

Analysis of Rainfall Characteristics in Billiri, Gombe State, Nigeria

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This study examined the patterns of rainfall in Billiri. Rainfall data for 40 years from 1977 to 2016 were collected from the Gombe State Agricultural Development Program (GSADP) Ladongor station in Billiri. Descriptive statistics for both rainfall and rainy days and the Seasonality Index (SI) of the rainfall were determined. Linear time series analysis was used to determine the nature of the trend of both rainfall and rainy days. To identify variation within the trends, both the rainfall and rainy days series were divided into four-decade, ten (10) years each from 1977-1986, 1987-1996, 1997-2006 and 2007-2016. Spearman's rank correlation was used to determine the relationship between rainfalls total and the number of rainy days, the result of the statistics shows that the maximum and minimum rainfall were 1407.9mm, and 363mm respectively while the maximum and minimum rainy days were 60 and 27 days respectively. The SI of the station was markedly seasonal with a long drier season and there are more years of negative anomalies than positive anomalies. The linear trends show that both the rainfall and the number of rainy days decreased over time. There was a change in the patterns of rainfall and rainy days in each decade. A very weak relationship existed between rainfall totals and the number of rainy days. The study recommends that the agricultural extension workers should inform the farmers about the recent trends of rainfall in the study area.

Keywords: Relative seasonality index, rainfall anomaly, trends of both annual rainfall and rainy days

Introduction

Rainfall is the primary source of moisture for rainfed agriculture. It is an important resource for human existence. Rainfall affects water table, crop production, and transportation and often results in extreme weather events such as floods and droughts. The fluctuations in rainfall patterns over the years make people uncertain about their activities, which directly affects their economic activities (Msheliza & Bello, 2016).

Globally there have been changes in the patterns of precipitation (Intergovernmental Panel on Climate Change [IPCC], 2007) and changes in the seasonality of rainfall of a large part of Africa and decadal variation in the Sahel and Guinea Coast of West Africa (Nicholson, Funk & Fink, 2018). Coming to Nigeria, there are common changes in point and transition from dry to wet (Upward shift

and significant variations of rainfall in all the climatic zones (Ogungbenro & Morakinyo, 2014).

Akinsanola and Ogunjobi (2014) reported that there have been statistically significant increases in precipitation in the vast majority of Nigeria. In the same vein, Ati *et al.* (2009) also reveal that there is a significant increase in annual rainfall amount in northern Nigeria. The length of the rainy season in Northern Nigeria is decreasing and the region is becoming drier as the rainy season is now spread within a few months, the frequency of dry spells of 5 days is decreasing while dry spells of 10, 15 or more days are on the increase (Sawa & Adebayo, 2011). On the specific, Aondover and Ming-Ko (1998) reported that changes in rainfall over the Sahelian region were driven by a reduction in the frequency of rain days and rainfall intensities between the months of August and September. According to Abaje, Ishaya & Usman (2010), there

was a decline in the annual rainfall yield in Kafanchan. Adebayo and Yahaya (2015) reported that rainfall was declining by about 5mm/year in the Savanna surge farm in Adamawa state. Ahmad and Ibrahim (2017) reported that the number of rainy days and the amount of rainfall received varies with latitude in Gombe state which affects agricultural production.

Most of the people in Billiri are peasant farmers, particularly those that depend on rain-fed agriculture for their survival and now there is a lot of uncertainty in the rainfall patterns which is why this study seeks to investigate the characteristics of rainfall in Billiri. The objectives of this study are to:

- i. analyze the trends of both annual rainfall and rainy days; and
- ii. determine the relationship between annual rainfall and rainy days.

Study area

Billiri is located between latitude $11^{\circ} 13' 31''$ E and Longitude $9^{\circ} 51' 53''$ N (Figure 1). It has an area of 737 km² with a population of 202,144 (National Population Commission, 2006). The climate of the Billiri area belongs to the Koppen's Aw climate with two distinct seasons, rainy seasons and dry seasons or summer and winter seasons. The rains start around April/May and end around October/November and it has an average rainfall of 794.13mm. The highest air temperature normally occurs between March/April and the lowest in December through February, it ranges from 25°C to 27°C. The vegetation of the area is the northern guinea savanna ecological zone (Nigeria Conservation Foundation-NCF, 2008). The dominant tribe in Billiri is Tangale and farming is the primary activity of the inhabitant of the study area.

