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ASSESSMENT OF CLIMATIC FACTORS AFFECTING MAIZE PRODUCTION OF SMALL-SCALE FAMERS IN BABATI DISTRICT

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ASSESSMENT OF CLIMATIC FACTORS AFFECTING MAIZE PRODUCTION OF SMALL-SCALE FAMERS IN BABATI DISTRICT

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A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partially Fulfilment of the Requirements for the Award of Science in Geoinformatics (BSc.GI) of Ardhi University

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Ardhi University dissertation titled **"Assessment of Climatic Factors Affecting Maize Production of Small-Scale Famers in Babati District"** in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geomatics at Ardhi University.

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Ms. B. KAIJAGE

SUPERVISOR

Date……………….

DECLARATION AND COPYRIGHT

I, KIUNSI MANASE E hereby declare that, the contents of this dissertation are the results of my own findings through my study and investigation, and to the best of my knowledge they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning.

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KIUNSI, MANASE E

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DEDICATION

I dedicate this dissertation to my Father Mr. Emanuel and Elly Kiunsi who has been a constant source of support and encouragement during the challenges of school and life. Am grateful for what you have done I love you and value you.

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ABSTRACT

The decline in maize production in Babati Region in Tanzania poses a significant threat to food security and nutrition, particularly among vulnerable populations such as children. Understanding the specific effects of climate change on maize production and exploring adaptive measures are crucial for addressing this problem and ensuring food security in the region. This research aims to address the decline in maize production in Babati Region by analyzing historical trends and production data. The study aims to investigate the specific impacts of climate change on maize cultivation in Babati, focusing on variables such as rainfall patterns and temperature variations. Results of trend analysis in rainfall revealed that trends in annual rainfall is not constant, has statistically significant increase and decrease randomly in different years at Babati where general annual rainfall in Babati showed a declining trend of 1.44 mm per year. Trend analysis of annual maximum temperature revealed varying temporal trend that there is an increase trend in maximum temperature of 0.01□ per year. The maize yield trend based on the observed information it shows the mazie yield trend is not constant, it decreases at an average of 0.005 tonnes per hector each year from 2000 to 2020. The findings contribute to the generation of knowledge, enabling farmers to adopt new practices and agronomic measures to increase production where the research outcomes also benefit researchers by providing a foundation for future studies and the development of improved methodologies. Agricultural institutions can utilize the results to perform analysis and modeling, leading to the development of new climate-resistant maize breeds.

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ACRONYMS AND ABBREVIATIONS

GDP	National Gross Domestic Product
MLR	Multiple Linear Regression
PET	Potential evapotranspiration
PRE	Precipitation
RMSE	Root Mean Square Error
TMA	Tanzania Meteorological Agency
TMN	Monthly average minimum temperature
TMX	Monthly average daily maximum temperature

CHAPTER ONE

INTRODUCTION

1.1 Background

The prevalence of hunger across Africa has led to increasingly severe problems affecting a significant number of individuals, particularly children under the age of five, who often suffer from malnutrition (FAO, 2019).One in nine people, particularly children, grapple with the dire consequences of hunger. Tanzania's equatorial location, which typically entails favorable seasonal rainfall for maize cultivation, the nation struggles with low maize production. The government's initiative, "kilimo kwanza," aimed at supporting local farmers, has yielded limited results in boosting production.

Tanzania possesses the ideal climate for cultivating various food crops, which has contributed to its agricultural growth. Notably, between 1961 and 1965, national maize production exhibited consistent growth, increasing by 4.6% during this period (Moshi). Maize, a vital food crop, is primarily cultivated by small-scale farmers. However, statistics from the 2000s indicate a decline in maize production as a rain-fed crop, maize is cultivated across the country, its availability being pivotal for ensuring food security due to its status as a staple food for the majority of the population. In the "State of Food Security and Nutrition in the World 2019" (SOFI 2019) report published by FAO in July 2019, it was revealed that the global number of hungry people had risen over the last three years, surpassing 820 million in 2018, affecting one in every nine individuals.

Approximately 85% of Tanzania's maize is cultivated by small-scale farmers operating on less than 10 hectares of land. Crop spans an average of two million hectares, representing around 45% of the country's cultivated area. A mere 10% of maize production occurs on medium-scale commercial farms (10-100 hectares), with the remaining 5% on large-scale commercial farms (>100 hectares). Between 1961-65 and 1985-95, the nation's maize production is estimated to have grown by 4.6%, attributed to a 2.4% increase in cultivation area and a 2.2% rise in yield. The increase in yield, average maize yields remain below 1.5 tons per hectare, although regions with high agricultural potential, such as the Southern Highlands, tend to exhibit higher grain yields (Moshi et al., 1990).

Babati, a region situated in Tanzania, is a poignant example of the significant consequences of climate change on maize production. Staple crop crucial to both the local economy and food security, maize in Babati faces numerous challenges due to shifting climatic patterns.

Maize cultivation is an intricate endeavor influenced by different factors, ranging from climate change and farming practices to technological advancements. Scientists predict increasing impacts of climate change on maize yields, particularly under rain-fed conditions (Jones and Thornton, 2003; Lobell et al., 2011), and especially when coupled with low soil fertility (Schmidt et al., 2012).

The effects of climate change extend beyond agriculture to encompass human health, water resources, and food security at local and global scales (Magadza, 2000). Climatic variables such as precipitation, solar radiation, humidity, temperature, and wind speed significantly influence global crop and livestock productivity (Ajadi et al., 2011). Climate change and variability directly and indirectly affect agricultural systems, potentially jeopardizing food security on local, regional, and global levels (Ajadi et al., 2011), the severity of which depends on the spatial scale of change (FAO, 2013). Studies have explored the effects of weather and climate on agricultural production, some have specifically focused on the impact of climate change on maize production (Magadza, 2000).

Adeleke and Goh (1980) define climate as the average atmospheric conditions over a substantial period. It involves systematic observation, recording, and processing of climate elements like rainfall, temperature, humidity, air pressure, wind, clouds, and sunshine. In relation to crop yield variability, Chi-Chung et al. (2004) suggest that precipitation and temperature exert opposing effects on corn (maize) yield levels and variability they propose that increased rainfall leads to higher yield levels and reduced variability, while temperature yields the opposite outcome. Bancy's (2000) study on the influence of climate change on maize production in semi-humid and semi-arid regions of Kenya suggests that countering climate change's negative effects might necessitate employing early maturing cultivars and adopting early planting practices.

1.2 Problem Statement

Despite Babati being a favorable climatic condition for maize production, the region is experiencing a decline in Maize production leading to food insecurity the problem is influenced by factor such as climate change. Understanding the specific effects of climate change on maize production and exploring adaptive measures are crucial to addressing the issue and ensuring food security in the region.

1.3 Research objectives

Under this section there are stated achievements under this study in general and specific terms.

1.3.1 Main Objective

Main objective is to understand how the climate factors are affecting maize production

1.3.2 Specific objectives

1. To analyze the current state of maize production in Babati by analyzing Historical trends, production data and yield levels
2. To identify the key factors contributing to the decline in maize production such as climate change, farm management practices and technological limitations
3. investigate the specific impacts of climate change on maize cultivation in Babati. Where we focus on variables such as rainfall patterns, temperature variations and extreme weather events

1.4 Significance of the Research

This study had being able to detect and rate the level of influence of climatic factors on maize production. This contributes to generation of knowledge since farmers can use the information gathered on the variable that has the greatest impact on production to change and adopt new practices to increase production. This could also help them figure out what's causing the differences in maize production between farms.

1.5 Beneficiaries

Users of the results of this research includes

i. Researchers

   The results and outcomes of this research can be used in future researches where by the researchers may use this study as a starting point for their own research, resulting in improved methodology or better strategies for generating better research results.

ii. Famers

   The outcomes of this study will enable the farmers to be able to plan and use mitigation measures by implementing procedures and agronomic practices that will help them boost their yields despite of the changing climatic factors.

iii. Agriculture institutions

   Will enable them to perform analysis and modeling so as to invent new breeds that are resistance to the climate change

iv. Government

   Aware of the performance of previous implemented policy such as kilimo kwanza and how to make decision concerning the ongoing climate change which is affecting the production of Maize

1.6 Scope and Limitations of the Research

Analysis of historical trends, identification of contributing causes, examination of the effects of climate change, and evaluation of government actions are the main topics of this study, which examines the drop in maize output in Babati Region and its effects on food security and nutrition.

The Babati Region of Tanzania is the sole geographic area of the study. The main restrictions on this research include time, complicated relationships among elements, generalizability to other places, and data availability and quality.

1.7 Description of study Area

The study was conducted within the Babati district of Northern Tanzania, spanning the region between the boundaries of Dareda and Bashnet. The study area is situated approximately within the latitude range of -4.264 to -4.2077 and the longitude range of 35.488 to 35.746. The elevation across the study site varies from 1,635 to 2,200 meters above sea level. Notably, this area is characterized by limited fertilizer use and encompasses a single growing season extending from November to June.

