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EFFECTS OF CLIMATE VARIABILITY ON MAIZE YIELD IN WUKARI LOCAL GOVERNMENT AREA OF TARABA STATE, NIGERIA

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ABSTRACT: *This study evaluated the impact of climate variability on maize yield in Wukari Local Government Area, Taraba State, from 1999 to 2018. Utilising an ex-post facto and analytical design, the quantitative research relied on secondary data from the Nigeria Meteorological Agency (NIMET) and Agriculture Development Program (ADP), Jalingo. Data analysis involved descriptive (time series trend analysis) and inferential statistics (Ordinary Least Square regression and correlation analysis). Findings indicated an increasing trend in average annual maximum temperature (62% variability) and a decreasing trend in average annual minimum temperature (44% variability). Additionally, there was an almost uniform but increasing trend in average annual rainfall (37% variability). Maize yield showed an increasing trend with a 50% variability. Correlation analysis revealed a non-significant strong positive relationship (r = 0.088, sig. 0.712 > 0.05) between average rainfall and temperature and a non-significant weak negative relationship (r = -0.072, sig. 0.762 > 0.05) between rainfall variability and maize yield. However, a significant moderate positive relationship (r = 0.564, sig. 0.010 < 0.05) was found between average temperature and maize yield. Linear regression analysis showed that 33% (r-squared: $r^2 = 0.333$) of the variation in maize yield was explained by changes in rainfall and temperature over the study period. The study concluded that rainfall and temperature significantly affect maize yield by 33%. Recommendations included adopting climate change mitigation and adaptation measures, such as using resistant and drought-tolerant species, and educating farmers on climate change impacts and adaptive strategies, including improved agricultural techniques and alternative water sources like irrigation and mulching, to ensure sustainable food security.*

KEYWORDS: Climate variability, Rainfall, Temperature, Maize yield, Effects.

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INTRODUCTION

Climate is the characteristic condition of the atmosphere near the earth's surface at a given place or region over a considerable period of time, usually 35 years and above (The Intergovernmental Panel on Climate Change [IPCC], 1992). Tim (2000) defined inter-annual climate variability as the observed inter-annual difference in value of specific climate variables within an averaging period (typically 30 years). Thus, climate variability can be regarded as variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events. Rainfall variability impact analysis is a way of looking at the range of consequences of a given rainfall event or change on given spatial phenomena (Kašpar,, Bližňák, Hulec & Müller, 2021).

Agriculture is highly dependent on climate and a critical part of the economy in most developing countries in Africa. Climate change and its variability are emerging as major challenges to agricultural development with the increasingly irregular and erratic nature of weather conditions placing an additional burden on food security and rural livelihoods (Food and Agriculture Organization [FAO], 2009). Climate variability has a direct and, in most cases, adverse influence on quality and quantity of agricultural crop production. The climate of an area is highly correlated to the crops cultivated and thus predictability of climate is imperative for planning of farm operations (Sowunmi, 2010).

Climate variability is expected to increase with global warming. Global warming refers to observed increase in temperatures over the last 50 years as a result of increased greenhouse concentrations in the atmosphere (Mikhaylov, Moiseev, Aleshin & Burkhardt, 2020). In the midst of the rise in global temperatures, changing local rainfall patterns, warming seas and melting of ice caps have been witnessed (Intergovernmental Panel on Climate Change [IPCC], 2007). Furthermore, global average temperatures are expected to increase by between 1.4°C and 6.4°C by 2100. This increase is above the threshold limit of 3oC beyond which it becomes impracticable to avoid dangerous interference with the global climatic system (World Trade Organization [WTO] & United Nations Environmental Programme [UNEP], 2009). This average is anticipated to be higher throughout Africa and Central Asia. In Africa average temperature is projected to rise 1.5 times more compared to the global level. Countries near the equator, many of which are developing, are likely to experience unbearable heat, more frequent droughts and ruined crops, exacerbating the hunger crisis (Food and Agriculture Organization [FAO], 2012; WTO & UNEP, 2009). However, increasing global temperature may have mixed outcomes, where crop production may increase in temperate regions but reduce yields in tropical regions (WTO & UNEP, 2009).

Beside the changes in temperature, over the years, rainfall patterns have changed, with cases of heavy rainfall at crop maturity and droughts occurring at critical stages of crop growth being common (Birech, Freyer, Friedel & Leonhartsberger, 2008). These changes are likely to severely compromise crop production and food security with colossal economic consequences in many African countries especially in sub–Saharan Africa (Gregory, Ingram & Brklacich, 2005). There is a likelihood that changes in temperature and rainfall patterns will affect the potential of crop production (Stern, 2007). The effects of climate variability on crop production could be direct or indirect. Directly the effect is through changes in temperature and precipitation that affect the

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timing of crop development (Joshi, Maharjan & Piya, 2011; Gbetibouo & Ringler, 2009; Gregory *et al.*, 2005). Rising temperatures are likely to reduce crop production in the long-term especially through reduction in the number of reliable crops growing days while changes in precipitation patterns are likely to increase short term crop failures and long-term production declines (Peiris, Crawford, Grashoff, Jefferies, Porter & Marshall, 1996; IPCC, 2007; Joshi *et al.*, 2011). Indirectly, climate variability may increase the population and growth of pests, insects, weeds and diseases making crop management difficult and costly. These conditions are likely to impact crop production in a negative way (Joshi *et al.*, 2011; Gbetibouo & Ringler, 2009).

According to IPCC (2007), because of climate change and variability there is an increased frequency and magnitude of extreme events. These events include storm and flash floods, droughts, heat waves or cold waves and coastal storms (Bedeke, 2023). These extreme events damage agricultural arable land and infrastructure. Increases of these events as experienced and projected in sub-Saharan Africa are likely to have adverse effects on crop production and food security raising the vulnerability of most developing countries (Bedeke, 2023; Wassmann & Dobermann, 2007; Schmidhuber & Tubiello, 2007).

In Taraba state, evidence of climate change includes delayed onset date of rains, increase in number of dry days during the raining season and increase in maximum temperature (Asa, Madaki & Jibo, 2024; Adebayo & Oruonye, 2012; Adebayo & Oruonye, 2013; Adebayo, 2012). This leads to warmer seasons, increased frequency and intensity of weather extreme events such as drought, decline in rainfall amount by about 15-20-person, increased incidence of dry spell (Adebayo, 1998; Anuforom, 2010 cited in Mohammed *et al.*, 2013). The problems of flood, high temperature and incidences of pests and diseases have also aggravated the farmers' loss which consequently increases the incidence of poverty and malnutrition in the state (Adebayo *et al.*, 2012). It is against this backdrop that this study assessed the effects of climate variability on maize (*Zea mays*) production in Wukari Local Government Area (LGA) Taraba State.

