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**Investigating the impact of Climate Variability on Crop: In Case
of Wag Himera, North and South Wello Zones in Amhara region**

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Approval sheet

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DECLARATION

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ABBREVIATION

AEZ	Agro-ecologicalZone
CCC	CanadianClimateCenter
CSA	CentralStatisticalAgency
CSIRO	CommonwealthScientificandIndustrialResearchOrganization
EEP	EasternEquatorialPacific
ENSO	ElNiñosouthernoscillation
FAO	FoodandAgricultureOrganization
GCM	GeneralCirculationmodel
GIS	Geographicinformationsystem
IDW	InverseDistanceWeighting
IPCC	IntergovernmentalPanelonClimateChange
MAE	MeanAbsoluteError
MPI	Max-PlankInstituteforMeteorology
NMA	NationalMeteorologicalAgency
NMSA	NationalMetrologicalServicesAgency
NOAA	NationalOceanicandAtmosphericAdministration
RMSE	Root-Mean-SquareError
SDSS	SpatialDecisionSupportSystem
SPSS	StatisticalPackageforSocialScience
SST	SeaSurfaceTemperature
SSTA	SeaSurfaceTemperatureAnomaly
UKMO	UnitedKingdomMeteorologyOffice
UNDP	UnitedNationsDevelopmentProgram
WMO	WorldMeteorologicalorganization

Abstract

Climate variability like temperature and rainfall is a common characteristic in Ethiopia and it exceedingly affects agriculture particularly in the northern parts of the country where rainfall is relatively scarce. Hence, understanding the spatio-temporal variability of rainfall is indispensable for planning mitigation measures during high and low rainfall times. This study examined the spatio-temporal variability and trends of rainfall in the WagHimera, North and South Wello Zones in Amhara region Ethiopia.

The coefficient of variation (CV) was employed to analyze rainfall variability while Sen's slope estimator were employed to examine the trend and magnitude of the rainfall changes, respectively. The association between rainfall, temperature and crop yield was also evaluated by the Pearson correlation coefficient (r) results. The area-averaged minimum and maximum temperature of the region is 26.2mm and 62.9 mm, and it varies from 10.46 to 39.34 mm and 24.06 to 76.7 mm respectively. The average annual temperature in the region is about 44.5 mm. The region is characterized by a diverse climate, which ranges from dry and hot lowlands to wet and cold highlands. The area-averaged annual minimum and maximum rainfall of the region is 629.33°C and 855.12°C, and it varies from 313.7°C to 660.7°C and 426.7°C to 899.3 °C respectively

Keywords: Climate variability, Crop Yield, IDW, Kriging, Spatiotemporal

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Even though Climate change is global, potential changes are not expected to be globally uniform; instead, there may be dramatic regional differences (Mullugojjam and Ferede, 2012). Climate change is real and happening now. Climate variability has changed and seasonal variability is often observed (Conway et al., 2005). The basic climatic elements such as rainfall and temperature show seasonal and annual variation to some extent different from normally expected climatic conditions.

Africa is one of the world regions where the effects of climate change are being felt particularly hard. Because of the lack of economic development and institutional capacity, African countries are among the most exposed to climate change risk (IPCC, 2001). In addition, in its report, IPCC (2007) declared that the region will be hard-hit by changing climate because of a lack of economic development and institutional capacity to deal with it. As the area strives to achieve sustainable development, national governments are grappling with difficult trade-offs and opportunity costs regarding climate change (Muller et al., 2010). Climate change impacts have the potential to undermine and even undo the progress made in improving the socioeconomic well-being of East Africans (Ayalew et al., 2012).

Climate variability and change likely are significant contributing factors in the food security challenges Ethiopia currently experiences. The Intergovernmental Panel for Climate Change (IPCC, 2001b) has expressed that as a result of climate change, developing countries, including Ethiopia, will experience a range of unfavorable impacts. Diminished resource exacerbates due to desertification and increased transmission of vector disease, and there are also predictions of increased incidence of extreme events and gradual change that would jeopardize national efforts in poverty reduction, economic growth and sustainable development. Climate change could affect the poverty reduction strategies of developing countries. Ethiopia is characterized by widely varied microclimates of all the regions

affected by climate change (NMSA, 1989) and is very sensitive to climatic changes, particularly rainfall variation.

Variability of rainfall and temperature is believed to be due to variations of tropical oceanic and atmosphere interaction, especially El Niño-Southern Oscillation (ENSO) (Haile, 1988). As climate change like ENSO leads to decreased yields, developing countries are further severe food security (Jochin, 2008).

Ethiopia's climate is influenced by general atmospheric and oceanic factors that affect the weather condition and the time of inception and intensity of the rains (Bekele, 1997). It has been affected by recurrent drought for a long time. The summer rainfall contributes about 74% of the annual rainfall in the country. Therefore, the failure of the summer rainfall has disastrous consequences for the country and the rest of East Africa (Robel, 2012). The failure of seasonal rainfall adversely affects the country's socio-economy, particularly food production (Babu, 1999b). Different research works have been carried out to alleviate this problem. The result indicated that the major cause of frequent drought in Ethiopia is climate variations across the country, especially rainfall variation (Babu, 1999b).

Ethiopia is one of the developing nations which experience extremely diversified climatic conditions that range from semiarid and desert to humid and warm types across its different parts (NMSA, 2001). To this end, there are various ways of categorizing the country's climate system into several agro-ecological zones (AEZs). Across its AEZs, there is a great variation in mean annual rainfall and temperature (NMA, 2007). In addition, the country's climate is also characterized by a history of climate extremes, changing trends in temperature and precipitation patterns. The trend is that average annual maximum and minimum temperature extents have also increased in the country (NMA, 2007).

Among the climate parameters that have exhibited a change in short and long-term trends are rainfall and temperatures. Previous assessments (Hulme et al., 2001) concluded that over-dependence on rain-fed agriculture and unpredictable temperatures contribute to food in security. In Sub-Saharan Africa, climate change has drastically reduced agricultural production through extreme weather events, such as recurrent drought and floods (Nhemachena and Hassan, 2007).

Although many studies were made on the issues of climate change and variability in different parts of the country such as study made by Woldamlak and Conway (2007) focusing on temporal and spatial variability of rainfall in the drought-prone Amhara region of Ethiopia and another study carried out by Mikias (2014) emphasizing on the effect of climate change and variability on the livelihoods of local communities the Case of central rift valley region of Ethiopia, the relationship between rainfall, temperature, and crop yield on crop production. Therefore, as an attempt to show the necessity of GIS and statistical tools 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 focused on climate variability impacts on crop yield analysis the Case of the northern part of Amhara region including Wag Himera, North and South Wello, Amhara region, Ethiopia due to the prevalence and largeness of the problem, as the study area is highly affected by prolonged drought because of climate variability.

1.2. Statement of the problem

Climate change is the most severe challenge that humanity may ever face. Hence, it has recently become a pressing issue in various national, regional, and international development, environmental, and political forums (Mikias, 2014). There is substantial concern over the global problem of climate change, and it is described as the most universal and irreversible environmental problem facing the Earth (IPCC, 2001b). It threatens the achievement of Millennium Development Goals aimed at poverty and hunger reduction, health improvement, and environmental sustainability (UNDP, 2010).

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

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

Climate variability is a significant contributing factor to the food security challenges Ethiopia currently experiences. Concerning this, Bishaw et al., (2013) argued that Ethiopia is especially mainly exposed to the risk of climate variability and change because a large population are poor and depend on agricultural income, which is highly sensitive to rainfall variability.

Its diverse agro-ecological zones are characterized by imposing various micro climates and corresponding weather patterns.

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

Many researchers now believe that several draughts in Africa, especially in Southern Africa and the Horn, are caused by the physical processes related to the occurrence of ENSO events thousands of miles away, along with sea surface temperature anomalies (SSTA) in the Southern Atlantic and Indian oceans combined with anthropogenic activities (Wolde-Georgis, 1997).

Invariably, with further significant variations in the rainfall and temperature characteristics of the area, scientific studies must be undertaken to provide society with accurate information on the real and potential impacts of extreme climatic variability, as well as the mitigation and adaptation options available. At this time when the world is grappling with diverse hurricanes, destructive thunderstorms, droughts and major flood episodes, efforts at finding explanations to these problems should be of great importance, since the environmental, social and economical cost of managing extreme climatic variability is bound to be enormous from the stand point of society and policy makers Ekpoh (2011).

As to the researcher's knowledge, studies relating to impact of rainfall and temperature on crop production are still infrequent. For example, study made by Woldamlak and Conway (2007) focusing on temporal variability of rain fall in the drought prone Amhara region of Ethiopia and another study carried out by Mikias (2014) emphasizing on the effect of climate change and variability on the livelihoods of local communities the Case of central rift valley region of Ethiopia. But most of the researchers are not focus on the spatio temporal variability. Fundamentally, this investigation focus primarily to fill the discrepancy not previously discussed and provide a cumulative knowledge in the area by incorporating the issue of GIS and statistical tools to climate change driving variables such as rainfall, temperature and its impact on crop production

1.3. Objectives of the study

1.3.1. General objective

The main objective of this study was to assess the impact of climate variability on crop production

1.3.2. Specific objectives

The specific objectives of this study was address:

- (1) To assess the spatial and temporal variability of temperature in the study area;
- (2) To assess the spatial and temporal variability of rainfall in the study area;
- (3) To evaluate the impact of rainfall and temperature variability on crop yields.

1.4. Research questions

The following research questions were addressed in this study:

1. To what spatial and temporal extent and intensity does temperature vary in the study area?
2. Does the spatial and temporal variability of rainfall significantly affect crop yields in the study area?
3. Do rainfall and temperature variability affect crop yields?

1.5. Significance of the study

The impact of climate change, especially in developing countries, has social, economic and political impact directly or indirectly. Ethiopia currently faces various problems resulting from climate variation even though the degree of climate change is not clearly identified (Simane, et al., 2016). In light of the situation and profile of the study area, analyzing major climate change elements have some paramount importance because it helps understand the likely causes of extreme events such as drought, and flood in the area. It also helps in ascertaining the vulnerability of the area's inhabitants due to temperature and rainfall variability. Furthermore, possible adaptations to the problem of rainfall extremes shall be proffered as it may help cushion the continuous disasters caused by climate change in the area.

The study also used as a benchmark for political leaders, administrators, and policymakers with facts that guide them in formulating policies regarding the adapting to the problems of climate change in the area. It is hoped that this research work also used as a benchmark for future studies as well as an understanding of climatic variability in the area and cross-

reference in general.

1.6. Delimitation of the study

The project is mainly designed to analyze climate variability impacts on crop production. Geographically, the scope of the study is confined to northern part of Amhara region (Wag Himera, North and south wello zones) found in Amhara National Regional State, Ethiopia, where both the distribution of rainfall and temperature are highly erratic in nature. More specifically, the various climate variables in this study, particularly rainfall, and temperature, was methodically analyzed using GIS and statistical tools.