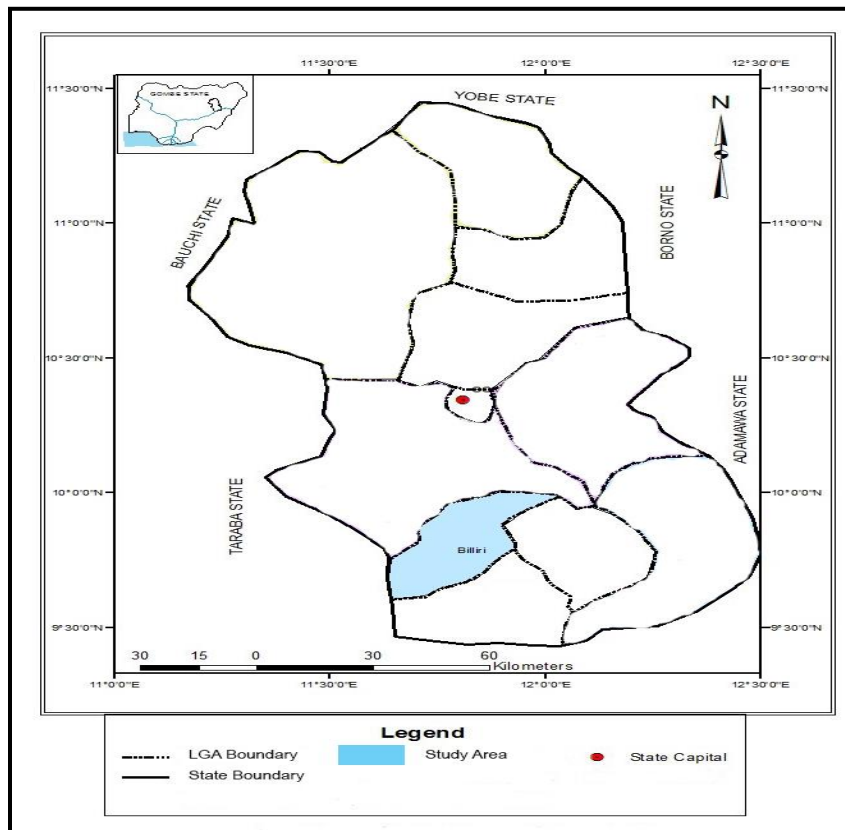


Figure 1: The Study Area

Source: Gombe State Ministry of Land and Survey (2012)

Materials and methods

Rainfall data of Billiri from the period 1977 to 2016 (40 years) were collected from Gombe State Agricultural Development Program (GSADP) Ladongor Station, which is the only functional station in the area. The data were subjected to a normality test using the standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics. The standardized coefficient of Skewness (Z_1) was calculated as:

$$Z_1 = \left[\frac{\sum_{i=1}^N (x_i - \bar{x})^3 / N}{\left(\sum_{i=1}^N (x_i - \bar{x})^2 / N \right)^{3/2}} \right] / \left(\frac{6}{N} \right)^{1/2} \dots\dots (1)$$

and the standardized coefficient of Kurtosis (Z_2) was calculated as:

$$Z_2 = \left[\frac{\sum_{i=1}^N (x_i - \bar{x})^4 / N}{\left(\sum_{i=1}^N (x_i - \bar{x})^2 / N \right)^2} \right] - 3 / \left(\frac{24}{N} \right)^{1/2} \dots (2)$$

Walsh and Lawler’s (1981) index was used to calculate the Relative Seasonality Index (SI) of the Rainfall, to determine the climate type. The formula is as follows:

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

Where:
 SI = seasonality index
 R = mean annual rainfall
 X_n = is the mean rainfall of month n

Table 1: Seasonality index classes

SI ₁	Rainfall Regime
≤ 0.19	Rainfall Spread throughout the year
0.20 – 0.39	Rainfall Spread throughout the year, but with a definite wetter season
0.40 – 0.59	Rather Seasonal with a short drier season
0.60 – 0.79	Seasonal
0.80 – 0.99	Markedly seasonal with a long dry season
1.00 – 1.19	The most rainfall in less than 3 months
≥1.20	Extreme seasonality, with almost all rainfall in 1 – 2 months

