9.67	38.67	2561	24.22
2020	9.63	38.63	2566	23.52	9.67	38.67	2561	23.52

Year	Lat	Lon	El	Temp(0c)	Lat	Lon	El	Temp(0c)
1990	10.12	38.25	2560	25.24	9.83	38.5	2510	23.73
1991	10.12	38.25	2560	25.69	9.83	38.5	2510	24
1992	10.12	38.25	2560	25.17	9.83	38.5	2510	23.75
1993	10.12	38.25	2560	24.82	9.83	38.5	2510	23.26
1994	10.12	38.25	2560	25.55	9.83	38.5	2510	24.05
1995	10.12	38.25	2560	25.91	9.83	38.5	2510	24.46
1996	10.12	38.25	2560	24.66	9.83	38.5	2510	23.12
1997	10.12	38.25	2560	26.01	9.83	38.5	2510	24.42
1998	10.12	38.25	2560	25.21	9.83	38.5	2510	23.72
1999	10.12	38.25	2560	25.12	9.83	38.5	2510	23.73
2000	10.12	38.25	2560	26.07	9.83	38.5	2510	24.62
2001	10.12	38.25	2560	26.4	9.83	38.5	2510	24.72
2002	10.12	38.25	2560	27.66	9.83	38.5	2510	25.85
2003	10.12	38.25	2560	27.2	9.83	38.5	2510	25.45
2004	10.12	38.25	2560	27.12	9.83	38.5	2510	25.41
2005	10.12	38.25	2560	26.58	9.83	38.5	2510	25.04
2006	10.12	38.25	2560	25.58	9.83	38.5	2510	23.97
2007	10.12	38.25	2560	25.6	9.83	38.5	2510	24.01
2008	10.12	38.25	2560	25.8	9.83	38.5	2510	24.35
2009	10.12	38.25	2560	26.24	9.83	38.5	2510	24.74
2010	10.12	38.25	2560	24.83	9.83	38.5	2510	23.29
2011	10.12	38.25	2560	26.05	9.83	38.5	2510	24.62
2012	10.12	38.25	2560	26.23	9.83	38.5	2510	24.67
2013	10.12	38.25	2560	25.13	9.83	38.5	2510	23.72
2014	10.12	38.25	2560	25.29	9.83	38.5	2510	23.88
2015	10.12	38.25	2560	26.85	9.83	38.5	2510	25.27
2016	10.12	38.25	2560	25.61	9.83	38.5	2510	23.94
2017	10.12	38.25	2560	25.81	9.83	38.5	2510	24.2
2018	10.12	38.25	2560	25.81	9.83	38.5	2510	24.15
2019	10.12	38.25	2560	25.8	9.83	38.5	2510	24.22
2020	10.12	38.25	2560	25.14	9.83	38.5	2510	23.52

Year	Lat	Lon	El	Temp(0c)	Lat	Lon	El	Temp(0c)
1990	9.34	38.75	2619	29.19	9.25	39.25	2655	22.23
1991	9.34	38.75	2619	28.77	9.25	39.25	2655	22.55
1992	9.34	38.75	2619	28.59	9.25	39.25	2655	22.21
1993	9.34	38.75	2619	28.07	9.25	39.25	2655	21.71
1994	9.34	38.75	2619	28.45	9.25	39.25	2655	22.63
1995	9.34	38.75	2619	28.06	9.25	39.25	2655	22.88
1996	9.34	38.75	2619	27.33	9.25	39.25	2655	21.48
1997	9.34	38.75	2619	27.84	9.25	39.25	2655	22.28
1998	9.34	38.75	2619	28.58	9.25	39.25	2655	22.31
1999	9.34	38.75	2619	28.07	9.25	39.25	2655	22.71
2000	9.34	38.75	2619	30.03	9.25	39.25	2655	23.75
2001	9.34	38.75	2619	29.79	9.25	39.25	2655	23.6
2002	9.34	38.75	2619	30.36	9.25	39.25	2655	24.47
2003	9.34	38.75	2619	29.56	9.25	39.25	2655	24.13
2004	9.34	38.75	2619	29.92	9.25	39.25	2655	24.05
2005	9.34	38.75	2619	28.96	9.25	39.25	2655	23.62
2006	9.34	38.75	2619	28.62	9.25	39.25	2655	22.8
2007	9.34	38.75	2619	28.8	9.25	39.25	2655	22.68
2008	9.34	38.75	2619	28.73	9.25	39.25	2655	23.24
2009	9.34	38.75	2619	29.52	9.25	39.25	2655	23.54
2010	9.34	38.75	2619	27.71	9.25	39.25	2655	22.2
2011	9.34	38.75	2619	29.83	9.25	39.25	2655	23.7
2012	9.34	38.75	2619	29.42	9.25	39.25	2655	23.65
2013	9.34	38.75	2619	27.15	9.25	39.25	2655	22.66
2014	9.34	38.75	2619	28.23	9.25	39.25	2655	22.65
2015	9.34	38.75	2619	29.89	9.25	39.25	2655	24.06
2016	9.34	38.75	2619	28.86	9.25	39.25	2655	22.73
2017	9.34	38.75	2619	29.38	9.25	39.25	2655	23
2018	9.34	38.75	2619	28.31	9.25	39.25	2655	22.87
2019	9.34	38.75	2619	29.02	9.25	39.25	2655	22.81
2020	9.34	38.75	2619	28.4	9.25	39.25	2655	21.81

