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By Gayos A. Garba Umar & Iliyasu M. Anzaku

Bayero University, Kano

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Keywords: climate, variability, maize, rainfall, temperature.

Author α: department of geography, faculty of environmental science, nasarawa state university, keffi.

Author σ: department of science, school of continuing education, Bayero university, Kano, Nigeria. e-mail: umar2garba@gmail.com

I. 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) defines 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, etc.) 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 (Chiew, 2002).

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).

According to Intergovernmental Panel on Climate Change (IPCC, 2007), "Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer)". While, climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Climate change and variability are closely linked in the climatic system, with long term scale climate change manifesting itself with episodes being observed in short term climate variability. Instances of climate variability consist of seasonal, annual and inter decadal variation in temperature and rainfall, extensive droughts, floods and conditions that result from periodic El Nino and La Nina events. Due to their close association, climate change and climate variability are concomitantly used together in research as well as in policy. Thus, in most cases extricating the impacts of climate change and climate variability has largely been difficult especially in the agricultural sector (Bizuneh, 2013).

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 (Solomon, 2007). In the midst of the rise in global temperatures, changing local rainfall patterns, warming seas and melting of ice caps have been witnessed (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 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).

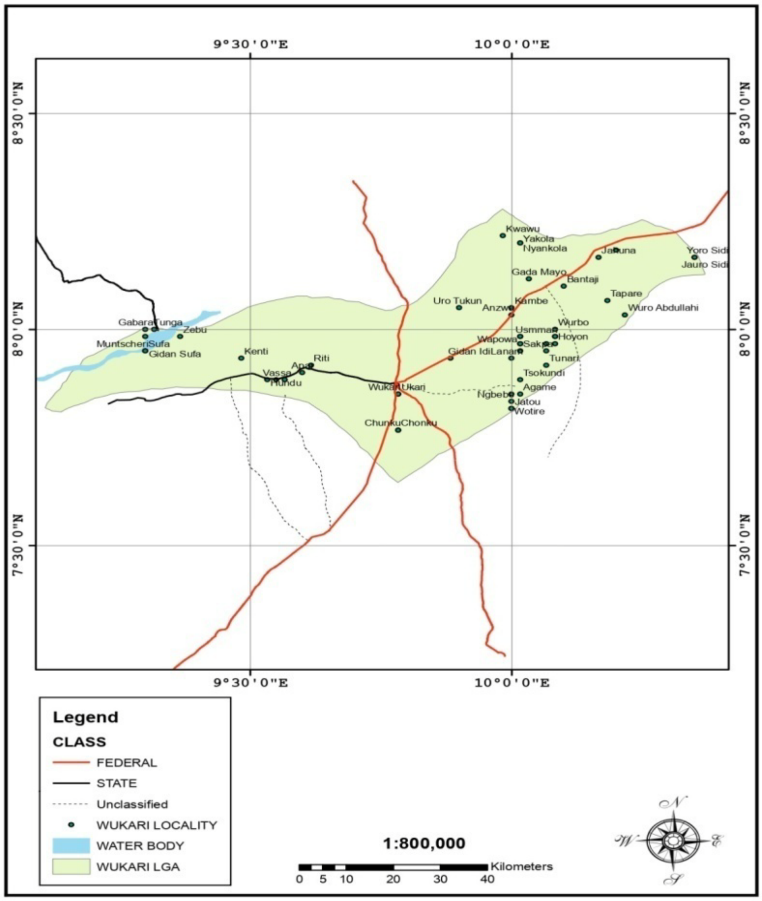
Beside the changes in temperature, over the years, rainfall patterns have changed, with cases of heavy rainfall at crop maturity and droughts occurring at critical stages of crop growth being common (Birech, Freyer, Friedel, & Leonhartsberger, 2008). These changes are likely to severely, compromise crop production and food security with colossal economic consequences in many African countries especially in sub Saharan Africa (Gregory, Ingram, & Brklacich, 2005). There is 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 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 crop 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).

Increase 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 (Mirza, 2003; Wassmann & Dobermann, 2007; Schmidhuber & Tubiello, 2007). It is thus on the premise of this background that the study was aimed at assessing the effects of climate variability on maize (*Zea mays*) yield in Taraba State.