1.7. This Outline

This thesis includes five chapters. The first chapter of the study is an introduction, which includes the study background, statement of the problem; objectives of the research and significance of the study as subdivision. Chapter two describes the basic concepts, definitions, and related review literature regarding to Climate variability and its impact on crop production and models for analysis the impact of climate variability on crop yield. Chapter three deals about the description of the study area, discussions of the data source, material, data processing, methods of data analysis, and general methodological flow charts. Chapter four includes the data analysis and results of the study. The last chapter, which is the fifth chapter, includes conclusions and recommendations.

CHAPTER TWO

2. LITERATURE RIVIEW

2.1. Basic concepts

Today, climate change is increasingly recognized as a critical challenge to ecological health, human well-being and future development (IPCC, 2007). It is one of the greatest challenges of humanity, affecting current generations. Agricultural activities are the most economic sectors in Ethiopia. This sector is always affected by climate variability. The impact of agriculture as a result of climate variability is largely occurred in dry land semiarid areas (Gizachew, 2010). Ethiopia 's climate is influenced by general atmospheric and oceanic factors that affect the weather system (Bekele, 1997). The El Niño-Southern Oscillation (ENSO) is one of the most important contributors to global inter- annual climate variability, but the relationship between seasonal climate and crop yield variations associated with ENSO remains inconclusive.

In light of the above induction, the aim of this chapter is to review literatures on climatevariability,its cause and impact on agricultural products.Accordingly,the review of literature help to high light previous studies on climate change with their underlying concepts so as to identify gaps in the literature and forward research questions for the study.

2.2. Climate variability and climate change

As stated inKeely (2009) climate variability is the way climate fluctuates yearly above or below a long-term average value and climate change is long term continuous change (increase or decrease) to average weather conditions or the range of weather. As drawn in the work of Yitea (2012) climate is described in terms of the variability of relevant atmospheric variables such as temperature, precipitation, wind, snowfall, humidity, clouds, including extreme or occasional ones over a long period in a particular region. The classical period for performing the statistics used to define climate correspond to at least 3 decades, and it is designated by"climate normal period",as defined by the World Meteorological

organization (WMO). As a result, the 30 year period proposed by the WMO should be considered more as an indicator than a norm that must be followed in all cases but other periods may be used depending on the purpose.

This definition of the climate as representative of conditions over several decades should of course not mask the fact that climate can change rapidly. Climate can thus be viewed as a synthesis or aggregate of weather in a particular area for a long time (Esubalew, 2014). Hochman *et al* (2013) stated that accumulation of crop yield and climate data for 15 or more years is useful in expressing seasonal climate variability and volatility of the correlation between climate and yield. The same source further underlined that the two most important factors determining an area's climate are air temperature and precipitation.

2.3. Interaction between ocean, atmosphere and climate variability

The most well-understood occurrence of climate variability is the naturally occurring phenomenon known as the El Niño-Southern Oscillation (ENSO), which results from an interaction between the ocean and the atmosphere over the tropical Pacific Ocean that has an important consequence for weather around the globe, particularly in the tropics (NOAA, 2011). The ENSO cycle is characterized by coherent and strong variations in sea-surface temperatures, rainfall, air pressure, and atmospheric circulation across the equatorial Pacific. The El Niño-southern oscillation (ENSO) phenomenon results from the interaction between the surface of the ocean and the atmosphere in the tropical Pacific. ENSO profoundly affects climatic variability in sub-Saharan Africa, including the Sahel, Ethiopia, equatorial eastern Africa, and southern Africa, where strong and persistent ENSO events create unique and persistent anomaly patterns in rainfall (Ogutu *et al.*, 2008). The impacts of El Niño on eastern and southern African rainfall exhibit specific spatial-temporal patterns depending on the space-time evolution of each ENSO event.

2.4. Precipitation and Temperature

Rainfall and temperature are the two most prominent variables influencing the climate of a region. Precipitation is the general term for rainfall, snowfall and other forms of frozen or liquid water falling from clouds. A changing climate can directly influence precipitation amount, intensity,

frequency and type. Large natural variability and strong geographic variations in these parameters are evident, substantially affected by atmospheric circulation patterns such as the El Niño Southern Oscillation (Esubalew, 2014). Increased warming accelerates evaporation and increases the amount of water vapor in the atmosphere, resulting in certain areas getting wetter and others getting drier. Widespread increases in heavy precipitation events have occurred even in places where total amounts have decreased (Kedir et al., 2013). Temperature is a measure of the intensity of heat energy produced by solar radiation. Temperature influences plant growth as it affects physiological processes such as photosynthesis, transpiration, respiration, germination, and flowering (Went, 1953 cited in Elodie, 2011).

2.5. Trends of Temperature and Rainfall

Trend analysis of annual rainfall in Ethiopia shows that rainfall remained more or less constant when averaged over the whole country while a declining trend has been observed over the Northern half of the country and Southwestern Ethiopia. On the other hand, recent climate trends based on UNDP climate data indicate change in temperature and rainfall. There is a clear and observable positive trend in temperature. Ethiopia shows a consistent warming trend, with observation of increasing minimum and maximum temperature over the past fifth years (Abaddi et al., 2023).

2.6. Tools for climate variability prediction

Previous studies on the impacts of rainfall variability on crop yield made use of only statistical-based technique in their analysis. Among these are the works by Tim (2000) and Adejuwon, (2004). GIS offers a mechanism to integrate many scales of data developed in/for agricultural research. Surprisingly, little systematic research has focused on the distribution patterns of the impacts of rainfall variability in terms of mapping the spatial and temporal impact using the GIS equipment. There is no doubt that farmers and Agricultural Agencies increasingly need detailed GIS maps of this kind as a means of Spatial Decision Support System (SDSS) to plan crops planting schemes and to monitor yield rates. Complementing statistics with GIS, remote sensing techniques has been historically used for agricultural applications and have been most fruitful (Uboldi and Chuvieco, 1997).

2.7. Impact of climate change on crops

Agricultural activity is highly dependent to the phenomenon of climate change. Assessments of the effect of climate change on agriculture focus on either crop yield or crop variability. Food especially food crops is a fundamental requirement in our everyday life. This is especially true in the developing world with predominant small land holders and subsistence farmers for whom the on-farm agriculture and off-farm agricultural labor provides the main source of food and income (Everlyne, 2015). Besides, the vulnerability of these smallholder and subsistence farmers is greatly influenced by changes in climate (Morton, 2007).

Different methods are used to evaluate the effect of climate change on yields. The two main techniques are (i) crop growth models and (ii) regression analyses. (Elodie, 2011).

2.8. Bio-physical crop growth models

Many climate change studies use crop growth models to quantify the response of crops to changes in weather conditions. Bio-physical models use daily weather data to simulate the biological development of a plant under given soil characteristics and management practices. Climate change assessments using crop growth models were first conducted in the 1980s (e.g. Santer, 1985). According to Sonka and Lamb (1987) cited in (Elodie, 2011), bio-physical crop growth models have several benefits. First, since these process-oriented models use daily climatic data, they can explicitly capture the effect of weather and its variability. Second, they also enable estimation of the effect of changes in management strategies. Third and most importantly, these models offer the possibility to simulate any potential weather condition. Consequently, bio-physical growth models are likely to be more accurate than models built uniquely on past trends as future climate conditions are likely to differ from past conditions.

In a more widespread assessment, Reilly et al. (2001) cited in Elodie, (2011) analyses the effects of temperature and precipitation changes on crop productivity in 45 sites across the US. They applied the UKMO and CCC scenarios to a dynamic crop model. In the UKMO scenario, temperature increases by 1.4°C by 2030 and by 3.3°C by 2095 and precipitation increases by 6% by 2030 and 23% by 2095. The CCC scenario predicts a temperature increase of 2.1°C by 2030

and 5.8°C by 2095 and a decline of 4% in precipitation by 2030 but a precipitation increase of 17% by 2095. Reilly et al. (2001) studied 21 crops, including maize. Maize yields are predicted to increase under both scenarios. However, by 2030, the impact is greater under the CCC scenario (+19%) than under the UKMO scenario (+17%). Conversely, by 2090, the yield increase is lower under the CCC scenario (+23%) than under the UKMO scenario (+23%).

As illustrated in this review of the literature, bio-physical models are widely used to estimate the impact of climate change on crop yields. However, these models have several limitations which may influence prediction accuracy. The main shortcoming is the need for daily weather data, which greatly limits the areas over which bio-physical models can be applied. Moreover, the outcome of these models can be uncertain as they often assume that weeds, pests and diseases are controlled for. Also, as remarked by Adams et al. (1990), they do not assume any constraints posed by soil nutrient limitations. Furthermore, Rosen Zweig and Parry (1994) note that predictions from bio-physical models may have a positive bias as they are calibrated under experimental conditions where yields are likely to be higher than in actual conditions.

2.9. Empirical Crop Models

Statistical methods to quantify the influence of climatic factors on crop yields date back to Hooker's (1907) climate-crop regression analysis. Advances in computational techniques have greatly assisted the application of regression techniques but their popularity is mainly due to their ability to distinguish the impact of weather on crop yields from other factors. The standard production function explains crop output at time t , Q_t , by a set of explanatory variables:

$$Q_t = f(A_t, L_t, M_t, F_t, D_t, C_t)$$

Where A_t is the area sown, L_t is the amount of labor employed, M_t is the quantity of machinery used, F_t is the fertilizer consumption, D_t is a vector of regional characteristics (e.g., soil quality, irrigation, etc.) and C_t is a vector of climate variables. The empirical estimation of this function is based on time series and/or cross-sectional observation data observed at the farm level or aggregated at the regional level. Regression analysis allows the quantification of the past effect of one factor (e.g. the effects of weather variation) on crop yields in an actual cropping context.

Therefore, in addition to facilitating impact assessment of past climate on crop yields, regression analysis provides coefficients to estimate the impact of future climate change (holding all other parameters constant).

Regression parameters characterizing the impact of past climate change can be used to predict future climate change impacts, assuming that the relationships they establish between yields and climate variables remain valid into the future. Based on a regression analysis of USA yields, Chen et al. (2004) predict, for 2090, a decrease in maize yield variability of up to 36.9% under a CCC scenario (+4.2°C) and by up to 26.8% under a UKMO scenario (+3.1°C). Corobov (2002) uses the results from his regression analysis on Moldova's 1960-1990 periods. The significant coefficients are retained to estimate the impact of future change of climate predicted by three GCMs (CSIRO, UKMO and MPI). Corobov (2002) forecasts decreases in maize yields from 4.5% in 2080 under the MPI scenario to 8.4% in 2080 under the UKMO scenario.

Shortcomings relating to the use of regression analysis to analyze crop yields are well known. Katz (1977) identifies numerous sources of bias in statistical estimates. Firstly, misspecification of the functional form can lead to incorrect estimates of the impact of climate change and emphasizes the need to model nonlinear relationships properly. The omission of some important variables might also lead to biased coefficients in the model (Elodie, 2011).

Furthermore, the correlation between different agro-climatic determinants makes it difficult for multiple regression analyses to identify the exact relationship between the dependent variable and each explanatory variable. This correlation might lead to incorrect signs (Katz, 1977) and/or increased variability of the coefficient estimates.

Besides estimation issues, estimated coefficients may not necessarily be valid for prediction as coefficients represent the impact of past climate conditions on agricultural outcomes. If future climate values are not within the range of previously observed values, and if there are non-linearity in the production function that are not apparent in the historical range of climate data, then the relationship between the dependent variable and climate conditions may change.

