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TRENDS IN RAINFALL ONSET, CESSATION AND LENGTH OF GROWING SEASON AND ITS IMPLICATION ON SORGHUM YIELD IN KATSINA STATE, NIGERIA.

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Abstract

This study assessed trends in rainfall onset, cessation and length of rainy season and its implication on sorghum yield in Katsina State, Nigeria. Rainfall data was used to characterise the climate of the study area and to show the relationship between rainfall characteristics and sorghum yield. Pearson's product moment correlation coefficient was computed to show the significant relationship of the rainfall and sorghum yield. The results showed that the rainfall series for the study area had no significant deviation from the normal curve (1.96) at 95% confidence level. The results further showed that annual rainfall total is increasing; rainfall onset and cessation dates are becoming late. There were also increase in the length of growing season, and in sorghum yield in the study area. The implication of the results shows that sorghum yield increases as rainfall amount increases. The study recommended viable adaptation strategies such as planting of improved seed varieties, application of organic manure such as cow dungs, and other decayed vegetative matter. The study further recommended continuous updating and monitoring of annual rainfall and sorghum yield data; and public enlightenment on the effects of climate change and rainfall variability.

Key Words: Cessation, Onset, Rainfall, Relationship, Sorghum.

1. Introduction:

Rainfall, the major index of climate change in the tropics is a vital climatic factor that determines vulnerability and yield level of crop production in Nigeria (Ayoade, 2004). The characteristics of rainfall in Nigeria (onset, cessation, Length of the Growing Season etc.) affects crop yield. Extremities of it often results in flooding or drought. Nigeria though blessed with an impressive size of arable land, has poor agricultural production that results in food shortage. Crop yields are directly affected by irregularities in rainfall pattern (Olarenwaju and Fayemi 2008).

Most agricultural planning (e.g., land clearing, crop selection, seed planting and crop harvesting) requires the knowledge of rainfall onset and cessation (Abaje, Sawa and Ati, 2014). For instance, the rainfall onset controls the best planting dates (when the soil moisture is sufficient to sustain the crop from seed germination to maturity), while the cessation and Length of Growing Season (LGS) determine the type of seed to plant (Mounkaila, Abiodun, Omotosho, Amekudzi, Yamba, and Codjoe, 2015). Therefore, agricultural activities and production becomes extremely vulnerable to the variability of the onset, cessation dates and length of the growing season (Dodd and Jolliffe 2001).

The agricultural activities in Katsina State are mainly rainfed. However, the rainfall characteristics in terms of length of growing season have always been uncertain due to high variability of onset and cessation of the rainy season. In some years, the rains start early while in others it arrives late (Abaje, 2007). The yearly variation makes the planning of sowing and the selection of the crop type and variety rather difficult. Generally, yields may suffer significantly with either a late onset or early cessation of the growing season, as well as with a high frequency of damaging variation within the growing season. The ability to predict effectively the onset of the rainy season therefore becomes vital (Iortyom, Iorsamber and Adelabu, 2017).

Food and Agricultural Organization (FAO, 2017) defined the start of the growing season as the date when precipitation exceeds half of the potential evapotranspiration. Cessation date means termination of the effective raining season. It does not imply the last day rainfall, but when rainfall can no longer be assured or be effective for crop production. Length of Growing Season is the period between the onset and cessation dates, which is the difference between the onset dates and the cessation dates of the rainy season.

Sorghum is a cereal grain crop mostly cultivated in Sub-Saharan African (SSA) countries and other parts of the world to enhance food security provide employment and generate income for rural farming households (Thabit, 2015). It is the world's fifth largest grain crop and it is the second most important crop in terms of tonnage in Africa. Sorghum is well adapted to growth in hot, arid or semi-arid areas. Sorghum is used for food, fodder and the production of alcoholic beverages. It is drought tolerant, heat tolerant and is especially important in arid regions. Although sorghum is an indigenous crop exceptionally adapted in the region, the yields are generally less than 1.5 t/ha. There are factors that affect the yield of sorghum, among them are: rainfall variability, poor soil fertility, and the non-availability of improved varieties or hybrids with significant yields superiority over farmers land race. Sorghum requires between 500 to 750mm of well-distributed rain for conducive for proper growth (Ati and Akinyemi, 2018).