II. Materials and Methods

a) *The Study Area*

i. *Location and Position*



Source: AGIS, 2019

Fig 1: Map of the study area

Taraba State is located in the North-East geographical zone of the country, with its head-quarters in Jalingo. It has sixteen (16) Local Government Areas (LGAs). The State has a total land mass of 51,000-kilometre square. It lies roughly between latitude $6^{0}30^{1}$ and $9^{o}36^{1}$N and longitude $9^{0}10^{1}$ and $11^{0}5^{1}$E. It is bounded on the North-East by Adamawa State and the West and South-East by Plateau and Benue States respectively. On its east border is the Republic of Cameroun. According to the 2006 Census figures released by the National Population Commission (NPC), Taraba State has a population of 2, 294, 800 people (NPC, 2006).

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 mile), located at 7°51′N 9°47′E. According to 2006 National population Census figures, Wukari has a population of 241,546 people (NPC, 2006).

b) *Nature and Sources of Data*

The study employed the use of secondary data in its analysis of the effects of climate change on maize yield in the study area. Climate data constituting of annual rainfall and temperature for Wukari Local Government Area of Taraba State for a period of twenty years (from 1999-2018) was obtained from the Nigeria Metrological Agency (NIMET) on a yearly basis, while data on the selected crop yield under study Maize) was obtained from Agriculture Development Program (ADP) Headquarters, Jalingo, Taraba State.

c) *Methods of Data Analysis*

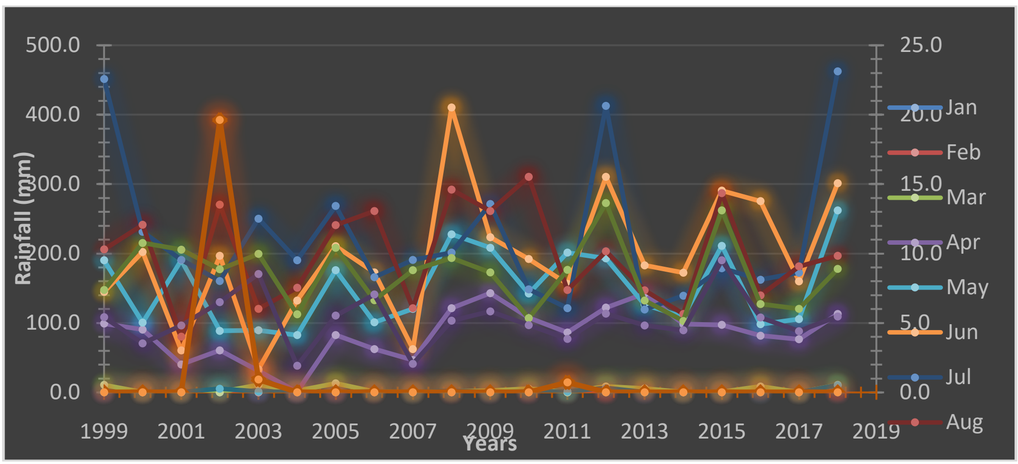
The data for this study were processed and analysed quantitatively. The quantitative data were analysed using both descriptive and inferential statistics with the help of Microsoft Excel and the E-Views 10 statistical package. The descriptive statistics employed in the study was the time series trend analysis, while the inferential statistics employed in the study was the Ordinary Least Square (OLS) regression, and correlation analysis to determine the effect of rainfall and temperature variability on maize (*Zea mays*) yield in the study area, as well as the relationship that exist between these variables under study.

III. Results and Discussion

a) 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.

b) Trend of Rainfall



Source: Author's computation, 2019.

Figure 1: Trend Chart of Monthly Rainfall Distribution in the Study Area

Table 1: Monthly and Average M*onthly Rainfall Distribution in the Study Area (mm)*

