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**Analysis of Rainfall Characteristics in Kaduna State, Nigeria from**  
**1999 – 2018**

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**ABSTRACT**

In the present time of changing climate, rainfall provides a vital information for effective agricultural and water resource planning and management. This study aimed at analyzing the rainfall characteristics in Kaduna state, Nigeria. Rainfall data of 20 years from 1999-2018 were obtained from the National Water Resource Institute Kaduna for the study. Walter's 1967 formula was used to calculate the rainfall Onset and Cessation dates while the Seasonality Index was calculated using the Walsh and Lawler's 1981 method. Results obtained revealed a decrease in trend for rainfall Onset and Cessation, Annual Rainfall amounts and also a negative trend in the Seasonality Index of the study area. While the Length of rainy season shows a positive trend for the reference period. The study suggests in-depth research in areas related to crop-climate relationship, so that variety of crops with optimum yield potentials will be cultivated in the area to feed the increasing population. This will help to avoid the risks of hunger and related food insecurity in the study area.

**Keywords:** Annual rainfall; Cessation; Onset; Seasonality index; Water resource.

## 1.0 INTRODUCTION

Precipitation is any solid or aqueous materials coming from the atmosphere (Aremu, 2020). Examples are dew, fog, water vapour, rainfall, sleet and ice (snow). Precipitation in form of liquid water (rainfall) always provides important information for effective agricultural and water resource planning and management in every part of the world (Ferijal, Batelaan, Shanafield and Alfahmi, 2022). In the present time of climate change, the amount of rainfall received in many parts of the world varies both in spatial and temporal scale (Mohamed, Afandi and El-Mahdy, 2022). The current population increase especially in the developing countries where there is much reliance on rain fed agricultural production, variation in rainfall amount received is one of the main factors affecting crop yield or productivity. (Panda, Sahu, Behera, Sayama, Sahu, Avtar, Singh and Yamada, 2019). This is because rainfall onset determines planting season and its cessation marks harvest period (Yusuf, 2021). And also, the presence or absence of rainfall especially in the tropical environments marks the wet and dry seasons (Aremu, 2008).

According to a sustainable development goal report, more than 650 million people are hungry

and some 2 billion people were suffering from food insecurity around the world (SDG, 2021), this means in places like the tropical environments where rainfall is seasonal, optimum amount of rainfall received determines crop yield. Where the rainfall reception is below the required level of any crop in question, the yield will be affected. Ati, Iguisi and Seidu (2009) reported that, high amount of rainfall above the optimum level required may be harmful to crop production and also the output. This can also be through direct physical damage, delayed planting and harvesting, restricted root growth, oxygen deficiency and nutrient loss (Li, Guan, Schnitkey, DeLucia and Peng, 2019).

In Northern part of Nigeria, rainfall is seasonal and controlled by two dominant air masses (Tropical continental and Tropical maritime Air masses) (Abaje and Oladipo, 2019). The relative seasonality of rainfall in this area has been 3 months or less and this time increases towards the Southern part of the country, with a clear single maxima shifting its peak from July and August in northern part to places in the south having double maxima with peaks in July and September (Odekunle & Adejuwon, 2007). This study aimed to investigate rainfall characteristics in Kaduna state, looking at Rainfall onset and cessation,

length of rainy season and seasonality fluctuations for two decades from 1999-2018 in order to provide insight for appropriate and proper agricultural planning policies and water resource management strategies.

## 2.0 MATERIALS AND METHODS

This section discusses the study area, methods employed in the study from data collection, data presentation and statistical analysis.

### 2.1 Study Area

Kaduna State is located between latitudes  $09^{\circ}02'$  and  $11^{\circ}32'$  north of the equator and longitudes  $06^{\circ}15'$  and  $08^{\circ}38'$  east of the prime meridian (figure 1) with an estimated land area of about  $46,053 \text{ km}^2$  (Abaje, Achiebo and Matazu, 2018). It shares boundaries with Nassarawa state and FCT to the south, Zamfara, Katsina and Kano states to the north, Niger state to the west and Bauchi and Plateau states to the east.

