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# Assessment of the Effect of Rainfall Variability on Maize Productivity in Kaduna State, Nigeria.

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## Abstract
*Understanding the link between climate and crop productivity is very important in ensuring the future of food security in every part of the world. Rainfall especially in the dry tropical environment is one of the main factor affecting crop productivity. This article aimed to assess the effects of rainfall variability on maize productivity in Kaduna state, Nigeria. Annual rainfall and crop yield data were retrieved from the Nigerian Meteorological Agency (Nimet) and Kaduna Agricultural Development Project (KADP), Kaduna respectively. Pearson product-moment correlation and multiple regression analysis were used to determine and assess the relationship between the rainfall indices and maize yield. The results of the correlation revealed that Length of rainy season has the strongest effects on maize yield in the study area with correlation coefficients of 0.501. The regression analysis showed that the selected rainfall indices accounts for 61.6 percent influence on maize yield in the study area during the reference period (1999-2018). The study recommends the judicious use of weather and climate forecast. This will help the farmers in proper timing during the crop production activities and also the selection of suitable crops for production to reduce the indiscriminate waste of valuable resources.*

**Keywords:** Effects, Maize, Productivity, Rainfall, Variability.

## INTRODUCTION
The understanding of the link between climate and crop productivity is very important in ensuring the future of food security in every part of the world (Ray, *et. al.,* 2015). In many poor developing countries, people engage in climate-sensitive activities especially agriculture for their livelihood support (Kyei-Mensah, *et. al.,* 2019). It is reported that, climate change is estimated to control more than 80% of rain-fed agricultural produce in sub-Saharan Africa (Rosegrant, *et. al.,* 2002) and climate variability is negatively affecting the agricultural sector through the major extreme weather event such as flood, drought, heat wave etc. Above all, the failure or success of many crop produced in the Sudano-Sahelian regions of West Africa under rain fed conditions are strongly attached to rainfall patterns (Traore, *et. al.,* 2013).

Rainfall especially in the dry tropical environment is one of the main factors affecting crop productivity (Panda, *et. al.,* 2019), this is because rainfall onset determines planting season and its cessation marks harvesting period. Where rainfall is optimum, crop productivity is usually high and if low, this determines low productivity (Ati, *et. al.,* 2009), this also means if the

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rainfall amount is too high, it results in poor productivity due to storm surges. Emeghara (2015) revealed that, an in-depth understanding and knowledge of the pattern of rainfall indices is a very important measure in determining crop productivity and also a vital prerequisite to combating food insecurity in many parts of developing countries.

Water availability is the sole factor in the maize crop life cycle, in many phonological stages such as germination, growth, flowering and grain development, water deficit can cause damage to its productivity (Heisey and Edmeades, 1999). Drought is harmful to maize growth and development (Rashid & Rasul, 2011). In simple words, drought is the lack of water availability. During stem elongation, the development and growth of leaves and stem is so rapid that it requires sufficient amount of water, the water stress at that stage can reduce the height of the maize plant and also affects the leaves (Muchow & Carberry, 1989). The most crucial time of water stress in maize crop is ten to fifteen days before and after flowering. At this stage if the water deficit occurs then the grain yield decrease two to three times more than the water deficit in another growing stage (Grant, *et. al.,* 1989).

It is a known fact that, there is large variation in the vegetation and agro climatic zones in Nigeria. This results to different agricultural activities including the cultivation of different types of crops (Murtala & Abaje, 2018). In this sense, rainfall fluctuations affects maize productivity as it affects the number of rainy days, length of rainy season and the length of maize growing season (Ammani, *et. al.,* 2012). Previous researches in the country have discussed the influence of climatic change on farming activities, yet much attention has not been given to a particular climatic element like temperature, precipitation, wind etc and its effect on a particular crop productivity. It is based on this facts that this article aimed at assessing the effects of rainfall variability on maize productivity in Kaduna state, Nigeria.

## MATERIALS AND METHODS

*Study Area*

Kaduna State lies between latitudes 09$^0$02' and 11$^0$32' north of the equator and longitudes 06$^0$15' and 08$^0$38' east of the prime meridian (see figure 1). It has an estimated land area of about 46,053 km$^2$ and shares boundaries with Nassarawa state and FCT to the south, Zamfara, Katsina and Kano state to the North, Niger state to the west and Bauchi and Plateau state to the east (Murtala, *et. al.,* 2021).