Linear Trend line analysis was used to determine the changes in both series rainfall and rainy days. A rainy day in this context is any rainfall value that is 0.3mm and above is referred to as a rainy day. To identify changes within the trends both annual rainfall and rainy days series were divided into ten (10) year non-overlapping sub-periods to determine the changes over time 1977-1986,1987-1996, 1997-2006 and 2007-2016.

$$Y_t = a + bt + e_t \dots\dots\dots (4)$$

where Y_t = the amount of rainfall
 a = intercept
 b= slope, which measures the rate of change in rainfall with time t
 e_t = random error component

Spearman’s rank correlation was used to determine the relationship between the rainfalls total and the number of rainy days. It is computed as:

$$sums = 1 - \frac{6 \sum d^2}{N(N^2-1)} \dots\dots\dots (5)$$

Analysis of variance (ANOVA) was used to test the association between rainfall totals and rainy days.

Results and discussion

Statistics of rainfall and rainy days are presented in (Table 2). The result of the normality test of Z_1 and Z_2 of rainfall and rainy day is less than 1.96. Therefore, the data was used without any form of transformation. The computed seasonality index is 0.82 therefore, Billiri is markedly seasonal with a long dry season. The mean of rainfall and rainy days (794.13mm) and (42 days) respectively. The standard deviation of rainfall and rainy days are (212.7mm) and (9.00 days) respectively. A maximum number of rainy days (60 days) was observed in 1985 and rainfall (1407.9mm) was observed in 1987 while the minimum volume of

rainfall (363.8mm) was observed in 1987 and rainy days of (27 days) were also observed in 2007.

Table 2: Analysis of volume of Rainfall Data and Rainy Days 1977 -2016

Statistics	Rainfall Totals (mm)	Rainy Days
Mean	794.13	42.00
Std. Deviation	212.75	8.66
Minimum	363.80	27.00
Maximum	1407.9	60.00
Kurtosis	0.949	-0.73
Skewness	0.644	0.26

The Trend of annual rainfall from 1977 – 2016

There is interannual variability in the volume of rainfall from year to year in Billiri. The coefficient of variation from year to year is 1.4% and a decreasing rate of -2.08mm per annum (Figure 2). The decreasing trend of rainfall in Billiri is about the findings of Msheliza and Bello (2016) who reported a decreasing trend of rainfall in Gombe state. Also, Abaje, Ishaya & Usman (2010) reported that rainfall yield in Kafanchan is declining and Logah *et al.* (2013) reported that there is a decline in mean annual rainfall for the period 1981-2010 with high rainfalls shifting to the South-western

corner of Ghana. This finding disagrees with the outcome of Adebayo and Abam (2015) who reported that annual rainfall in Michika shows an increasing pattern and also Tigray Abaje, Achiebo & Matazu (2018) who revealed that there is an increase in annual rainfall amount in recent years in Kaduna state. The implication of this decreasing rainfall will hurt agriculture, particularly crop production. It directly affects their moisture requirement which may eventually affect the developmental process of the area because the majority of the inhabitant rely on rainfed agriculture as their means of livelihood.