Climatologically, the study area lies within the Tropical wet and dry climate zone (Aw) as according to Koppen's climate classification. It has an average annual rainfall of about 2000mm in wet years and as low as 500mm in drought years. Months with highest rainfall months being August and September. The mean annual rainfall of the study area is 1453.1mm (Yusuf, 2021). Rainfall usually commences in late April and ends in October. The dry season sets in by late October and ends in late April of the following year.

Temperature is high throughout the year with highest average monthly value of about  $28.9^{\circ}\text{C}$  and the lowest average monthly value of  $22.9^{\circ}\text{C}$  to  $23.1^{\circ}\text{C}$  (Abaje and Oladipo, 2019). The hottest months in this part of the country are March and April with mean monthly temperature of about  $31^{\circ}\text{C}$  while the coolest months are December and January with mean monthly temperature of about  $21^{\circ}\text{C}$  (Murtala and Abaje, 2018).

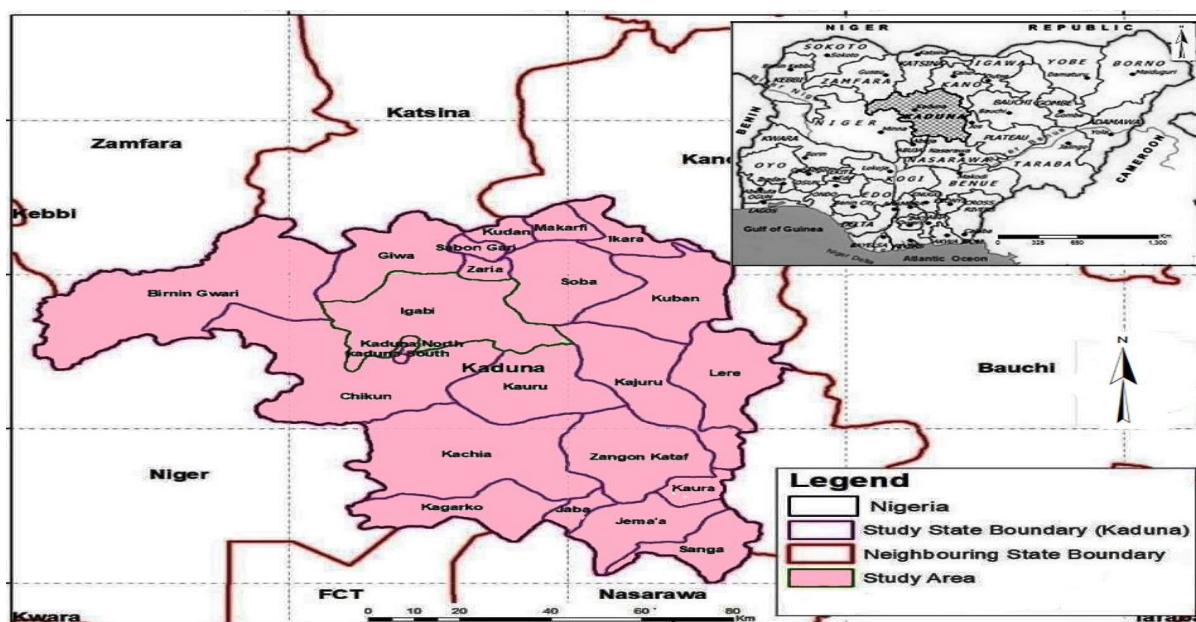


Figure 1: Map of the study area

Under the combined influence of the North Easterly and the South Westerly winds, the climate of the study area is also influenced by the movement of the Inter-Tropical Discontinuity (ITD) (Abaje and Oladipo, 2019). The ITD is a slanting surface where Tropical Maritime and Tropical Continental air masses meet. This moves from north to south and from south to north depending on the time of the year. The North East trade wind blowing from Sahara desert results to harmattan and blows over the study area from late October to February of the following year; while

the south west trade wind which is composed of moist and relatively cool air originates from the ocean blows across the study area from late April to October bringing rainfall (Sawa and Adebayo, 2011). The mean relative humidity in the study area ranges from 70% to 90% in the rainy season and reduces to about 30% during the dry season (Abaje and Oladipo, 2019). The area also consists of tall woodland and long grass savanna species with gallery forest along the main water courses (Murtala and Abaje, 2018).