The study area lies in the tropical wet and dry climate zone (Aw) characterized by strong seasonality in rainfall and temperature distributions. The wet season lasts from April through October with a peak in August, while the dry season extends from November of one calendar-year to April of the next (Murtala, *et. al.,* 2018; Murtala and Abaje, 2018). It has an average annual rainfall of about 2000mm at the extreme southern part of the state and about 600mm annual average at the extreme northern part (Abaje, *et al.*, 2016). Months with the highest rainfall are between July and August and rainfall usually commences in late April and ends in October (Murtala, *et al.,* 2018). The dry season sets in by late October and ends in late April of the following year. The rainfall length varies from 120 days to 200 days in the study area (Yusuf, 2021).

Based on the 2006 population census, Kaduna state has a population of 6,113,503 and as at 2022 the population was projected to be 9,032,200 people at the growth rate of 2.5%. The main economic activity is agriculture both crop production and animal rearing. These are carried out mostly in small scale both in rainy and dry seasons. Other people are into non-agricultural activities such as civil service, local trading, skilled and unskilled labour etc (Murtala *et al.,* 2021).


Figure 1: Map of the Study Area

*Data Collection*

For this study two sets of secondary data were required. The Daily rainfall data (mm) from 1999-2018 was retrieved from the database of the Nigerian Meteorological Agency (Nimet) and maize yield data in tons from 1999-2018 was retrieved from the Kaduna Agricultural Development Project (KADP), Kaduna. The daily rainfall data (mm) collected for the study was used to derive rainfall onset date, cessation date, length of the rainy season, annual rainfall and seasonality index.

*Analysis of Data*

Relationships between each of the rainfall indices and maize yield was analyzed through the use of the Pearson product-moment correlation method. The Pearson product-moment correlation was used to test the magnitude of the relationship between rainfall indices and maize yield in the study area within the research reference period. This is calculated using the Pearson product moment correlation equation below.

$$r = \frac{\frac{1}{n}\sum(x_1 - \bar{x})\,(y_1 - \bar{y})}{\sigma x\, \sigma y} \quad \ldots\ldots (1)$$

$$\sigma x = \frac{\sqrt{\sum(x_1 - \bar{x})^2}}{n} \quad \ldots\ldots (2)$$

$$\sigma y = \frac{\sqrt{\sum(y_1 - \bar{y})^2}}{n} \quad \ldots\ldots (3)$$

Where: r is the coefficient of correlation, $\sigma x$ is the standard deviation of $x$, $\sigma y$ is the standard deviation of $y$, $x_1$ is the score of the first variable, $y_1$ is score of the second variable and $n$ is the number of variables.
For testing for significance of 'r' (two-tailed at 0.05 significant levels) the equation is given below as:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \quad \ldots\ldots (4)$$

Where: $n-2$ = degree of freedom, $n$ = sample size of paired scores, $r$ = coefficient of correlation, $t$ = testing for the significance of '$r$'.
Also, multiple linear regression analyses was used in predicting crop yields. The yield was expressed as dependent variable ($y$) and rainfall indices as independent variables ($x$). The general form of multiple linear regression equation is presented below:

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 \quad \ldots\ldots (5)$$

Where: $y$ = Maize yield in tons, $a$ = Constant, $b$ = is the rise or fall as $x$ changes, $x_1$ = Total annual rainfall (mm), $x_2$ = Onset dates of rain, $x_3$ = Cessation dates of rain, $x_4$ = Length of the raining season and $x_5$ = Seasonality Index.

## RESULTS AND DISCUSSION

The Statistical Package for Social Science (SPSS) version 25 and Microsoft Excel (version 2016) were the softwares used for the data analysis and the discussion of relationship between rainfall indices and maize yield in the study area for the reference period (1999-2018) are presented below:

*Relationship between Rainfall indices and Maize Yield*

The Pearson product moment correlation was used to test the relationship between rainfall parameters and maize yield. These relationships are shown in table 1 below:

Table 1: Relationship between Rainfall Indices and Maize Yield

| Variables | $r$ | $r^2$ | $r^2$ x 100 | 100 - $r^2$ | Computed '$t$' | Critical '$t$' |
|---|---|---|---|---|---|---|
| Annual rainfall and maize yield | 0.479 | 0.229 | 22.944 | 77.056 | 2.315 | 2.1009 |
| Onset date of rain and maize yield | -0.463 | 0.214 | 21.437 | 78.563 | -2.216 | 2.1009 |
| Cessation date of rain and maize yield | 0.349 | 0.122 | 12.180 | 87.820 | 1.580 | 2.1009 |
| Length of raining season and maize yield | 0.501 | 0.251 | 25.100 | 74.900 | 2.456 | 2.1009 |
| Seasonality index and maize yield | -0.303 | 0.092 | 9.181 | 90.819 | -1.349 | 2.1009 |

From table 1, the correlation of annual rainfall and maize yield (r = 0.479) shows a weak positive correlation and accounts for 22.944 percent variation in maize yield. The computed 't' value is 2.315 which is greater than the critical 't' value of 2.1009 at 0.05 two tailed level of significance. Therefore, it can be concluded that there is significant relationship between annual rainfall and maize yield in the study area. The implication is that increase in annual rainfall in the study area may lead to increase in maize yield. This finding is in concordance with the study of (Shugaba, 2017) which also revealed a weak positive correlation of annual rainfall with millet in Jigawa state.

Rainfall onset date, cessation date and seasonality index show a weak relationship with (r = -0.463), (r = 0.349) and (r = -0.303) respectively. These indicate an early rainfall onset date, late cessation date and short spread of rainy season (with most rain in three or less than three months) in the study area. These findings is in line with the research of (Shugaba, 2017) and (Shugaba and Ahmed, 2020) which revealed a weak relationship between rainfall onset date, cessation date and seasonality index with millet yield in Jigawa state.

Length of rainy season has the strongest effects on maize yield in the study area with correlation coefficients of 0.501 and it account for 25.100 percent variation in maize yield. The computed *'t'* value is 2.456 which is greater than the critical *'t'* value of 2.1009 at 0.05 two tailed level of significance. Therefore, there is a significant relationship between length of rainy season and maize yield in the study area. This may imply that, increase in length of rainy season may lead to increase in maize yield in the study area. This finding is not in line with the study of (Shugaba, 2017) and also disagrees with the finding of (Shugaba and Ahmed, 2020) which revealed a weak correlation with millet yield in Jigawa state.

*Regression Analysis for Rainfall Indices and Maize Yield*
The multiple regression analysis was used in predicting annual maize yield based on the studied rainfall effectiveness parameters. The result of this analysis is presented in table 2 below.

Table 2: Regression for Rainfall Indices and Maize Yield

| Variables | Coefficient | t - Value | Sig. of t | $R^2$ |
|---|---|---|---|---|
| Maize Yield | | 0.723 | 0.49 | 61.6 |
| Annual rainfall | -0.54 | -0.317 | 0.76 | |
| Onset Date of Rain | -0.279 | -0.539 | 0.605 | |
| Cessation Date of Rain | 0.253 | 0.295 | 0.776 | |
| Length of Raining Season | 0.118 | 0.132 | 0.898 | |
| Seasonality Index | -0.232 | -0.591 | 0.571 | |

The result in table 2 indicates that the selected rainfall indices, accounts for 61.6 percent influence in maize yield in the study area. Rainfall amount in July has the highest influence on maize yield with the regression coefficient of 0.543. The remaining 38.4 percent influence in maize yield could be due to soil fertility, pest and diseases, time of planting, ability of farmers to obtain soft loans and fertilizer from local, state or federal governments. This finding is close to the findings of Emeghara (2015) whose work revealed that onset date of rainfall, cessation date of rainfall, length of rainy season and dry spell account for 52.1 percent variation in maize yield in Sokoto state. This is far from the findings of Shugaba (2017) whose work revealed that precipitation effectiveness indices account for 40.6 percent variation in millet yield in Jigawa central senatorial zone.

## CONCLUSION

In conclusion, there is no doubt that rainfall is one of the most important factors that determine maize productivity in Kaduna state during the study reference period (1999-2018). In essence, the study revealed how significant rainfall is in determining maize yield, even though, other factors play a vital role in that purpose. This means climate change at a local scale in this area may risk people lives to food insecurity through hunger and diseases. The research suggests an in-depth research into climate-crop relationship and encourage farmers about the use of weather forecast. This will help the farmers in proper timing during the crop production activities and also the selection of suitable crops for production to reduce the indiscriminate waste of valuable resources.

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