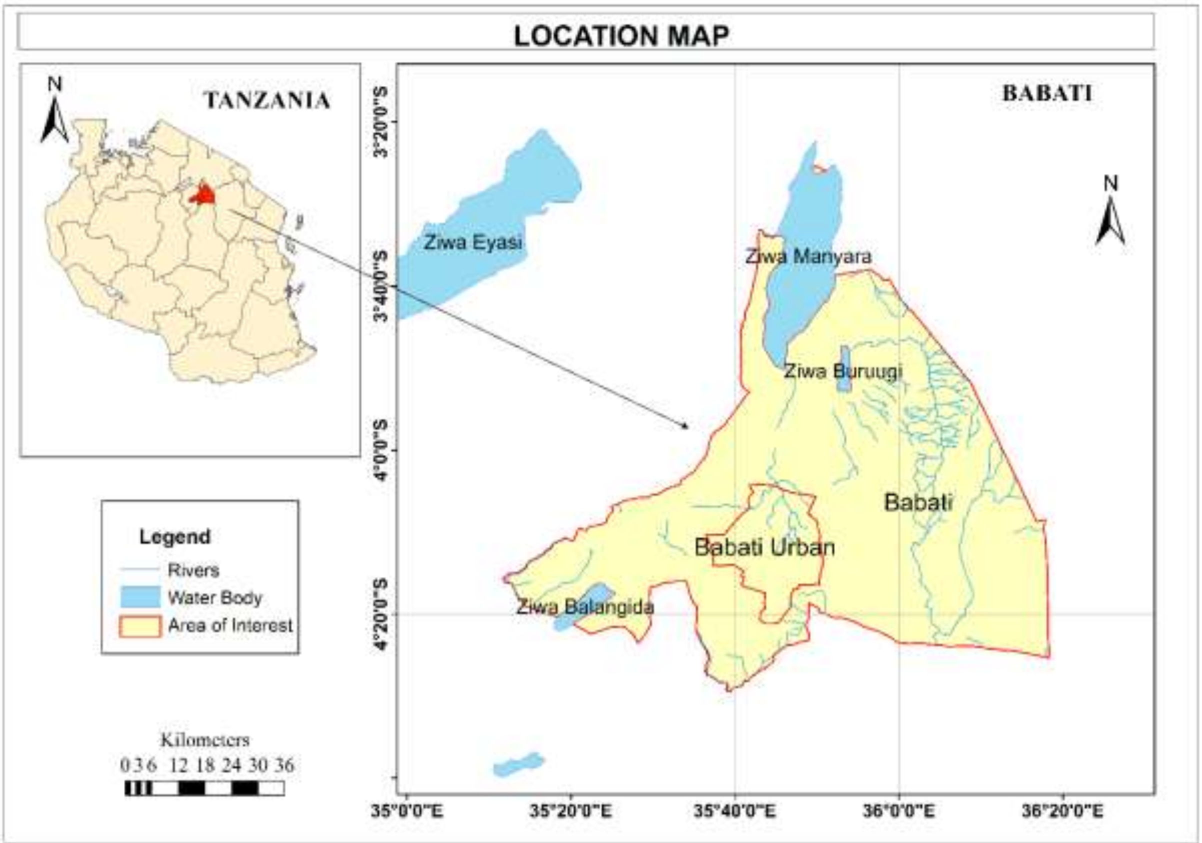

Figure 1.1 Location of the study area

1.8 Dissertation Organization

This dissertation consists of five chapters (5), explaining in detail all the methods and the results obtained in assessment of how climate factors such as temperature and rainfall are affecting maize production.

Chapter 1

This chapter explains the background of the study, which gave rise to the problem. The objectives, research questions, significance and beneficiaries of the research that provide an overview of the research results, significance, beneficiaries, scope and limitation to show the research extent.

Chapter 2

This chapter gives the review of the study describing information from several literatures about climate change, food security. It explains climate variability in relation to maize production.

Chapter 3

This chapter describes the methodology utilized to achieve the research objectives as well as a flow chart that explains the entire process of reaching the goals of the study. The methods for data collecting and processing.

Chapter 4

This chapter provides the analysis and discussion of the results. It shows the results obtained in this study and the results obtained by previous studies which provides the path to achieving the research objectives.

Chapter 5

This chapter contains the conclusion and recommendations for the study. Whereas the conclusion based on the research objectives as well as recommendations based on the research findings

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

In this chapter provides a review of various literatures related to climate change, climate variability, trend analysis of climate variables, maize crop yield production and food security

2.1.1 Climate

Climate, representing the average weather conditions over a given area, encompasses various meteorological factors such as temperature, humidity, cloud cover, precipitation, air pressure, and wind patterns. While daily weather changes are observable, more subtle climatic shifts occur over extended periods. Babati's climate is characterized by distinctive variations in temperature and rainfall, which significantly impact agricultural productivity and food security within the region.

2.1.2 Climate Change

Climate change denotes significant shifts in the mean or variability of climate, persisting over decades. Its global implications encompass a range of challenges, including temperature fluctuations, altered rainfall patterns, and increased incidences of pests and diseases. These changes have dire consequences for agricultural production, quality, and productivity, often impacting vulnerable regions like Babati. Notably, rainfall has exhibited a concerning decrease, while temperatures have experienced alarming increases. Such transformations pose a considerable threat to Tanzania's socio-economic progress, jeopardizing human lives, food resources, and water reserves.

2.1.3 Climate variability

Climate variability refers to deviations from the mean state of climate variables across temporal and spatial scales beyond those of individual weather events. It results from internal and external processes inherent to the climate system. While climate variability operates over shorter intervals, climate change encompasses longer timescales. Within Babati, variations in precipitation and temperature occur, shaping the dynamics of crop production. These variations, especially when prolonged, can exert considerable influence on agricultural output, necessitating adaptive strategies. According to predictions, climate change will have a variety of effects on Tanzania, including an increase in temperature and changes in rainfall patterns, as well as an increase in extreme events, sea level rise, and water resource depletion (Msangi, 2020). By 2100, temperatures are expected to climb by 2-4 °C, warming up more in the interior of the country and during the dry season (Mwatawala, 2016). According to numerous general circulation models (GCMs) and climate trends, rainfall over Tanzania's southwest highlands will decline in the future, whilst rainfall over the country's northern and eastern highlands and the Lake Victoria basin would somewhat increase (Ngailo, 2014).

2.1.4 Climate variability impacts on crop production

The production of agriculture is negatively impacted by climate change and the rise in extreme weather occurrences (Prakash, 2020). Multiple general circulation models (GCMs) are used to analyze climate trends and scenarios. Projected temperature increases have an impact on the wilting and drying of plants, the proliferation of pests, weeds, and diseases, and shortfalls in crop yields (Chiagoziem, 2017). Additionally, the anticipated increase in rainfall is likely to have an impact on infrastructure damage, pest infestations, disease outbreaks, and leaching of nutrients, which would lead to low crop yields and a disruption of the food supply chain (Ramamasy, 2007). Technology, genetics, climate, soil, fertilizer treatments, tillage, irrigation management, population density, planting date, and depth are some of the factors that affect agricultural production and their variability (Irmak, 2018). These include things like weather and climate, which have been shown to significantly affect crop yield trends despite technological advancements and other factors (Kotani, 2017). Weather and climate are important drivers or influences of agricultural production systems. Climate change affects environmental conditions by increasing temperatures, especially during extreme events like heat waves, altering the seasonality of rainfall, increasing the frequency and severity of floods and droughts, and causing sea level rise (SLR). Beyond the effects of changes in climatic conditions, climate variability is predicted to have substantial effects on food production in some locations in the future. This includes an increase in the frequency and intensity of extreme events. According to (Mwatawala, 2016), intra- and interpersonal fluctuations in precipitation and temperature have an impact on Tanzania's crop production. Increases in seasonal temperature have the biggest effect on yields. According to this study, by 2050, average maize, sorghum, and maize yields in Tanzania will decrease by 13%, 8.8%, and 7.6%, respectively, as a result of expected seasonal temperature increases of 2 °C (Pedram, 2011). By 2050, crop yields may also be affected, albeit to a lesser extent, by potential changes in seasonal total precipitation as well as intraseasonal temperature and precipitation variability. For maize, sorghum, and maize, a 20% increase in intra-seasonal precipitation variability lowers agricultural production by 4.2%, 7.2%, and 7.6%, respectively (Pedram, 2011).

2.1.5 Food security

Tanzania is ranked 94th out of 113 nations in Global Food Security Index, showing overall poor progress toward food security targets. North, east and northwest are much vulnerable to food shortage this is due to lower rainfall. High food pmaizes, agricultural pests and illnesses, and a lack of farm inputs are all factors hurting the populations food security (Economist & Unit, 2016). People experiencing moderate food insecurity are typically unable to eat a healthy, balanced diet on a regular basis because of income or other resources constraints (Development, 2021)

2.2 Regression analysis

This is a statistical technique used to investigate the relationships among different variables where there is variable X, called an independent or explanatory variable, or simply a regressor and the variable Y, refered to as the dependent or target variable. Regression is used to determine the strength of the relationship between dependent variable Y, and a series of other changing variables known as independent variables (Majumadar et al.,2017)

2.2.1 The simple linear regression

The relationship between an independent variable X and an explanatory variable Y is explained as linear model as shown in the equation below

$$\mathbf{y = \beta 0 + \beta_1 x_1 + \cdots + \beta n + \varepsilon} \qquad 2.1$$

In the above equation Y is approximately a liner function of x, and ε measures the discrepancy in that approximation. In nutshell ε contains no systematic information for determining *Y* that is not already captured in x. The coefficient $\beta_{1,}$ called the slope, may be interpreted as the change in *Y* for unit change in x. The coefficient $\beta_{0,}$ called the constant coefficient or intercept, is the predicted value of *Y* when x = 0

2.2.2 The Multiple linear regression

This is a variant of liner regression analysis where by this model is built to establish the relationship that exists between one dependent variable and two or more independent variable. In matrix form before applying the multiple linear regression to forecast the crop yield, it's necessary to know the significant attributes from the database. The attributes which are not significant should be neglected, p-value test is performed on the database to find the significant attributes and multiple linear regression is applied only on the significant. (Majumdar et al., 2017)

2.3 Trend Analysis

In this paper we used the Mann-Kendal test, a non-parametric statistical test based on rank system, to detect the trend in long-term rainfall data series. The MK test is mainly used for detecting trend in hydro-climatic data series as the lower sensitivity to any sudden change. To perform this test, it is essential to evaluate the presence of serial correlation within the data series. A positive serial correlation can support the expected number of bogus positive products in the MK test. For this reason, the serial correlation must be excluded prior to applying the MK test. To eliminate the serial correlation, the trend free pre-whitening (TFPW) technique proposed by Yue and Wang was used.

2.3.1 Mann-Kendall (MK) test statistic

The MK test is a rank-based non-parametric method used to check any trend in a given time series against the null hypothesis of no trend. (Mann 1945; Kendall 1975). Used to analyze data collected over time for consistently or decreasing trends.