Major rivers that drain the study area are River Kaduna, River Wonderful in Kafanchan, River Kagom, River Gurara and River Galma and several other (Abaje, Sawa, Iguisi and Ibrahim, 2016). Located within the broad gentle undulating plain with the height ranging between 450 - 750m above sea level (Sawa and Adebayo, 2011); the study area has geological unit composed of igneous rock, bounded gneisses and migmatites with locally extensive area of meta-sedimentary rock as schist, phyllite, quartzite and marble giving the soils to developed on weathered regolith rich in fine grained quartz and oligoclase (Yusuf, 2021).

Human activities in the area are enormous due to the various potentials to support different population group. These activities include fishing (around river Kaduna), animal husbandry (Zaria, Makarfi, Igabi), extensive land cultivation (Saminaka, Zonkwa, Makarfi, Igabi and Kafachan), mining and quarrying (Nok, Kaduna, Zaria), manufacturing and construction (Kaduna, Zaria), trading and artisans (Zaria, Kaduna, Kafachan). The study area is an industrial centre of Northern Nigeria. The manufacturing products are in textiles, machinery, aluminum and petroleum products. Other light manufacturing includes plastics, pharmaceuticals, leather goods and furniture (Abaje *et al.*, 2016).

**2.2 Methods of Data Collection**

The study uses daily rainfall data (mm) from 1999-2018 which was gathered through a secondary source of data collection technique Daily rainfall data (mm) was sourced from the National Water Resources Institute Kaduna. This data was used to derive the rainfall indices of rainfall onset and cessation dates, length of the rainy season, annual rainfall and seasonality index. These indices were later subjected to time series analysis (using the trend lines) so as to identify the direction of changes.

**2.2.1 Rainfall Onset Date**

This study uses Walter, 1967 formula for the derivations of rainfall onset and cessation dates. Onset of rainfall is when the moisture in the soil can permit crop germination. In 1967, Walter came up with a formula that could be used to determine onset date and relate soil moisture index to monthly rainfall with the assumption that the soil moisture index required for plant to germinate is 51mm with a mathematically expressed as:

$$\text{Onset Date} = \frac{T(51-x)}{T_2} \dots\dots\dots (1)$$

Where

*T* is the number of days in the first month in which cumulative monthly rainfall is equal to or greater than 51mm, *x* is the rainfall total of the previous month and

*T<sub>2</sub>* is the total rainfall of that first month with cumulative rainfall equal to or greater than 51mm.

**2.2.2 Rainfall Cessation Date**

Cessation means the termination of effective rainy season. It does not imply the last day of rainfall, but when rainfalls can no more be assured or effective, thus the amount of water in the soil can no longer support the development of crops. This is computed in the same way as the onset date but the computation is taken in the reverse order from December.

$$\text{Cessation Date} = \frac{T(51-x)}{T_2} \dots\dots\dots (2)$$

where

*T* is the Number of days in the last month in which cumulative monthly rainfall is equal to or greater than 51mm,

*x* is the rainfall total of the previous month and

*T<sub>2</sub>* represent the Total rainfall of that last month with cumulative rainfall equal to or greater than 51mm.

**2.2.3 The length of the rainy season (LRS)**

This is determined by number of days between onset date and cessation date (Walter, 1967). Once the onset, cessation dates are known the length of rainy season can be determined by counting the number of days between onset date and the cessation date of that particular year.

For annual rainfall, monthly rainfall records are added yearly to give the annual rainfall totals for the year (Sawa and Adebayo, 2011). Rainfall records of all the 12 months of the year are added together to give annual rainfall for each year.