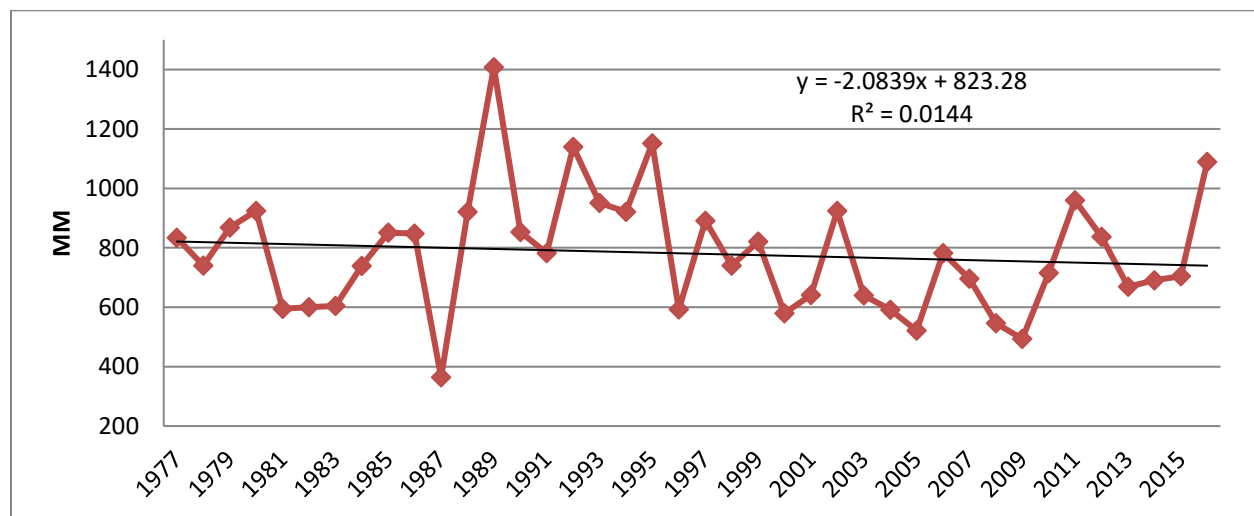


Figure 2: Trend of the Annual Rainfall in Billiri, 1977-2016

Decadal changes in rainfall patterns

The decadal variation of rainfall totals shows that there is a decline in the first trend of rainfall from 1977 – 1986 (Figure 3). The coefficient of variation

is (1.08%) and a declining trend of -4.2 mm per year, this indicates the ending of the Sahelian drought of the 1970s to early 1980s. The second Decade (Figure 4) shows an increasing trend of

11.4mm per year with a coefficient of variation (1.39%). This result is in line with the finding of Ati *et al.* (2009) who reported an increasing volume of rainfall in northern Nigeria.

The rainfall in the third decade (Figure 5) indicates a decreasing trend of -19.3mm with a coefficient of variation of (17.84%) while the fourth decade (Figure 6) indicates an increasing trend of 64mm coefficient of variation of (30%). The

increasing trend in Figure 6 is about the finding of Akinsanola and Ogunjobi (2014) who reported that there have been statistically significant increases in precipitation in the vast majority of Nigeria. The pattern of the four decades indicates a decrease and increase from one decade to another. Based on the result obtained, it implies that there is an increasing and decreasing (fluctuating) trend of rainfall after each decade.