Previous works on rainfall onset, cessation and the LGS employed different techniques depending on the rain generating mechanisms of the region in question. Ilesanmi (1972) empirically formulated the onset, advance and cessation of the rains in Nigeria. Oshodi (1971) used a simple pentad method to arrive at similar isochrones of the onset of the rains in Nigeria.

Sivakumar (1988) carried out an analysis of long-term daily rainfall data for 58 locations in the southern Sahelian and Sudanian climatic zones of West Africa. The study showed that a significant relationship exists between the onset of rains and the LGS. Oladipo and Kyari (1993) investigated the fluctuation in the onset, cessation and LGS in Northern Nigeria and reported that the length of the growing season is more sensitive to the onset of the rains than to the cessation. Reliable prediction of rainfall characteristics, especially the onset, is needed to determine a less risky planting date or planting method, or sowing of less risky types/ varieties of crops in responsive farming (Stewart, 1991).

Agriculture would be seriously affected by increased variability and trends in the characteristics of rainfall in an environment where one of the major limiting factors of agricultural production is the amount of water available through rainfall. Agriculture is a vibrant occupation in the study area and anything affecting agricultural yields will affect the livelihood of the people. Sorghum is widely cultivated in Katsina because of its drought resistant nature and values. This research therefore examines trends in rainfall onset, cessation and LGS and its implication on sorghum yield in Katsina. The study has covered a temporal scope of thirty-seven (37) years, from 1981 to 2018. The study relates the effect of rainfall onset, cessation and LGS of the yields of sorghum.

2. Study Area

The study area lies between latitudes 11°08 'N and 13°22'N and longitudes 6°52'E and 9°20'E and occupies an area of about 24,194 square kilometres. It has a population of 5,801,584 comprising 2,948,279 males and 2,853,305 females, based on 2006 population census. It shares boundaries with Kano and Jigawa States in the East, Kaduna State in the South, Sokoto and Zamfara States to the West, as well as International border with Niger Republic to the North. The major ethnic groups are Hausa and Fulani. Administratively, the State is divided into thirty - four (34) Local Government Areas. The main occupations of the people are farming, cattle rearing and crafts (National Bureau of Statistics, 2011).