METHODS AND MATERIAL

The Study Area

Wukari Local Government is situated in the southern part of Taraba state. It is bordered to the north by Ibi Local Government Area, east by Gassol Local Government Area, from the south by Donga Local Government Area of Taraba State, and to the west by Ukum Local Government Area of Benue State. The Local Government Area has a total area of 4,308km^2 (1,663 square miles), located at 7°51′N 9°47′E (Figure 1). According to the 2006 National Population Census figures, Wukari has a population of 241,546 people (NPC, 2006).

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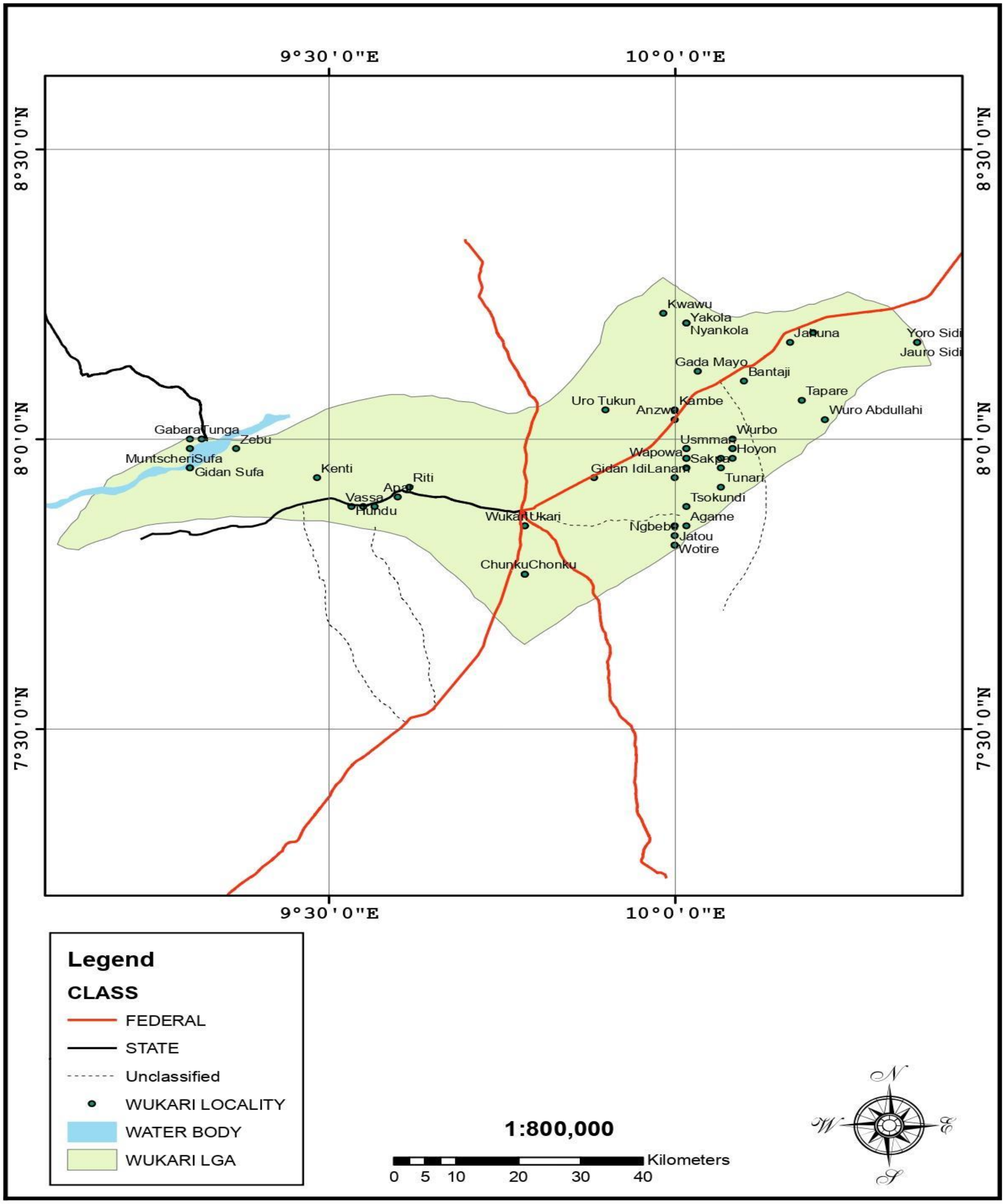

Fig 1: Map of the study area
Source: NAGIS, 2020.

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Methods

The study used secondary data for the analysis of climate change impact on maize yield, case of Wukari Local Government Area in Taraba State from 1999 to 2018. Climate data which include annual rainfall, temperature as well maize yield were sourced NA meta from Nigeria Meteorological Agency (NIMET 2016) while maize from ADP in Jalingo. Climatic records (rainfall and temperature) for the period 1999-2018 were extracted from NIMET annual publications of climatic variables while maize yield data was extracted from ADP annually. Descriptive analysis as well inferential analysis was used to find patterns in data for this purpose. Excel and EViews 10 were selected respectively (Quantitative method). For the descriptive statistics, we employed time series trend analysis which included the inferential methods such as Ordinary Least Square (OLS) regression and correlation analysis.

Microsoft Excel linear trend function and line chart for the time series data were used to analyse trends of climate variability. Trend analysis of time series showed the general increase or decrease in climatic variables over time, and further brought long-term patterns on rainfall amount, temperature profiles as well maize yield.

OLS regression analysis was performed to capture the effect of climate variability on maize yield We computed T-tests, coefficients of determination (R^2 and adjusted R^2), F-tests over standard error tests to test the contribution that climate variation made for changes on maize kernels in different altitudinal zones along with years. A functional relationship was established between the maize yield (dependent variable) and rainfall, temperature (independent variables).

The relationship is expressed as follows:

$$mY = f(Rf \text{ and } T) \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad (3.1)$$

Where: mY = maize output

Rf = Rainfall

T = Temperature

Writing equation 3.1 in the linear form, it becomes:

$$mY = \alpha + \beta_1 Rf + \beta_2 T + e \quad - \quad - \quad - \quad - \quad - \quad - \quad (3.2)$$

Where: mY = the dependent Variable

α = the intercept of the regression equation

β_1 = the regression coefficient of Rf

β_2 = the regression coefficient of T

e = the residual or random error terms which represent other variables that are not included in the model but have effect on maize yield.

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The theoretical apriori expectation of the parameters coefficients was that;

$$\beta_1, \beta_2 > 0$$

The Correlation Analysis: Correlation deals with the degree of relationship that exists between two or more variables. A correlation analysis was analysis carried out in the study to establish the various degrees of relationship that exist between the variables under consideration in the study. In carrying out the correlation analysis, the Karl Pearson's Product Moment Correlation Coefficient was adopted.