Year	Lat	Lon	El	Temp(⁰ c)	Lat	Lon	El	Temp(⁰ c)
1990	9.8	38.4	2560	25.24	9.9	38.35	2568	25.24
1991	9.8	38.4	2560	25.69	9.9	38.35	2568	25.69
1992	9.8	38.4	2560	25.17	9.9	38.35	2568	25.17
1993	9.8	38.4	2560	24.82	9.9	38.35	2568	24.82
1994	9.8	38.4	2560	25.55	9.9	38.35	2568	25.55
1995	9.8	38.4	2560	25.91	9.9	38.35	2568	25.91
1996	9.8	38.4	2560	24.66	9.9	38.35	2568	24.66
1997	9.8	38.4	2560	26.01	9.9	38.35	2568	26.01
1998	9.8	38.4	2560	25.21	9.9	38.35	2568	25.21
1999	9.8	38.4	2560	25.12	9.9	38.35	2568	25.12
2000	9.8	38.4	2560	26.07	9.9	38.35	2568	26.07
2001	9.8	38.4	2560	26.4	9.9	38.35	2568	26.4
2002	9.8	38.4	2560	27.66	9.9	38.35	2568	27.66
2003	9.8	38.4	2560	27.2	9.9	38.35	2568	27.2
2004	9.8	38.4	2560	27.12	9.9	38.35	2568	27.12
2005	9.8	38.4	2560	26.58	9.9	38.35	2568	26.58
2006	9.8	38.4	2560	25.58	9.9	38.35	2568	25.58
2007	9.8	38.4	2560	25.6	9.9	38.35	2568	25.6
2008	9.8	38.4	2560	25.8	9.9	38.35	2568	25.8
2009	9.8	38.4	2560	26.24	9.9	38.35	2568	26.24
2010	9.8	38.4	2560	24.83	9.9	38.35	2568	24.83
2011	9.8	38.4	2560	26.05	9.9	38.35	2568	26.05
2012	9.8	38.4	2560	26.23	9.9	38.35	2568	26.23
2013	9.8	38.4	2560	25.13	9.9	38.35	2568	25.13
2014	9.8	38.4	2560	25.29	9.9	38.35	2568	25.29
2015	9.8	38.4	2560	26.85	9.9	38.35	2568	26.85
2016	9.8	38.4	2560	25.61	9.9	38.35	2568	25.61
2017	9.8	38.4	2560	25.81	9.9	38.35	2568	25.81
2018	9.8	38.4	2560	25.81	9.9	38.35	2568	25.81
2019	9.8	38.4	2560	25.8	9.9	38.35	2568	25.8
2020	9.8	38.4	2560	25.14	9.9	38.35	2568	25.14

Year	Lat	Lon	El	Temp(⁰ c)	Lat	Lon	El	Temp(⁰ c)
1990	9.55	38.88	2654	22.14	9.5	38.67	2700	23.73
1991	9.55	38.88	2654	22.6	9.5	38.67	2700	24
1992	9.55	38.88	2654	22.25	9.5	38.67	2700	23.75
1993	9.55	38.88	2654	21.8	9.5	38.67	2700	23.26
1994	9.55	38.88	2654	22.81	9.5	38.67	2700	24.05
1995	9.55	38.88	2654	23.08	9.5	38.67	2700	24.46
1996	9.55	38.88	2654	21.75	9.5	38.67	2700	23.12
1997	9.55	38.88	2654	22.64	9.5	38.67	2700	24.42
1998	9.55	38.88	2654	22.23	9.5	38.67	2700	23.72
1999	9.55	38.88	2654	22.46	9.5	38.67	2700	23.73
2000	9.55	38.88	2654	23.37	9.5	38.67	2700	24.62
2001	9.55	38.88	2654	23.41	9.5	38.67	2700	24.72
2002	9.55	38.88	2654	24.64	9.5	38.67	2700	25.85
2003	9.55	38.88	2654	24.09	9.5	38.67	2700	25.45
2004	9.55	38.88	2654	24	9.5	38.67	2700	25.41
2005	9.55	38.88	2654	23.52	9.5	38.67	2700	25.04
2006	9.55	38.88	2654	22.61	9.5	38.67	2700	23.97
2007	9.55	38.88	2654	22.58	9.5	38.67	2700	24.01
2008	9.55	38.88	2654	23.09	9.5	38.67	2700	24.35
2009	9.55	38.88	2654	23.42	9.5	38.67	2700	24.74
2010	9.55	38.88	2654	21.95	9.5	38.67	2700	23.29
2011	9.55	38.88	2654	23.4	9.5	38.67	2700	24.62
2012	9.55	38.88	2654	23.53	9.5	38.67	2700	24.67
2013	9.55	38.88	2654	22.31	9.5	38.67	2700	23.72
2014	9.55	38.88	2654	22.49	9.5	38.67	2700	23.88
2015	9.55	38.88	2654	23.88	9.5	38.67	2700	25.27
2016	9.55	38.88	2654	22.55	9.5	38.67	2700	23.94
2017	9.55	38.88	2654	22.79	9.5	38.67	2700	24.2
2018	9.55	38.88	2654	22.69	9.5	38.67	2700	24.15
2019	9.55	38.88	2654	22.8	9.5	38.67	2700	24.22
2020	9.55	38.88	2654	22.08	9.5	38.67	2700	23.52