2.3.2 R2 and Adjusted R2

Coefficient of determination R^2 measures the proportion of the variation in your dependent variable(Y) explained by your independent variables(X) for a linear regression model. R^2 shows how well terms (data points) fit a curve or line. Adjusted R^2 also indicates how well terms fit curve or line, but adjusts for the number of terms in a model. If you add more and more useless variables to a model, adjusted r-squared will decrease. If you add more useful variables, adjusted r-squared will increase. Adjusted R^2 will always be less than or equal to R^2 (Ciaburro, 2018)

2.3.3 Scatter plot and correlation

Scatter plot displays the strength, direction, and form of the relationship between two variables. A scatter plot is used graphically to represent the relationship between two variables, most scatter plots contain a line of best fit, which is a straight line drawn through the center of the data points that best represents the trend of the data (Yolanda, 2019). Correlation coefficient measuring the strength of that relationship. All correlations have two properties; strength and direction. The strength of a correlation is determined by its numerical value and it indicates how strong the relationship is between the two variables. The direction of the correlation is positive or negative. The closer a positive correlation lies to +1, the stronger it is, while the closer a negative correlation is to -1, the stronger it is. If the numerical values of a correlation are the same, then they have the same strength no matter if the correlation is positive or negative (Yolanda, 2019).

2.3.4 Hypothesis Testing in Multilinear Regression

To test a hypothesis in statistics, the three steps are performed, which includes formulating a null (H0) and alternative hypothesis (H1), Building a statistic to test the hypothesis made, to define a decision rule to reject or not to reject the null hypothesis (Ezequiel, 2013). The aim of hypothesis test is to check the model parameters if are helpful in measuring the usefulness of the model. According to (Steveny, 2020), the errors, in the model are to be normally independently distributed with mean zero and variance α2.The linear relationship between the dependent and independent variables can be determined or checked by testing the significance of the regression, this can be done by using the null hypothesis (H0) and the alternative hypothesis (H1). The rejection of (H0) indicate that at least one of the independent variables contribute significant to the model. The P-value can be used to test the hypothesis, such that to reject the (H0) the P-Value for F-Statistics is less than α (Usually less than 0.05 the null hypothesis is rejected hence the alternative hypothesis) while the null hypothesis is not rejected when $\alpha<$p-value. Therefore, the p-value is an indicator of the level of adminissibility of the null hypothesis. The higher the p-value, the more confidence we can have in the null hypothesis, which is p-value allows the determination of significance levels of those in which the null hypothesis is rejected (Ezequiel, 2013).

2.4 Multilinear Modeling using R software

In multilinear regression modeling using R Software, regression model using the lm () function is created. The model determines the value of the coefficients using the input data. Using R software data are modified, and the rainfall and temperature influencing factors that may be seen the use of R to formulate the multilinear regression model, prediction of the new value and checking the validation can be done following the normal steps on multilinear regression modeling (Steveny, 2020). The multilinear regression should start with a scatter plot of the response versus the predictor, with an examination of appropriate graphs, such as a scatter plot matrix (Steveny, 2020). This technique of using R studio is used to find and to show the causal effect relationships between the variables (Steveny, 2020). The result of scatter plot matrix suggests the good start of multilinear regression modeling, based on little or no curvature observed in any of the panels of the plot. Linear regression is to be fit based on the number of predictors suggested, that is k (Steveny, 2020).

2.5 Farm Management Practices

Farm management practices in Babati are pivotal for ensuring agricultural productivity and food security in the region these practices encompass crop rotation, diversification, and improved seed varieties to optimize yield potential. Soil conservation techniques like contour plowing and terracing are employed to prevent erosion and maintain soil fertility, while water management strategies such as rainwater harvesting and irrigation address the challenges of variable rainfall patterns. Integrated pest management combines natural predators and judicious pesticide use to combat pests and diseases sustainably. Additionally, adopting conservation agriculture, efficient fertilizer application, and livestock integration fosters sustainable and diversified farming systems. Access to knowledge exchange, training, and market opportunities further enhance Babati's agricultural practices, ultimately contributing to resilient and sustainable food production amidst changing climatic conditions.

2.6 Government initiatives and Policies

The Tanzanian government has undertaken substantial initiatives to confront climate change and environmental challenges within the nation, exemplified by its endorsement of international and regional environmental treaties (NEMC, 1994; URT, 2007). However, effective implementation of these objectives has been impeded by systemic issues such as corruption, technological obsolescence, limited expertise, and governmental capacity constraints in tackling environmental concerns. In the specific context of Babati and the concerning decline in maize production, these government initiatives hold implications for small-scale farmers. Pertinent policies addressing environmental preservation and climate adaptation may indirectly influence farming practices, altering cultivation methods to align with sustainability goals the outcomes of these initiatives could signify an enhanced emphasis on climate-resilient agricultural practices, potentially fostering the adoption of innovative strategies among small-scale farmers to mitigate the adverse effects of climate change on maize production.

CHAPTER THREE

METHODOLOGY

3.1 Overview

This chapter gives an overview of the techniques, including everything from data collection through results. It comprises the techniques used for data collecting, data preprocessing, and data analysis to provide the results. In order to accomplish its main goal, this study adopts the Multilinear Regression technique for data processing and trend analysis of maize yield and meteorological variables. The trend line slope was taken into consideration when predicting the future maize yield. Figure 3.1 provides a summary of this study's step-by-step procedure performance.

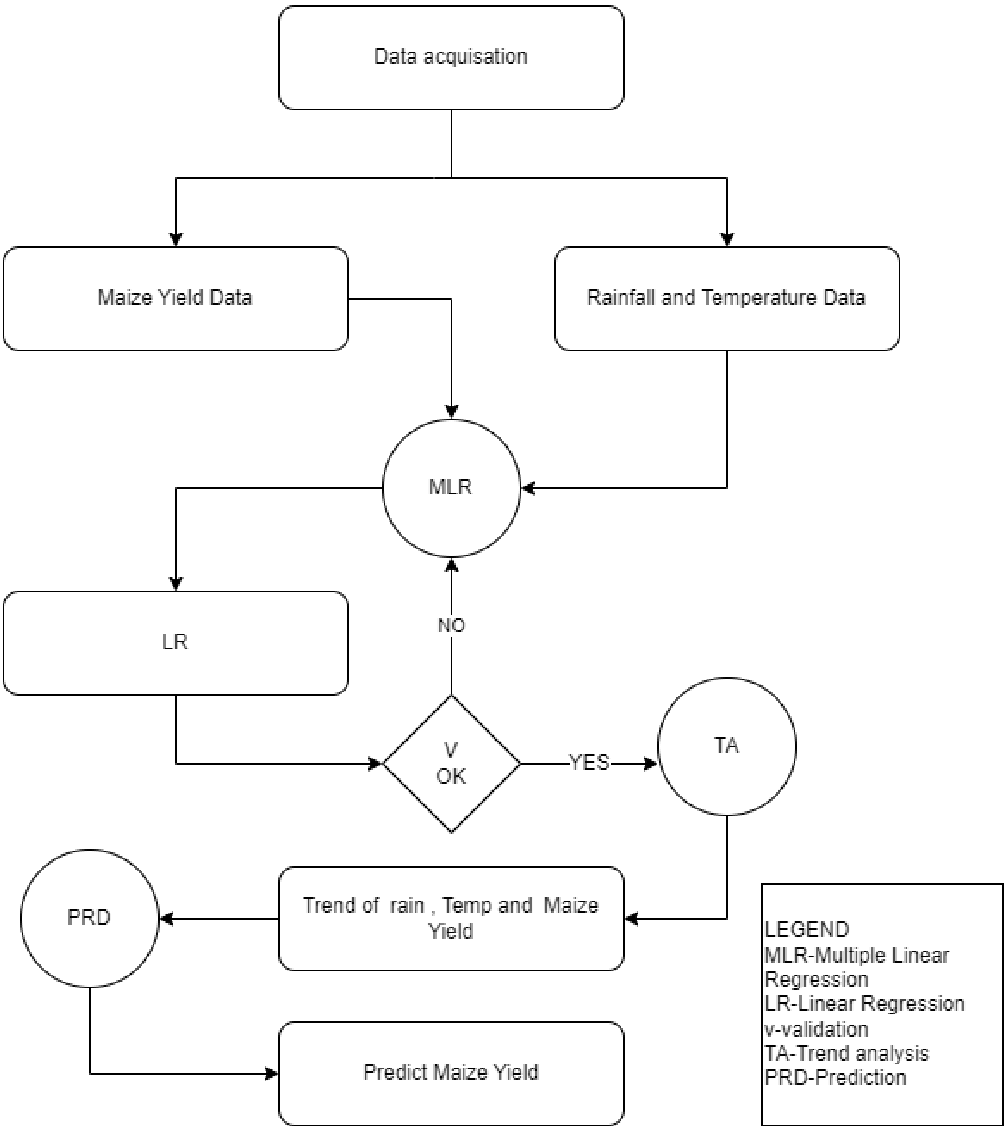

Figure 3.1 Methodological flowchart

3.3 Data Acquisition

The data used in this study includes Babati district maize yields for 2000-2020 in tones per hectares, temperature (Tmax and Tmin) in ℃ and rainfall in mm per year summarized in Table 3.1. The maize yield data were obtained from IITA where these data were used to obtain the production trend in the study area. Temperature, rainfall data were downloaded freely from Terr climate database having a spatial resolution of approximately 4km.

Table3.1 Characteristics of research data

NO	DATA	SOURCE	Duration	Format
1	Maize yield data	IITA	2010-2020	csv
2	Temperature	(http://www.climatologylab.org/terraclimate.html)	2000-2020	csv
3	Rainfall	(http://www.climatologylab.org/terraclimate.html)	2000-2020	csv

3.4 Methods

The multilinear regression mathematical model that has been adopted in this research as it is shown in the equation 3.1 with β0, β1, β2, β3, β4 regression coefficients, maize yields as dependent variable and annual rainfall, maximum temperature and minimum temperature as independent variables.

$$\text{Maize yield} = \beta 0 + \text{Rainfall}.\beta 1 + \text{Tmax}\beta 2 + \text{Tmin}\beta 3 + \varepsilon \qquad 3.1$$

3.4.1 Data preparation and pre-processing

In order to use the remote sensing data, pre-processing was required so as to prepare the data for further analysis. The preprocessing steps involved in both the rainfall, and temperature data was aggregation. Aggregation of the monthly rainfall, and temperature data was done to obtain the annual estimates of the variables, which are required for analysis of annual trends. Correlation analysis between the maize yield data and rainfall, and temperature data was performed so as to understand the relationship between the dataset either they have a strong relationship or a weak relationship. The data were then combined and arranged on excel as csv file format ready for processing.