Decision Rule

A two-tailed test is considered statistically significant if the value of $P < 0.05$. Hence, if the value of $P > 0.05$, the null **hypothesis** was rejected and the alternative **hypothesis** accepted. Hence, the null hypotheses were accepted and the alternative **hypothesis** rejected.

RESULT AND DISCUSSION

The Trend of Rainfall and Temperature in the Study Area

Discussed below are the results of objective one, which deals with the trend of rainfall and temperature in the study area.

Trend of Rainfall

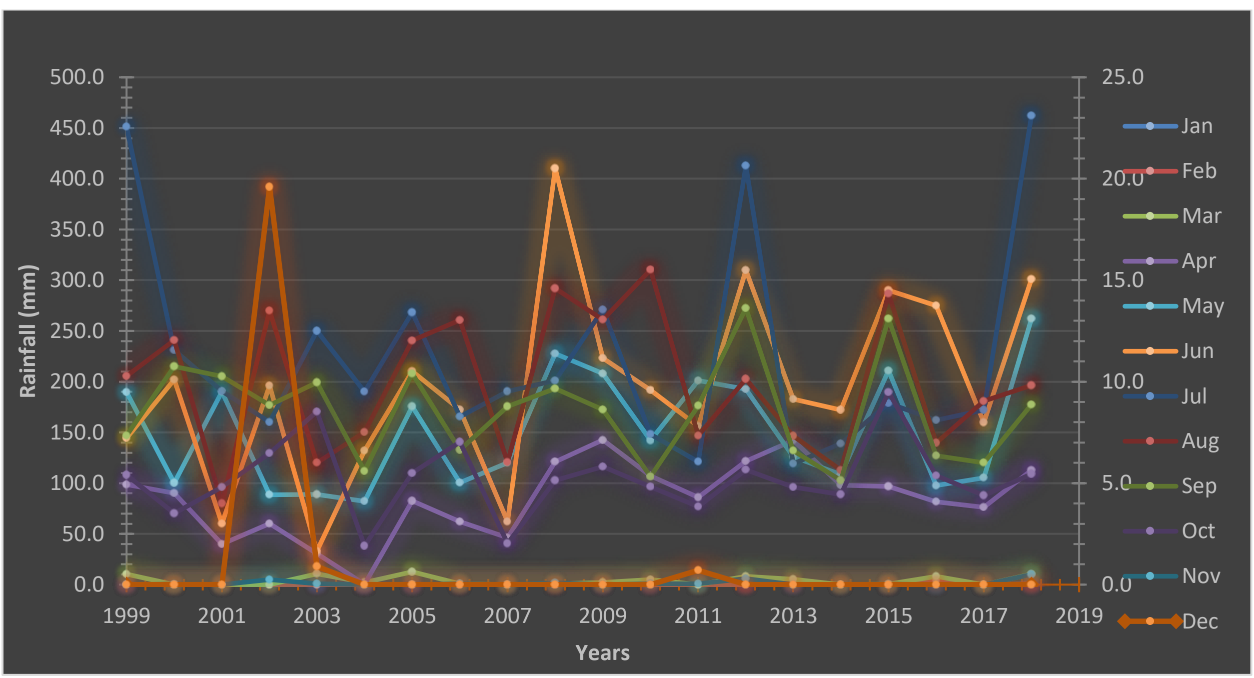

Fig 2: Trend Chart of Monthly Rainfall Distribution in the Study Area
Source: Authors' Computation, 2019.

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The data presented in Appendix I depicted the distribution of rainfall in the study area over a spread of twenty years on a monthly basis. The data also showed the average monthly rainfall distribution in the study area as well. The data presented in the table was a true representation of the pattern of rainfall in Wukari Local Government Area of Taraba State and thus showed the level of variability of rainfall in the study area as a result of the impact of climate change over the years. Looking at the results, it could be observed that the month of January over the past twenty years has never experienced rainfall in the study area. While other parts of Nigeria did experience what is considered unlikely rainfall during this month, Wukari Local Government Area was an exception, usually because it is located at the North-east part of the country, and because the month of January is considered the peak period of harmattan/dry season.

Besides the month of January that did not experience rainfall in the study area, the months of February through December recorded rainfall in the study area at a fluctuating rate. However, it is important to note that the months of February, December, November and March recorded the lowest drop of rainfall in the study area across the entire time frame under consideration. As depicted, the month of February experienced rainfall only in the year 2013 and 2018, recording an average rainfall of 0.3mm, while the month of December experienced rainfall in the year 2002, 2003, and the year 2011, recording an average rainfall of 1.1mm during these periods. In the same vein, the study area experienced rainfall in the month of November in the year 2000, 2002, 2003, 2006, 2008, 2010, 2011, 2012, 2015, and the year 2018, recording an average rainfall of 1.4mm across these years. Unlike the months of February, December and November, the month of March in the study area experiences more frequent rainfall over the time frame under consideration. It is however important to state that the frequent rainfall experienced during this month was less significant, as an average rainfall of only 3.8mm was recorded across the entire years under consideration.

The trend chart depicted in Figure 2 depicted and provided a vivid picture of the nature of rainfall variability on a monthly basis in the study area across the entire years under consideration in the study. From the trend chart, it can be observed that the peak periods of rainfall in the study area occurs in the months of June, July, August, and the month of September respectively. From the data presented in Appendix I, it can be observed that the month of June recorded an average rainfall of 194.2mm, while the month of July recorded an average rainfall of 224.2mm. Furthermore, the months of August and September recorded an average rainfall of 198.2mm and 170.7mm respectively. It is however important to explicitly state that the month of July is the peak period of rainfall in Wukari Local Government Area of Taraba State.

From the scattered plot in the trend chart, it could be observed that the highest drop of rainfall in a singular month was experienced in the month of July, in 1999 and 2018 respectively. During these periods, total rainfall for the month in question was recorded at 451.1mm (in the year 1999) and rainfall was recorded at 462.2mm (in the year 2018) respectively. Close to these figures for total rainfall for a singular month, is the month of June, 2008. During this period, rainfall was recorded at 410.2mm. For non-peak periods of rainfall, the month of December recorded significant rainfall for a singular month, at 19.6mm in the year 2002.

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Appendix II gave a detailed account of the rainfall trend rainfall variability in Wukari Local Government Area of Taraba State. Depicted in Figure 3, the trend plot in the chart showed a fluctuating trend mean rainfall in the study area. From the trend chart, it could be observed that from the period of 1999 to 2001 recorded a decreasing trend in average rainfall at 112.9mm for the year 1999, 95.8mm for the year 2000, and 71.8mm for the year 2001. The year 2002 experienced a slight increase in the average annual rainfall in the study area, recorded at 92.2mm. In 2003 and 2004, a decrease in the average annual rainfall was experienced. Within these two years, average annual rainfall was recorded at 75.4mm, and 58.9mm respectively.