**2.2.4 Seasonality Index**

This measures the spread and steadiness of the rainfall during the wet season. Walsh and Lawler, (1981) mathematically expressed seasonality index as the sum of the absolute deviations of the mean monthly rainfall from the overall monthly mean multiplied by the exponent of the mean annual rainfall given as:

$$SI = \frac{1}{R} \sum \left| \bar{x}_n - \frac{R}{12} \right| \dots\dots\dots (3)$$

Where  
 $SI$  is the Seasonality index,  
 $\bar{x}_n$  is the mean rainfall of the month ...n and  
 $R$  is the mean annual rainfall.  
 The higher the  $SI$  values, the shorter the spread of  
 the rainy season, implying the drier the place, and

vice versa. According to Walsh and Lawler (1981), the seasonality of a place can be used to classify a place into one of seven classes. They provided an interpretation table for seasonality index in table 1 below.

**Table 1: Classification of Seasonality Index of Rainfall**

| S/No | SI Class    | Rainfall Regime                             |
|------|-------------|---|
| 1    | $\leq 0.19$ | Very equitable (no dry season)              |
| 2    | 0.20 – 0.39 | Equitable but with a definite wet season    |
| 3    | 0.40 – 0.59 | Rather seasonal with a shorter drier season |
| 4    | 0.60 – 0.79 | Seasonal                                    |
| 5    | 0.80 – 0.99 | Markedly seasonal with a long drier season  |
| 6    | 1.00 – 1.99 | Most rain in three months or less           |
| 7    | $>1.99$     | Extreme, rainfall below 1-2 month(s)        |

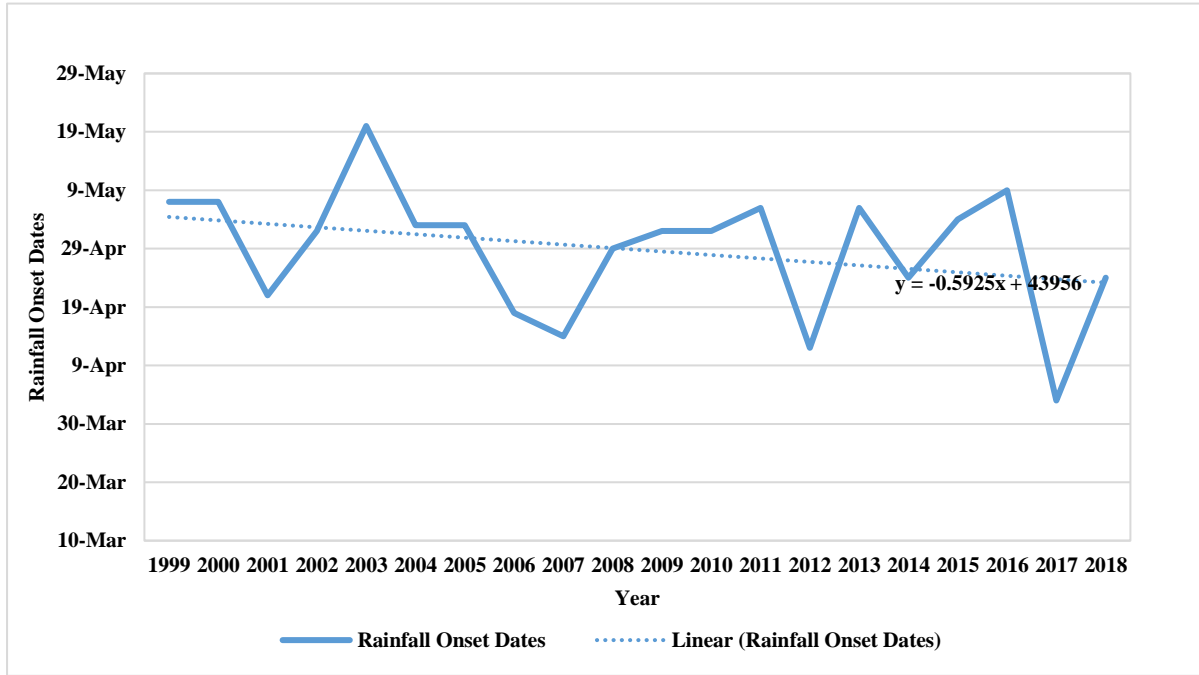
Adopted from Walsh and Lawler (1981)