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1999	0.0	0.0	10.2	98.6	189.8	144.4	451.1	205.5	147.0	108.0	0.0	0.0
2000	0.0	0.0	0.0	90.2	100.2	202.0	231.0	240.9	215.0	70.2	0.5	0.0
2001	0.0	0.0	0.0	40.0	190.0	60.1	190.6	80.0	205.3	96.1	0.0	0.0
2002	0.0	0.0	0.0	60.3	88.4	196.2	160.2	270.0	176.9	129.6	5.0	19.6
2003	0.0	0.0	10.5	30.6	89.0	33.1	250.0	120.0	199.1	170.4	0.9	0.9
2004	0.0	0.0	2.0	0.4	82.1	132.1	190.2	150.3	112.0	38.1	0.0	0.0
2005	0.0	0.0	12.6	82.4	175.6	210.2	268.2	240.6	208.0	110.1	0.0	0.0
2006	0.0	0.0	0.8	62.1	100.5	172.5	165.6	260.8	132.6	140.6	0.8	0.0
2007	0.0	0.0	0.0	46.2	120.0	62.1	190.4	120.8	175.6	40.7	0.0	0.0
2008	0.0	0.0	0.9	121.0	227.5	410.2	201.0	291.8	193.2	102.8	1.8	0.0
2009	0.0	0.0	2.2	142.6	208.1	223.3	271.0	261.0	172.5	116.4	0.0	0.0
2010	0.0	0.0	5.0	107.2	142.0	191.7	148.2	310.3	106.6	96.5	0.8	0.0
2011	0.0	0.0	0.0	86.0	201.0	156.0	121.1	147.0	176.1	76.9	0.9	0.7
2012	0.0	0.0	8.2	121.6	192.6	310.0	412.6	202.8	272.5	113.1	6.0	0.0
2013	0.0	0.8	5.2	142.1	126.0	182.7	119.1	146.6	132.1	96.2	0.0	0.0
2014	0.0	0.0	0.0	98.1	108.4	172.1	139.0	112.8	102.7	89.0	0.0	0.0
2015	0.0	0.0	0.5	96.8	210.9	290.2	178.6	286.5	262.0	189.8	0.5	0.0
2016	0.0	5.0	8.2	81.5	97.7	275.0	162.1	139.5	127.0	107.5	0.0	0.0
2017	0.0	0.0	0.0	76.1	105.2	159.8	172.2	181.0	120.0	87.9	0.0	0.0
2018	0.0	0.8	10.2	112.7	262.0	301.0	462.2	196.5	177.4	109.1	10.1	0.0
Average Monthly Rainfall	0.0	0.3	3.8	84.8	150.9	194.2	224.2	198.2	170.7	104.5	1.4	1.1

Source: Nigeria Meteorological Agency (NIMET), Taraba State, 2019.

The data presented in Table 1 depicts the distribution of rainfall in the study area over a spread of twenty years on a monthly basis. The data also shows the average monthly rainfall distribution in the study area as well. The data presented in the table is a true representation of the pattern of rainfall in Wukari Local Government Area of Taraba State and thus shows 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 presented in the table, it can be observed that the month of January over the past twenty years has never experienced rainfall in the study area. While other part of Nigeria does experience what is considered unlikely rainfall during this month, Wukari Local Government Area is 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.

Beside 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 in the table, 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 month of February, December and November, the month of March in the study area experience 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 for across the entire years under consideration. The trend chart depicted in Figure 1 depicts and provides a vivid e 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 Table 1, 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 month of August and September recorded and average rainfall of 198.2mm and 170.7mm respectively. It however important to explicitly state that the month of July is the most peak period of rainfall in Wukari Local Government Area of Taraba State.

From the scattered plot in the trend chart, it can be observed that highest drop of rainfall in a singular month was experience on the month on July, in the 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, on the month of December recorded significant rainfall for a singular month, at 19.6mm in the year 2002.