From the trend chart, it could be observed that a significant increase in average annual rainfall in the year 2005 coursed an upward shift in the trend plot, as the average annual rainfall for this year was recorded at 109.0mm. This increase was however temporary as a decline in average annual rainfall was experienced in the year 2006 and 2007. During these years, average annual rainfall was recorded at 86.4mm and 63.0mm respectively.

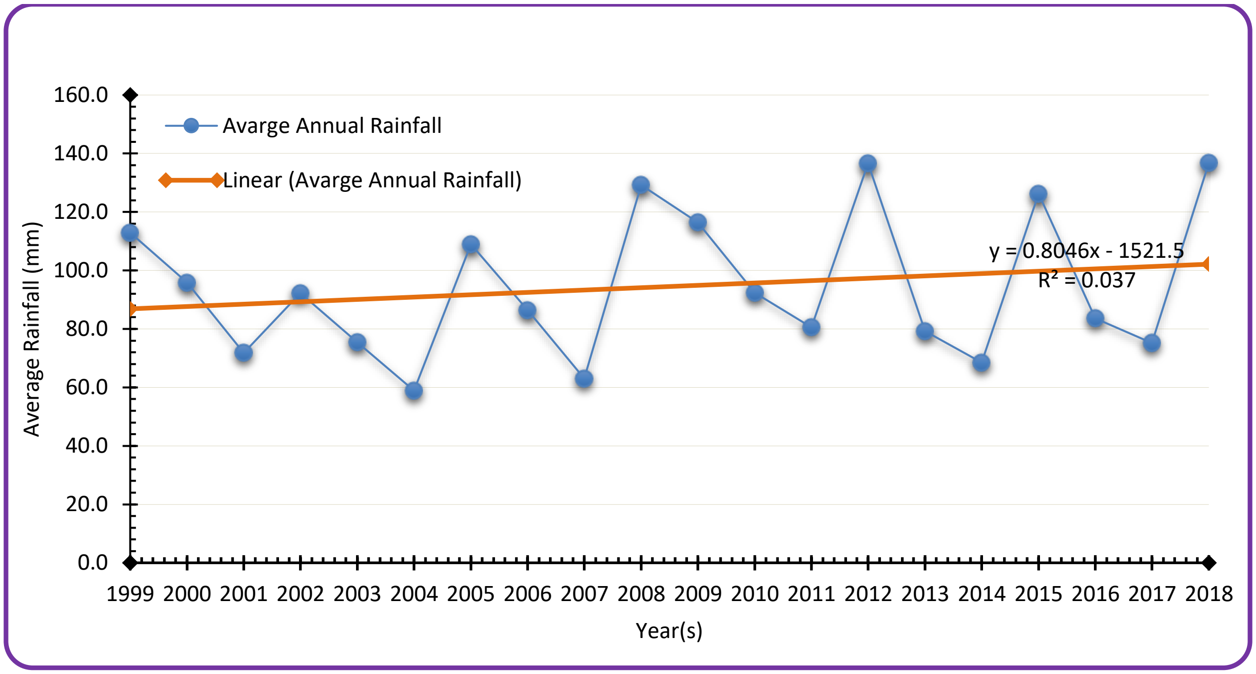

Figure 3: Trend Chart of Annual Average Rainfall

Source: Authors' Computation, 2019.

While the improvement in average annual rainfall was experienced in the years 2008 and 2009, it is important to note that this improvement can be said to be a remarkable increase compared to the preceding three years, as the average annual rainfall recorded were; 129.2mm and 116.4mm. The year 2010 and 2011 recorded a steady decline in the average annual rainfall of the study area. This decline is made vivid, as depicted by the downward slope of trend plot in the figure above. During these periods, the following amount of average annual rainfall was recorded; 92.4mm, and 80.5mm respectively. A look at the trend plot showed that an upward movement occurred in the year 2012. This upward movement by interpretation signified an increase in the average annual rainfall in the

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year concerned. The year 2013 and 2014 recorded a significant decline in the average annual rainfall of the study area. This decline is made vivid by a significant downward shift in the trend plot presented in the figure above. In this year, average annual rainfall was recorded at 79.2mm and 68.5mm. It

Compared to the previous year (2013 and 2014), the year 2015 recorded an increase in average annual rainfall at; 126.3mm, while the year 2016 and 2017 experienced a decrease in average annual rainfall at 83.6mm and 75.2mm. Worthy of note here is that the year 2018 recorded the highest average annual rainfall in Wukari Local Government Area of Taraba State across the period of 1999 to 2018, recording rainfall of 136.8mm. The value of r^2 in the trend equation indicates a variation in trend of annual rainfall at 37 percent.