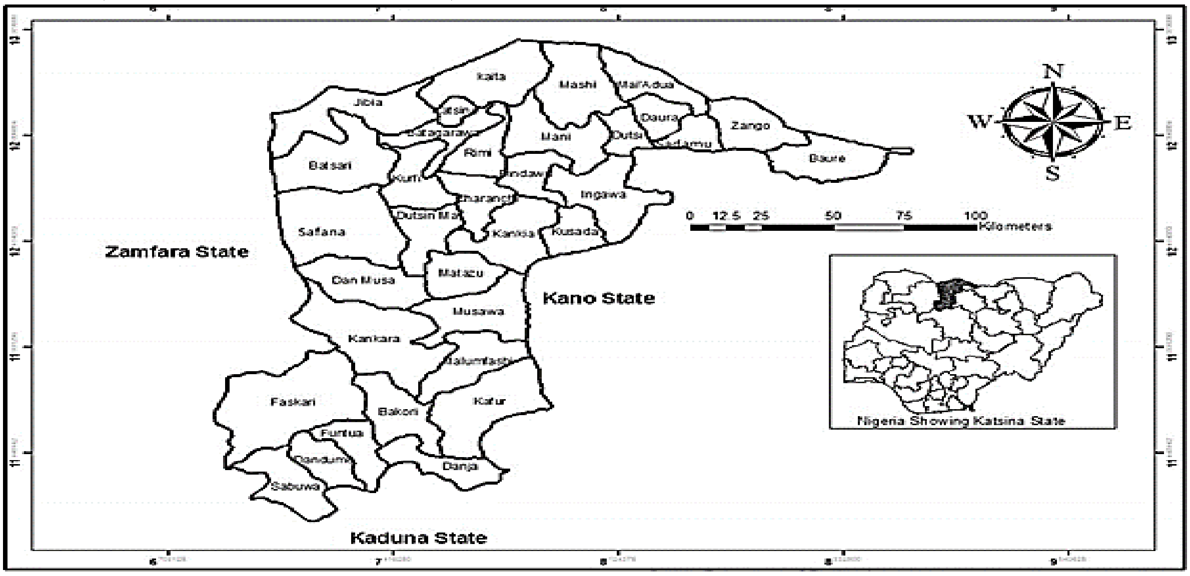

Figure 1: Map of Katsina
Source: Adapted from Katsina Administrative Map

The climate is the tropical continental type, classified as Koppen's Aw. Rainfall is between May and September with a peak in August. The average annual rainfall is about 700mm per annum with temperature ranging from 29°- 31°C. Highest temperature occurs in April/May and the lowest in December to February (Abaje, Sawa and Ati, 2014). The highest diurnal ranges of temperature are in the dry season. According to Abaje (2007) the state is characterized by four seasons based on the effect of climatic controls and temperature conditions namely: the dry and cool season (Kaka) which last from mid-November to the end of February; the dry and hot season (Bazara) which lasts from March to April and may extend to mid-May; the wet and warm season (Damina) which begins around May and ends in September, over 90% of the annual rainfall is recorded during this season; and the dry and warm season (Rani) which starts at the end of the rains, and ends about mid-November with the onset of the harmattan. The soil type of the region is mostly sandy loam which support crops like millet, beans, groundnut, sorghum, cotton, and sesame. The vegetation is the Sudan type with predominantly grass and few scattered trees, however, occasional wood land exist in some areas such as Runka Forest Reserve found in Safana and Dan-Musa LGAs (Abaje, 2007)

3. Materials and Methods

3.1 Source and type of data

The study design involved the collection and analyses of rainfall data (1981 - 2018) for Katsina station from Nigerian Meteorological Agency (NIMET), Lagos. Yield data for sorghum in tons/ha (1991 – 2018) were sourced and used from State Ministry of Agriculture archives. Available literature such as journals, textbooks, conference proceedings, seminar papers, thesis, reports and web references were also consulted for the literature and properly referenced.

3.2 Test for normality

The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) were calculated and used to test for normality of the annual rainfall series (1981-2018) for the study area.

The standardized coefficient of Skewness (Z_1) was calculated as;

$$Z_1 = [(\sum_{i-1}^{n} (x_i - \bar{x})^{3/N}) / [(\sum_{i-1}^{n} (x_i - \bar{x})^{2/N})^{3/2}] / (^6/_N)^{1/2} \text{ --- Eq. 1}$$

The standardized coefficient of Kurtosis (Z_2) was determined as;

$$Z_2 = [(\sum_{i-1}^{n} (x_i - \bar{x})^{4/N}) / [(\sum_{i-1}^{n} (x_i - \bar{x})^{2/N})^2] - 3 / (^{24}/_N)^{1/2} \text{ ----------------------------------- Eq. 2}$$

where, $\bar{x}$ is the long term mean of x_i values and N is the number of years in the sample. These statistics were used to test the null hypothesis that the individual temporal samples came from a population with a normal (Gaussian) distribution. Thus, if the computed absolute value of Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at the 95% confidence level. Generally, the annual rainfall data have shown a great tendency of normality. As a result, the data were used without any transformation.

3.3 Rainfall Characteristics

The monthly rainfall data obtained from NIMET office, Lagos for thirty-seven years (1981 –2018) was added for each of the years to give Total Annual Rainfall (TAR) received in the study area. The Standard deviation (SD), Long term mean and Coefficient of variation (CV) were all determined and used in analysing annual rainfall over the study area. Scientifically, it is computed using the following formula:

$$CV = {}^{SD}/_{\bar{x}} \text{ ---Eq. 3}$$

where CV is Coefficient of variation, SD is the standard deviation and $\bar{x}$ mean for rainfall.

According to Australian Bureau of Meteorology (2009) and Hare (2003), magnitude of coefficient of variability is classified as follows: < 20% as less variable, 20- 30% as moderately variable, and > 30% as highly variable and vulnerable to drought.

The annual rainfall range for the study area was determined from the maximum and minimum rainfall for the 37 years from 1981 - 2018. Greater disparity in rainfall values indicates greater irregularity and variability in rainfall pattern for the study area.

3.4 Relationship between rainfall and sorghum yield

The Pearson's Product Moment Correlation coefficient (***r***) was computed to see if there was any significant relationship of the rainfall (independent variables) on sorghum yield (dependent variable, **Y**) from 1991 – 2018. It is a form of linear regression analysis used to ascertain the strength or index of crop-climate relationship. Pearson was employed because the distribution is bivariate, continuous and normal. Both sorghum yield and rainfall data were harmonized by dividing by 100. The value ***r*** must fall within the ranges of $-1 \leq 0 \leq +1$. If the values tend towards +1, it indicates a perfect positive relationship but if it tends to -1, a perfect negative relationship has been established. If it is 0, there is no relationship established.