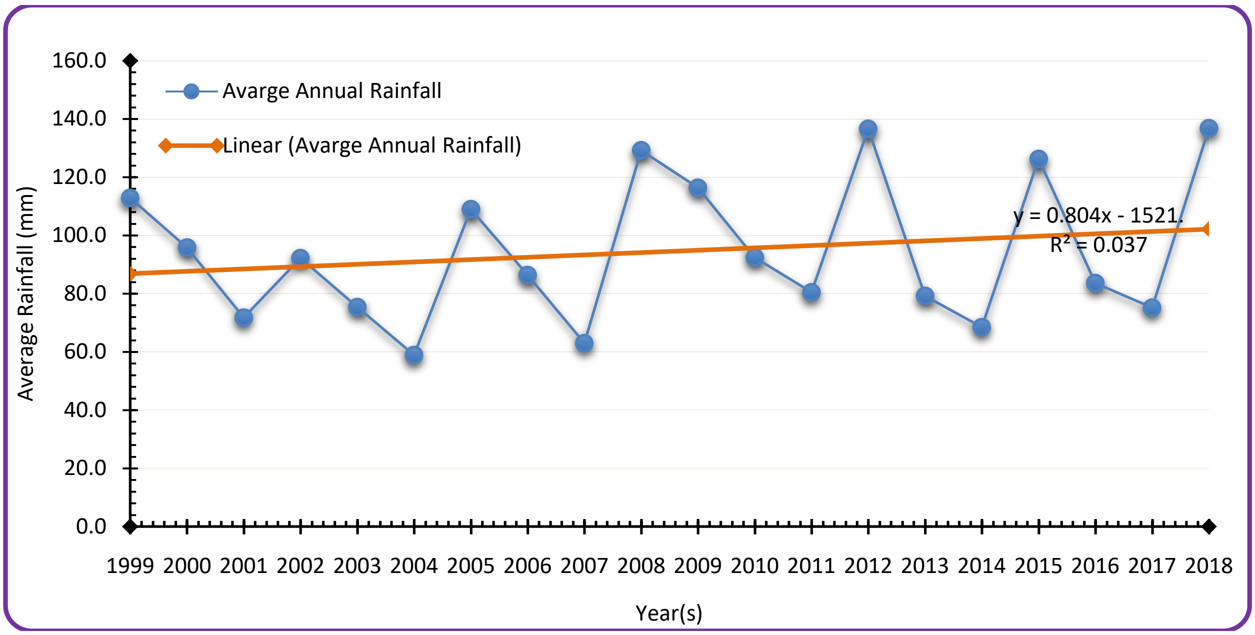
Table 2: Total and Average Annual Rainfall Distribution in the Study Area

S/N	Years	Total Annual Rainfall (mm)	Average Annual Rainfall (mm)
1	1999	1354.6	112.9
2	2000	1150.0	95.8
3	2001	862.1	71.8
4	2002	1106.2	92.2
5	2003	904.5	75.4
6	2004	707.2	58.9
7	2005	1307.7	109.0
8	2006	1036.3	86.4
9	2007	755.8	63.0
10	2008	1550.2	129.2
11	2009	1397.1	116.4
12	2010	1108.3	92.4
13	2011	965.7	80.5
14	2012	1639.4	136.6
15	2013	950.8	79.2
16	2014	822.1	68.5
17	2015	1515.8	126.3
18	2016	1003.5	83.6
19	2017	902.2	75.2
20	2018	1642.0	136.8
Total		**22681.5**	**1890.1**

Source: Nigeria Meteorological Agency (NIMET), Taraba State, 2019.

Table 2 gives a detailed account of the rainfall trend rainfall variability in Wukari Local Government Area of Taraba State. Depicted in Figure 2, the trend plot in the chart shows a fluctuating trend mean rainfall in the study area. From the trend chart, it can be observed that from the period of 1999 to 2001 recorded decreasing trends 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 the year 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 can be observed that a significant increase in average annual rainfall in the year 2005 coursed and upward shift in the trend plot, as the average annual rainfall for this year was recorded at 109.0mm.This increase was however temporal 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.



Source: Author's computation, 2019.

Figure 2: Trend Chart of Annual Average Rainfall

While the improvement in average annual rainfall was experienced in the year 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 these 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 the following amount of average annual rainfall was recorded; 92.4mm, and 80.5mmrespectively. A look at the trend plot shows that an upward movement occurred in the year 2012. This upward movement by interpretation signify an increase in the average annual rainfall in the 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 significant downward shift in the trend plot presented in the figure above. In this years, average annual rainfall was recorded at 79.2mm and 68.5mm. It

Compared to preceding year (2013 and 2014), the year2015recorded 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 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.