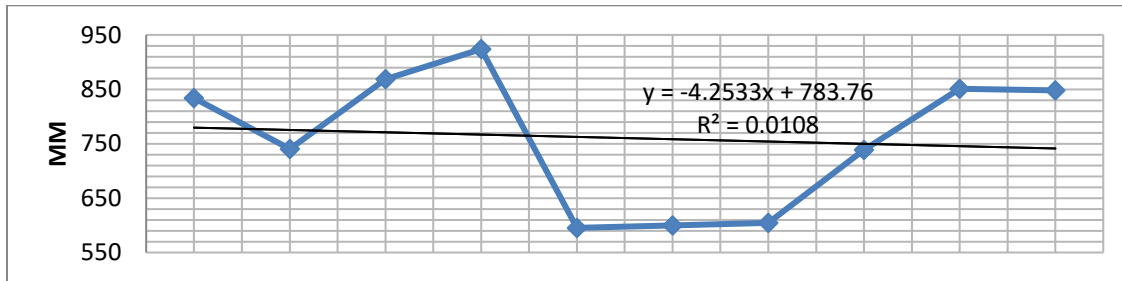


Figure 3: Trend of Rainfall from 1977 - 1986

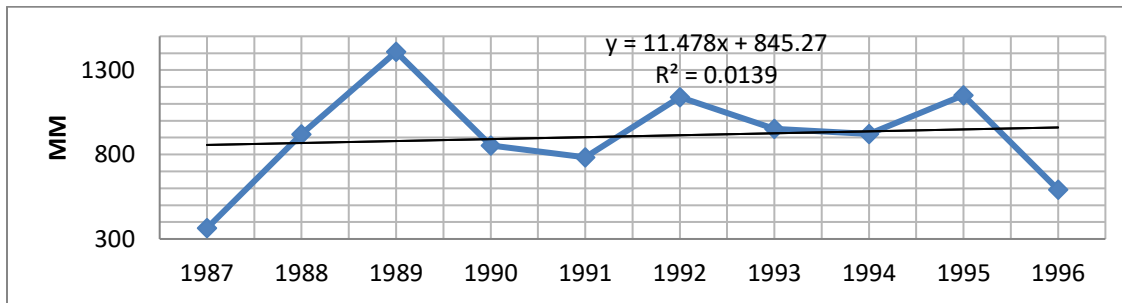


Figure 4: Trend of Rainfall from 1987 - 1996

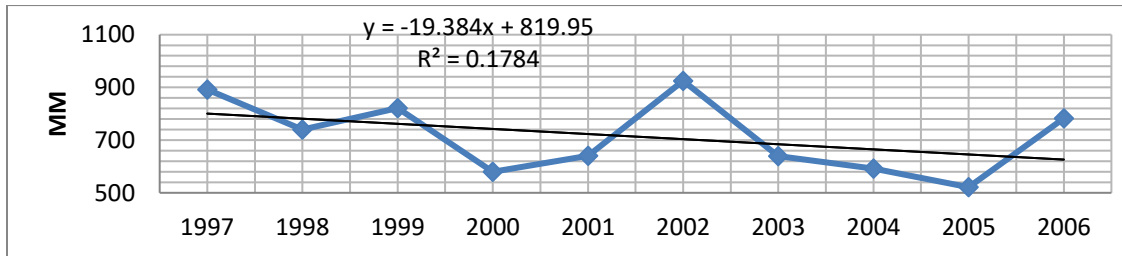


Figure 5: Trend of Rainfall from 1997 - 2006

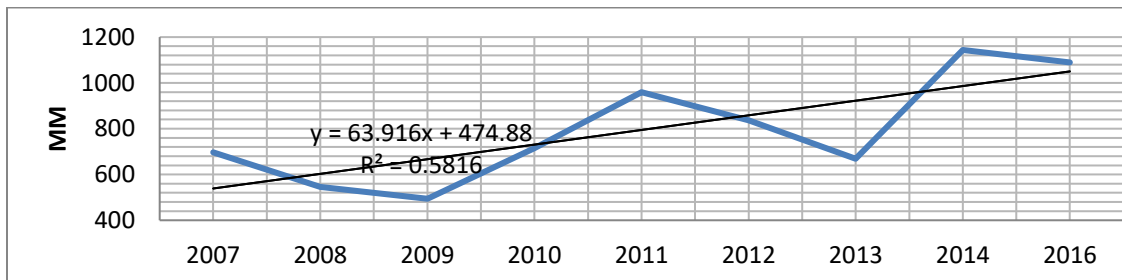


Figure: 6 Trend of Rainfall from 2007 - 2016

The trend of rainy days from 1977-2016

The Billiri shows a decreasing trend with its highest value for the period (60 rainy days) recorded in 1985 and the lowest value (27 rainy days) recorded in 2007 Figure 7 and (Table 1). The mean and standard deviation values of the rainy days over the

period are 42 days and 9 days respectively, this implies that there is an interannual variability of the rainy days in Billiri during the study periods. The changes in the rainy days in the study area may affect the crop’s production cycle, particularly those with a long production cycle.

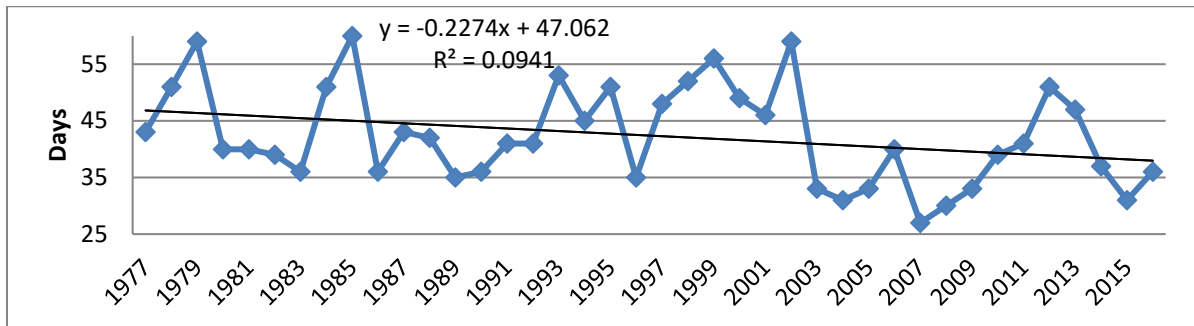


Figure 7: Trend of Rainy Days from 1977 - 2016

Decadal changes in rainy days from 1977 – 2016

The decadal changes in rainy days (Table 2) show that there is a decreasing trend from 1977 – 1986, an increasing trend in the second from 1987 – 1996, a decreasing trend in the third decade from 1997 – 2006, and an increasing trend in the fourth decade from 2007 – 2016.