Trend of Temperature in the Study Area

The Trend of Average Annual Maximum Temperature in the Study Area

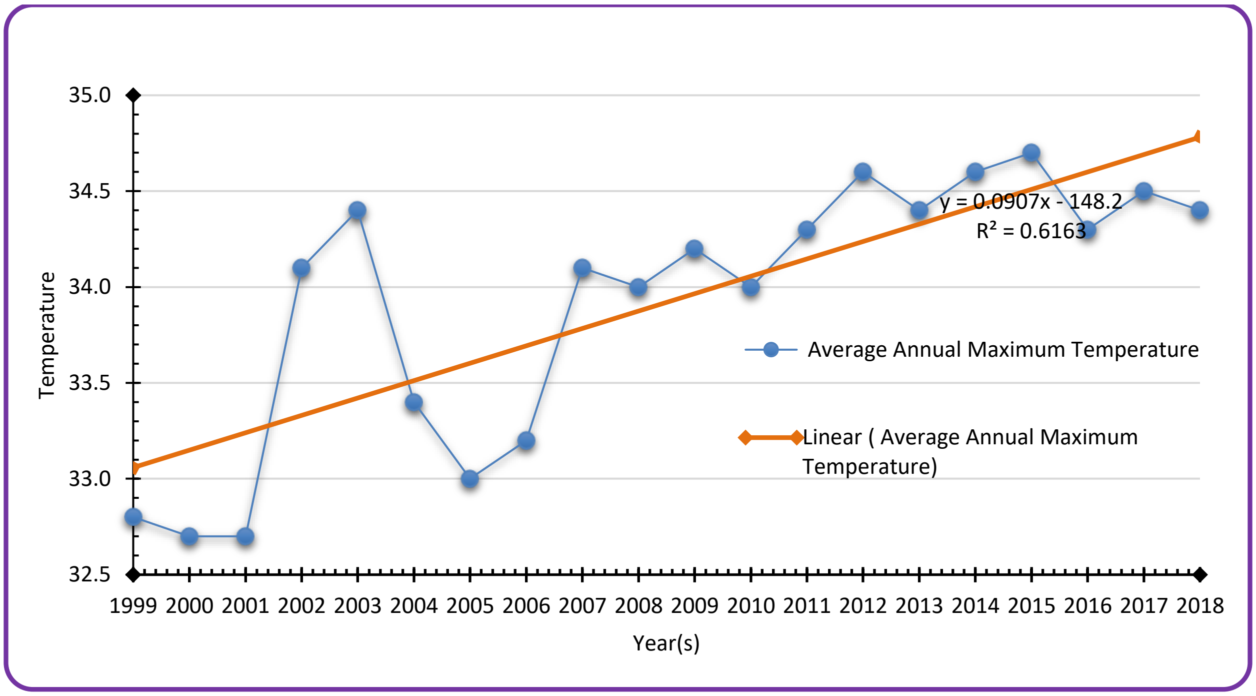

Figure 4: Trend Chart of Average Annual Maximum Temperature

Source: Authors' Computation, 2019.

The scatter plot depicted in Figure 4 represented the average annual maximum temperature trend in the study area across the period under consideration. From the chart, it could be observed that the trend plot is upward sloping in nature. The upward sloping plot of the linear trend line indicates an increasing trend in average annual maximum temperature in the area of study over the time frame under consideration.

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If we critically observe the trend plot from the period of 1999 to 2001, it will be noted that there was a steady decline in the average annual maximum temperature within these periods. In 1999, the average annual maximum temperature was recorded at 32.8ºC. In 2000, average annual maximum temperature recorded a slight increase compared to the preceding year, at 32.7ºC. While the year 2001 experienced the same average annual maximum temperature as that of the year 2000 at 32.7ºC. Compared to the years 1999-2001, the years 2002 and 2003 recorded a significant increase in the average annual maximum temperature in the study area, as depicted by the sharp upward movement of the trend plot chart. The increase in the average annual maximum temperature was indeed significant, as temperatures of 34.1ºC and 34.4ºC were experienced.

The sharp decline in the average annual maximum temperature experienced in the study area in the year 2004 and 2005 as depicted by the sharp downward slope of the trend plot. This sharp decline in average annual maximum temperature was however immediately accompanied by a gradual and steady increase in the average maximum temperature between the periods of 2006 to 2009 as depicted by the upward movement in the trend plot. Within these years the following average annual maximum temperature figures were recorded; 33.2ºC, 34.1ºC, 34.0ºC, and 34.2ºC respectively. While the average annual maximum trend in temperature in the study area was steadier and increasing during the periods discussed above (i.e., from 2006 to 2009), the year 2009 experienced a slight decline in average maximum temperature at 34.0ºC. The years 2011-2015 however experienced a much increasing but fluctuating trend in the average annual maximum temperature in the study area at; 34.3ºC, 34.6ºC, 34.4ºC, 34.6ºC, and 34.7ºC respectively. However, the year 2016-2018 experienced a fluctuating decline in the average annual maximum temperature, at 34.3ºC, 34.5ºC and 34.4ºC respectively.

Generally, the degree of variation in increase or decrease in a trend analysis is determined by the nature of the trend line. The degree of reliability of a trend line is determined by the nature of its R-square value. A trend line is said to be most reliable when its r-square value is at or near one (1). There are many types of trend line that can be employed in a trend analysis. However, for the purpose of this research, the researcher employed the linear trend line, because it is the best-fit straight line that can be used with a simple linear data set. The upward sloping nature of the linear trend line in the figure above thus implies a steady increase in Average maximum temperature in the study area over a 21-year period. Notice that the r-square value is 0.6163. This value is not 1, as such cannot be said to be a good fit of the line to the data. The value however implies that the degree of increase in the average annual maximum temperature in the study area over a 21-year period is 62 percent.

The Trend of Average Annual Minimum Temperature in the Study Area

Figure 5 depicts the trend of average annual minimum temperature in Wukari Local Government Area of Taraba State. A careful look at the trend plot shows a decreasing trend in the average annual minimum temperature in the area of study over the time frame under study. A gradual and steady decrease in average minimum temperature was recorded within the periods of 1999 to 2001 at 21.8ºC, 21.7ºC, and 21.6ºC respectively. However, the year 2003 experienced a significant rise in the average temperature of the study area as depicted by the upward movement of the trend chart. During this period, the average temperature recorded was 22.7ºC. From the trend chart, it

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can be observed that a decline in average temperature was experienced in the study area in the year 2004 and 2005, compared to the year 2003. More so, a constant level of average temperature was recorded (in the year 2004 and 2005). During these periods, the average temperature of the study area was 22.2^{o}C respectively.

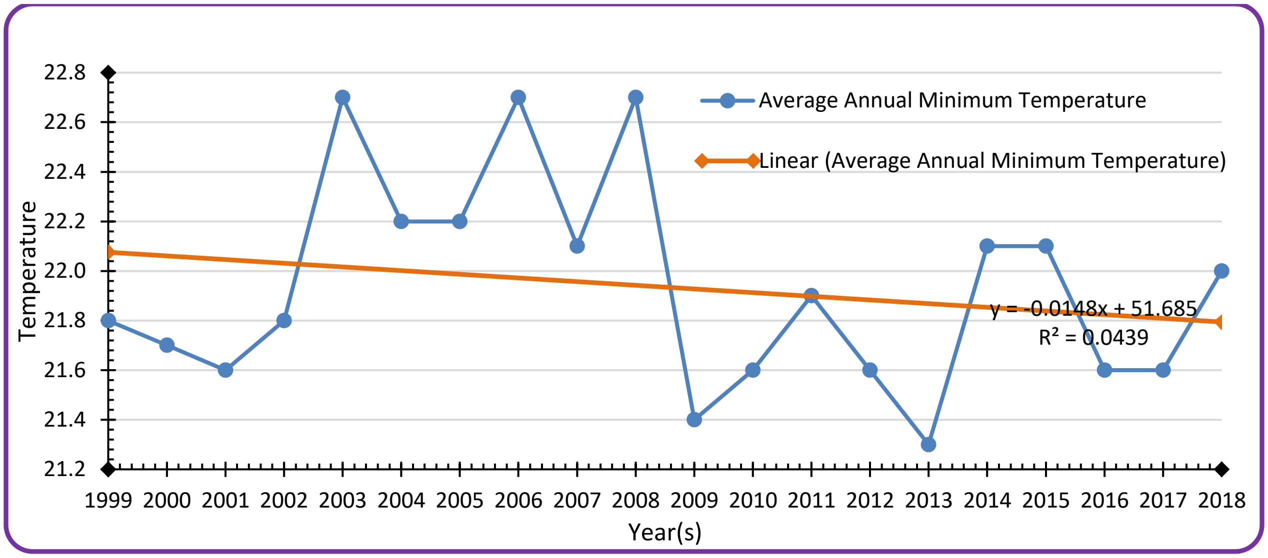

Figure 5: Trend Chart of Average Annual Minimum Temperature

Source: Authors' Computation, 2019.

