

Impacts of Climatic Parameters on Cereal Crops in Katsina State, Nigeria

Dogonyaro, J.B.¹, Abaje I.B.^{1*} & Bello Y.¹

¹Department of Geography and Regional Planning, Federal University Dutsin-Ma, Nigeria.

Corresponding author's e-mail: abajebest@gmail.com Tel: +2348036642086

ABSTRACT

The study examined the impact of climatic parameters (rainfall and temperature) on cereal crops (millet and sorghum) in Katsina State, Nigeria. The study entailed a trend analysis of the climatic variables, estimating the crop yield within the period examined and assessing the relationship between climatic variables and crop yield. Thirty (30) years (1989 - 2018) data of monthly rainfall, temperature, millet and sorghum yield were used for the study. Linear regression was used to determine the linear trends of weather parameters and crop yield. The relationships between the climatic parameters and crop yield were tested using Pearson's product moment correlation coefficient. The result revealed that the linear trend lines for both rainfall and temperature showed an increasing trend within the period examined. The production of millet and sorghum was fluctuating from year to year. The result of the Pearson's product moment correlation coefficient showed a weak negative relationship ($r = -0.052$) between rainfall and millet production; a positive relationship between rainfall and sorghum (0.012) and also a positive relationship between temperature and sorghum (0.733). Variation in both temperature and rainfall were not directly related to the variation noticed in the output of the two major cereal crops (millet and sorghum) in the study period. The study therefore recommends collaboration between agricultural extension agents and the Nigerian Meteorological Agency (NiMet) to guide farmers in the state on stabilizing their millet and sorghum cropping calendar in accordance with weather forecasts since both rainfall and temperature have no significance relationship with cereal crops yield.

Keywords: Millet, Rainfall, Sorghum, Temperature, Trend.

1. INTRODUCTION

Climatic parameters such as rainfall, sunshine hours, temperature, relative humidity and wind are the key factors influencing cereal crops production. Cereal crops are the major food used by many households in northern Nigeria (Haruna and Tasi'u, 2017). The recent changes in weather and climatic variables as a result climate variability and change are affecting the quantity of cereal crop production in the region. According to Malla (2008), changes in

temperatures pattern were affecting crop production in Nepal. Silungwe *et al.* (2019) noted that spatiotemporal variability of daily rainfall is the most critical climatic factor affecting pearl millet production than total seasonal and erratic rainfall rainfall amount. Sridhara *et al.* (2020) observed that maximum temperature influences *rabi* sorghum production than minimum temperature. *Rabi* sorghum is grown between October to November in Karnataka, India because it has been found to tolerate higher

temperatures and moisture stress to a larger extent (Sridhara *et al.*, 2020).

The major cereal crops used by the people of Katsina State are millet (*Pennisetum americanum* L.) and sorghum (*Sorghum bicolor* L. Moench.) which are under the threat of crop failure. Various models have been used to predict the relationship between rainfall and cereals crops. For example, Adejuwon (2005) reported that the predicted models generated for the yield of millet and sorghum was significant at $\alpha \leq 0.05$ in Nigeria. Abdullahi *et al.*, (2006) observed that rainfall and trend variables were significant ($p \leq 0.01$) for both production and yield function of millet in Borno and Yobe States.

The relationship between rainfall variability parameters and millet yield was correlated with annual rainfall and length of growing season in

Kano State and it showed a positive relationship (Haruna and Tasi'u, 2017). However, no significant relationship was found between millet and sorghum yields with the rainfall variability parameters in Gusau and Sokoto (Haruna and Tasi'u, 2017). Therefore, this paper aims to determine the relationship between weather parameters (rainfall and temperature) and cereal crop yield in Katsina State, Nigeria. Specifically, the study entailed a trend analysis of the climatic variables, estimating the crop yield between 1989 to 2018 and assessing the relationship between climatic variables and crop yield within the period examined.