3.4.2 Data processing

The data arranged in csv file were added in R-statistics software and the dataset were split as training set (60%) and as test set (40%). The training set data were used to build the model and test set were used to validate the model. In order to perform MLR modelling the data should be normally distributed and there should not be multicollinearity problem between independent variables. The collected maize yield data were statistically analyzed to check if the data is normally distributed. 60% of the maize yield data, rainfall and temperature data were then used to calibrate the model (Training sets), where the model was fitted in the datasets. The model was formulated with the dependent variable of annual maize yield and independent variables as annual rainfall, maximum temperature and minimum temperature as they are shown on the regression model as it was formulated on the software. In building the model the backward elimination method was used. It started by fitting all the possible predictors in the model, then the predictors with highest p-value were removed and the model was fitted again. Equation 3.5 illustrates the model used to fit the datasets.

$$\text{Maize yield} = \beta0 + \text{Rainfall}.\beta1 + \text{Tmax}\beta2 + \text{Tmin}\beta3 + \varepsilon \qquad 3.5$$

The formulated model was run and provides the summary that provides the model adequacy and effect of the variables towards the prediction of new data. After running the model, the p-value of F-Statistics was 4.045e-07, with the Multiple R-Squared (R^2 =0.8956) and Adjusted R-Squared (Adjusted R^2 =0.8732) highly correlated and closer to each other, showing that the model adequacy is perfect for prediction and its variables can be used. See the Summary of the regression model as illustrated on Table 3.2.

3.4.3 Trend analysis of maize yield and climatic variables

The analysis of trends was done using linear regression equation shown in equation 3.2 with the y-axis the variable, m the trend line slope and the x-axis the years so as to detect general of a relationship between variables and project the future direction of this pattern. The variables were plotted against time in years and the trend line showed the slope of direction of the pattern. For a negative slope trend, it implied the decrease in the variable each year while the positive slope implied the increase in variable per each year. The equation used to perform Trend analysis is as shown in equation 3.2.

$$y = mx + c \qquad 3.2$$

3.4.4 Predicting future Maize yield

The prediction was done considering the trend line slope where as in order to get the future two years variable, the slope was multiplied with two then the value obtained was added to the last value of the variable during trend analysis as shown in the equation 3.3 and 3.4.

Predicted maize yield 2024= maize yield2020+ (slope*2) 3.3

Predicted maize yield 2024= maize yield 2020+ (slope*2) 3.4

3.5 Software utilized

In this research, the software used was R programming language through the R studio platform. R programming language was used in the data processing of maize yield, rainfall, and temperature data such processes include the extraction of rainfall, and temperature data for the study, manipulation of data to obtain monthly and annual rainfall, and temperature for the years 2000-2020, model validation, determining the trend of temperature, rainfall, and maize yield.

There are number of software used to achieve the final product based on the research objectives as shown below

Table 3.2 summary of software used

S/N	SOFTWARE	USES
01	ArcGIS	Data presentation, analysis and pre-processing
02	RStatistic	Data processing
03	Microsoft Excel	Data preparation

In adoption of the best MLR model the factors that were considered in checking the model adequacy included; the coefficient of determination (R^2), the root means square error of the model, significance code. A good MLR model is the one that has lowest RMSE and high R^2.

3.8 Model Validation

In the validation process, a deliberate selection of 40% of the maize yield data was employed to rigorously test and validate the model's estimations. This proportion was chosen to strike a balance between having a sufficiently representative dataset for validation purposes and ensuring that a substantial portion of the data remains available for training the model. This allowed for a robust assessment of the model's predictive performance. The model's predictive capabilities were leveraged to generate forecasts for the designated validation dataset the predicted values were then compared against the actual maize yield values. This comparative analysis provided a comprehensive evaluation of the model's accuracy and effectiveness in estimating real-world maize yield outcomes, which ultimately contributes to the reliability and applicability of the model's results.

CHAPTER FOUR

RESULTS, ANALYSIS AND DISCUSSION

4.1 Overview

In this chapter the results obtained through the implementation of research methodology and discussion are presented according to the intended objectives of this research which was to model the climate variability in relation to maize production using remote sensed data. These results include graphs showing trend of rainfall, temperature, maize yield, graphical representation of predicted maize yields. In the discussion section the existing adaptation strategies in maize farms were reviewed in relation to the trend in yield per hectare from the year 2000-2020 in Babati District so as to identify the suitable adaptation strategy that should be recommended while looking at climate condition using the results from the research analysis.

4.2 Model Validation

The validation of the model was done by comparing the values of test sets and predicted maize yields and by checking the correlation of maize yield data on the same years between observed and predicted maize yields which provide the coefficient of determination, R^2 of 0.9444 which is a strong relationship. The observed yield test set and the predicted dataset were compared as shown in Table below.

Table 4.1 Observed Yields and Predicted Yields

Year	Observed Yields(ton/ha)	Predicted Yields(ton/ha)
2010	2.77	2.97
2011	1.9	2.15
2012	2.1	2.66
2013	2.5	2.66
2014	1.56	1.68
2015	2.40	2.9
2016	2.32	2.46
2017	2.12	2.33
2018	2.19	2.08
2019	1.8	1.45
2020	2.3	2.1

Figure 4.1 below shows clear visual representation of the observed maize yields and the corresponding predicted maize yields for each year is provided. One key observation is the consistent pattern of the predicted yields closely aligning with the observed yields across most years. This alignment shows accurately estimating maize yields for these specific timeframes.However, it's essential to note that certain years exhibit noticeable deviations between the observed and predicted yields. For instance, in the years 2011, 2014, and 2019, the predicted yields slightly overestimate the observed yields. On the other hand, in the years 2015 and 2020, the predicted yields are notably higher than the observed yields.

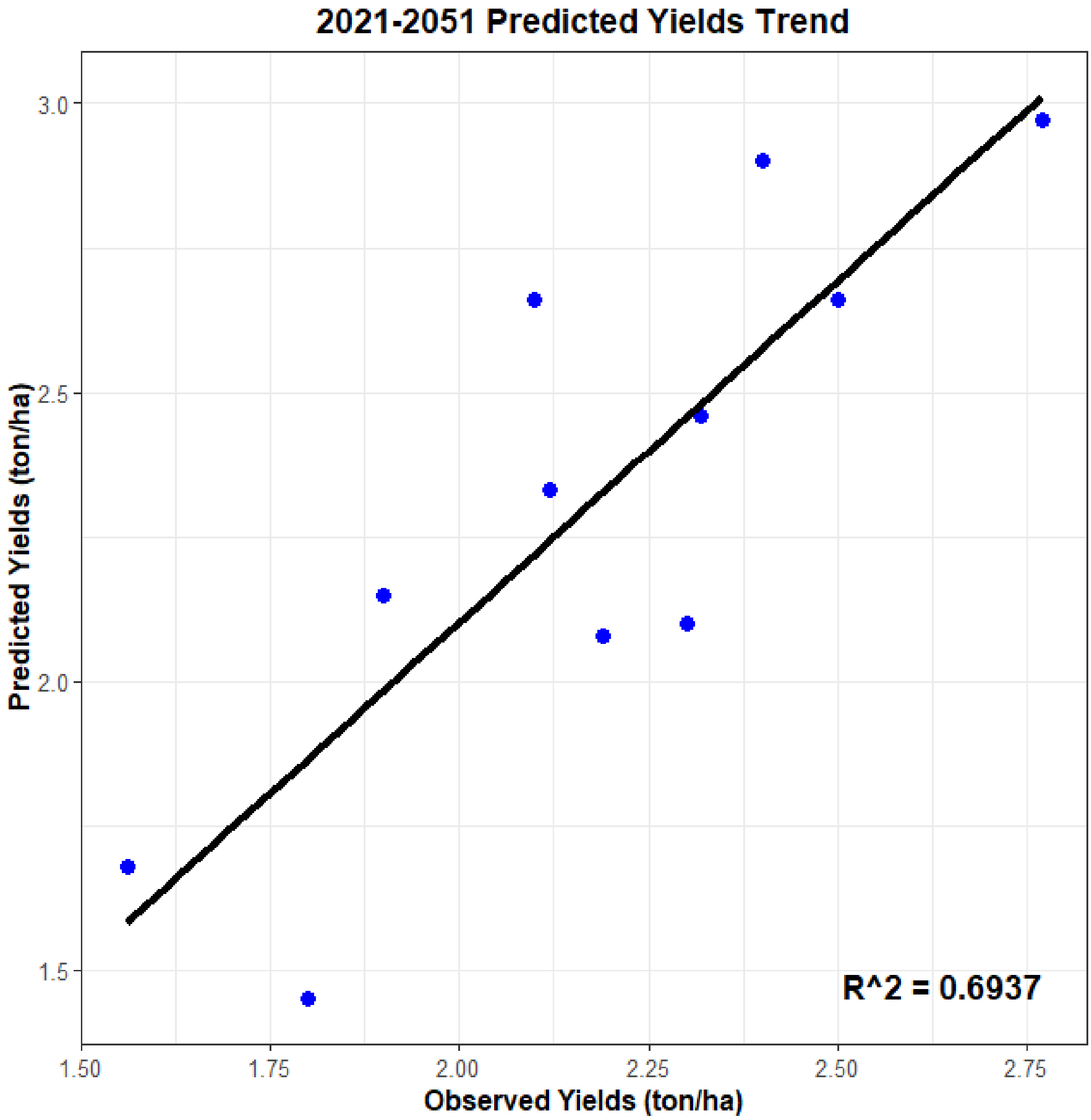

Figure 4. 1 Observed maize yields and predicted maize yields

4.3 Babati Maize yield trend

Annual Babati maize yield for 20 years (2000-2020) was found to range from 1.4 and 3.5 tonnes per hectors. The maize yield trend based on the observed information it shows the mazie yield trend is not constant, it decreases at an average of 0.005 tonnes per hector each year from 2000 to 2020 this trend underscores a broader pattern wherein maize yield experiences a general decrease over the years. This tells the situation of prediction also, that maize yield is decreasing over each year, not continuously but randomly, since sometimes it falls, then increase again. R-squared value of 0.048613 indicates that only about 4.86% of the variability in maize yield can be explained by the predictors in the regression model, suggesting a limited ability of the model to capture the underlying trends or factors influencing maize yield.