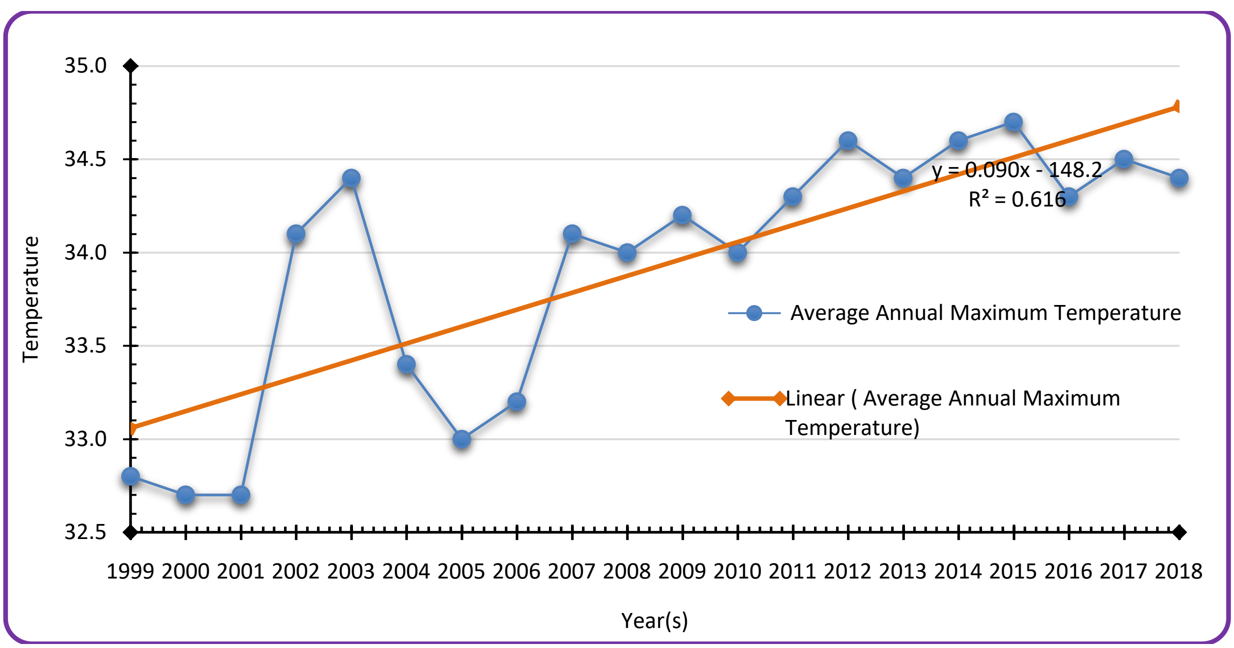
c) Trend of Temperature in the Study Area

Table 3: Temperature Distribution in the Study Area

S/N	Year	Total Max. Temperature (ºc)	Average Max. Temperature (ºc)	Total Min. Temperature (ºc)	average min. temperature (ºc)	Average Temperature (ºc)
1	1999	393.4	32.8	261.8	21.8	27.3
2	2000	392.9	32.7	260.1	21.7	27.2
3	2001	392.3	32.7	259.0	21.6	27.15
4	2002	408.7	34.1	261.6	21.8	27.95
5	2003	413.3	34.4	272.3	22.7	28.55
6	2004	400.3	33.4	266.8	22.2	27.8
7	2005	396.2	33.0	266.0	22.2	27.6
8	2006	398.8	33.2	272.2	22.7	28.0
9	2007	408.9	34.1	264.8	22.1	28.1
10	2008	407.7	34.0	272.5	22.7	28.4
11	2009	410.7	34.2	256.6	21.4	27.8
12	2010	408.5	34.0	258.6	21.6	27.8
13	2011	411.4	34.3	263.1	21.9	28.1
14	2012	415.7	34.6	258.9	21.6	28.1
15	2013	413.1	34.4	255.5	21.3	27.9
16	2014	414.9	34.6	264.6	22.1	28.4
17	2015	416.5	34.7	264.8	22.1	28.4
18	2016	411.4	34.3	259.1	21.6	28.0
19	2017	413.7	34.5	258.7	21.6	28.1
20	2018	413.1	34.4	264.0	22.0	28.2

Source: Nigeria Meteorological Agency (NIMET), Taraba State, 2019.

d) The Trend of Average Annual Maximum Temperature in the Study Area



Source: Author's computation, 2019.