2. MATERIAL AND METHODS

2.1 Study area

Katsina State is located between Latitude $11^{\circ} 52' 45''$ N and $12^{\circ} 58' 54''$ N and Longitude $6^{\circ} 48' 45''$ E and $8^{\circ} 56' 51''$ E. It borders with Niger Republic in

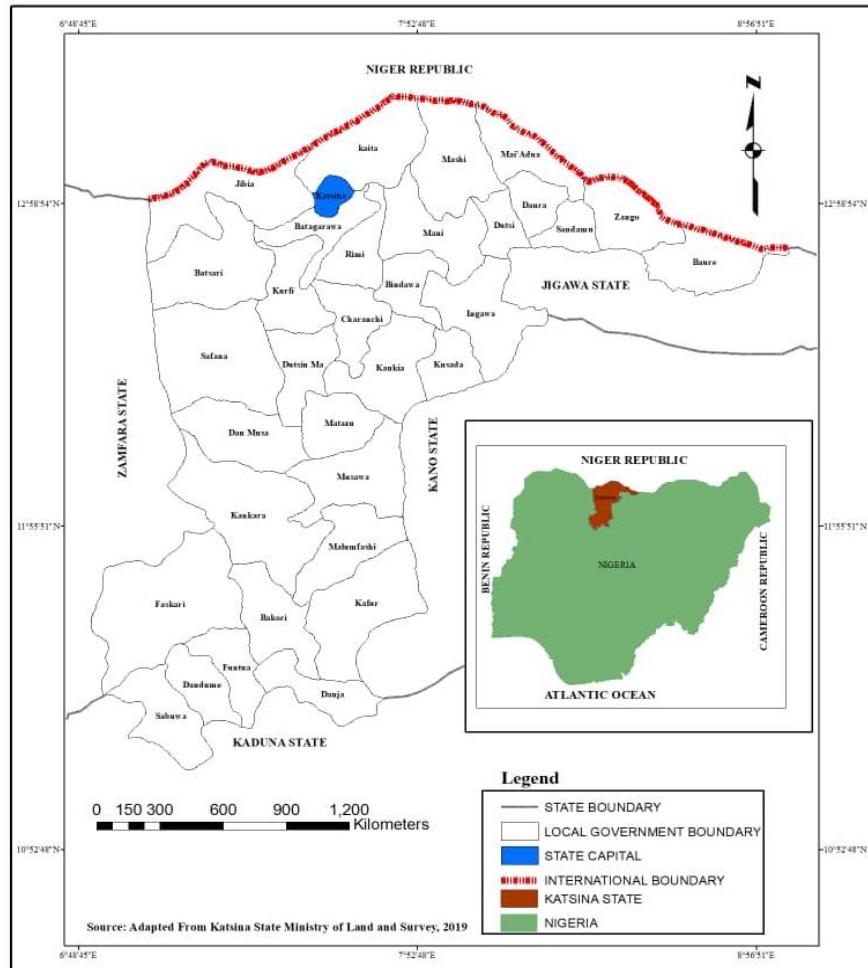


Figure 1: Geographical Location of the Study Area

the North, Zamfara State to the West, Kaduna State to the South, and Jigawa and Kano to the East (Figure 1).

Table 1: Statistics for crop and climatic variable

Statistics	Millet (ton/ha)	Sorghum (ton/ha)	Temperature (°c)	Rainfall (mm)
Mean	247.91	303.26	26.86	560.42
Std. Deviation	60.85	79.13	0.599	168.20
Minimum value	152.05	155.12	25.75	259.80
Maximum value	397.70	418.00	28.00	900.30

Source: Authors' computation, 2021

The climate of area is the tropical wet and dry type, classified by Köppen as Aw climate. It is characterized by strong seasonality in rainfall and relatively high temperature. The rainfall is about 1000mm per annum in the southern parts of the State to less than 600 mm in the northern parts and occurs in only five months in the year between May and October (Ati *et al.*, 2017). The daily sunshine duration is 8 hours; with air temperature and evaporation rate constantly high (Abaje and Ogoh, 2018). The mean temperature is about 26.86°C, the minimum and maximum temperature values are 28.00°C and 25.75°C respectively for the study period. The vegetation is the Sudan Savannah type, made up of short grasses of about 1-2 meters' height and stunted trees. The predominant trees species are locust beans, acacia, and baobab (Abaje, 2007).