Finally, data requirements place a major constraint on regression analyses. Data are not always accurately measured or even available. The use of experimental data addresses the former problem but such data are costly (Elodie, 2011).

2.10. Geo-Statistical Methods

Sample data can provide valuable information, but due to many constraints, it is difficult to get the whole region sample data. So that ,geo-statistics models predict the value in unsampled location and quantify the uncertainty of prediction. Meteorological stations are located in sparse and in the places which are often not of interest for different human activity. The value of climate elements cannot be measure in all point of the region but only in sample points. Spatial interpolation may be used to estimate the values in such areas where there is not measurement (Yang et al., 2004). Many research works show the importance of interpolating values of climate variables from stations to large areas (van der Heijden and Haberlandt, 2010).

Spatial interpolation can be used to estimate climatological variables at other locations. Although there are several methods to perform this, it can be difficult to determine which one best reproduces actual condition. Each method has advantages and disadvantages depend strongly on the characteristics of the data set: a method that fits well with some data can be unsuitable for a different set of data. Thus, criteria must be found to decide whether the method chosen is suited for the temperature or precipitation data set (Yitea, 2012).

Commonly used interpolation methods in ArcGIS may be either deterministic or stochastic. Deterministic methods don "t use probability theory (e.g. proximal) or on indication of extent of possible errors, whereas stochastic methods provide probabilistic estimate or incorporate the concept of randomness. Spline and Inverse Distance Weighting (IDW) are assessed as deterministic interpolation methods, where as Kriging is stochastic, which mostly used in Arc GIS More over, Spline and Inverse Distance Weighting (IDW)

Are exact type of deterministic interpolation methods and Kriging is exact type of stochastic interpolation methods. In exact methods the Local neighborhood search approach generates a surface that passes through its control points. In the other hand, approximate methods the global search approach predicts a value that differs from its known value.

Inverse distance weight (IDW) assigns a default rate of change (power value) that is regularly utilized for interpolation. A common fatal error of GIS analysts is the assumption that spatial dependence is uniform among different variables. Assuming that spatial autocorrelation is spatially constant, as well as constant between two different Variables decreases reliability. Kriging provides a more reliable interpolation because it examines specific sample points to obtain a value for spatial autocorrelation that is only used for estimating around that particular point; rather than assigning a universal distance power value. Kriging method are successful in the spatial interpolation of meteorological elements such as temperature, rainfall (Zhou et al., 2005 cited Yitea, 2012).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Location of the Study Area

This study was conducted in the northern part of Amhara region Wag Himra, North and South Wello zones in the Amhara National Regional State. The zones are located in the eastern part of the region. The capitals of the Wag Himra, South and North Wello zones are Sekota, Dessie and Weldia, respectively.

The study area are located between $10^{\circ}12''$ to $12^{\circ}22''$ N latitude and $38^{\circ}30''$ to $40^{\circ}14''$ E longitude (Figure 1) and cover about 39,000 km². Sekota, Dessie and Weldia are about 675, 410 km and 521 km north of the Ethiopian capital, Addis Ababa, respectively.

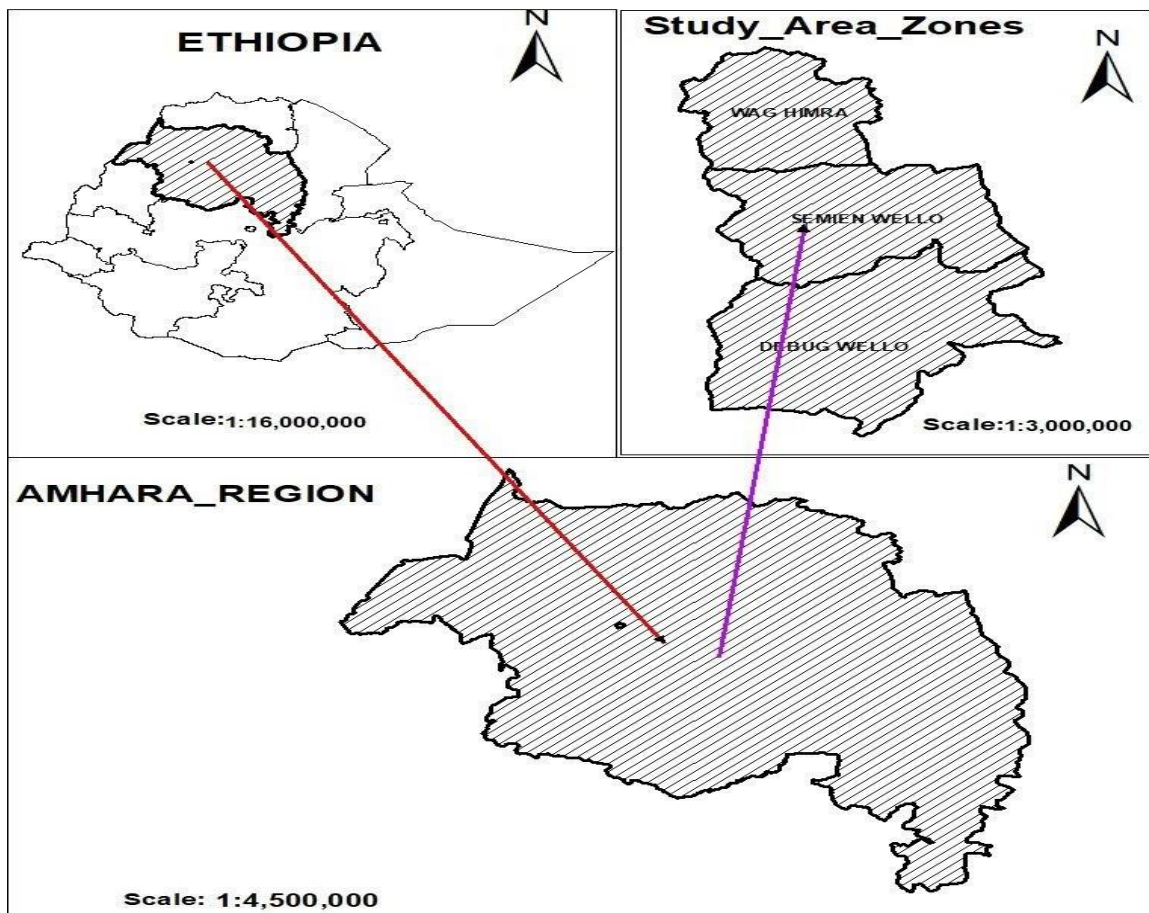


Figure 3.1. Location map of the study area

3.2. Data type and Data Sources

The data types that was used in this study are daily maximum, minimum temperature and daily rainfall data from the National Meteorological Agency of Ethiopia. Daily maximum temperature, minimum temperature, and daily accumulated precipitation data are recorded from Meteorological stations placed in the study area from 2001-2020 for 20 years. This is supported by (Hochman et al,2013) that accumulation of crop yield and climate data for a period of 15 or more years useful in expressing seasonal climate variability and volatility of the correlation between climateandyield.The study was analyze the minimum, maximum and mean monthly, and yearly rainfall, and maximum and minimum temperature.

Agricultural statistics long-term Cropdat (2001-2020), aggregated at the level of Administrative Zones, are collected from Sirinka Agricultural Research Institute found in North Wello.

3.3. Techniques of Data Analysis

The main objective of this study is to assess the impact of climate variability on crop production of the study area by quantifying the relationship of the agricultural output to rainfall and temperature. To assess the impact of climate variability on agricultural production, it is necessary to understand seasonal rainfall and temperature. ArcGIS 10.8.1software wasappliedto spatial and temporal climate variability analysis. In addition, spatial interpolation techniques that maybe used to estimate the values in areas without measurement wasperformed using the GIS environment. Correlation coefficient and regression analyses was carried out to determine the climate-crop yield relationship using the Statistical Package for Social Science (SPSS) software.

Accordingly, time series, regression and correlation analyses of rainfall, temperature and crop yields as well as spatial and temporal variability of rainfall and temperature was assessed to address the stated research objectives. Detail explanation, why correlation and regression was used and whatvariables was correlated during 2001-2020, is given below.

3.3.1. Test of Homogeneity

Data quality control was carried out to identify inconsistencies to rectify erroneous data and attain valid inference from the results of analysis. The errors could be attributed to instruments,

observation procedures, transmission, recording, coding and decoding, and data processing.

A test for data homogeneity was done using single mass curve technique to check for consistency or reliability of data set. This technique involved plotting cumulative rainfall, minimum and maximum temperature, and crop yield against time. If the results of plotted value gives straight line, the data set are regarded as homogenous while broken or discontinuity of this straight line means that there exists heterogeneity in data set (Lam, 2011).

3.3.2. Geo-statistical Methods

Sample data can provide valuable information, but getting the entire region sample data is challenging due to many restrictions. So that, geo-statistics models predict the value in an unsampled location and quantify the uncertainty of the prediction. Kriging provides a more reliable interpolation because it examines specific sample points to obtain a value for spatial autocorrelation that is only used for estimating around that particular point; rather than assigning a universal distance power value.

Inverse distance weight (IDW) interpolation technique assigns a default rate of change (power value) that is regularly utilized for interpolation. IDW depends solely on the distance to the prediction location. Kriging is one of the best estimation approaches of weather conditions at unsampled locations in which the region is large and limited low density of base stations where the distribution of the station is unrepresentative of topographic variability and geographic features (Hunter and Meentemeyer, 2005). With the kriging method, the weights are based on the distance between the measured points, the prediction location, and the overall spatial arrangement of the measured points. Because of the above explanation, kriging Geo-statistical interpolation technique was implemented in this study.

3.3.3. Spatial and Temporal variability of Temperature and Rainfall Analysis

To show temperature variability of the study area spatially and temporally, monthly, seasonal and annual minimum and maximum temperature data was used. Similarly, monthly, seasonal and annual distribution of rainfall in the study area was also evaluated. The spatial and temporal analysis of temperature and rainfall was performed using the GIS environment.

3.3.4. Correlation Analysis

Correlation is the degree of interdependence between variables. Correlation sometimes called association, is a measure of the relationship between two variables.

The correlation coefficient r is an index that measures the strength and direction of a linear relationship between two variables (Lam, 2011). This study was used correlation coefficient (r) to investigate the relationship between weather parameters (rainfall and temperature) and crop yields. This was done using Pearson's coefficient formula given by;

$$r_{xy} = \frac{\left[\sum xy - \frac{\sum x \sum y}{n} \right]}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{n} \right) \left(\sum y^2 - \frac{(\sum y)^2}{n} \right)}}$$

Where

r = correlation coefficient,

x = weather parameters (rainfall, temperature and ENSO) Y = crop yield

N = number of years

Significance of correlation coefficient

The student's t - test will be used to test the significance of the correlation coefficient. The formula for t - test is given by;

$$t_{n-2} = \frac{r}{\sqrt{\frac{1-r^2}{n-2}}}$$

Where r = correlation coefficient, t = student's statistical t -test, n =number of observation.