The year 2006 experienced an increase in the average temperature in the study area at 22.7^{o}C, compared to the years 2004 and 2005. However, this increase was a one-off, as the year 2007 experienced a decline in average temperature. The average temperature recorded during this period (2007) was 22.1^{o}C. More so, the year 2008 experienced an increase in the average temperature in the study area at 22.7^{o}C. From the trend chart, it can be observed that there is a steep downward slope in the trend plot. This steep downward slope indicates a significant drop in the average temperature of the study area in the year concerned, which in this case was the year 2009. During this period, the average temperature of the study area was 21.4^{o}C. Given this significant decline in the average temperature in the study area, the year 2010 and 2011 experienced a steady increase in average temperature in the study area at 21.6^{o}C and 21.9^{o}C respectively. In the same vein, the movement of the trend chart depicts a decline in average temperature of the study area in the year 2012 and 2013 respectively. During these periods, the average temperature recorded were 21.6^{o}C and 21.3^{o}C.

Compared to the year 2012 and 2013, the year 2014 and 2015 recorded a steady increase in average temperature in the study area. More so, this increase was at a constant digit for both years. Explicitly, the average temperature recorded was at 22.1^{o}C respectively. A decline in average temperature was experienced in the year 2016 and 2017. More so, the decline was at a constant digit similar to the experience of the year 2012 and 2013, but at a different value (21.6^{o}C), while the year 2018 experienced an increase in average temperature at 22.0^{o}C.

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It is important to point out here that the year 2013 recorded the least average temperature experienced in the study area between the year 1999 and 2018, at 21.3°C, while the highest average temperature recorded in the study area across the time frame under study was 22.7°C, recorded in the year 2003, 2006, and 2008. More so, uniformity in the value of average temperature was experienced in the study. For instance, the year 2004 and 2005 recorded the same average temperature (22.2°C), 2003, 2006, and 2008 at 22.7°C, 2010 and 2012 at 21.6°C, 2014 and 2015 at 22.1°C, and the year 2016 and 2017 at 21.6°C. The value of r^2 in the trend equation shows the degree of variation in the average temperature in the study area. The value indicates a 44 percent decreasing trend in the average temperature of the study area between the year 1999 and 2018.

The Trend of Maize Yield in the Study Area

The results and analysis presented in this subsection provided answers to the second research question raised, and satisfied the second objective of the study.

The trend of maize yield between the periods 1999 to 2018 in the study area was generated from the data presented in Appendix IV and depicted in Figure 6. The trend presented in the chart above reveals an increasing trend in maize yield in the study area over the period under study, as depicted by the trend line. In 2000, a sharp increase in yield was experienced, as 13.24t/ha was recorded. A slight decrease in yield was experienced in the year 2001, as 12.99t/ha of maize was recorded. This decrease in yield was however, only temporal, as the year 2002-2017 experienced an increase in yield, compared to the years that precede them. Although variations in terms of increases and decreases in yield were experienced, it is important to note that these decreases cannot be classified as a significant decrease in yield.

Between the years 2002 to the years 2005, a steady increase in yield was experienced at 13.9t/ha, 13.76t/ha, 14.02t/ha and 16.21t/ha respectively. Worthy of note here is the fact that the year 2005 recorded the highest yield in maize in the study area over the entire period under consideration in this study. Compared to the year 2005, the period of 2006 to 2009 recorded a decrease in maize yield, as 14.18t/ha, 14.99t/ha, 14.94t/ha and 14.91t/ha were recorded respectively.

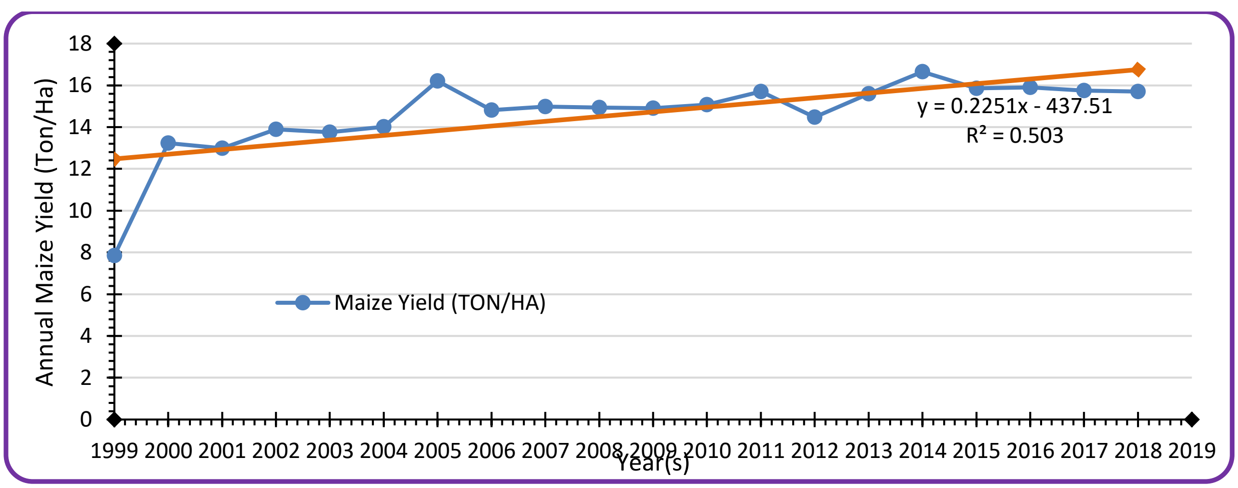

Figure 6: Trend of Maize Yield
Source: Authors' Computation, 2019.

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In 2010 and 2011, 15.08t/ha and 15.71t/ha yield was recorded, representing an increase as compared to the 2006 to the year 2009. While, in the year 2012, a decrease in yield was recorded at 14.47t/ha. A steady increase was experienced from the period of 2013 to 2017 at 15.6t/ha, 16.65t/ha, 15.85t/ha, 15.9t/ha and 15.75t/ha, respectively. Thus, it should be noted that the year 2005 recorded the highest amount of maize yield at 16.21t/ha in the study area, between the period of 1999 to 2018. The trend equation indicated a variation in maize yield in the study area over the period under consideration at 50 percent as indicated by the value of r^2. This by implication simply implies that there is a significant variation in the trend of maize yield in the study area over the period under consideration.