2.2 Data Collection

Monthly rainfall and temperature data for the period of thirty (30) years (1989-2018) for Katsina State were obtained from the Nigeria Meteorological Agency (NiMet). The second set of data were the crop yields (for millet and sorghum) in tons/ha for the period under study. This was obtained from Katsina State Agricultural and Rural Development Authority (KTARDA) headquarters in Katsina.

2.3 Data Analysis

Descriptive statistics was used to analyze the characteristics of climatic variables and crop yields under investigation. Linear regression was used to determine the linear trends of weather parameters; (specifically, temperature and rainfall) and crop yield (millet and sorghum). The formula for the linear regression is given as:

$$y = a + bx \quad \text{eq. 1}$$

Where a the intercept of the regression line on the y-axis; b is the slope of the regression line.

The values of a and b can be obtained from the following equations:

$$a = \frac{\sum y - b(\sum x)}{n} \quad \text{eq. 2}$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad \text{eq. 3}$$

Similarly, the relationship between the climatic parameters and crop yield in the study area was tested using Pearson's product moment correlation coefficient, given as:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2} \sqrt{\sum (y - \bar{y})^2}} \quad \text{eq. 4}$$

Where: r = correlation coefficient

x and y = individual observations of dependent and independent variables respectively

\bar{x} and \bar{y} = mean of dependent (x) and independent (y) variables respectively.

Crop yield values were used as dependent variables and climatic parameter values as the independent variables. Microsoft Excel version 13 and SPSS version 23 software were used for the analysis.

3. RESULTS AND DISCUSSION

3.1 General statistics of crop yield and climatic parameters

The statistics of both the crop and the climatic variables are presented in Table 1. The result shows that the maximum millet production for the period under study is 397.7 ton/ha while the minimum production is 152.05 ton/ha. The mean production for the periods is 247.9 ton/ha while the standard deviation is 60.85. The standard

deviation in production for sorghum is for the period 79.13 tons/ha. The mean temperature and rainfall are 26.86°C and 560.4 mm respectively, the maximum and minimum values of temperature are 25.75°C and 28.00°C respectively, while the highest and lowest amount of rainfall are 259.8 mm and 900.3 mm respectively. The standard deviation of the annual rainfall is 168.2, and when compared with the mean, it shows that there is a great deviation from the normal condition.

3.2 Trends of Rainfall and Temperature

The trend of rainfall from 1989 to 2018 is presented in Figure 2. The figure shows that the highest amount of rainfall (900.3 mm) was recorded in 2007 while the lowest amount (259.8 mm) was recorded in 1996. The pattern of the rainfall trend fluctuates from the beginning to the end of the series. The linear trend line shows an

rainfall amount in recent years. The temperature pattern of the study area is presented in Figure 3. It shows an increasing trend from the beginning to the end of the series with an increasing rate of $0.025^{\circ}\text{C}/\text{yr}^{-1}$. The series contribute ($R^2 = 13.38\%$) with the maximum temperature value of 28.00°C recorded in 2016 and minimum temperature of 25.75°C recorded in 1994. The mean temperature of the series is 26.86°C, with a standard deviation of 0.60. This indicates that there is a great disparity between the mean temperature and the standard deviation in Table 1. This study is in agreement with Abaje and Oladipo (2019) which shows an increasing temperature trend in Kaduna State. Bello *et al.*, (2020) also showed increasing trends in temperature pattern in Nafada, Dadin-Kowa and Billiri stations. An examination of the 5-year moving average also revealed an increasing trend in recent years.