Figure 3: Trend Chart of Average Annual Maximum Temperature

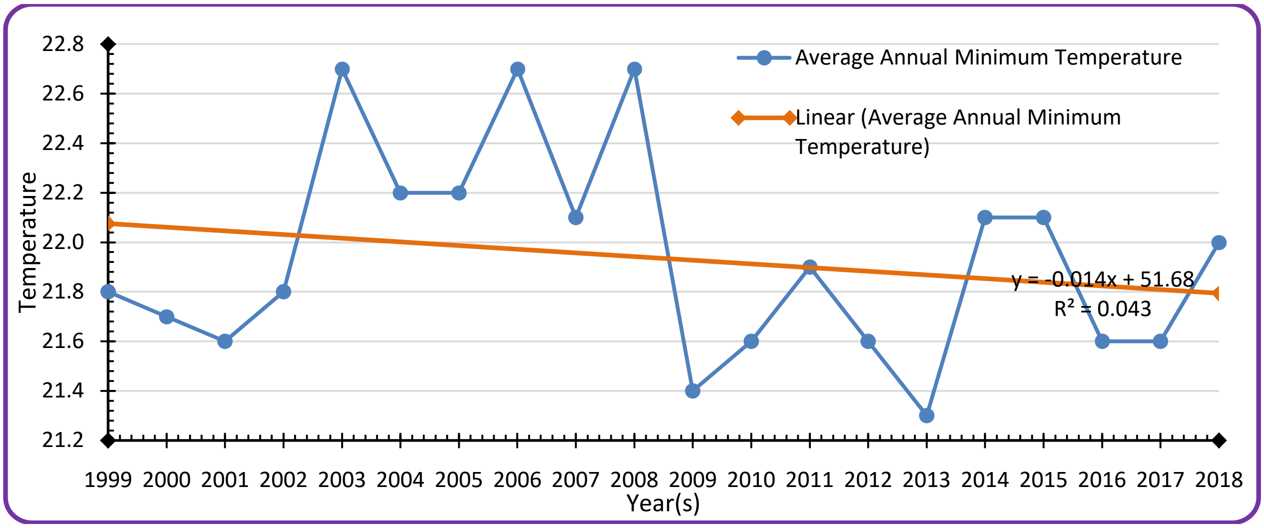
The scatter plot depicted in Figure 3 represents Average annual maximum temperature trend in the study area across the period under consideration. From the chart, it can be observed that the trend plot is upward sloping in nature. The upward sloping plot of the linear trend line indicates an increasing trend in average annual maximum temperature in the area of study over the time frame under consideration. 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 32.8°c. In 2000, average annual maximum temperature recorded a slight increase compared to the preceding year, at 32.7°c. While the year 2001 experienced the same average annual maximum temperature as that of the year 2000 at 32.7°c. Compared to the year 1999-2001, the year 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 the average annual maximum temperature was indeed significant, as temperature of 34.1°C and 34.4°C was 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; 33.2°c, 34.1°c, 34.0°c, and 34.2°c 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 34.0°c. The year 2011-2015 however experience a much increasing but fluctuating trend in the average annual maximum temperature in the study area at; 34.3°c, 34.6°c, 34.4°cc, 34.6°c, and 34.7°c respectively. However, the year 2016-2018 experienced a fluctuating decline in the average annual maximum temperature, at 34.3°c, 34.5°c and 34.4°c 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 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.

e) The Trend of Average Annual Minimum Temperature in the Study Area

Figure 4 depicts the trend of average annual minimum temperature in Wukari Local Government Area of Taraba State. A careful look shows 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 21.8°c, 21.7°c, and 21.6°crespectively. 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 22.7°c. From the trend chart, it 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°c respectively.



Source: Author's computation, 2019.

Figure 4: Trend Chart of Average Annual Minimum Temperature

The year 2006 experienced an increase in the average temperature in the study area at 22.7°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°c. More so, the year 2008 experienced an increase in the average temperature in the study area at 22.7°c. From the trend chart, it can be observed that there is steep downward slop 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°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°c and 21.9°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 temperatures recorded were 21.6°c and 21.3°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°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°c), while the year 2018 experienced an increase in average temperature at 22.0°c.

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% decreasing trend in the average temperature of the study area between the year 1999 and 2018.