The Coefficient of Determinism (**R**) was also used to ascertain the extent or degree of percentage or proportion to which independent variables (**X_1** and **X_2**) influenced the outcome of dependent variables (**Y**). An R-value of high percentage, ≥ 60% depicts greater or very significant influence, a moderate percentage ranging from 40 – 59% shows moderate influence while a low percentage ranging from 0 – 39 % depicts an insignificant or poor influence. The results of analyses were presented in tables, charts and bar graph using Microsoft Excel.

4. Results and Discussion

4.1 General statistics of rainfall characteristics for Katsina climatic station

The rainfall characteristics and attributes showing Total Annual Rainfall (TAR), Long-term mean, Standard deviation (SD), Coefficient of Variation (CV), Annual Rainfall range and normality test for Katsina station are summarized in Table 1.

Table 1- Summarized Rainfall Statistics for Katsina climatic station (1981 - 2018).

Stations	TAR (mm)	Long Term Mean (mm)	SD (mm)	CV (%)	Annual Rainfall Range (mm)	Z_1	Z_2
Katsina	37033.28	587.83	174.95	29.8	884.2	-0.278	0.416

***** Significant deviation at 95% confidence level

Source: NIMET, *Lagos office and Author's Field work analysis (2020)*

The annual rainfall series for the Katsina climatic station was subjected to the normality test using the coefficients of Skewness (**Z_1**) and Kurtosis (**Z_2**) as shown in Table 1. Both results showed that the series for Katsina station had no significant deviation from the normal curve (1.96) at 95% confidence level showing normal distribution of data since the results were below 1.96. Table 1 also illustrated that the magnitude of Coefficient of Variation (CV) showed that Katsina was moderately variable at 29.8%. The result further shows a greater disparity in annual range of rainfall values. The study area (884.2mm) had great tendencies of increasing rainfall, which raises serious concerns of rainfall irregularity and variability for the state.

4.2 Trends in TAR for Katsina climatic station

Figure 2 show the annual rainfall trends for Katsina station.

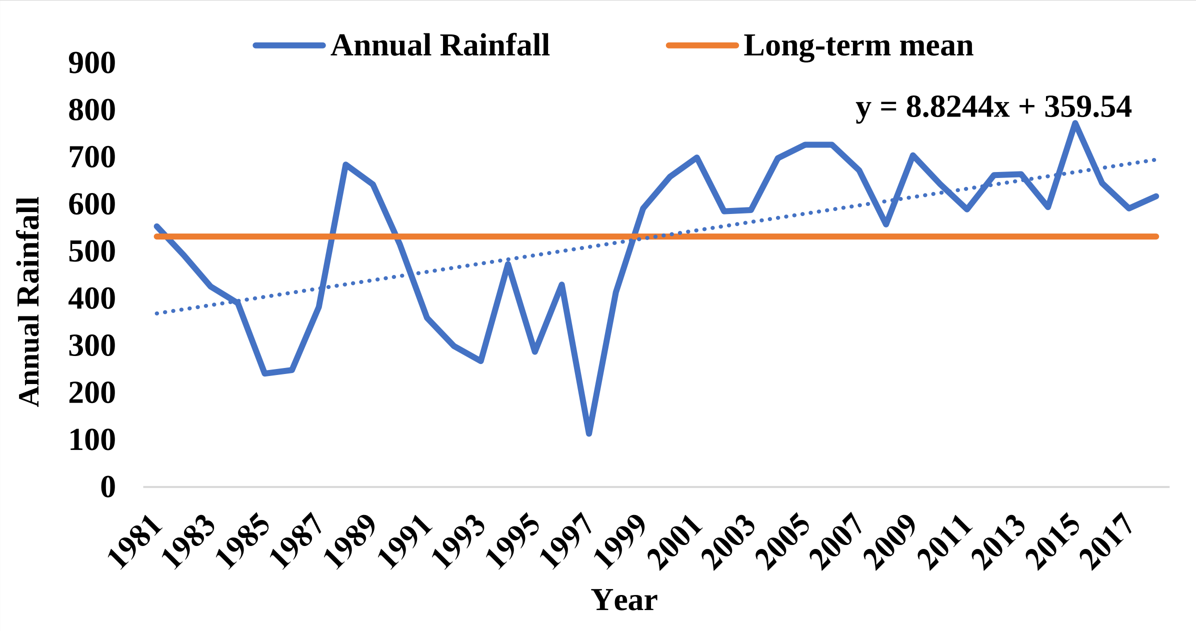

Figure 2 – Trend in Annual Rainfall for Katsina (1981-2018)