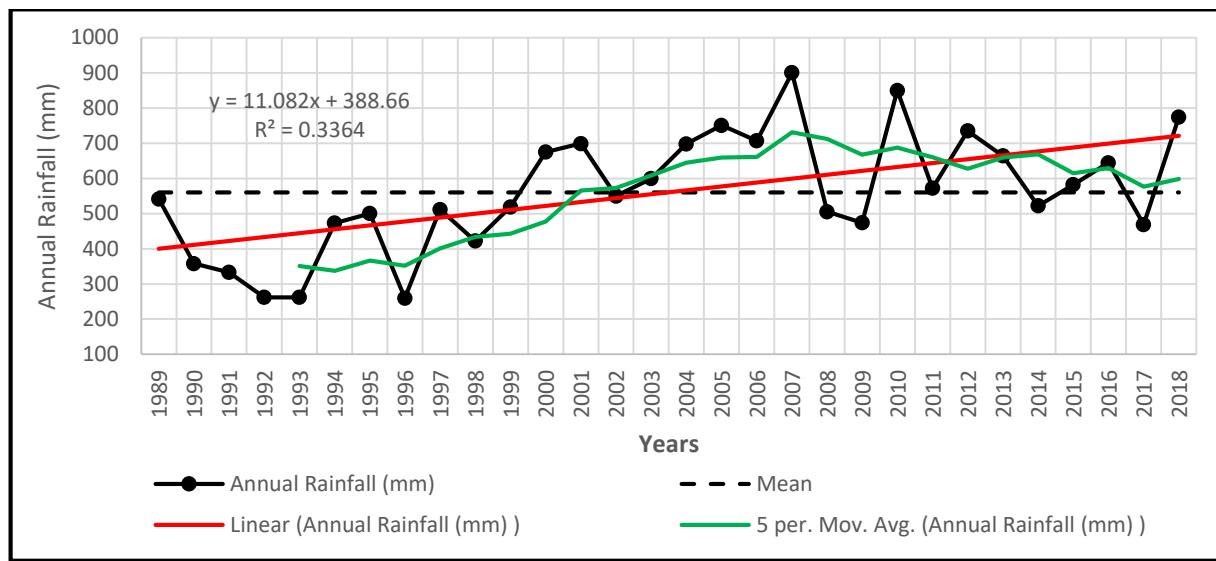


Figure 2: Trend of Rainfall in Katsina from 1989 – 2018

increasing trend at the rate of 11.08 mm/yr^{-1} and contributes ($R^2 = 33.6\%$) to the model. The 5-year moving average showed an increasing trend from the beginning of the data series to the end of the study period. This finding is in line with that of Abaje *et al.*, (2018) and Abaje and Oladipo (2019) which found an upward trend in annual rainfall in Kafanchan, Zaria and Kaduna stations. Similarly, Bello *et al.*, (2020) reported an increasing trend in rainfall pattern in Gombe station. This is an indication that the northern part of the country is experiencing increasing trend of

3.3 Trend of Millet and Sorghum Production

The production of millet during the study period have been fluctuating from year to year, this is due to the variation in rainfall and temperature in the area. The pattern of millet production from the year 1989-2018 is presented in Figure 4. The figure revealed that the highest millet production was recorded in the year 2008 with about 397.70 ton/ha whereas the least production was recorded in year 2007 with about 152.05 ton/ha. The mean production and standard deviation were 247.91 and 60.85 respectively (Table 1). The trend