### 3.0 RESULTS AND DISCUSSION

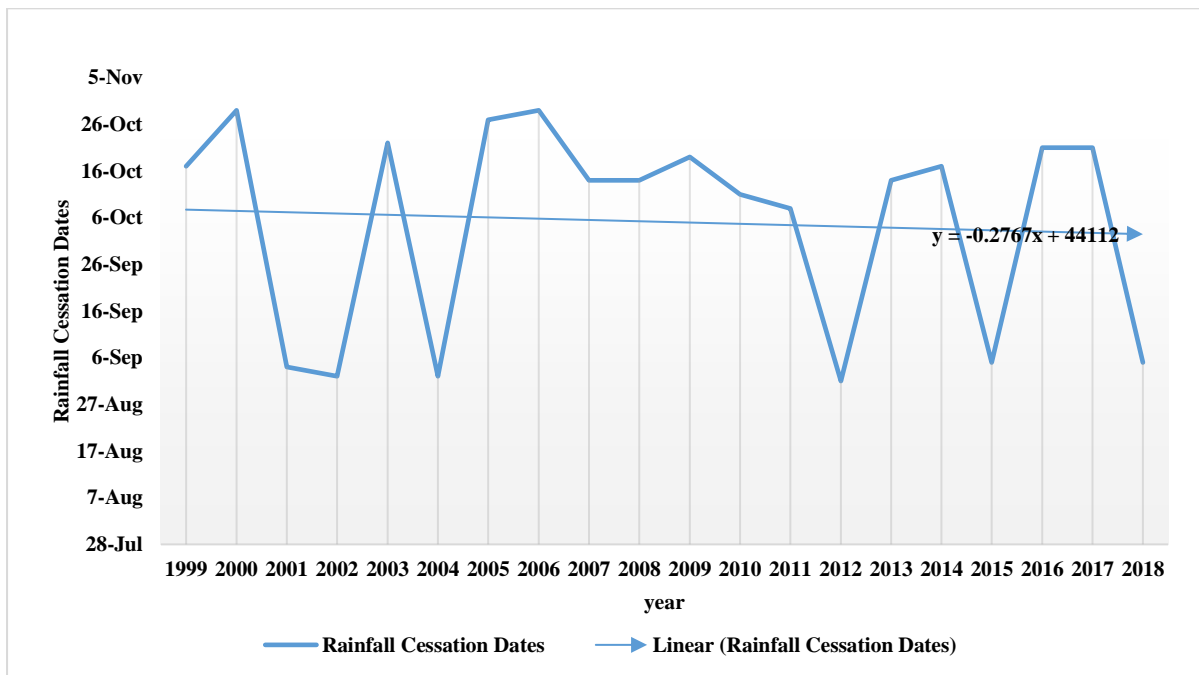
This section analyses and interprets the findings of the research.