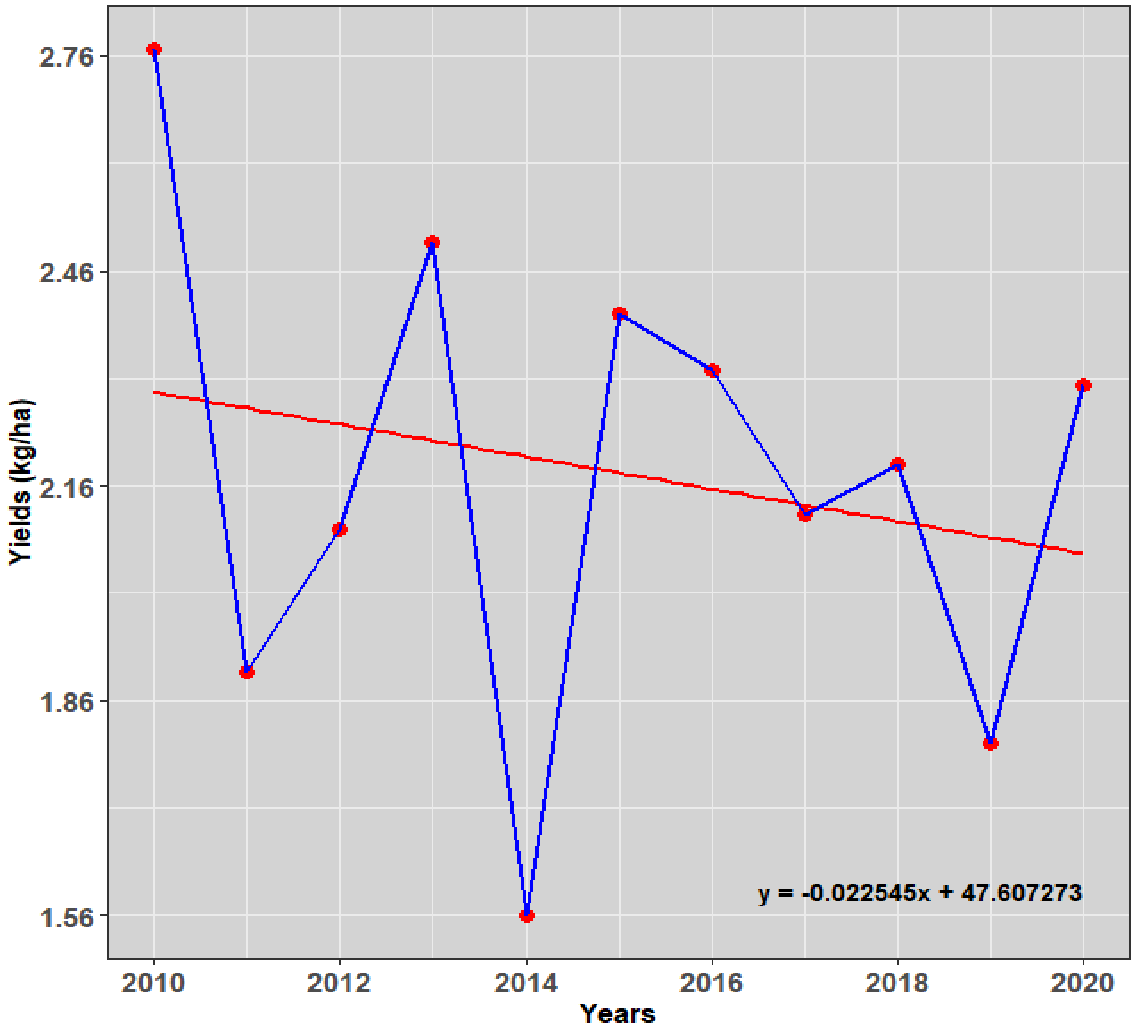

Figure 4.2 shows the Maize yield variation over the graph each year, from 2000 to 2020.

4.4 Rainfall Trend over the study period.

Annual Babati rainfall for 20 years (2000-2020) was found to range from 574.15 to 1395.93 mm per annum. Results of trend analysis in rainfall revealed that trends in annual rainfall is not constant, has statistically significant increase and decrease randomly in different years at Babati. Figure 4.3 represents the trend variation in annual rainfall over each year. General annual rainfall in Babati showed a declining trend of 1.44 mm per year. The decreasing trend in annual rainfall was significant ($p<0.1$) in most of the years during the period 2000-2020.

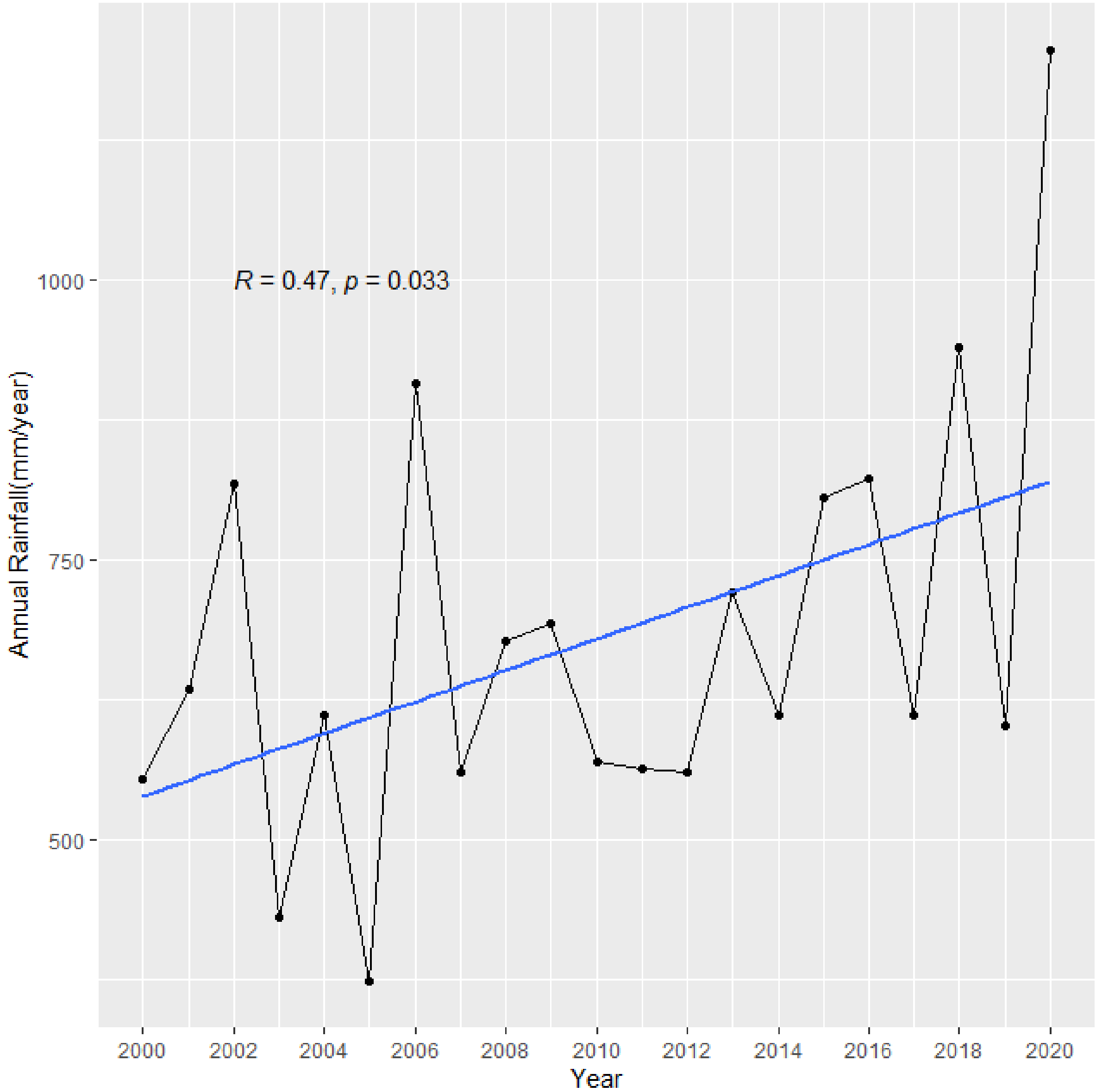

Figure 4.3 Babati Rainfall trend from 2000-2020

Figure 4.4 below shows the relationship between rainfall and maize yield with a correlation coefficient (r) of 0.95, which indicates a strong positive relationship between rainfall and maize yield. That was for most years the maize yield is high when rainfall is high and maize yield is low when rainfall is also low and optimal. This indicates that rainfall is highly significant to maize yield.