3.3.5. Regression Analysis

Regression analysis is used to relate crop yield data to weather data considering the same area (Parry et al., 1988a) providing quite effective estimates of crop yield when Regression analysis approach is useful in crop yield is affected by weather factors such as rainfall or temperature (Parry et al., 1988b). Thus regression analysis was used in this research to estimate the impact of temperature and rainfall on crop yield.

Regression equation takes the form:

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n + \varepsilon$$

Where

Y=estimated crop yield a = Y intercept

$b_{1\text{through}n}$ = regression coefficients for each of the independent variables X_1 through X_n and ε = is an error term.

Testing the model performance

The crop productions was evaluated using three goodness-of-fit measures: the coefficient of determination (r^2), the index of agreement (d), and the mean absolute error (MAE).

The coefficient of determination (r^2) is the square of the correlation coefficient. It describes the proportion of the total variance in the observed crop data explained by climate variables. It ranges from 0 to 1, where the higher value indicates better agreement between observed and predicted data. One of the problems with r^2 is that its values are highly sensitive to outlie

The index agreement(d) is calculated using;

$$d = 1.0 - \frac{\sum_{i=1}^N (P_i - O_i)^2}{\sum_{i=1}^N (|P_i - \bar{O}| + |O_i - \bar{O}|)^2}$$

Where N is number of years, O_i and P_i are the observation and the prediction for year i, respectively. \bar{O} is the mean of observations. The index of agreement measures the degree to which the predicted data approach the observed data. The index of agreement varies between 0 and 1, where 0 indicates no agreement between predicted and observed data, and 1 indicates perfect agreement.

The mean absolute error iscalculated using;

$$MEA = \frac{1}{N} \sum_{i=1}^N |P_i - O_i|$$

MEA represents overall errors. It is less sensitive than Root-mean-square error (RMSE) to errors to largely predicted departures from the mean, and is therefore considered a more robust measure of accuracy.

3.4. Trend Analysis

Trend means the general tendency of the data to increase or decrease during along period. Temperature, rainfall, and agriculture production data are made over time and therefore are referred to as time series data, which is defined as asequence of observations that varies over time(Lam,2011).Trendis defined as the general movement of a series over an extended period the long-term change in thedependent variable over a long period of time (Mallika, 2013). Graphical method is the most convenient and popular way of presenting data variation (Lam, 2011).

In this study, graph was used to represent annual variations of rainfall, temperature, SSTA and annual crop yield and the magnitude of trend in the time series was determined with the help of SPSS software and MATLAB software.

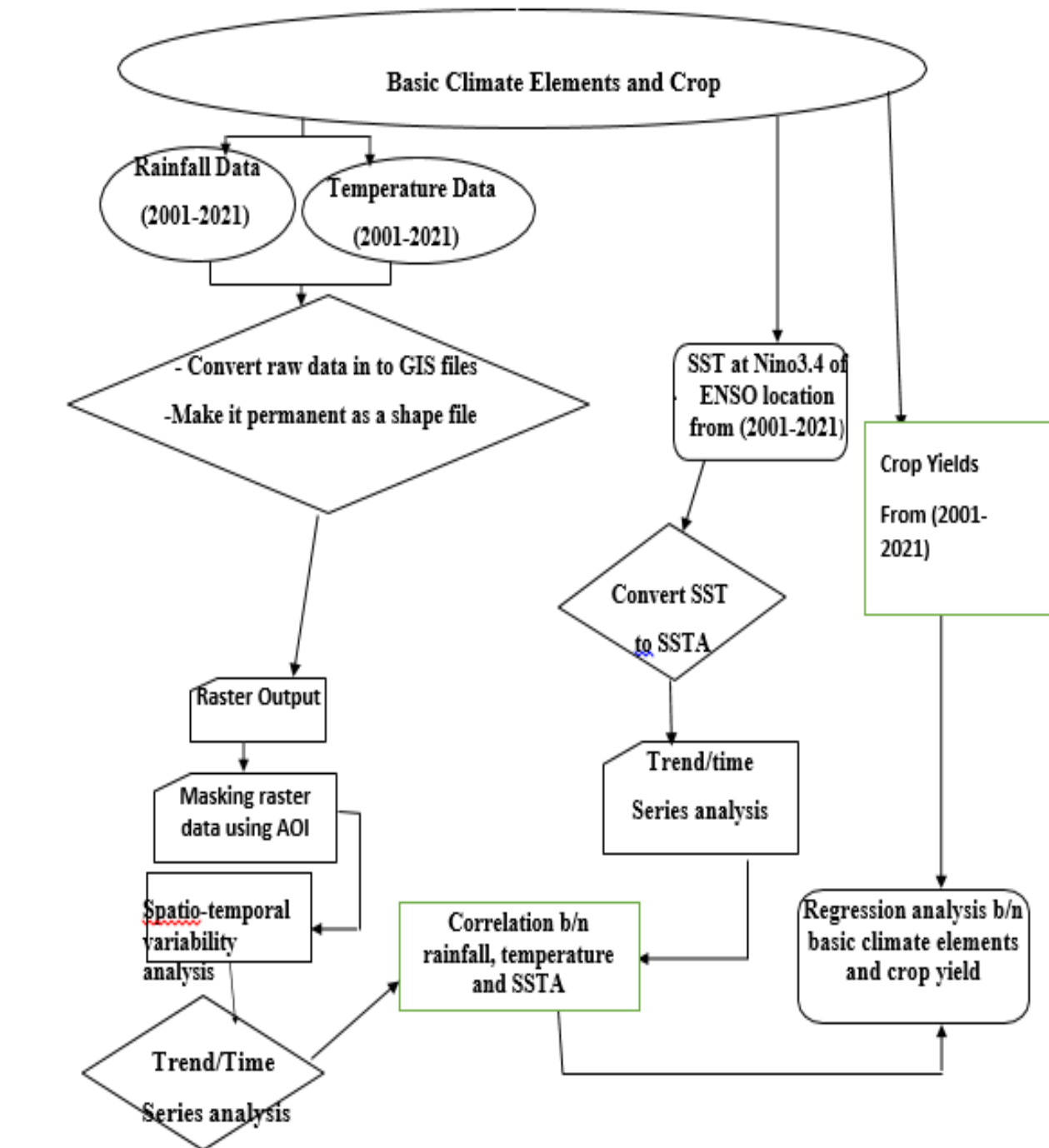


Figure 3.2. Schematic flowchart that describes the methodology of the study

CHAPTER FOUR

4. Result and Disucation

4.1. Spatio-temporal variabrityand Trends of Temperature

The region is characterized by a diverse climate, which ranges from dry and hot lowlands to wet and cold highlands. The area-averaged minimum and maximum temperature of the region is 26.2mm and 62.9mm, and it varies from 10.46 to 39.34mm and 24.06 to 76.7 mm respectively (figure4.1). The average annual temperature in the region is about 44.5 mm.

In the Central Rift Valley Region (CRVR), part of the theregionMatewos and Tefera (2020) found that annual rainfall is 1101.27 mm. The region receives rainfall for 7 months from April to October although there was a modest reduction in June. The region receives a high average monthly rainfall between July and October with the second season between April and June.

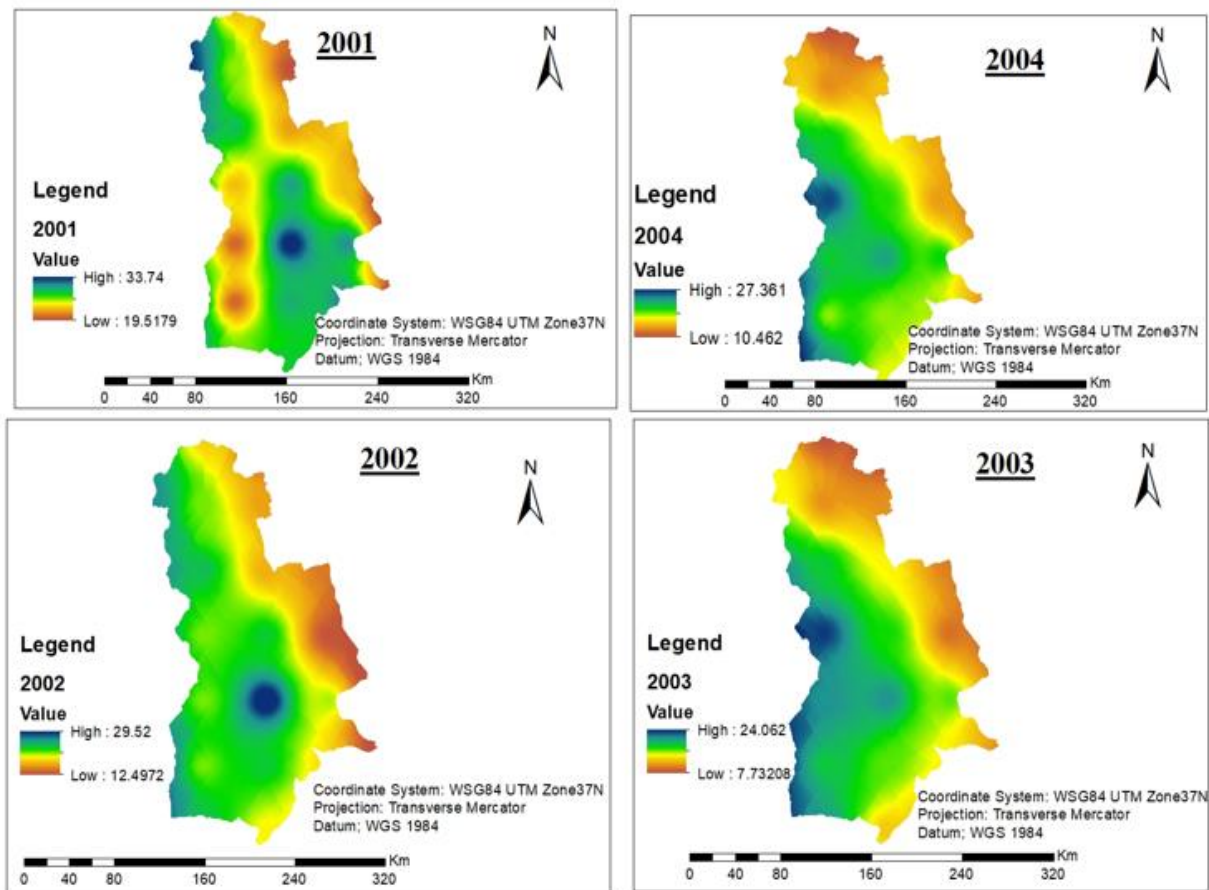


Figure 4.1. Average annual temerature variation (in °C) across the the study area for 2001–2004