**Table 2: Computed Rainfall Indices for Kaduna State (1999 -2018)**

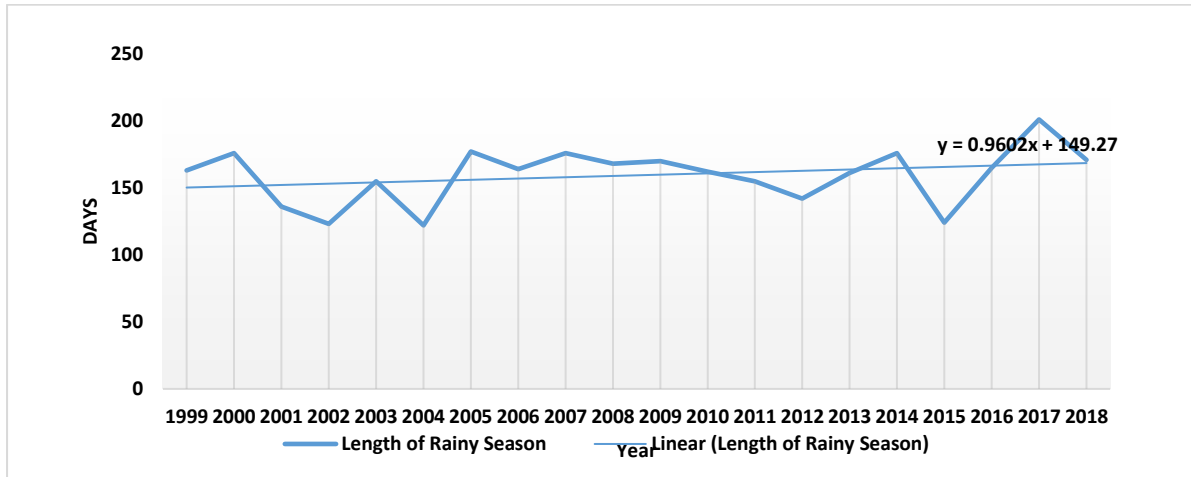
| Year | Maize yield<br>(ton/annum) | Annual<br>Rainfall<br>(mm) | Onset<br>Dates | Julian<br>Day | Cessation<br>Dates | Julian<br>Day | L.R.S | S.I  |
|------|----------------------------|----------------------------|----------------|---------------|--------------------|---------------|-------|------|
| 1999 | 697700                     | 1285.7                     | 7-May          | 127           | 17-Oct             | 299           | 163   | 0.99 |
| 2000 | 547900                     | 1253.4                     | 7-May          | 128           | 29-Oct             | 303           | 176   | 1.02 |
| 2001 | 547100                     | 1178.4                     | 21-Apr         | 111           | 4-Sep              | 247           | 136   | 1.05 |
| 2002 | 554200                     | 1208.2                     | 2-May          | 122           | 2-Sep              | 245           | 123   | 1.07 |
| 2003 | 554600                     | 1453.5                     | 20-May         | 140           | 22-Oct             | 295           | 155   | 0.99 |
| 2004 | 643200                     | 1611.1                     | 3-May          | 124           | 2-Sep              | 246           | 122   | 0.96 |
| 2005 | 865200                     | 1121.2                     | 3-May          | 123           | 27-Oct             | 300           | 177   | 1.00 |
| 2006 | 904200                     | 1397.4                     | 18-Apr         | 108           | 29-Oct             | 302           | 164   | 0.97 |
| 2007 | 966300                     | 1946.2                     | 14-Apr         | 104           | 14-Oct             | 288           | 176   | 1.02 |
| 2008 | 987200                     | 1934.7                     | 29-Apr         | 120           | 14-Oct             | 288           | 168   | 1.17 |
| 2009 | 1011800                    | 1872.4                     | 2-May          | 122           | 19-Oct             | 292           | 170   | 0.91 |
| 2010 | 798600                     | 1899                       | 2-May          | 122           | 11-Oct             | 284           | 162   | 0.97 |
| 2011 | 720924                     | 1666.3                     | 6-May          | 126           | 8-Oct              | 281           | 155   | 0.99 |
| 2012 | 785840                     | 1580                       | 12-Apr         | 103           | 1-Sep              | 245           | 142   | 0.95 |
| 2013 | 616359                     | 1668                       | 6-May          | 126           | 14-Oct             | 287           | 161   | 1.01 |
| 2014 | 620400                     | 1322.4                     | 24-Apr         | 114           | 17-Oct             | 290           | 176   | 1.11 |
| 2015 | 639012                     | 1103.2                     | 4-May          | 124           | 5-Sep              | 248           | 124   | 1.11 |
| 2016 | 658182                     | 1190.4                     | 9-May          | 130           | 21-Oct             | 295           | 165   | 1.11 |
| 2017 | 855637                     | 1298.8                     | 3-Apr          | 93            | 21-Oct             | 294           | 201   | 0.86 |
| 2018 | 881306                     | 1071.4                     | 24-Apr         | 114           | 12-Oct             | 285           | 171   | 0.92 |
| mean | 742783.0                   | 1453.1                     | 28-Apr         | 119.1         | 6-Oct              | 280.7         | 159.4 | 1.0  |