Source: *Author's fieldwork analysis (2020)*

Trends in annual rainfall series from 1981 to 2018 as presented in Figure 2 showed that the annual rainfall in Katsina State is increasing. The linear equation is y= 8.8244x + 359.5438 showing a positive trend line. Significant decline below normal condition occurred between 1991 and 1997 after which, a near normal condition above the mean occurred till the end of the data. The result agrees with the findings of Suleiman, Abdulhamid and Kasimu (2020) which reported an apparent increase in rainfall amount in Katsina State. These findings further disagree with the observations made by Abaje, Ishaya and Usman (2010), and Abaje, Ati and Iguisi (2012) that the Sudano-Sahelian Ecological Zone of Nigeria has been experiencing decreasing number of drought occurrences and consequently increasing wetness over the recent years.The onset dates, cessation dates and LRS in Katsina are presented in Table 2.

Table 2: Analysis of Onset, Cessation and Length of Growing Season in Katsina

Years	Onset dates	Cessation dates	Length of Growing Season
1981	30-May	25-Sept	118
1982	5-Jun	6-Oct	123
1983	15-Jun	16-Sept	93
1984	15-Jun	11-Oct	118
1985	20-May	26-Sept	129
1986	5-Jul	26-Sept	83
1987	30-May	21-Sept	112
1988	5-Jun	26-Sept	113
1989	10-Jun	6-Oct	118
1990	25-May	6-Sep	104
1991	15-May	1-Oct	139
1992	20-May	16-Sep	119
1993	30-Jun	21-Sep	81
1994	31-May	11-Oct	133
1995	20-Jun	26-Sep	98
1996	31-May	30-Sep	122
1997	25-May	26-Sep	124
1998	31-May	26-Sep	118
1999	5-Jul	6-Oct	93
2000	5-Jun	6-Oct	123
2001	31-May	16-Sep	108
2002	25-Jun	11-Oct	109
2003	31-May	11-Oct	134
2004	20-May	26-Sep	130
2005	20-Jun	1-Oct	103
2006	20-Jun	1-Oct	103
2007	20-May	21-Sep	124
2008	10-Jun	1-Oct	113
2009	25-May	16-Oct	144
2010	25-Jun	1-Oct	98
Mean	**07-Jun**	**29-Sep**	**114 days**

Source: Fieldwork 2020

Table 2 shows that the earliest onset dates for rainfall in the study area was 15th May (1991), the latest onset was 5th July (1999), while the mean onset for the period reviewed was 7th June. The earliest cessation date was 6th September (1990); 16th October (2009) was the latest cessation date, while 29th September was the mean cessation date. 1993 had the least LGS (81 days); 2009 and 2017 had the highest LGS with 144 days. The mean LGS was 114 days.