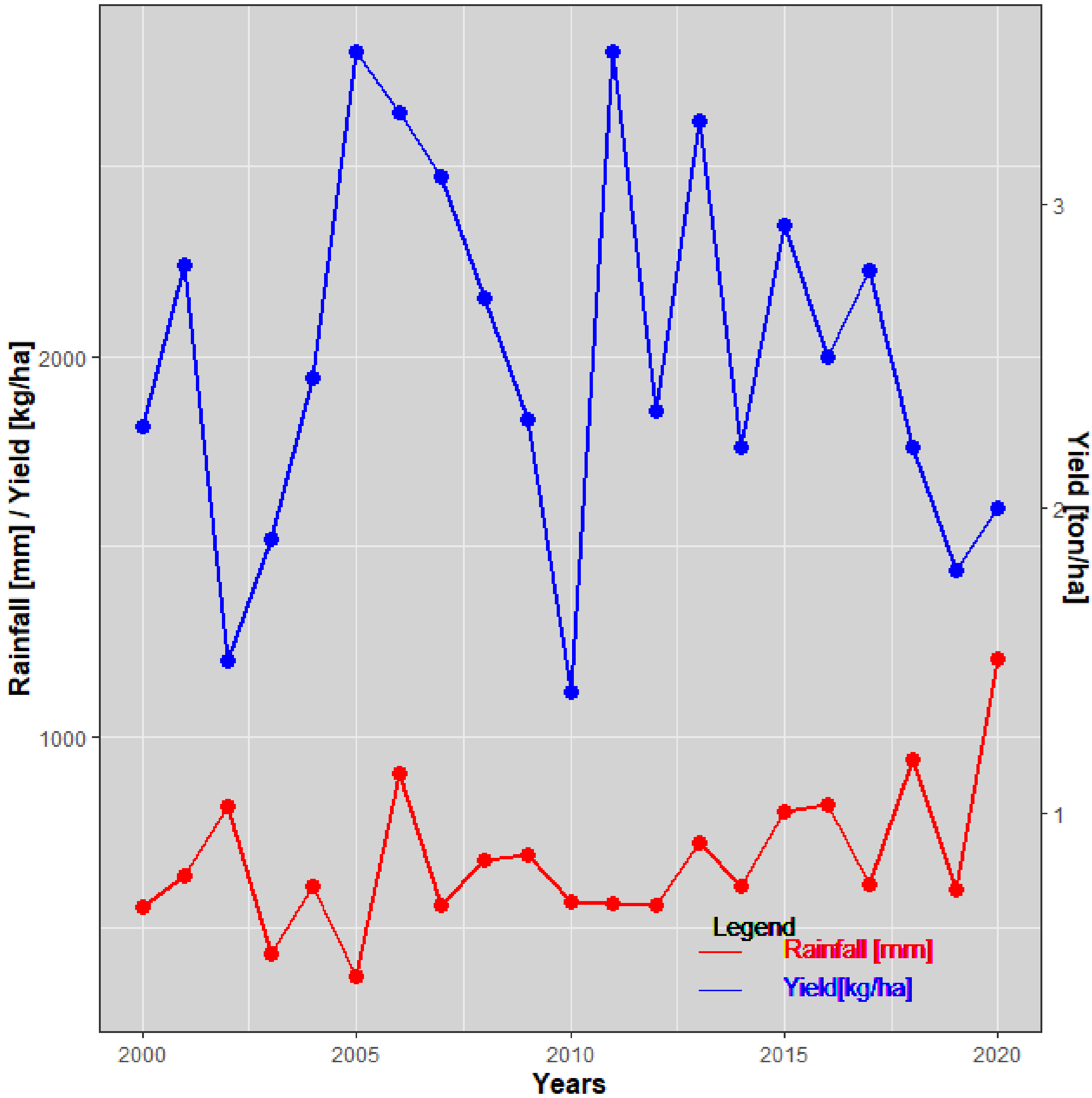

Figure 4.4 Babati Yields and Rainfall trend from 2000-2020

4.5 Maximum Temperature Trend

Annual Babati maximum temperature for 20 years (2000-2020) was found to range from 20.0941 to 28.9132 °C. Trend analysis of annual maximum temperature revealed varying temporal trend that there is an increase trend in maximum temperature of 0.01℃ per year as illustrated in

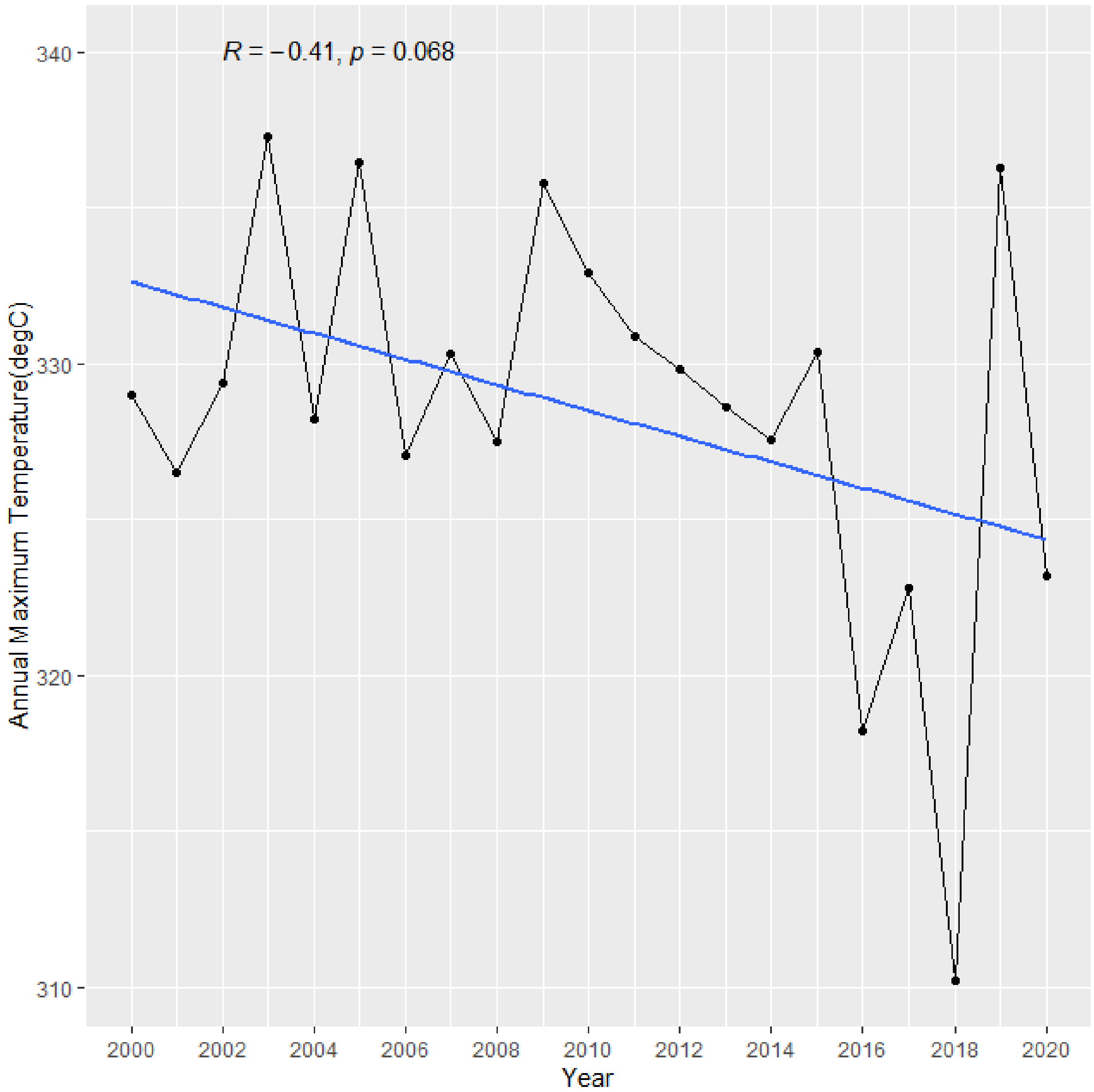

Figure 4.5 High temperature had significant effect in maize yields.

The figure 4.6 below represents distribution map which reveals the variation of maximum temperature of Babati the northern part of Babati receives high maximum and in the southern plains of Babati the temperature is low.

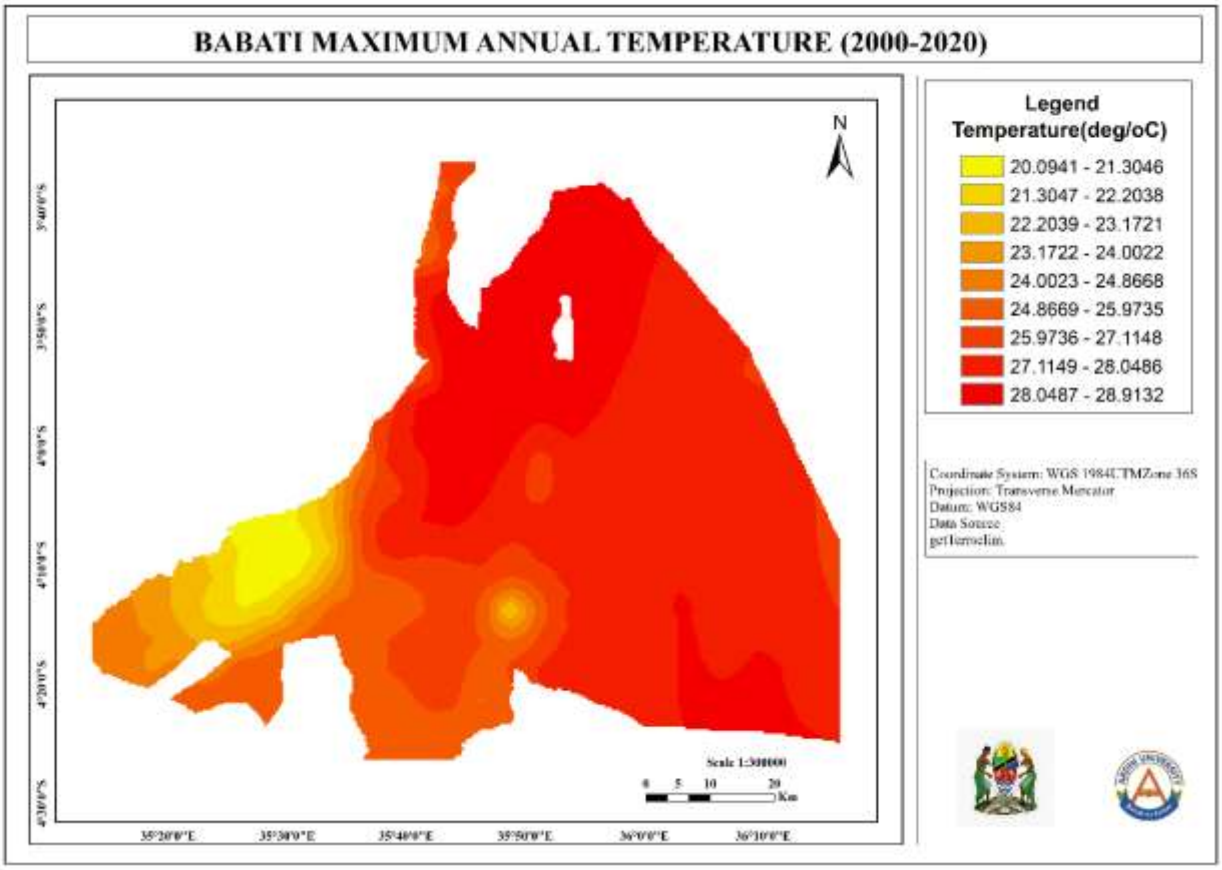

Figure 4.6 Babati Yield and Temperature trend from 2000-2020

Figure 4.7 below shows the relationship between Maximum temperature and maize yield with a correlation coefficient(r) of -0.95, which indicates a strong negative relationship between maximum temperature and maize yield. That is maize yields are high when the maximum temperature is low or optimal and the maize yields are low when maximum temperature are high. This indicates that maximum temperature affects maize yield negatively.