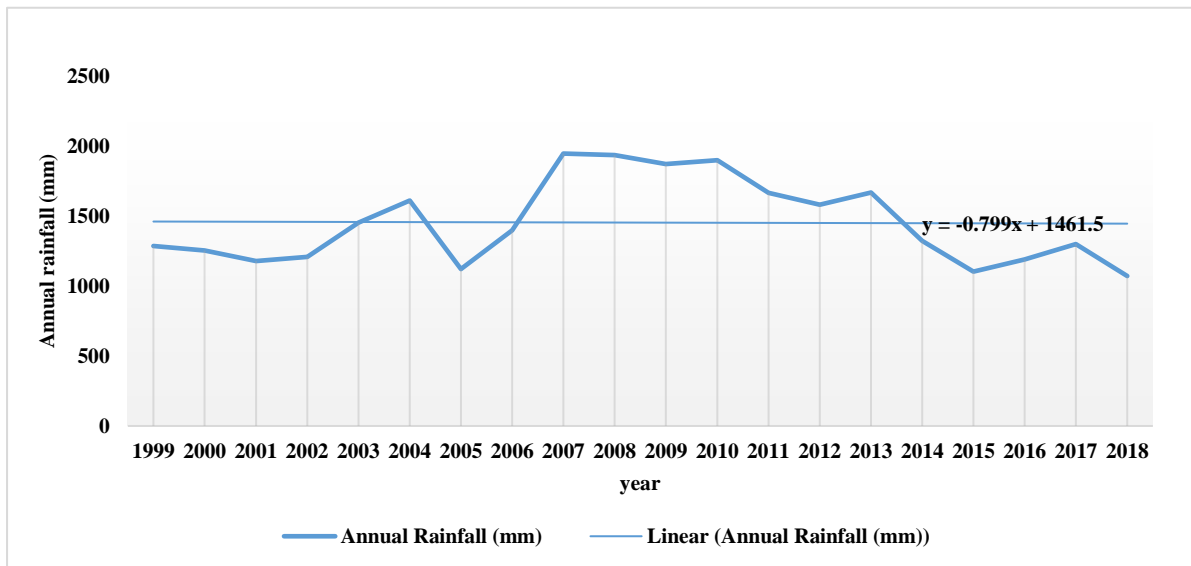
**Figure 2: Trend in Onset Dates of Rainfall in Kaduna State (1999 – 2018)**  
 Source: Field Survey, 2023



**Figure 3: Trend in Cessation Dates of Rainfall in Kaduna State (1999 – 2018)**  
 Source: Field Survey, 2023



**Figure 4: Trend in Length of Rainy Season in Kaduna State (1991-2018)**  
Source: Field Survey, 2023



**Figure 5: Trend in Annual Rainfall in Kaduna State (1999 - 2018)**  
Source: Field Survey, 2023



**Figure 6: Trend in Seasonality Index in Kaduna State (1999 - 2018)**

Source: Field Survey, 2023

#### 4.0 DISCUSSION

Discussions on the findings of this research are presented below.

##### 4.1 Trend in Onset Dates of Rainfall in Kaduna State from 1999 - 2018

Yearly rainfall onset date plays an important role in determining rain-fed agricultural production activities in any part of the world. The trend lines showing the onset dates of rainfall in the study area presented in figure 2 shows a decreasing trend in rainfall onset dates in Kaduna state during the study reference period (1999-2018). Rainfall onset dates commenced between 3<sup>rd</sup> of April and 20<sup>th</sup> of May in the study area. This is the period when moisture in the soil can permit germination of crops and it therefore means that crop production in the study area commences a little earlier than some neighboring northern states. This could be due to its relative positioning being aligning more to the south bordering the tropical hinterland climate with rainforest vegetation. Significant parts were contained in the Guinea Savannah vegetation zone, while other parts fall within the Sudan vegetation.