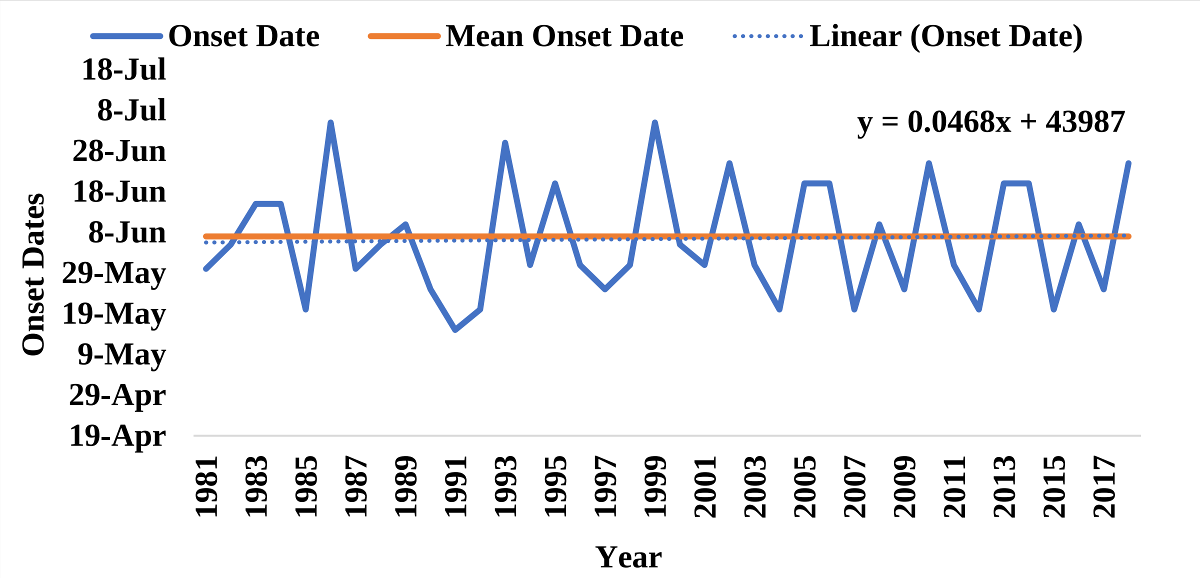

Figure 3: Trend in Rainy Onset Date for Katsina (1981 - 2018)

Figure 3 shows that the mean onset date for Katsina is 7th June which appears to be late. The trend line equation as given is y = 0.0468x + 43987. This shows that the onset date is increasing and becoming late. This observation spells doom for sorghum farmers in the area who depend majorly on rainfall for farming activities. If it continues to increase, this could affect the planting season. The implication of this is that if the trend of onset is moving from April to May or June, it may lead to a decrease in the LGS which can lead to decrease in sorghum yield. Sorghum requires rainfall of about 80 days. This study confirms the findings of Ikpe (2014) which reported late onset of rainfall and consequently low yield in grain production in Sokoto State. The result further agrees with the findings of Umar, Isah, Bello and Abubakar (2015) which stated that 67.9% of the farmers in Sokoto State agreed that onset of rainfall starts by April/May. These results show the reality of climate change in the Northern region of Nigeria. As sorghum is widely cultivated in Katsina, which is the crop used by the locals to prepare soft foods such as Pap, Fura and Gruvel, this will affect the income and available food for consumption, if it is affected by the changes in onset and cessation (Eludoyin, Nero, Abuloye, Eludoyin and Awotoye, 2017).

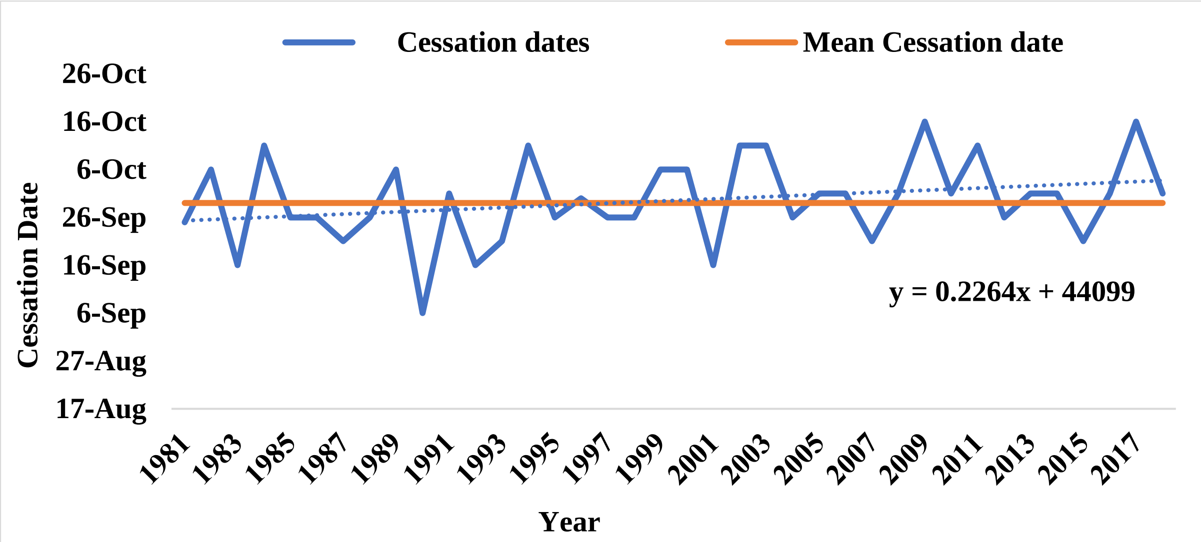

Figure 4: Trend in Cessation Date for Katsina (1981-2018)