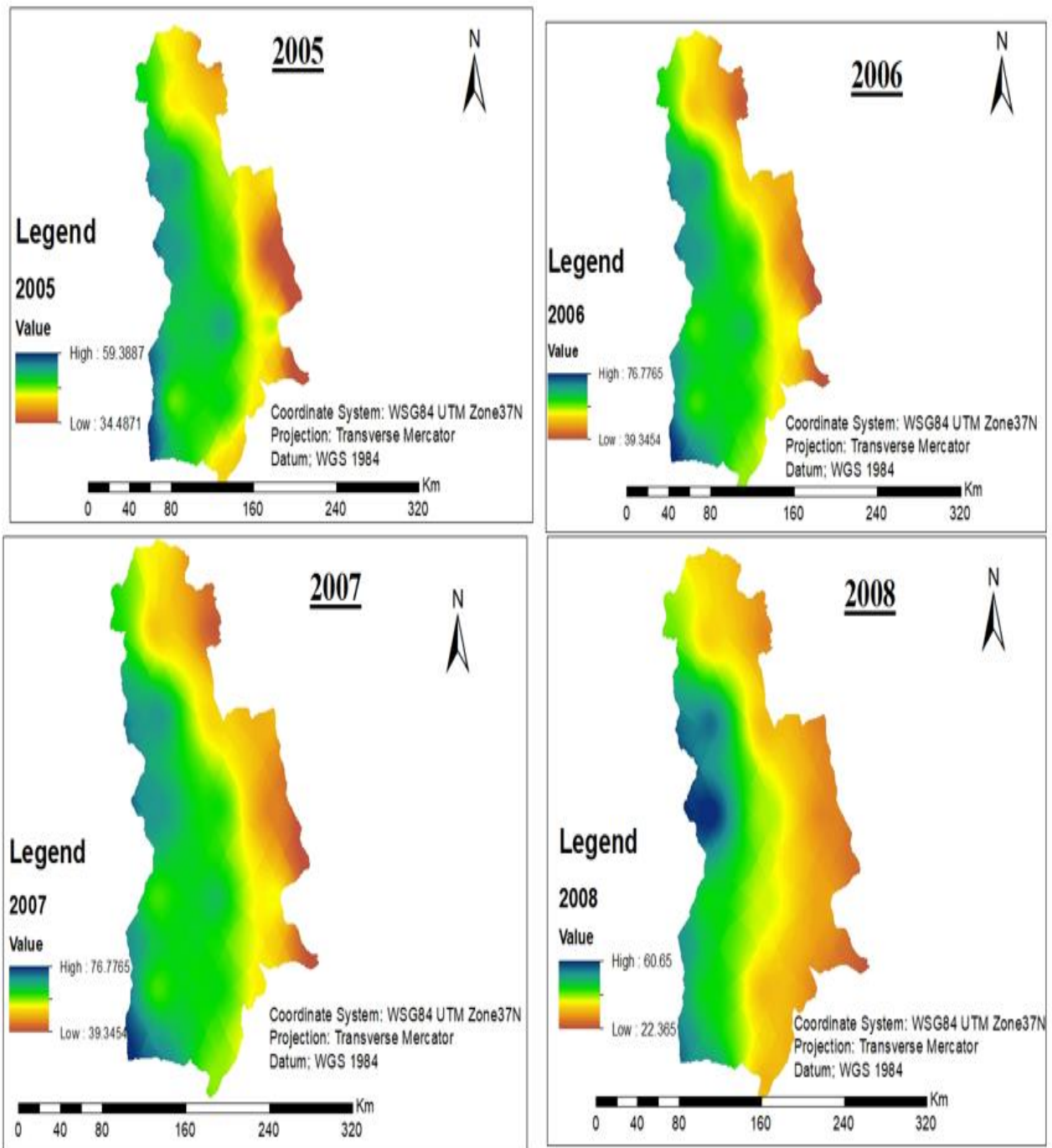


Figure 4.2. Average annual temperature variation (in °C) across the the study area for 2005–2008

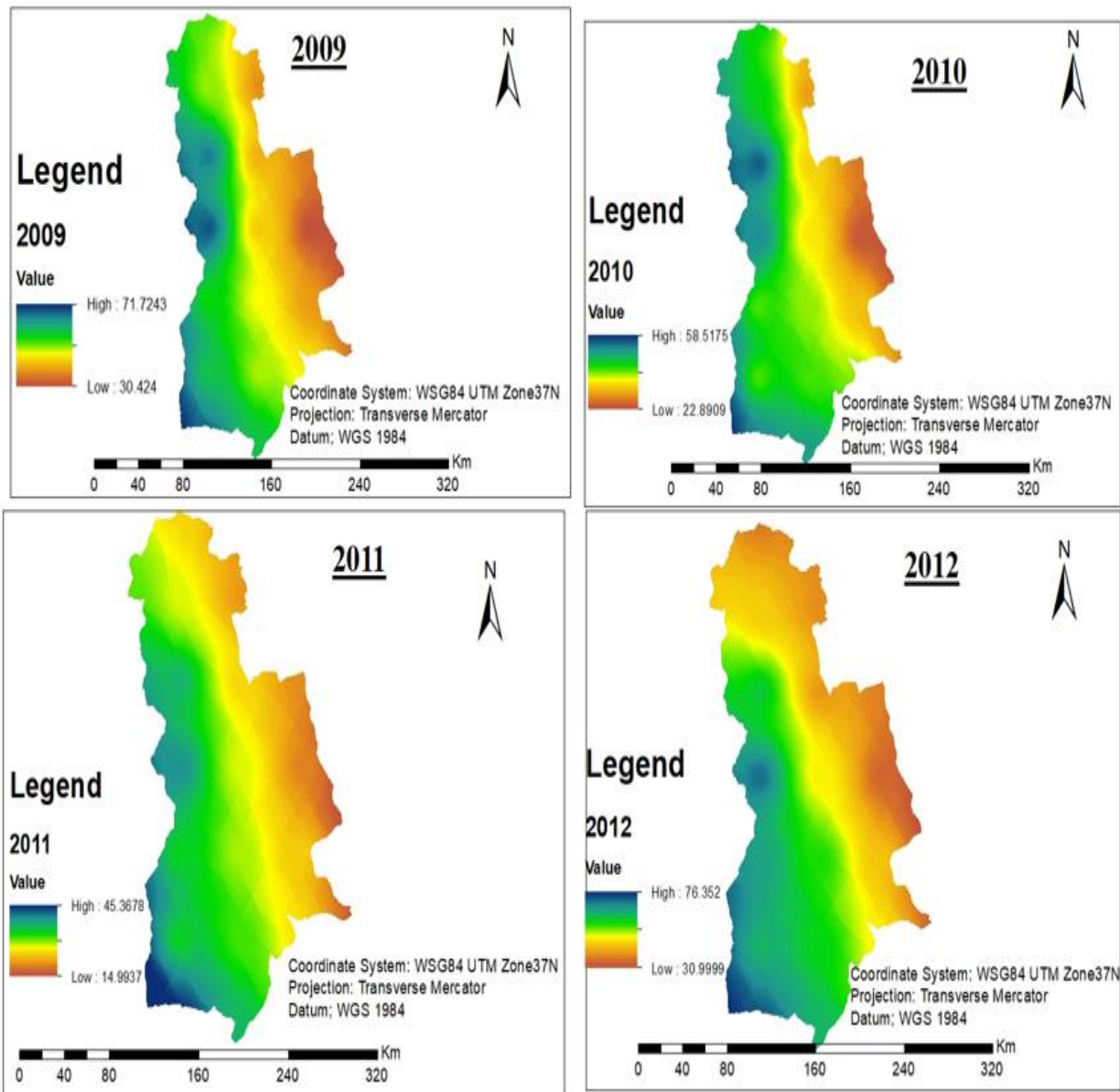


Figure 4.3. Average annual temperature variation (in °C) across the the study area for 2009–2012

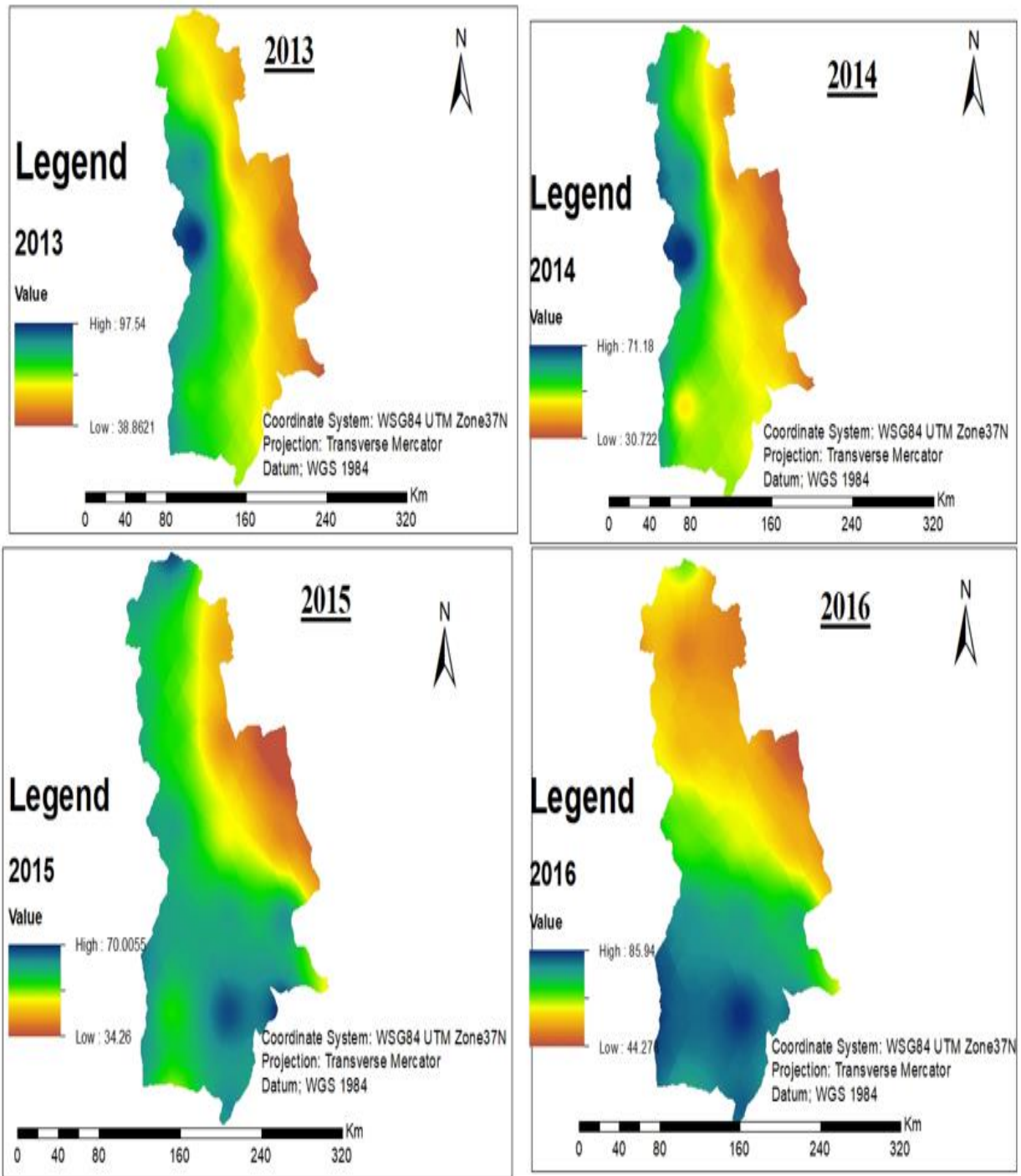


Figure 4.4. Average annual temperature variation (in °C) across the the study area for 2013–2016