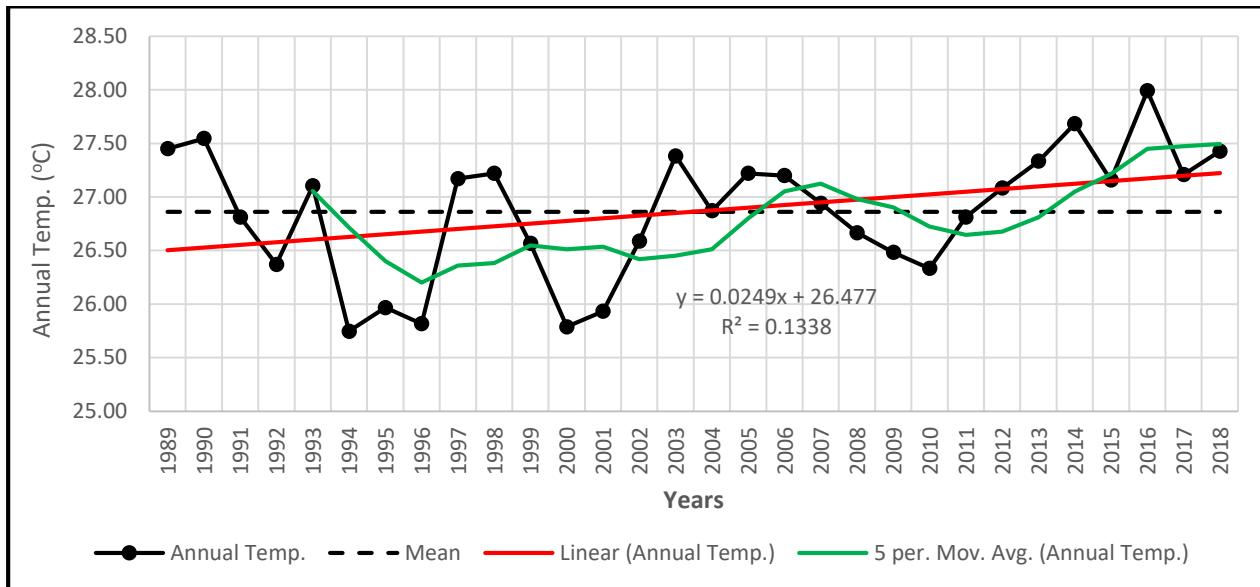


Figure 3: Trend of Temperature from 1989 – 2018

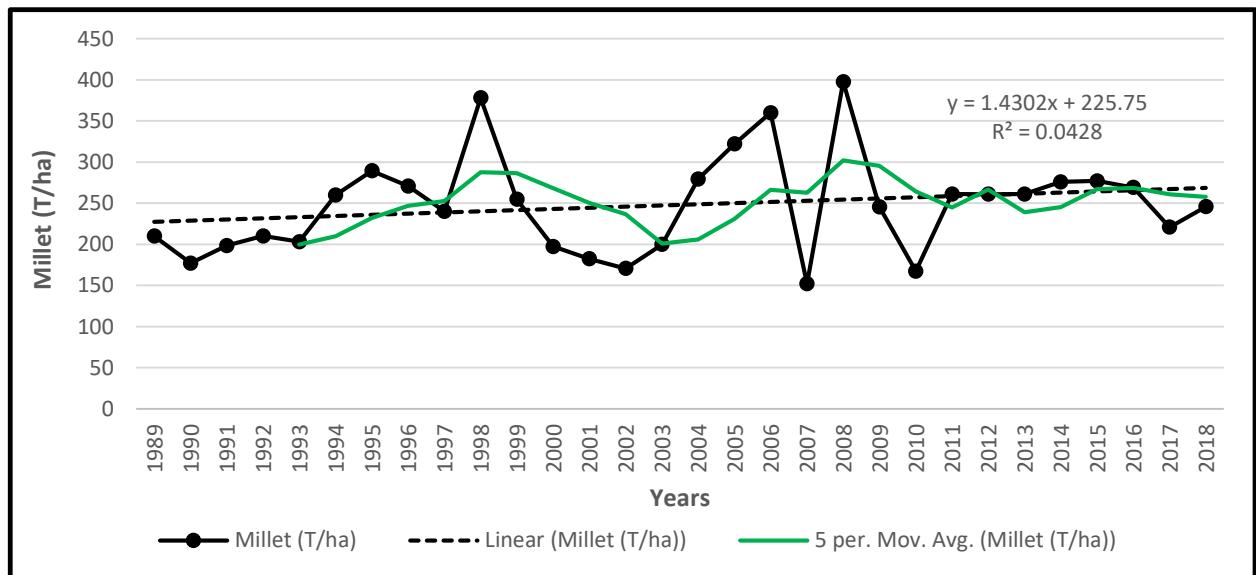


Figure 4: Trend of millet production from 1989-2018

indicates an increase pattern at the rate of 1.4 ton/ha year⁻¹ which contribute ($R^2 = 4.2\%$) to the model. The findings by Uduma *et al.* (2016) also showed an increase in millet yield in Zamfara State under the same climatic conditions as the study area.