This means that the decadal trend of rainy days changes each decade as in the case of rainfall. By implication, the crop that has a long production cycle will be affected by the decreasing number of rainy days while those with short periods may not be affected except when the volume rainfall required to be exceeded or is insufficient for production.

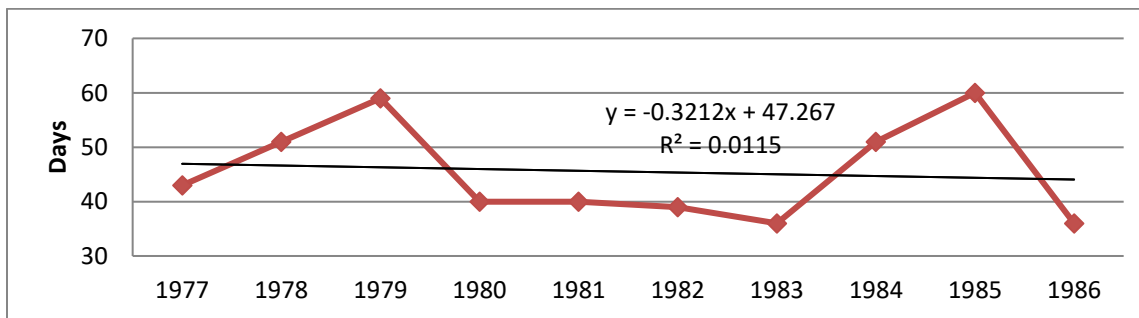


Figure 8: Trend of Rainy Days from 1977 - 1986

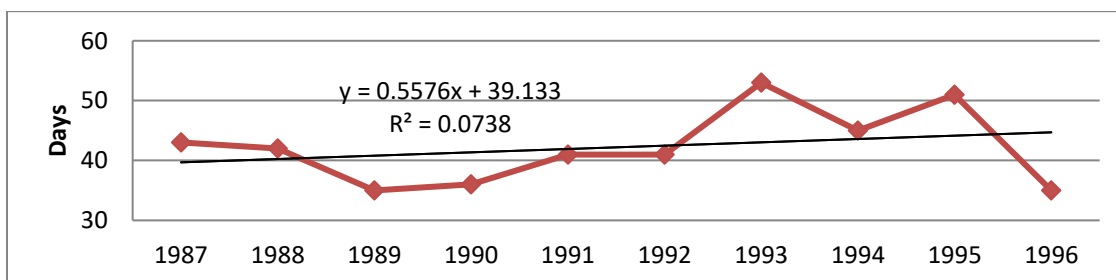


Figure 9: Trend of Rainy Days from 1987 - 1996

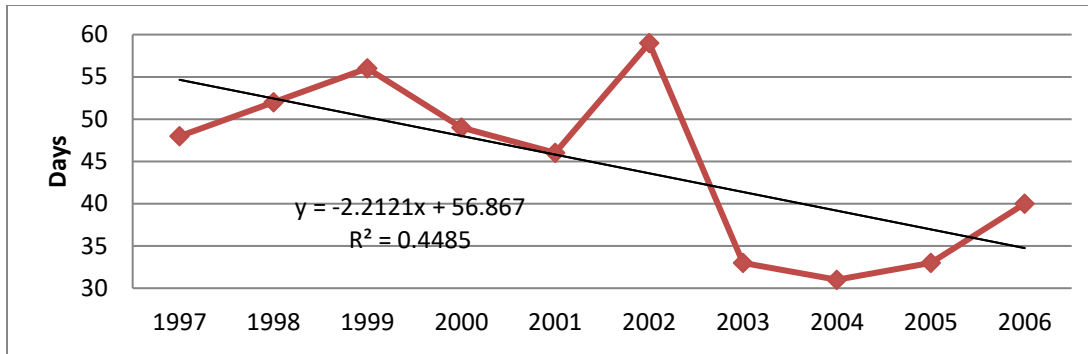


Figure 10: Trend of Rainy Days from 1997 - 2006

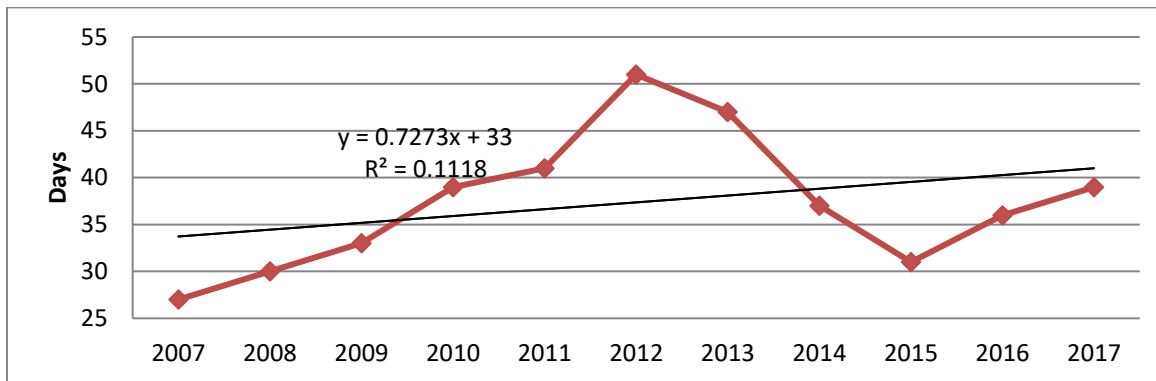


Figure 11: Trend of Rainy Days from 2007 - 2016

Table 3: Summaries of the Decadal Changes of Rainfall and Rainy Days

	1977 – 1986	1987 – 1996	1997 – 2006	2007 – 2016
Rainfall	Decrease	Increase	Decrease	Increase
Rainy Days	Decrease	Increase	Decrease	Increase

Table 4: Decadal Correlation Value between Annual Rainfall and Rainy Days

	1977- 1986	1987 – 1996	1997 – 2006	2007 - 2016
Correlation	0.4018	0.0667	0.7046	0.3368
Coefficient	40.18	6.67	70.46	33.68

The decadal correlation presented in Table3 shows that there is a weak (0.4018) relationship between the variable in the first decade (1977-1986), second decade (1987 – 1996), and the fourth decade (2007 – 2016) of 0.0667 and 0.3368 respectively while

there was a strong relationship in the third decade (1997 – 2006) (0.7046). By implication, the third decade proves to be years that were economically viable for rain-fed agriculture.