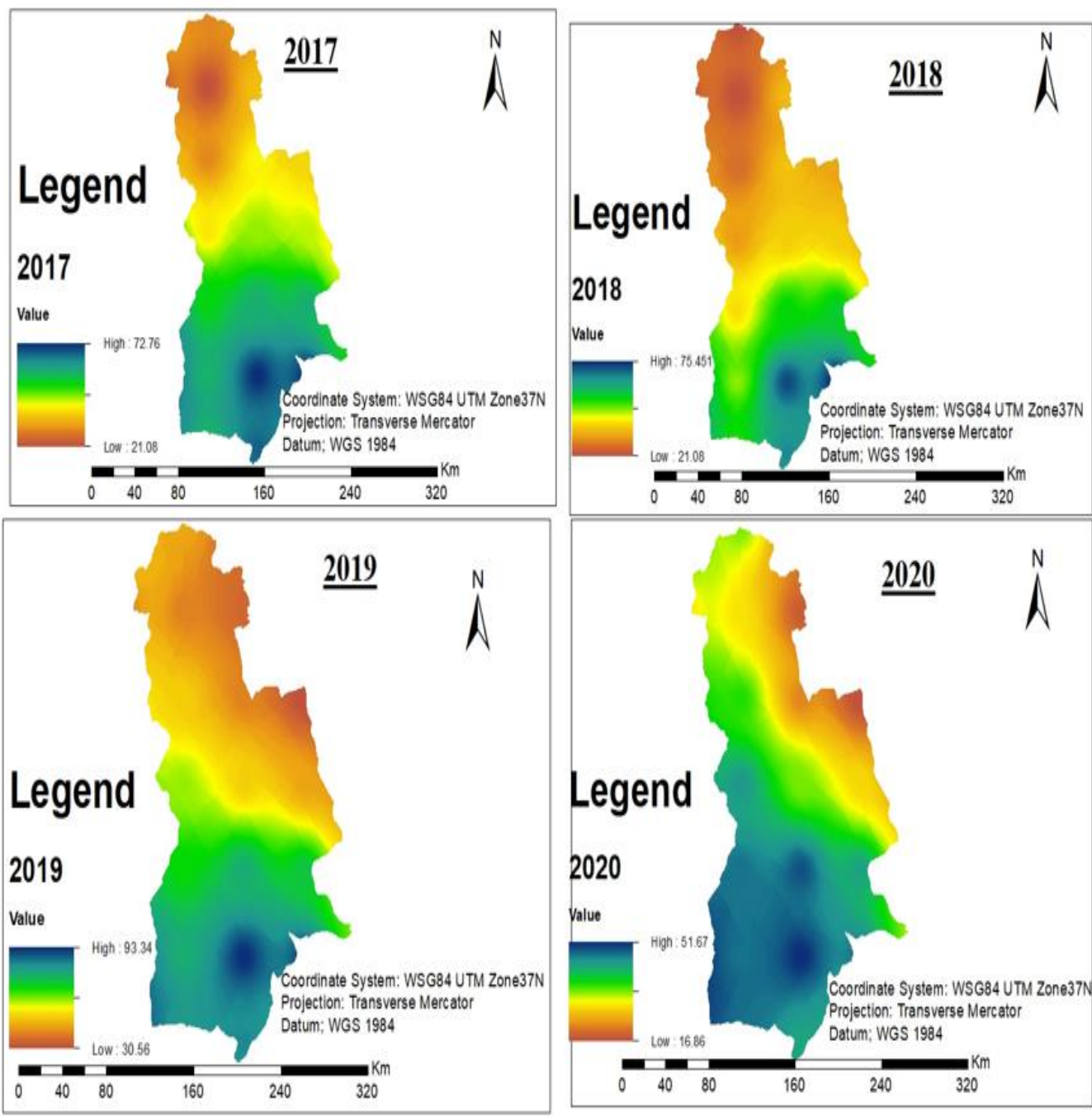


Figure 4.5. Average annual intemperature variation (in°C) across the the study area for 2017–2020

Table 4.1. Summary of Annual temeratuareof the Study Area

Year	Minimum	Maximum	Mean
2001	19.5179	33.74	26.62895
2002	12.4972	29.52	21.0086
2003	7.73208	24.062	15.89704
2004	10.462	27.208	18.835
2005	34.4871	59.3887	46.9379
2006	39.3454	76.7765	58.06095
2007	39.3454	76.7765	58.06095
2008	22.365	60.65	41.5075
2009	30.424	71.7243	51.07415
2010	22.8909	58.5175	40.7042
2011	14.9937	45.3678	30.18075
2012	30.9999	76.352	53.67595
2013	38.864	97.54	68.202
2014	30.722	71.18	50.951
2015	34.26	70.0055	52.13275
2016	44.27	85.94	65.105
2017	21.08	72.71	46.895
2018	21.08	75.451	48.2655
2019	30.56	93.34	61.95
2020	16.86	51.67	34.265

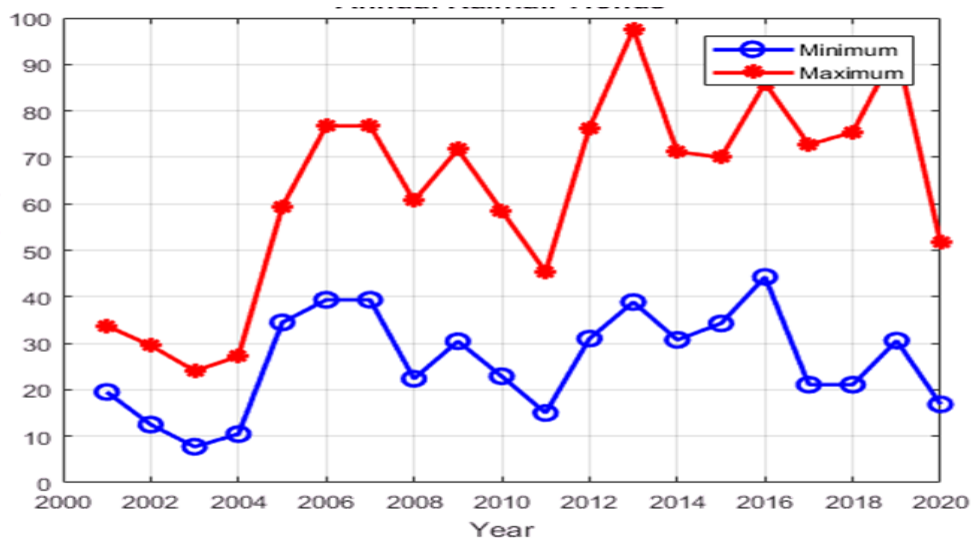


Figure 4.6. Trend of temperature in the study area

4.2. Spatio-temporal variability of Annual Rainfall

The region is characterized by a diverse climate, which ranges from dry and hot lowlands to wet and cold highlands. The area-averaged annual minimum and maximum temperature of the region is 629.33 mm and 855.12 mm, and it varies from 313.7 mm to 660.7 mm and 426.7 mm to 899.3 mm respectively.

The average annual temperature in the region is about 742.23 mm. In the Central Rift Valley Region (CRVR), part of the area region Matewos and Tefera (2020) found that annual rainfall is 1101.27 mm.

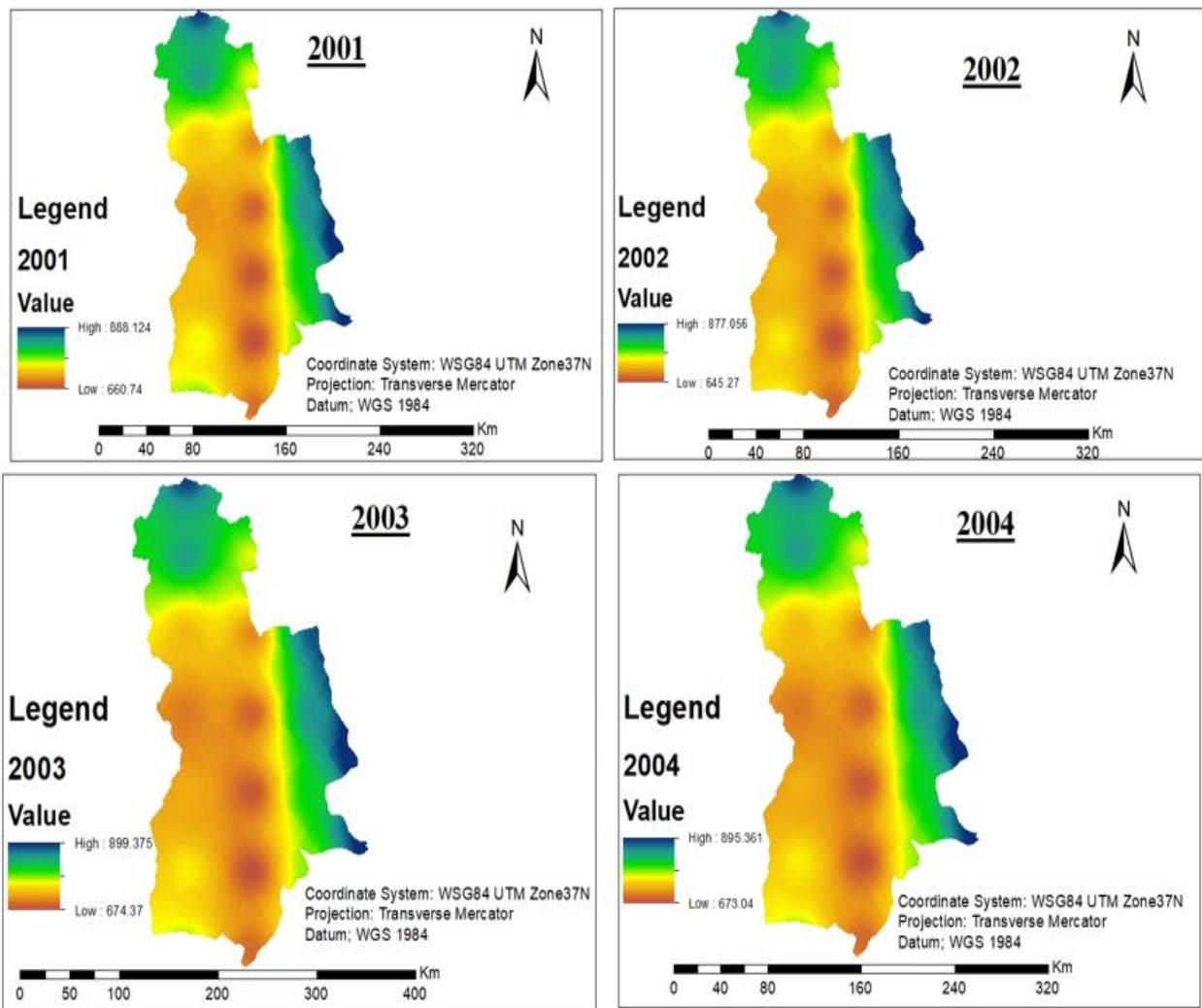


Figure 4.7. Average annual rainfall variation (in mm) across the the study area for 2001–2004