The pattern of Sorghum production from the year 1989 to 2018 is presented in Figure 5. The series shows sharp increase in production from the year 2011 to 2015. It equally portrays an increasing pattern with a yearly rate of 3.98 ton/ha which

contributed 19.6% to the model. The highest production was recorded in 2014 with about 418 ton/ha, while the least production was recorded in 2007 with about 155.12 ton/ha. These findings also agree with the result of Uduma *et al.*, (2016) which found an increased yield in Sorghum in Zamfara State.

3.4 Relationship between Climatic Parameters and Cereal Crop Yield

The result of Pearson product moment correlation analysis between rainfall and millet production

from 1989 to 2018 is presented in Table 2. Rainfall is the independent variable while millet is the dependent variable.

lowest value of sorghum was recorded. This means that excess rainfall affects the yield and production of sorghum. The results in Table 2

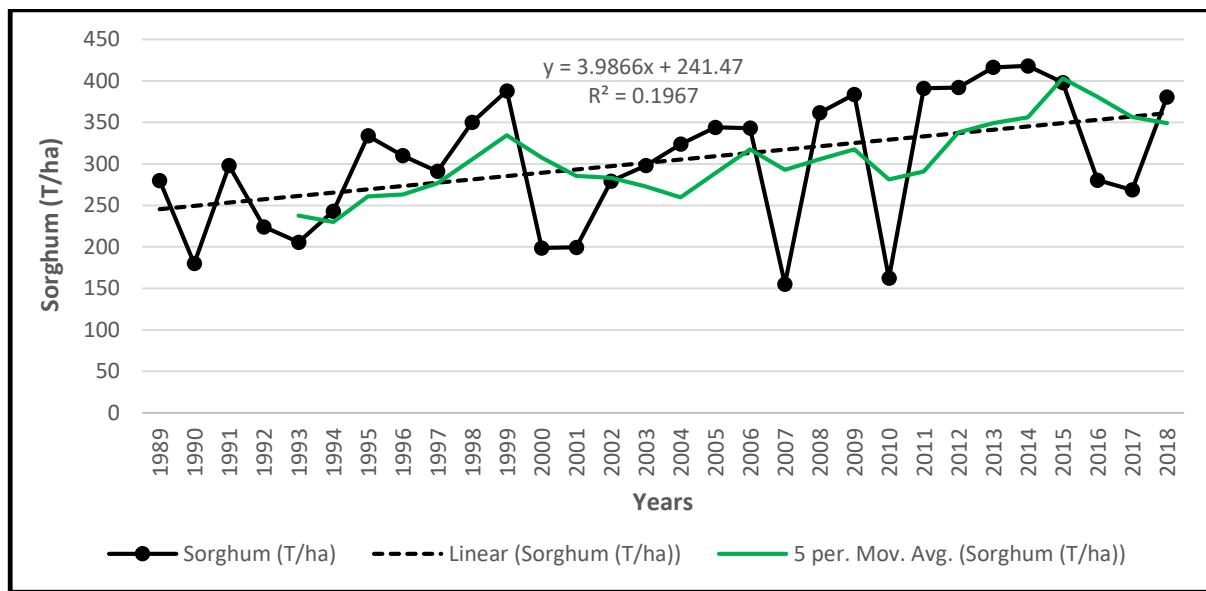


Figure 5: Trend of Sorghum Production

Table 2: Correlation between Rainfall, Sorghum, Temperature and Millet

		Rainfall	Tem.
Millet	Pearson Correlation	-.052	.104
	Sig. (2-tailed)	.785	.586
Sorghum	Pearson Correlation	.009	.120
	Sig. (2-tailed)	.961	.529
N		30	30

The result shows a weak negative relationship ($r = -0.052$) between rainfall and millet production. This result did not relate with the findings of Uduma *et al.* (2016) which indicated a positive relationship between millet yield and annual rainfall in Zamfara State. The highest rainfall amount and the least millet value produced were recorded in 2007. This means that excess amount of rainfall received affected the millet yield in 2017. The result shows a positive relationship ($r = 0.009$) between rainfall and sorghum production. The year 2007 recorded the highest amount of rainfall and in the same year, 2007,

shows no significant relationship between temperature and millet yield ($r = 0.104$). This result does not agree with the findings of Gurusamy *et al.*, (2020) who reported that temperature had a significant relationship on millet yield. Results also show no significant relationship exists between temperature and sorghum ($r = 0.120$). These results contradict Prasad *et al.*, (2008) who found a significant relationship between temperature and sorghum yield.