Relationship between Rainfall, Temperature, and Maize yield, in the Study Area

Presented and analysed below are results that satisfy the third objective of the study, and answers the third research question raised in chapter one.

Table 1: Correlation between Rainfall, Temperature, and Maize Yield in the Study Area

		Average Rainfall (mm)	Average Temperature (^oC)	Maize Yield (TON/HA)
Average Rainfall (mm)	Pearson Correlation	1	0.088	-0.072
	Sig. (2-tailed)		0.712	0.762
	N	20	20	20
Average Temperature (^oc)	Pearson Correlation	0.088	1	0.564**
	Sig. (2-tailed)	0.712		0.010
	N	20	20	20
Maize Yield (TON/HA)	Pearson Correlation	-0.072	0.564**	1
	Sig. (2-tailed)	0.762	0.010	
	N	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Source: IBM SPSS version 26 Pearson Product Moment Correlation analysis result, 2020.

The relation between rainfall, temperature, and maize was examined through the Pearson Product Moment Correlation and a two-tail test employed. The result extract presented in Table 1 showed the correlation coefficient between average rainfall and average temperature at 0.088. This by interpretation indicated a strong positive linear correlation (relationship) between the average rainfall and average temperature in the study area between 1999 and 2018. The significant value (2-tailed test) of the correlation coefficient between average rainfall and average temperature was 0.712. This thus implies that though there is a strong positive linear correlation (relationship) between rainfall and temperature in the study area between 1999 and 2018, this relationship was not statistically significant (since 0.712 > 0.05).

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The result extract also revealed the correlation coefficient between rainfall variability and maize yield in the study area at -0.072. This coefficient, by interpretation, implies a weak negative correlation (relationship) between average rainfall variability and maize yield in the study area between 1999 and 2018. The significant value (2-tailed test) of the correlation coefficient between average rainfall variability and maize yield was 0.762. This, by implication, implies that the weak negative linear correlation between average rainfall and maize yield in the study area was not statistically significant (since 0.762 > 0.05). Hence, the null hypothesis which posited that there was a significant relationship between rainfall variability and maize yield in the study area was rejected.

The correlation analysis revealed the correlation coefficient between average temperature variability and maize yield in the study area between 1999 and 2018 at 0.564. This correlation coefficient by interpretation, implies a moderate positive linear correlation (relationship) between average temperature and maize yield in the study area over the time frame under study. The significant value (2-tailed test) of the correlation coefficient between average temperature and maize yield was 0.010. This, by implication, implies that the moderate positive linear correlation between average temperature variability and maize yield in the study area was statistically significant (since 0.010 < 0.05). Hence, the null hypothesis which posited that there was a significant relationship between temperature variability and maize yield in the study area was accepted.

Effects of Rainfall and Temperature Variability on Maize Yield in the Study Area

The results presented and analysed in this subsection satisfy the fourth objective of the study, and answered the fourth research question raised earlier (see chapter one). In order to evaluate the effects of rainfall and temperature variability on maize yield in Wukari Local Government Area of Taraba State, a linear regression analysis was carried out. Regression analysis by definition is a set of statistical processes for estimating the relationships among variables. A regression analysis was employed because it helps one understand how the typical value of the dependent variable (or criterion variable) changes when any one of the independent variables is varied, while the other independent variables are held constant. The results presented in Table 2 revealed the regression coefficients of the variables of the study, while Table 3 revealed the summary results of the regression model.

Table 2: Regression Coefficients

Model	Unstandardized Coefficients		Standardised Coefficients	t	Sig.	Std. Error of the Estimate
	B	Std. Error	Beta			
Constant	-61.140	26.435		-2.313	0.034	1.62138
Average Rainfall	-0.009	0.015	-0.123	-0.618	0.544	
Average Temperature	2.743	0.949	0.575	2.890	0.010	

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Source: IBM SPSS version 26 linear regression analysis, 2020.

Juxtaposing the above result extract into the linear regression model postulated in chapter three of the study, then;

$mY = \alpha + \beta_1 Rf + \beta_2 T + e$ = regression equation

mY = -61.140 + (-0.009) + 2.743 + 1.62138

From the results of the regression coefficient (Table 2), it can be observed that the constant parameter α is negatively related to Maize yield in the study area across the time frame under study, with a *t*-value of -2.313. The *p*-value of the constant parameter of 0.034 implies a statistically significant negative relationship (0.034 < 0.05) between the constant parameter and the dependent variable of the study. The coefficient of $\beta_1 Rf$ (average rainfall) revealed a negative relationship between rainfall and maize yield in the study area, with a coefficient value of -0.009. The *t*-value of the coefficient of $\beta_1 Rf$ (average rainfall) was -0.618, with a *p*-value of 0.544. This thus implies that the negative relationship between the dependent variable (maize yield) and average rainfall in the study area was not statistically significant (0.544 > 0.05). The coefficient of the β_1 does not conform with the theoretical apriori expectation of posited that $\beta_1 > 0$.

The results also revealed the regression coefficient of average temperature in the study area. From the results, the coefficient of $\beta_2 T$ (average temperature) was 2.743. This coefficient implied a positive relationship between maize yield and average temperature in the study area across the time frame under study. The *t*-value of coefficient of $\beta_2 T$ (average temperature) was 2.890, with a *p*-value of 0.010. This by implication implied that the positive relationship between maize yield and average temperature in the study area was statistically significant (0.010 < 0.05) (Asa & Zemba, 2024). More so, the coefficient of β_2 conforms with the theoretical apriori expectation that $\beta_2 > 0$.

Table 3: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	Sig	Durbin-Watson
1	0.577[a]	0.333	0.254	1.62138	4.243	0.032[b]	1.412

a. Predictors: (Constant), Average Temperature (^{o}c), Average Rainfall (mm)
b. Dependent Variable: Maize Yield (TON/HA)

Source: IBM SPSS version 26 linear regression analysis, 2020.

The result in Table 3 presented the model summary of the linear regression analysis of the study. From the results, the correlation of result (R = 0.577) indicated a strong positive linear relationship between the dependent variable and the independent variables in the regression model. The results further depicted the effect of variation rainfall and temperature on maize yield in the area of study with value of the coefficient of determination, also known as the r^2, as well as the coefficient of the adjusted coefficient of determination, also known as the Adjusted r-square $\bar{R}^2$. The coefficient of determination (r-square: r^2) by definition is the proportion of the variance in the dependent variable (maize yield in this case), that is predictable from the independent variable(s) (rainfall,

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and temperature), which arrived at 0.333. This thus implies that 33 percent of the variation in maize yield was explained by the variation in rainfall, and temperature between the periods of 1999 and 2018 in Wukari Local Government Area of Taraba State.