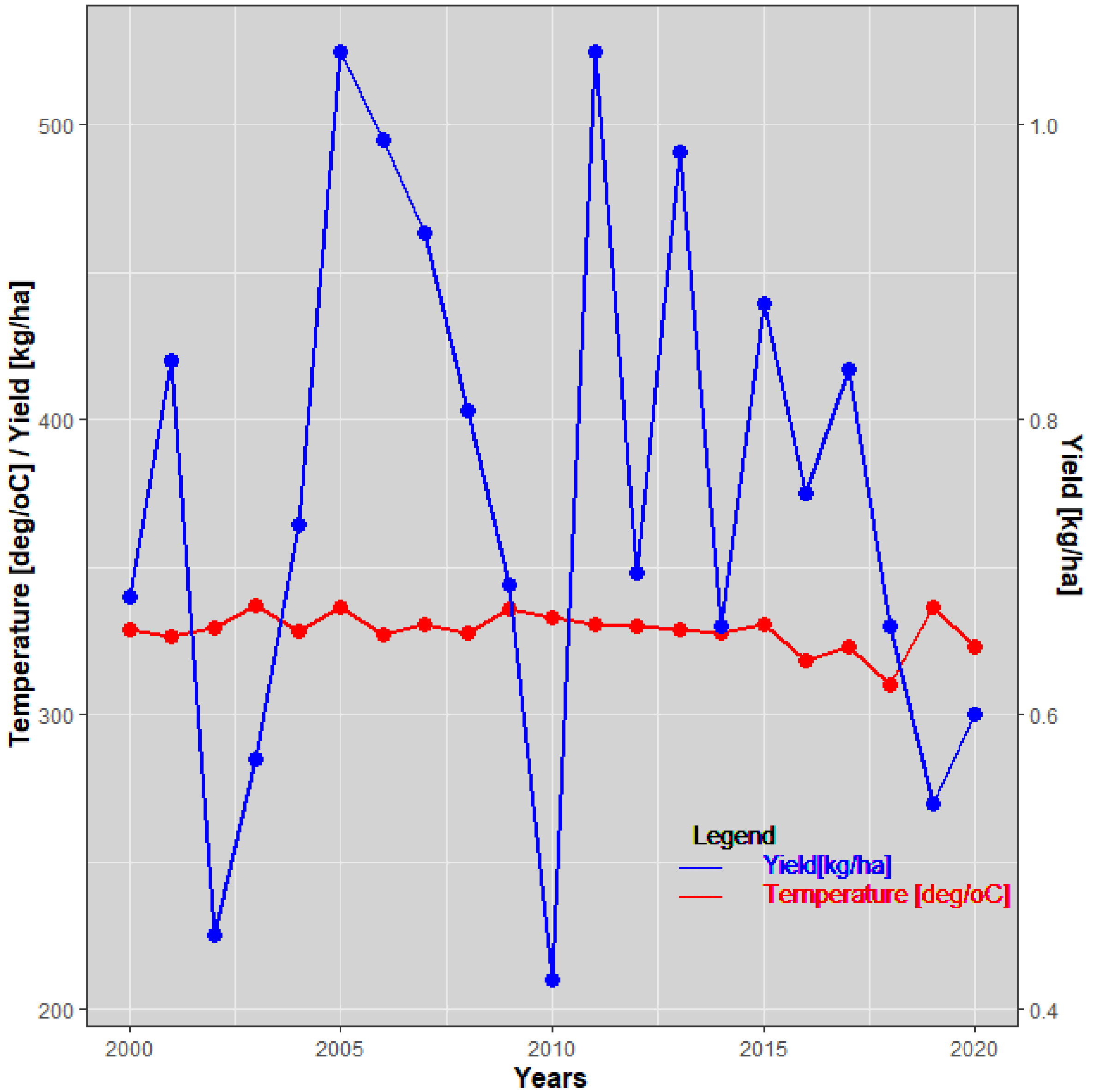

Figure 4.7 Babati Yield and Temperature trend from 2000-2020

4.6 Minimum Temperature

Annual Babati minimum temperature for 20 years (2000-2020) was found to range from 11.01 to 12.95 °C. Analysis of annual minimum temperature also revealed varying temporal trend that there is an increase trend in minimum temperature of 0.01℃ per each year. Figure 4.7 show the relationship between minimum temperature and maize yield with a correlation coefficient (r) of -0.27, which indicates a strong negative relationship between minimum temperature and maize yield. That is maize yields are high when the minimum temperature is low or optimal and the maize yields are low when minimum temperature are high. This indicates that minimum temperature affects maize yield negatively.

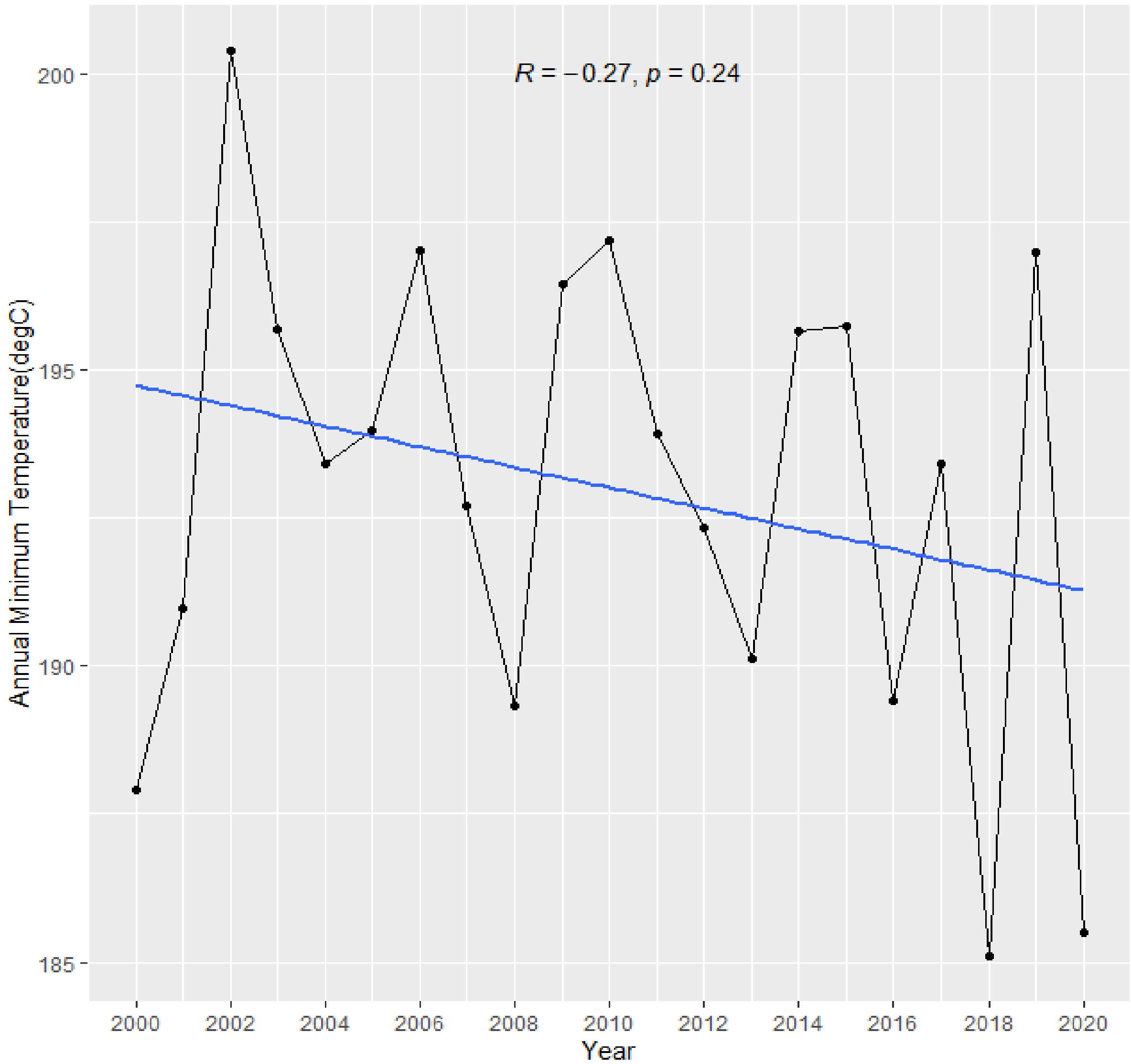

Figure 4.8 Babati minimum Temperature trend from 2000-2020

4.7 Maize Yield Prediction

Babati Maize yield prediction was done for 20 years (2021-2051), the prediction of maize yield follows the same trend as it studded on the trend analysis. Thus, the predicted maize yield information is useful to both expected users. The results aim to help farmers, decision makers and agricultural scientists at Babati district in Manyara region to come up with proper mitigation and adaptation measures to cope with climate variability. However, on the results obtained, one thing can be studded from the observed and predicted maize yield information that the range of maize yield decreases each year, as it is shown on trend analysis of maize yield. This tells the truth of the prediction that it adopts the existing maize yield experience as it has been decreasing from 2000 to 2020, and thus the prediction adopts the same that maize yield will always keep decreasing even for the upcoming years than the predicted ones. Figure 4.9 illustrates the predicted maize yield trend with a decreasing trend of 0.005 tons per hectors each year.