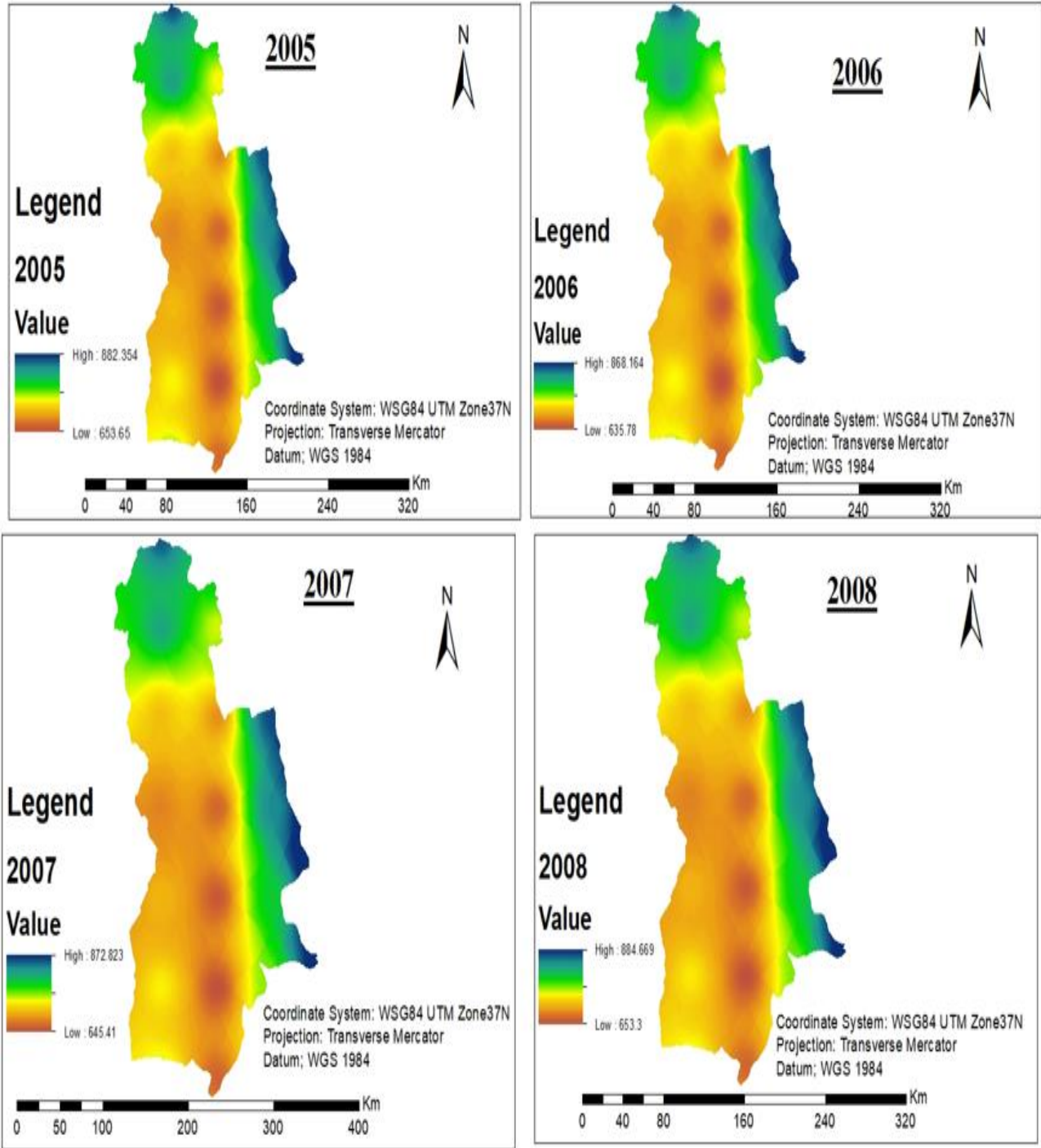


Figure 4.8. Average annual rainfall variation (in mm) across the the study area for 2005–2008

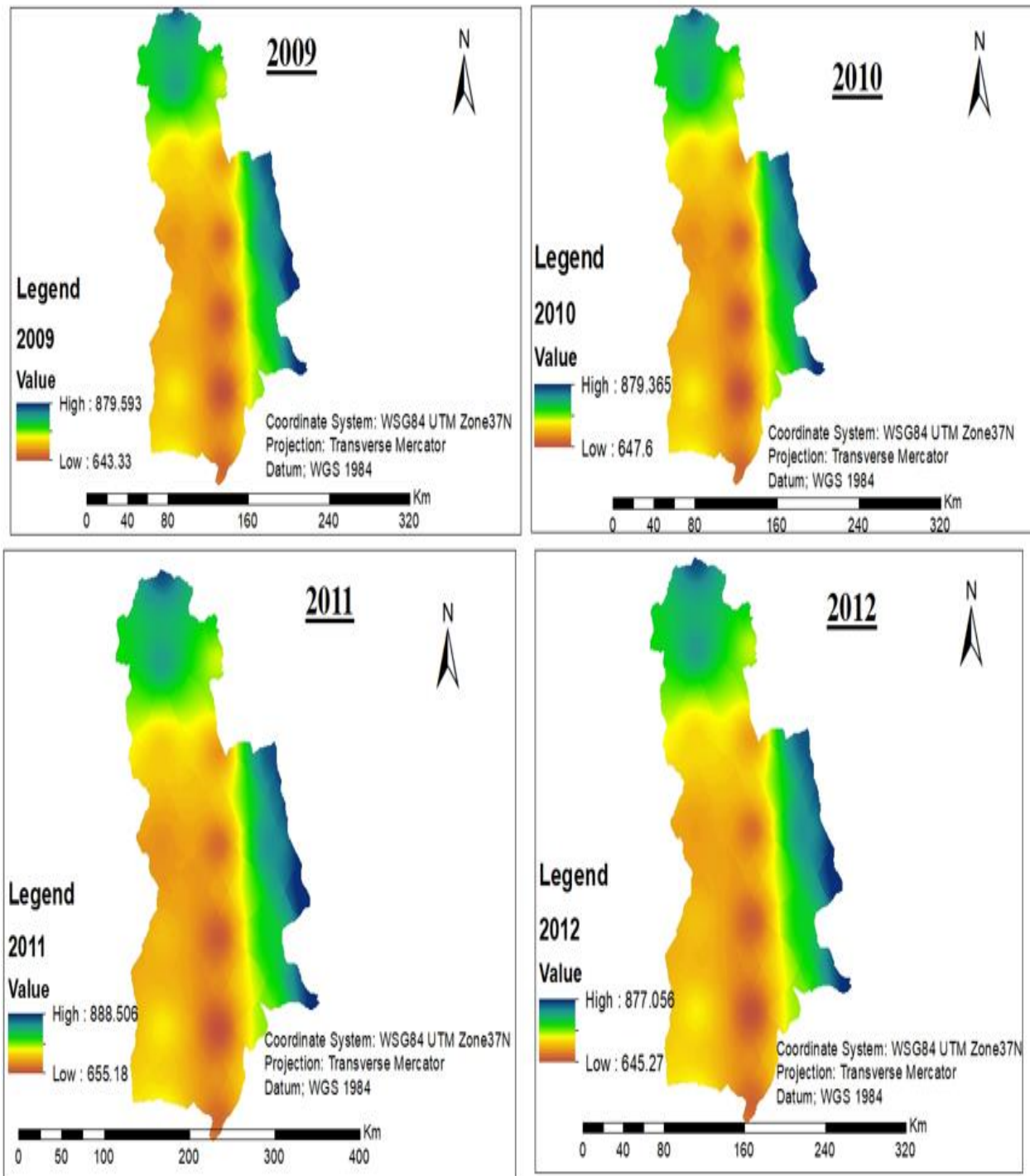


Figure 4.9. Average annual rainfall variation (in mm) across the the study area for 2009–20012

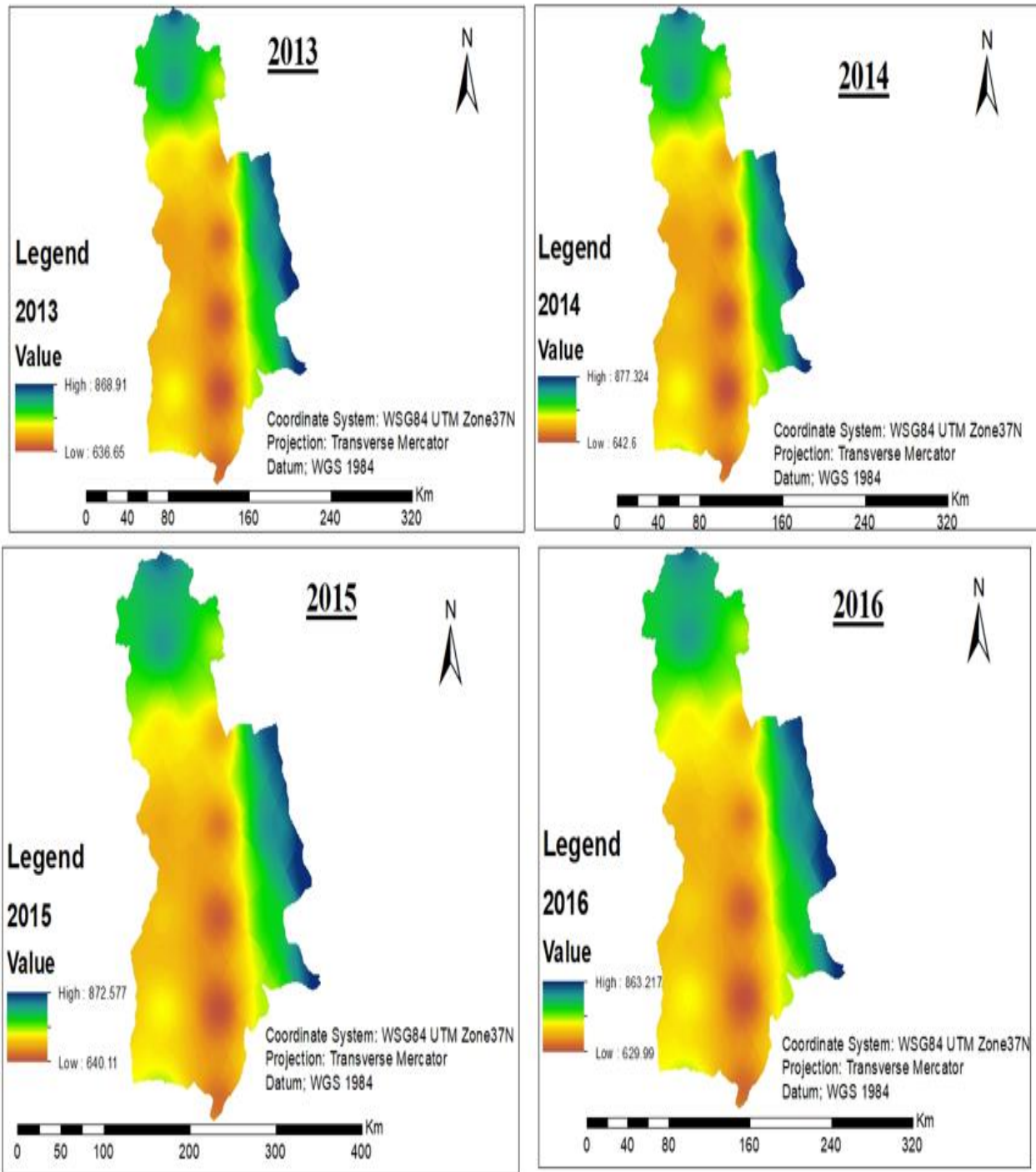


Figure 4.10. Average annual rainfall variation (in mm) across the the study area for 20013–20016