Figure 4 shows that the mean cessation date is 29th September which appears to be early. The trend line equation, y = 0.2264x + 44099 depicts an increasing cessation date of rainfall which means that rainfall duration now extends towards the end of the year. This is a good omen for grain farmers because this result compliments for the late onset date as shown in Figure 3. According to Oruonye, Ahmed, Gambo and Tukura (2016), early cessation of the rainy season will result in the cutting short of the growing season of crops and consequently result in crops failing to reach their physiological maturity stage. Iortyom, Iorsamber and Adelabu (2017) in their study, titled “The effect of onset and cessation of raining season on crop yield in Lafia” reported that early cessation of raining season has more effect on crop yield as compared to onset of raining season, especially when the crop is approaching its fruiting stage, they require more water for growth. Early cessation affects the development of the crop. For example, between 500 to 750mm of well-distributed rain is conducive for proper growth of sorghum, anything less will negatively affect the yield. They further counselled farmers and others interested in agro allied services to ensure early planting of crops in order to avoid being caught up by the early rainfall cessation.

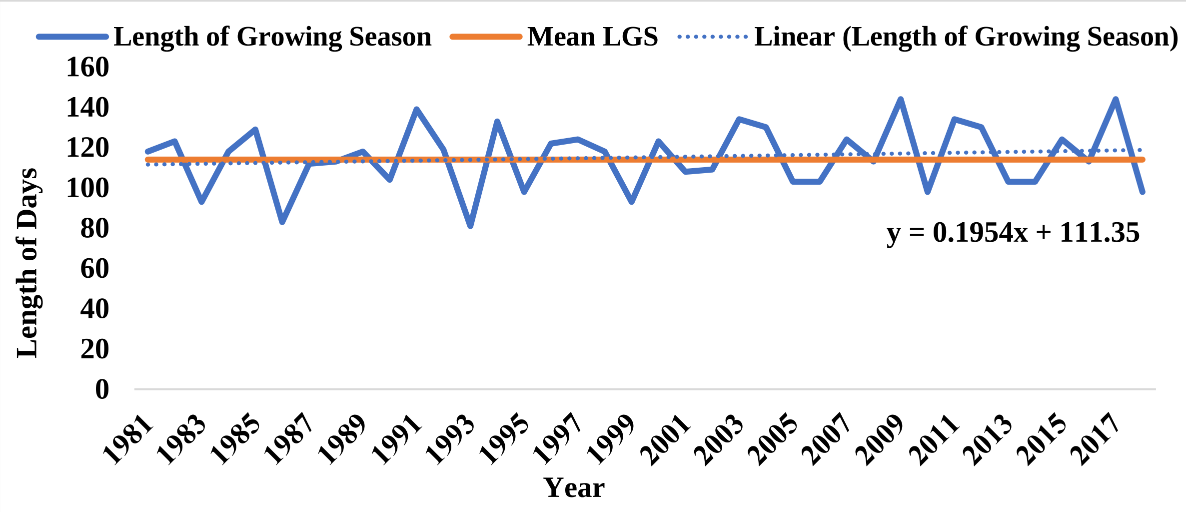

Figure 5: Trend in Length of Growing Season for Katsina (1981-2018)

Figure 5 shows that the mean of the LGS is 114 days (almost 4 months) and the trend line equation is y = 0.1954x + 111.35 showing that the LGS was increasing. This increase is a good omen for Katsina farmers because crops can thrive within this period and develop well

.

4.3 Relationship between TAR and Sorghum yield in Katsina climatic station

The Pearson Product Moment Correlation (r) and Coefficient of Determinism (R) were both used to determine the relationship between TAR values and sorghum yield data for Katsina from 1991-2018. Table 3 shows the relationship between TAR and sorghum yield.