The use of the adjusted r-square is an attempt to take account of the phenomenon of the r-square automatically and spuriously increasing when extra explanatory variables are added to the model. It is a modification due to Henri Theil (1961) r-square that adjusts for the number of explanatory terms in a model relative to the number of data points. The adjusted r-square can be negative, and its value will always be less than or equal to that of r-square. Unlike r-square, the adjusted r-square increases only when the increase in r-square (due to the inclusion of a new explanatory variable) is more than one would expect to see by chance.

In other words, the adjusted coefficient of determination ($\bar{R}^2$) is taken into consideration when the degree of freedom increases or decrease. This is to correct the defect of the inclusion of additional explanatory variables in the initial function. From the result extract of the regression analysis, the $\bar{R}^2$ was arrived at 0.254. This by implication implies that over 25 percent of the total variation in maize yield is explained by the variation in the explanatory variable (rainfall, and temperature) after taking into consideration.

The standard error of the regression estimate was 1.62138, while the Durbin-Watson test of 1.412 indicated the presence of positive autocorrelation in the regression. The F-statistic value of 4.243 shows the overall estimated regression model was at the conventional significance level of 0.05 level of significance, and found to be statistically significant. This was as a result of the F-statistics (4.243) found to be greater than the critical F-statistics significance of 0.032, which is less than 0.05 ($0.032 < 0.05$) at 5 percent level of significance. Hence, the research hypothesis which posited that rainfall and temperature variability have a significant effect on maize yield in the study area was accepted.

DISCUSSION OF FINDINGS

This study investigated the impact of climate variability on maize yield in Wukari Local Government Area of Taraba state. The findings reflected the realities of Wukari variability of climatic conditions and are in line with similar studies that adopted descriptive and inferential statistical techniques, adopting rainfall and temperature as climatic variables. This study found that the peak period of rainfall in Wukari Local Government Area of Taraba State occurs in the month of June through September. The results of the study revealed that the month of July is the most peak period of rainfall in the study area. Given that the study covered rainfall distribution between the year 1999 and 2018, the results of the study revealed that the year 2018 recorded the highest total annual and annual average rainfall in the study area at 1642.0mm and 136.8mm respectively. In the same vein, the results of the study revealed a 37 percent variation in rainfall distribution in the study area between the year 1999 and 2018. The results agreed with the study by Asa and Zemba (2024) on recent variations and current patterns in rainfall and temperature in Southern Taraba. Their study showed that from 1993 to 2022, annual precipitation in Southern Taraba including Wukari area ranged from 733.85 mm to 2238.4 mm, with a shift in the onset of rain from

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March-April to April-May in some areas, while the cessation of rain remained largely unchanged. Additionally, there was a decrease in precipitation in Ibi, Donga, and Takum, and a significant overall increase in temperature across all stations during the study period.

In assessing the trend in temperature variability in the study area, the results of the study revealed an increasing trend in average annual maximum temperature in the study area across the time frame under consideration. Specifically, the results revealed a 62 percent variability in the average annual maximum temperature in the study area, and a decreasing trend in the average annual minimum temperature in the study area, with 44 percent variability across the time frame under consideration. With respect to the trend of maize yield in the study area, the results of the study revealed an increasing trend in maize yield in the study area between the year 1999 and 2018, with a 50 percent variation in yield.

The correlation analysis revealed the degree of the relationship that exists between rainfall, temperature, and maize yield in the study area across the time frame under consideration. The results revealed a non-statistically significant strong positive linear correlation (relationship) between the average rainfall and average temperature in the study area. More so, the correlation analysis also revealed a non-statistically significant weak negative correlation (relationship) between average rainfall variability and maize yield in the study area. However, a statistically significant moderate positive linear correlation (relationship) was found between average temperature and maize yield in the study area over the time frame under study.

In assessing the effects of rainfall and temperature on maize yield in the study area, the linear regression analysis was carried out in line with the model specifications posited in chapter three. The results revealed that 33 percent of the variation in maize yield is explained by the variation in rainfall, and temperature between the periods of 1999 and 2018 in Wukari Local Government Area of Taraba State. Hence, rainfall and temperature affected maize yield in the study area by 33 percent.

CONCLUSION

In conclusion, rainfall and temperature affected maize yield in Wukari Local Government Area of Taraba State. Maize yield soared at minimal ambient temperature than at high temperature, that is, maize yield is linearly associated with minimal and average atmospheric temperature. Intriguingly, maize yield was inversely associated with maximum atmospheric temperature. That is, diminishing returns sets in at maximum temperature while optimal yield occurs at minimum temperature. Regarding rainfall, maize yield was inversely associated with rainfall. For optimal maize yield, low (minimal) temperature and low rainfall are *sine qua non*. Equations of line of best fit and trend line are extrapolated for each graph. Linear regression equation was used to generate predictive equations for estimating maize yield using temperature, rainfall and their composite.

Crops are vulnerable to the effects of climatic variations and this precipitates poor yields. Besides the fact that the crop yields are climate reliant, other variables such as farm administration systems, seed type, soil fertility, pest and planting period may contribute fundamentally to varieties in crop

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yield. This study would appreciate the recommendations outlined in this work to be disseminated to redress the depleting crop yield experienced by the farmers in Wukari Local Government Area for a sustainable future. Subsequently, for future study, specific technologies and administration styles may need to be developed to ensure the sustainability of agricultural products.

RECOMMENDATIONS

To ensure that the negative effect of rainfall and temperature variability on crop yield is reduced and maize production generally enhanced in Wukari Local Government Area, the following recommendations were made by the researcher:

1. Farmers should adopt climate change and variability mitigation, and adaptive measures. These include use of resistant varieties, and drought tolerant species. More so, the government of Taraba State and concerned Non-Governmental Organisations (NGOs) should train and equip farmers with weather forecast information to forestall hunger and food insecurity situations in the state.

2. There is a need for the Ministry of Agriculture and Taraba State Agricultural Development Programme to educate farmers and farm agents on the realities and effect of climate change and variability, as well as adaptive measures that can be taken. This includes better and practicable environmental policies, improved agricultural techniques, alternative source of water which will include irrigation farming, and mulching, vis-à-vis creating sustainable food security.

3. Investment should be made by farmers, the government of Taraba State, and relevant stakeholders involved in agricultural development, to supplement rain-fed agriculture and appropriate coping strategies to adopt in the face of climate variability. More so, efforts by the Ministry of Agriculture of Taraba State should be geared towards increasing the technical manpower of farmers.

4. Government of Taraba State needs to invest and pay more attention to the agricultural sector, especially food production, and provide resilient species, as well as mitigation aids that will promote agricultural production.

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