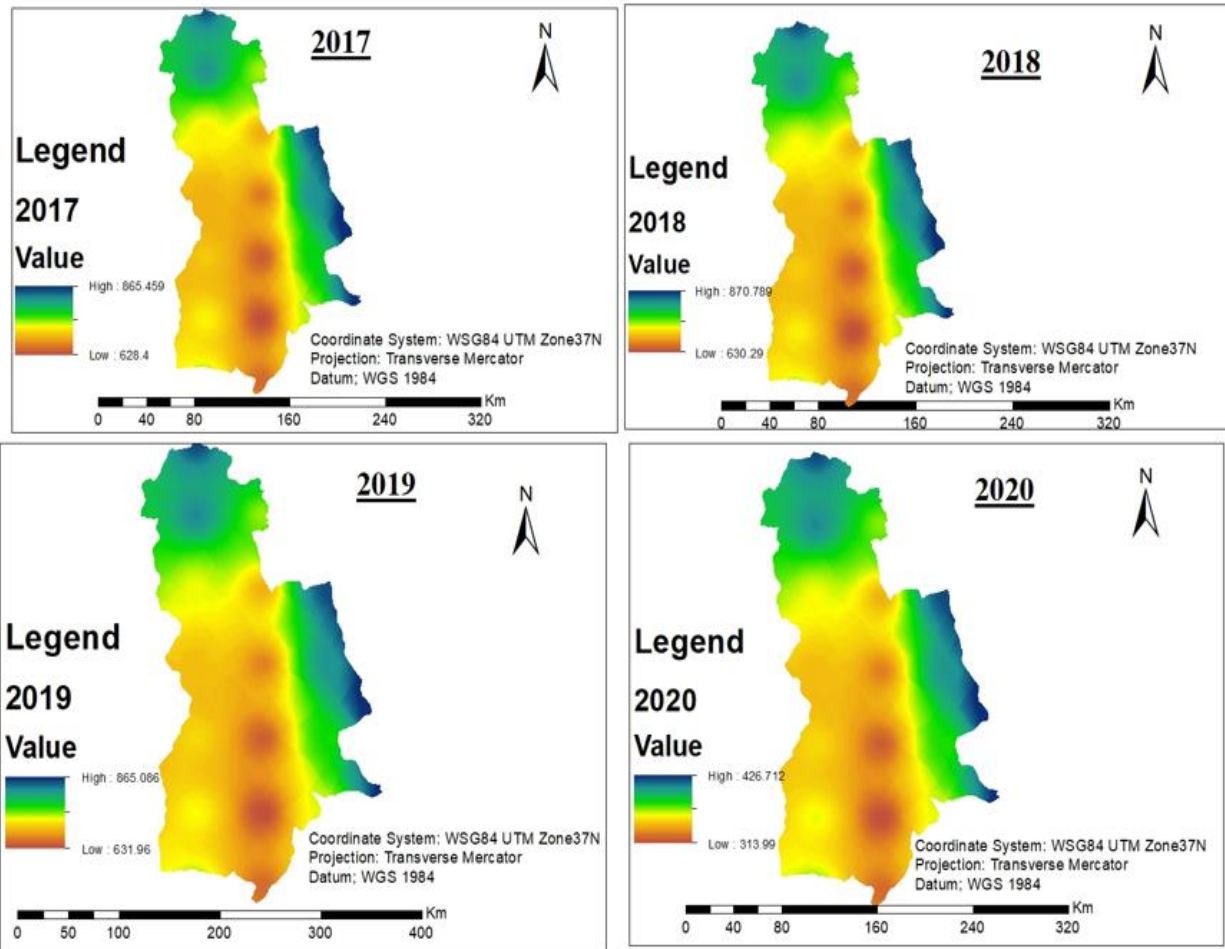


Figure 4.11. Average annual rainfall variation (in mm) across the the study area for 2017- 2020

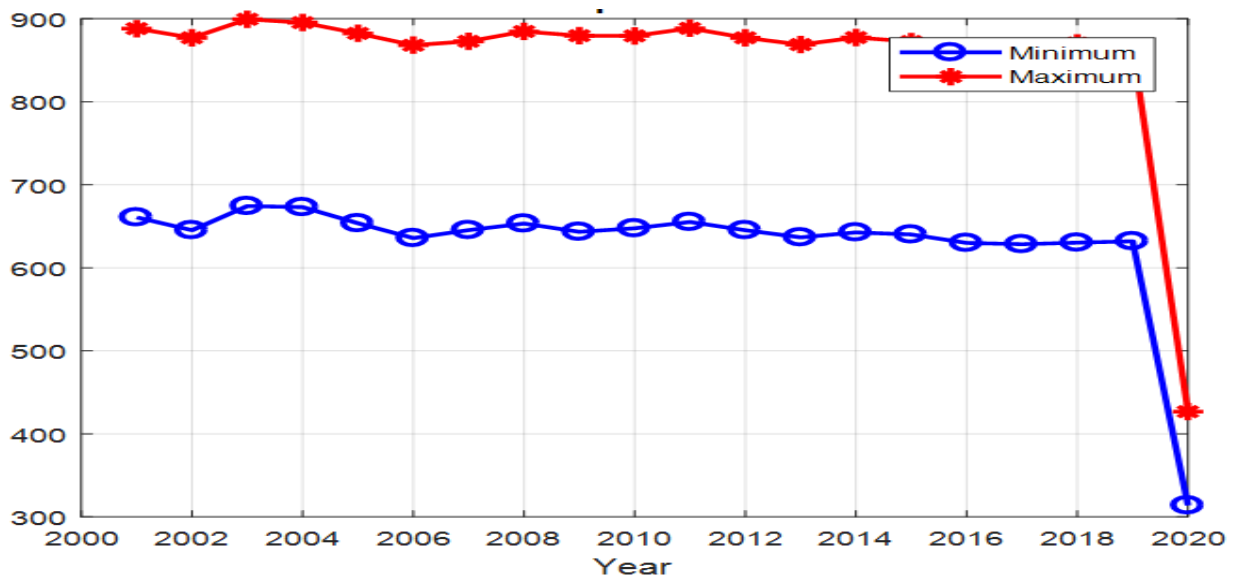


Figure 4.12: Trend of rainfall in the study area

4.3. Crop Yield Sensitivity to Climate Variables (Observed Data)

In the correlation and regression analysis of temperature, rainfall crop yield, our findings show significant relationships among these variables. The correlation coefficients indicate the strength and direction of the linear relationships, while regression analyses provide insight into the productive power of these factors on the crop yield.

The correlation coefficient (ρ) is a measure that determines the degree to which the movement of two different variables is associated. The most common correlation coefficient, generated by the Pearson product-moment correlation, is used to measure the linear relationship between two variables. However, in a non-linear relationship, this correlation coefficient may not always be a suitable measure of dependence.

The possible range of values for the correlation coefficient is -1.0 to 1.0. In other words, the values cannot exceed 1.0 or be less than -1.0. A correlation of -1.0 indicates a perfect negative correlation and a correlation of 1.0 indicates a perfect positive correlation. If the correlation coefficient is greater than zero, it is a positive relationship. Conversely, if the value is less than zero, it is a negative relationship. A value of zero indicates that there is no relationship between the two variables. Depend on this as we have seen below the correlation coefficient of sorghum with rainfall and taff with rainfall is 0.466 and 0.545 respectively. This indicates that both sorghum and taff has direct correlation but taff has stronger correlation as compared with sorghum. The correlation coefficient of sorghum with temperature and taff with temperature are 0.483 and -0.208 respectively indicates that temperature has weak negative correlation with taff and temperature has weak positive correlation with sorghum as we have seen in the table below.

Table 4.2. Correlation coefficient of climate with crop yield

	<i>Surgum</i>	<i>Taff</i>	<i>MeanRainfall</i>	<i>MeanTemp</i>
Surgum	1			
Taff		1		
MeanRainfall	0.466862	0.545978	1	
MeanTemp	0.4839005	-0.2088	-0.962129887	1

To assess, to what extent the variations in crop yield are determined by climate variables and to investigate the importance of spatial scale, crop yield sensitivity to climate variables. The climate-induced variations in crop yields are estimated using the coefficient of determination (R²). Table below shows the correlation coefficient (r) and coefficient of determination (R²) calculated between crop yields and climate variables. R² explains percentage variations of both surgum and taff crops yield explained by temperature and precipitation. Correlation coefficient (r) and Coefficient of determination (R²) in % calculated between observed surgum and taff yields based on PBS yields with observed temperature and precipitation in the study area from 2003 -2014 period. Bold numbers show the strong correlation, i.e., more than or equal to 0.30 between crop yields with climate variables and star shows the statistically significance level.

Table 4.3: Indicator of significance of climate for crop yield

Surgum Yield vs. Temperature and Precipitation				Taff Yield vs. Temperature and Precipitation			
Temperature		Rainfall		Temperature		Rainfall	
Corr (r)	R ² (%)	Corr (r)	R ² (%)	Corr (r)	R ² (%)	Corr (r)	R ² (%)
0.483	0.23	0.466	0.217	0.55	0.30	-0.209	0.043

** sign indicates significant at 0.01 level of significance.

CHAPTER FIVE

5. CONCLUSION and RECOMMENDATION

5.1. CONCLUSION

The objective of this study is to improve understanding of the impact of climate variability on crop yields in the study area. Our results confirm the importance of climate-related assessments in crop yields. The results confirm that climate variables (i.e., temperature and precipitation) play a major role in crop development and growth. However, the degree of crop yield relationship strength with climate variables varies from crop to crop and time to time. Crop yields (i.e., Sargam and Taff the most dominant crop in the area) show sensitivity to climate variables. The region is characterized by a diverse climate, which ranges from dry and hot lowlands to wet and cold highlands. The area-averaged minimum and maximum temperature of the region is 26.2mm and 62.9 mm, and it varies from 10.46 to 39.34 mm and 24.06 to 76.7 mm respectively. The average annual precipitation in the region is about 44.5 mm.

The region is characterized by a diverse climate, which ranges from dry and hot lowlands to wet and cold highlands. The area-averaged annual minimum and maximum temperature of the region is 629.33°C and 855.12°C, and it varies from 313.7°C to 660.7°C and 426.7°C to 899.3 °C respectively.

In general the spatio-temporal variability of temperature and rainfall has its own impact on the productivity of crop.

5.2. RECOMMENDATION

This study has presented a detailed analysis of spatio-temporal rainfall variability in the study area from 2001 to 2020. Depending on the scope of the study, the following recommendations were drawn: The study did not cover the seasonal effect of climate variability on crop productivity. So, it is good to assess the seasonal spatio-temporal variability and its impact on crop yield because of the climate situation is different from season to season. It is also necessary to assess the effect of SST with climate and assess the impact of SST on crop yield like rainfall and temperature.

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