Table 3: Relationship between TAR and Sorghum yield (1991-2018)

Station	Pearson Correlation (r)	Determinism Coefficient (R) (%)
Katsina	0.7413*	74.1*

* Significant at 95% confidence level and perfectly correlated

Table 3 shows that for Pearson coefficient (r), TAR values for Katsina is significantly, positively and perfectly correlated with sorghum yield data from 1991-2018. The Determinism coefficient (R) for the station was very high indicating that their climatic conditions greatly affected the outcome of yield. However, an increase in rainfall amounts in the study area led to their increase in grain yield. The implication of the above discussion as observed by the correlation results for Katsina is that, sorghum thrives well even when rainfall amounts increases or declines (Sawa, 2002). Further implication of the above findings for Katsina is future occurrences of flood episodes of diverse magnitude.

4.4 Trends in Sorghum yield pattern for Katsina climatic station

Trends in sorghum yield pattern (tons/hectare) are showed in Fig. 6.

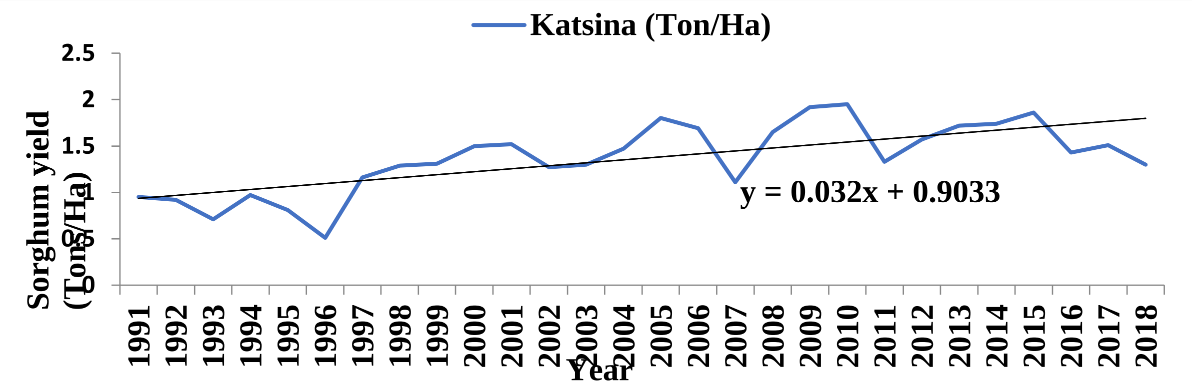

Figure 6 – Trend in Sorghum yield pattern for Katsina (1991-2018)
Source: *Author's fieldwork analysis (2020)*

Figure 6 indicates an increasing positive trend in sorghum yield (ton/ha) for Katsina with the trend line equation recorded as; y = 0.032x + 0.9033. From the beginning of the data, there was a gradual but significant increase in yield pattern until the end of the data. That sorghum yield is increasing in Katsina as rainfall amount increases confirms the findings of Ikpe (2014), which reported that sorghum yield increase as rainfall amount increases in Sokoto State.

4.5 Suggested Adaptation Strategies

For continuous increase in sorghum yield in the study area, sorghum farmers should employ certain measures for boosting and better productivity in the study area, which may include the following:

i. Application of organic manure such as cow dungs, bird droppings, green manure, farm wastes, compost and other decayed vegetative matter; and fertilizers made up of Nitrogen, Phosphate, Potassium, Potash and Calcium are all important to soil fertility.

ii. Developing a more improved grain processing and storage facility is vital for sorghum grains and should be encouraged and provided for local farmers to reduce pest attacks on yield.

5. Conclusion

This study has analysed trends in rainfall onset, cessation and LGS and its implication on sorghum yield in Katsina. From the trends in TAR and Sorghum yields for Katsina station, it was observed that a near normal trend line occurred for all trends. At the end of each data, the trend lines appeared to converge at or slightly converge with the normal condition or long-term mean. The trend line equations fell within the ranges of -2≤ 0 ≤ +2 trends for TAR values, which were both outside this range. The results showed an increasing annual rainfall total, late onset, late cessation and increase in sorghum yield.

Sorghum yield thrives when rainfall increases.

6. Recommendations

1. Updating, improving and monitoring of annual rainfall and sorghum yield data in Katsina State
2. Late planting of sorghum in cases of high rainfall and early planting in cases of low rainfall
3. Educating the public on effects of climatic change and variability so that grain farmers can have better experience when planting season begins.

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