Table 5: Test of Association

Source of Variation	SS	df	MS	F	P- Value	F crit
Between Groups	10897736.58	1	10897736.58	527.2698132	1.90E-36	3.963472051
Within Groups	1612122.356	87	20668.23533			
Total	12509858.94	79				

Table 4 shows that there is no significant difference between annual rainfall and the number of rainy days in the study area at a 0.05 level of significance

Anomalies of rainfall and rainy days

The anomalies of rainfall in Figure 12 begin with positive variability in 1977 and drops off in 1978 with two years of positive rise in 1979 and 1980. There was another drop from 1981 to 1985. The maximum positive anomaly of 3mm was observed

in the year 1989 and the maximum negative of -2mm was observed in 1987. The result from Figure 12 shows that there were 18 years (44%) of positive anomalies and 22 years (55%) of negative anomalies. Therefore, there were more years of negative anomalies than years of positive anomalies. These results are in line with the findings of Odjugo (2005) who reported (65%) below the normal anomalies. The rainfall pattern in Billiri has been unstable for a long period.

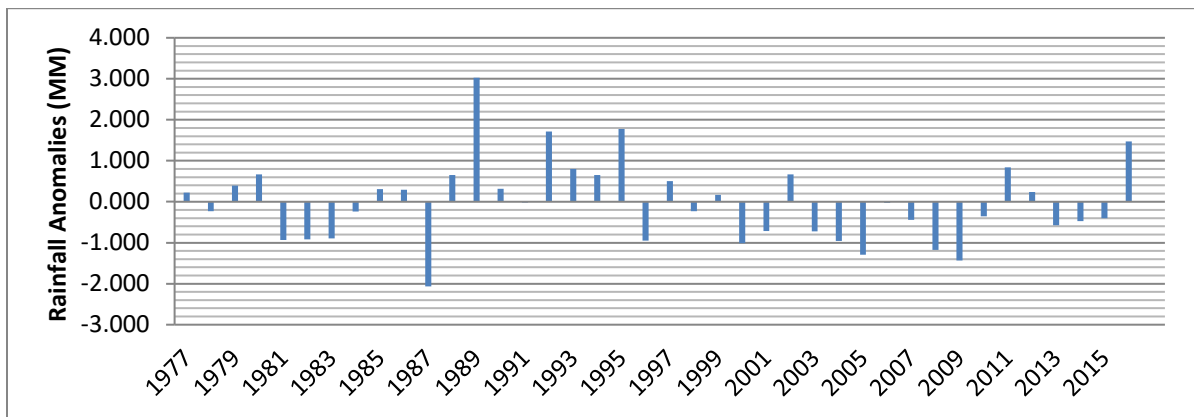


Figure 12: Rainfall anomalies of Billiri from 1977- 2016

Figure 13 depicts the standardized anomalies of rainy days over Billiri, indicating both positive and negative anomalies. It clearly shows positive anomalies from 1977 -1979 and negative anomalies from 1980 -1983. The maximum positive anomaly