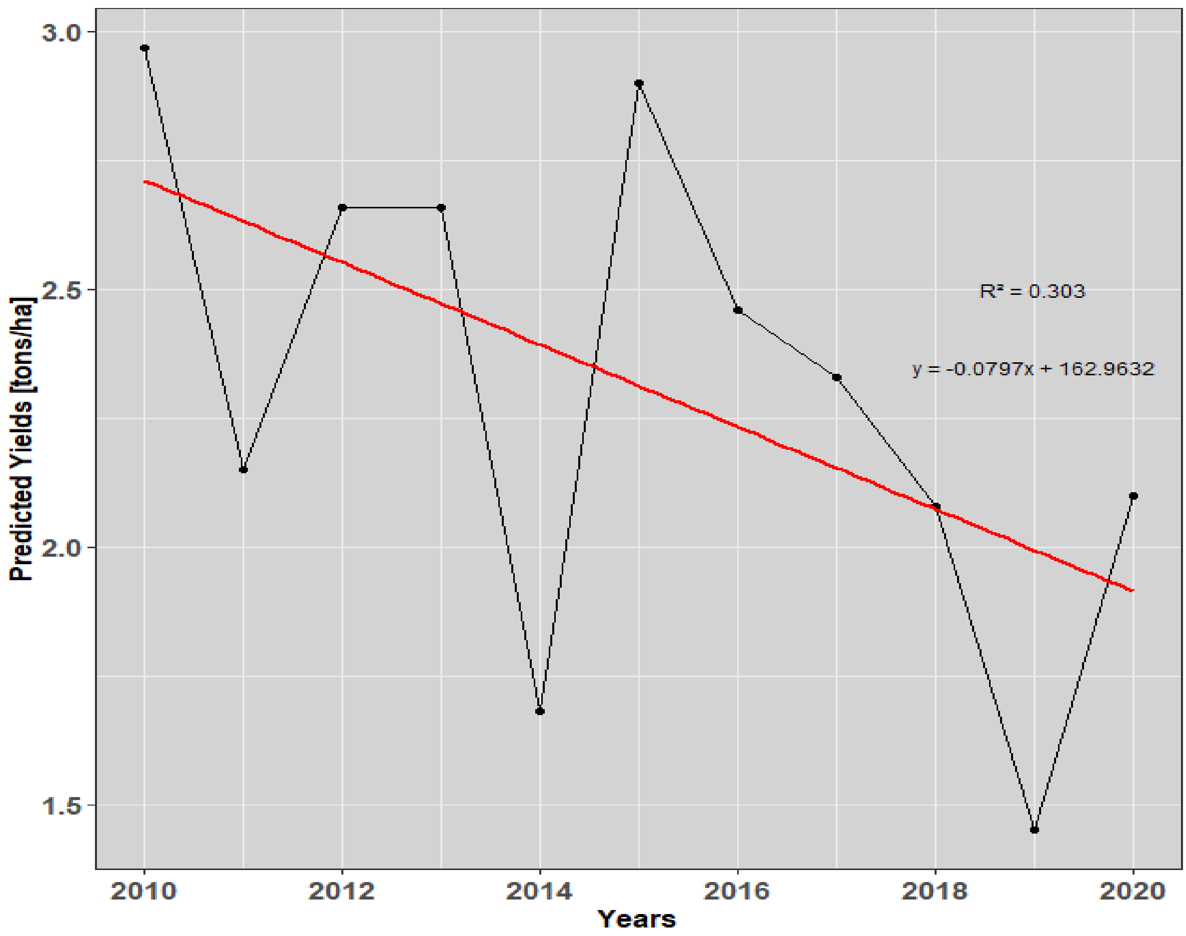

Figure 4.9 yield trend over predicted years

The coefficient estimate table below present the results of the regression analysis, providing insights into the relationships between the variables and the response. Notably, the intercept exhibits a statistically significant positive effect on the response, as indicated by its low p-value (2.4e-05) and high t-value (6.36). Regarding temperature variables, Tmax (maximum temperature) demonstrates a negative relationship with the response, indicating that an increase in Tmax is associated with a decrease in the response, though its significance is marginal (p = 0.03). Conversely, Tmin (minimum temperature) has a positive impact on the response, with a higher Tmin linked to an increase in the response, and this impact is statistically significant (p = 0.01). Rainfall plays a substantial role, showing a highly significant positive effect on the response (p = 1.01e-07), with an increase in Rainfall corresponding to an increase in the response variable. The coefficient estimates and their associated statistics collectively provide valuable insights into the predictive power and significance of these variables in the regression model.

Table 3.3 Regression model summary

coefficient	Estimate	Std Error	t-value	Pr(>│t│)	Significance code
(intercept)	11.83	1.86	6.36	2.4e-05	***
Tmax	-0.4	0.16	-2.49	0.03	*
Tmin	0.45	0.14	3.23	0.01	**
coefficient	Estimate	Std Error	t-value	Pr(>│t│)	Significance code
Rainfall	0.003	0.0003	9.93	1.01e-07	***

4.8 Discussion of results

4.8.1Effects of climate variability on maize yield

The research analyzed the yields of maize from the year 2000-2020 in relation to extracted annual rainfall, maximum temperature and minimum temperature. The research has found out that maize yield trend is decreasing every year at an average of 0.005 tons per hector. These results were in agreement with the study by (Rowhan, 2011) on climate variability and crop production in Tanzania. Rowhan report that changes in climate between and within seasons have a significant relationship between maize yield and seasonal mean precipitation, with an increase in precipitation favoring yields.

4.8.2 Effects of temperature on maize yield

The research found out that Maximum Temperature was observed to rise at range of 0.01℃ each year and minimum temperature was found to rise at a range of 0.01℃. This indicates that as time goes on temperatures are increasing which is likely going to affect maize production since optimal temperature for maize cultivation is between 25℃ and 35℃.These results were in agreement with the study by (Nagabhatla, 2016) on impacts of temperature and rainfall variation on maize productivity. The result indicated that temperature higher than the average temperature of 21-23℃ during the ripening period had a negative impact on maize yield and results in the production of poor-quality maize. Maximum and minimum temperatures of the region were found to rise in the 20 years (2000-2020).

4.8.3 Effects of rainfall on maize yield

The research found out that rainfall trend was decreasing at a range of 1.4mm each year which indicates there is a need to put efforts on adaptation strategies so as to cope with the effects of such changes given that maize requires much more water than any other crop.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Overview

In order to address the research questions for the study, which are compiled in the conclusion, this chapter is based on the data from the results and analysis chapter. where the recommendation is also included

5.2 Conclusion

In conclusion, this study has shed important light on how climate factors (rainfall, temperature, etc.) relate to maize output in the Babati Region. The results show a substantial positive correlation between rainfall and maize yield of 0.95, suggesting that more rainfall has a favorable impact on maize production. However, there was a strong negative association between temperature and maize yield, with values of -0.99 and -0.93, respectively, indicating that higher temperatures are bad for maize output.

The research discover concerning trends over a thirty-year period, shows a case that decreasing pattern in rainfall with a negative slope of 1.44mm and contrasting positive slopes of 0.6mm and 0.01°C for temperature. These observations hold crucial implications for the region's agricultural landscape and overall food security.

The survey also revealed a worrying reduction in the output of maize in the Babati Region, which has contributed to food insecurity, particularly among weaker groups like children. Climate change has become one of the main causes of this reduction. This study attempts to address the issue and guarantee food security in the area by comprehending the particular impacts of climate change on maize production and investigating adaptive methods.

The specific goals of this study include assessing the state of maize production in Babati at the moment, pinpointing the main causes of the decline, looking into the effects of climate change on maize farming, and assessing the success of current government programs like the kilimo kwanza program in assisting maize farmers.

The study reveals that annual rainfall exhibits a non-constant pattern, with statistically significant fluctuations of increase and decrease occurring randomly across different years. The general trend, however, indicates a concerning decline in annual rainfall at a rate of 1.44 mm per year. The examination of annual maximum temperature highlights diverse temporal trends, with an observed increase of 0.01°C per year. Notably, the maize yield trend emerges as similarly variable, exhibiting a non-constant trajectory marked by an average annual decrease of 0.005 tonnes per hectare from 2000 to 2020. These findings emphasize the intricate interplay between climatic variables and agricultural output in Babati, calling for adaptive strategies to address the evolving challenges and ensure sustainable agricultural productivity in the face of changing environmental dynamics.

5.3 Recommendations

This study in view of the findings and conclusion made recommends the following,

- Encourage early planting and the use of early maturing cultivars: Given the negative effects of climate change on maize output, it is advised to encourage early planting and the use of early maturing cultivars. By synchronizing the agricultural growth cycle with more favorable environmental conditions, these approaches can help reduce the dangers brought on by changing climate patterns, such as unpredictable rainfall and elevated temperatures.

- Improve climate information services: Farmers must have access to fast, accurate climatic information in order to make informed decisions and adjust their farming techniques. In order to provide farmers with accurate predictions, early warning systems, and advice on climate-resilient farming techniques, it is advised to strengthen climate information services and extension programs. This gives farmers more control over how they schedule their planting, irrigation, and other agricultural activities, reducing the effects of climate fluctuation.

- Improve soil fertility management: The effects of climate change on maize output might be made worse by low soil fertility. Implementing efficient soil fertility management approaches, such as good nutrient management and soil conservation methods, is therefore essential. To increase the resiliency and production of their maize crop, farmers should get education and help in adopting sustainable soil management measures.

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