Table 3 shows the result of the regression analysis between sorghum and rainfall and temperature. Based on the Durbin –Watson statistics result (1.80), it shows that the result is best, linear and unbiased estimate. The regression result shows a positive relationship between rainfall and sorghum (0.012) and a similarly positive relationship between temperature and sorghum at (0.733). The result reveals that an increase in

Table 3: Regression analysis between sorghum, rainfall and temperature

Variable	Coefficient R ²	Std. Error	t-Statistic	Prob.
Constant	3.146338	5.386329	0.584134	0.5640
Rainfall	0.012099	0.180594	0.066993	0.9471
Temperature	0.733003	1.714700	0.427482	0.6724

Dependent Variable: Sorghum

rainfall by 1% will lead to increase in the production of sorghum by 1.2% per annum. This result relates with the findings of Haruna and Tasi'u (2017) who also reported a positive relationship between sorghum and rainfall, and 1% increase will lead to increase in production by (68.1%). Similarly, an increase in temperature by 1% will lead to 73% increase in sorghum production. However, there is no significant relationship between rainfall, temperature and sorghum production.

Table 4 shows the result of regression analysis between millet, rainfall and temperature. Based

4. CONCLUSION

This paper examined the relationship between weather parameters (rainfall and temperature) and cereal crop yield in Katsina State, Nigeria. The findings show an increasing trend in rainfall and temperature during the under the period studied. There is a negative relationship ($r = -0.052$) between rainfall and millet production and a positive relationship ($r = 0.009$) between rainfall and sorghum production. Also, there is a positive relationship between temperature and crop yield (millet and sorghum) at ($r = 0.104$), ($r = 0.120$) respectively. The highest cereal crop

Table 4: Regression Analysis between Millet, Rainfall and Temperature

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Coefficient	3.996970	4.480607	0.892060	0.3802
Temperature	0.500071	1.426370	0.350590	0.7286
Rainfall	-0.029723	0.150227	-0.197851	0.8446

Dependent Variable: Millet

on the Durbin –Watson statistics result (1.78), it shows that the result is best, linear and unbiased estimate. There is a positive relationship between temperature and millet production in the study area (0.05). An increase in temperature by 1% will increase the millet production by 5%. However, there is a negative relationship between rainfall and millet production in the study area (-0.029). An increase in one (1) % of rainfall will reduce millet production by 2.9%. This result disagrees with the findings of Haruna and Tasi'u (2017) who reported a positive relationship between rainfall and millet yield where 1% increase in rainfall leads to 61.7% increase in the production of millet. Bello (2012) also reports that 1% in rainfall leads to 62% and 73.5% increase millet production in Kura and Dambatta respectively. Poudel and Shaw (2016) noted that there is positive relationship between millet yield and maximum temperature and it contributes 37.2% to the variation between climatic variables and millet yield. While Toure *et al.* (2018) reported that increase in temperature will affect millet grain yield in Sudanian and Sahelian zones, further studies by Adam (2021) noted that there is a weak correlation between climatic variables (rainfall and temperature) and millet production with coefficient of variation of (7.5%).

production was recorded in 2014 with about 418 ton/ha, while the least production was recorded in 2007 with about 155.12 ton/ha. However, findings indicate that the relationships between climatic parameters and crop yield were not significant even though temperature has more probability to increase crop yield than rainfall.

The study therefore recommends collaboration between agricultural extension agents and the Nigerian Meteorological Agency (NiMet) to guide farmers in the state on stabilizing their millet and sorghum cropping calendar in accordance with weather forecasts since both rainfall and temperature have no significance relationship with cereal crops yield. Similarly, cereal research institutes should be adequately funded to develop high yielding varieties. Further studies on other factors affecting cereal yield in the study area is also recommended.

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