was observed in 1985 and the maximum negative was observed in 2007. There were 42.5% of positive anomalies and 57.5% of negative anomalies.

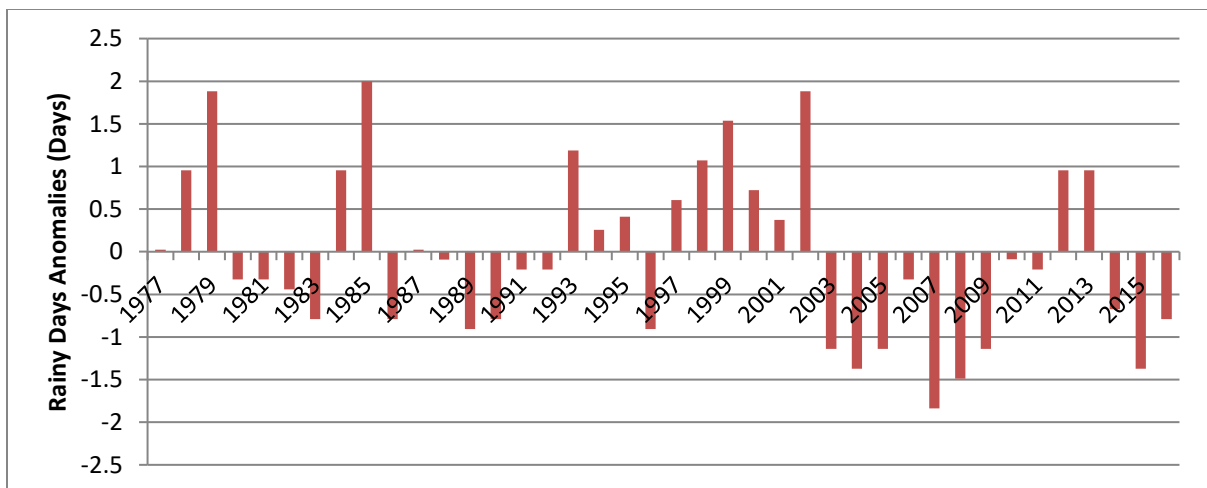


Figure 13: Rainy Day’s anomalies of Billiri from 1977- 2016

Conclusion

There were temporal changes in rainfall yield and rainy days in Billiri. The maximum and minimum volume of rainfall was 1407.9mm and 363mm while the maximum and minimum number of rainy days was 60 days and 27 days. The SI of the station was markedly seasonal with a long drier season. Generally, there was a decreasing trend of both rainfall and rainy days, and there was a decadal variation in their patterns. A very weak relationship existed between annual rainfall and the number of rainy days. There were more years of negative anomalies of both rainfall and rainy days than years of positive anomalies.

The decreasing trend might hurt rain-fed agriculture, particularly crop production which the majority of the inhabitants of the study area rely on. The decreasing volume of rainfall may equally affect the recharging of the groundwater table which is a vital resource for digging wells and boreholes which are sources of water for domestic uses. It may also affect the volume of water in the river which is the major source of water for irrigation activities. The instability in the rainfall pattern may affect the development in the area because most of the inhabitants of the study area depend on rainfall as their major resource for their livelihood.

From the foregoing, it is recommended that:

- (i) agricultural extension workers should educate farmers about adapting their farm calendar and choice of crops in line with present realities;
- (ii) in this vein, agricultural extension workers should provide the annual NIMET seasonal rainfall predictions to inhabitants of the study area, particularly arable crop farmers; and
- (iii) A study should be done to identify the existing climate early warning systems in the study area to provide an entry point for Non-Governmental Organizations (NGOs), Community-Based Organizations (CBOs), Agricultural Extension workers and Individuals who work with local farmers in the study area.

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