##### 4.2 Trend in Cessation Date of Rainfall in Kaduna State from 1999 - 2018

The rainfall cessation dates in the study area presented in figure 3 shows a decreasing trend. Rainfall cessation date is between 3<sup>rd</sup> of September and 28<sup>th</sup> of October with the cumulative mean date of 6<sup>th</sup> October. This indicates a slight delay in rainfall cessation date in the study area and it also implies that many crops produced in the area will have adequate soil moisture available for their later stage of development. Therefore, crop cultivation should be done within the time frame (late April to early October) to avoid reduction in soil moisture.

##### 4.3 Trend in Length of Rainy Season in Kaduna State from 1999 - 2018

The length of the rainy season in the study area presented in figure 4 shows a positive trend with equation of  $y = 0.9602x + 149.27$ , this indicates an upward trend in length of rainy season. For the reference period (1999-2018), the result depicts fluctuations in length of days of rainy season in

the study area. It was observed that there is a drop in length of rainy season in the years 2002, 2004 and 2015. Then a significant rise in length of rainy season was observed in the years 2000, 2005, 2014 and 2017. The length of rainy season ranges between 122 days in 2004 and 201 days in 2017. And the cumulative mean of the length of rainy season is 159 days (table 2). This signifies that the duration of the rainy season in the study area is gradually widening over the years. This implies that, with increase in the length of rainy season, and other factors of crop production such as fertilizer application, farming methods, use of pesticides etcetera, the productivity of the crops produced in the study area would increase. This finding is in line with the study of Shugaba, (2017) which revealed an upward trend in length of rainy season in Jigawa central senatorial zone. But not in concordance with the research findings of Sawa and Adebayo (2011) and Emeghara (2015) whose works revealed a downward trend and gradual decrease in length of rainy season in most of the extreme northern states of Nigeria.

##### 4.4 Trend in Annual Rainfall from the Year 1999 - 2018

The total annual rainfall received in the study area presented in figure 5 shows a decreasing trend during the reference period ( $-0.799x + 1461.5$ ). This is not a welcome development in both agricultural and water resource sector in the study area, as there may be a decrease in moisture for crop production. From the above result (figure 5), there are fluctuations in annual rainfall based on individual years with a drop in the year 2001, 2005, 2015 and 2018 and a rise in the year 2004, 2007, 2010 and 2013 with the total mean annual rainfall of 1453.1mm (see table 2). Cumulatively for the whole reference period (1999-2018), there is a systematic drop in rainfall from 2002, 2005, 2014, 2017 and 2018 in almost all the growing season months. This finding is in concordance with the study of Hassan and Abdulhamid (2012) which revealed decreasing annual rainfall in Katsina and not in line with the finding of (Shugaba, 2017) which revealed increasing annual rainfall in Jigawa.

##### 4.5 Trends in Seasonality Index from 1999 - 2018

The seasonality index of the study area presented in figure 6 revealed a negative trend ( $y = -0.0011x + 1.021$ ). Seasonality index is between 0.86 and 1.11 for the whole reference period (1999 – 2018). The mean seasonality index value is 1.0 which means the study area have most rain in three months or less and the area falls within the Sudan Savanna climatic type (Yusuf, 2021). The trend equation means that there is short spread of rainfall in the study area. This finding is in line with the findings of Sawa and Adebayo (2011) and Shugaba, (2017) which concluded that there is decline in the spread of rainy season in northern Nigeria, especially the extreme north. This is due to the influence and fluctuations of ITD as earlier stated.

## 5.0 CONCLUSION

There is no doubt, information on rainfall characteristics play a vital role in agricultural planning policies and water resource development strategies. In this current regime of climate change where rainfall fluctuation directly affects agricultural productivity, knowledge of rainfall characteristic is of utmost importance. In Kaduna state, these characteristics revealed that rainfall onset starts around April and cessation around October. This period can accommodate a wide range and variety of crops to be produced with potential optimum yield in this area. The length of rainy season is widely spread while the annual rainfall amount decrease during the reference period. The study suggest further researches in areas related to crop-climate relationship, for this will give an insight on the rightful crops to be produced, so that the increasing population in this area should not be at risk of food insecurity.

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