f) The Trend of Maize Yield in the Study Area

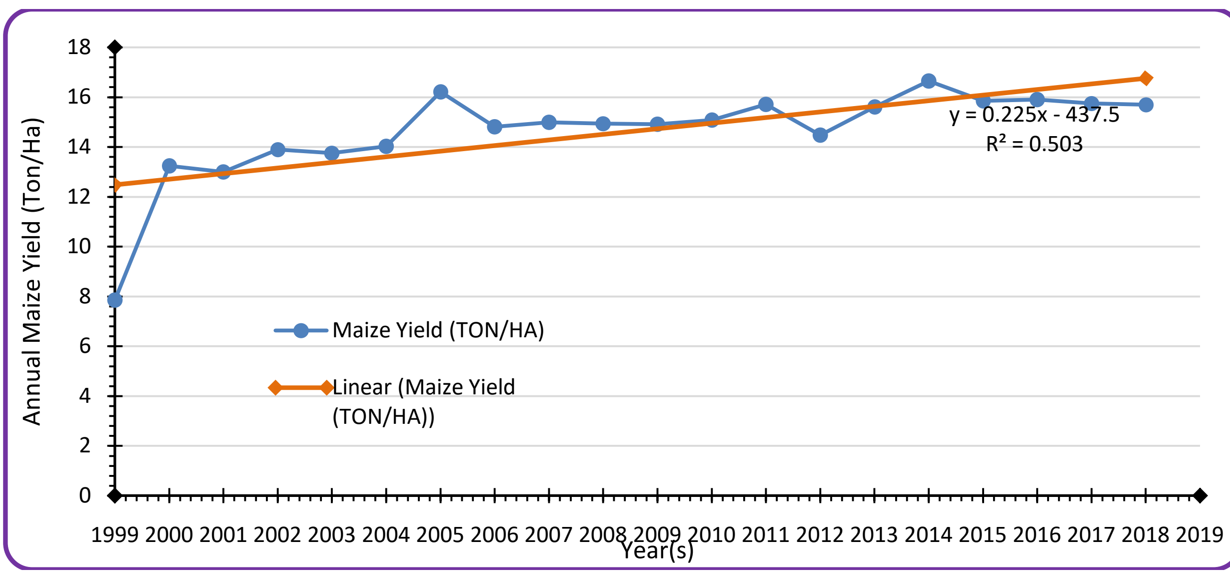
The results and analysis presented in this sub-section provided answers to the second research question raised, and satisfy the second objective of the study. The trend of maize yield between the periods 1999 to 2018 in the study area was generated from the data presented in the Table 4.3 and depicted in Figure 4.5. 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 year 2000, a sharp increase in yield was experience, 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 increase in yield, compared to the years that precede them. Although variations in terms of increases and decrease in yield were experienced, it is important to note that these decreases cannot be classified as a significant decrease in yield.

Between the year 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 overt 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.

Table 4: Maize yield Output in Wukari Local Government Area of Taraba State

S/N	Years	Maize Yield (TON/HA)
1	1999	7.85
2	2000	13.24
3	2001	12.99
4	2002	13.90
5	2003	13.76
6	2004	14.02
7	2005	16.21
8	2006	14.81
9	2007	14.99
10	2008	14.94
11	2009	14.91
12	2010	15.08
13	2011	15.71
14	2012	14.47
15	2013	15.60
16	2014	16.65
17	2015	15.85
18	2016	15.90
19	2017	15.75
20	2018	15.70
Total		308.16

Source: Taraba A.D.P HQRS, Jalingo, Taraba State, 2019.



Source: Author's computation, 2019.

Fig. 5: Trend of Maize Yield

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 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 indicates 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.

g) 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 5: Correlation between Rainfall, Temperature, and Maize Yield in the Study Area

		Average Rainfall (mm)	Average Temperature (°c)	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 (°c)	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, 2019.

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 5, shows the correlation coefficient between average rainfall and average temperature at 0.088. This by interpretation indicates 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).

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 a significant relationship between 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 a significant relationship between relationship between temperature variability and maize yield in the study area was accepted.

h) 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 4.6a revealed the regression coefficients the variables of the study, while Table 4.6b revealed the summary results of the regression model.

Table 4.6: Regression Coefficients

Model	Unstandardized Coefficients		Standardized 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	

Source: IBM SPSS version 26 linear regression analysis, 2019.

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

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

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

From the results of the regression coefficient, 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 to the theoretical aprior 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 implies a positive relationship between maize yield and average temperature in the study aera 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 implies that the positive relationship between maize yield and average temperature in the study area was statistically significant ($0.010 < 0.05$).More so the coefficient of β_2 conforms to the theoretical aprior expectation that $\beta_2 > 0$.

Table 4.7: 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 (°c), Average Rainfall (mm)							
b. Dependent Variable: Maize Yield (TON/HA)							

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

The result extract in Table 4.7 presents the model summary of the linear regression analysis of the study. From the results, the correlation of result ($R = 0.577$) indicates a strong positive linear relationship between the dependent variable and the independent variables in the regression model. The results further depict 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, and temperature), was arrived at 0.333.This thus implies 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.

The use of the adjusted r-squareis an attempt to take account of the phenomenon of the r-square automatically and spuriously increases when extra explanatory variables are added to the model. It is a

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modification due to Henri Theil (1961) r-square of 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 indicates 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.

IV. Conclusion

In conclusion, rainfall and temperature affect maize yield in Wukari Local Government Area of Taraba State. Maize yield soars 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 yield. This study will 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.

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